CHANGES IN CALCAREOUS NANNOPLANKTON IN THE CRETACEOUS-TERTIARY BIOTIC CRISIS AT ZUMAYA, SPAIN

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ABSTRACT: In an essentially uninterrupted sedimentary sequence, the biotic crisis at the end of the Cretaceous began roughly 10,000 years before its climax. There was a gradual transition from a normal Cretaceous nannoflora to one composed of long-ranging forms characteristic of ecological stress. This transition accelerated a few thousand years before the boundary. Characteristically Paleocene species began to appear at the boundary, but the stress-adapted species remained dominant for about a million years. The crisis was ecologically very long, but it may have had a sharp climax. Evidence from foraminifera generally parallels that from nannoplankton but gives additional information. (Prepared by editors.)

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INTRODUCTION

The Cretaceous-Tertiary Crisis. Paleontologists have recognized the occurrence of a major biotic crisis at the end of Cretaceous time for well over a century. The dinosaurs on land, the rudists and inoceramids on the sea floor, and the ammonites and great marine reptiles of the pelagic realm died out. The coccolithophyceans, planktonic foraminifera and belemnites suffered nearly complete extinction, while many other groups of organisms were markedly reduced in numbers of taxa. A great many hypotheses have been advanced to explain this phenomenon, among them cosmic radiation (Schindewolf, 1954) and more specifically the appearance of a supernova in proximity to the solar system; toxic trace element concentrations (Cloud, 1959); drastic fluctuations in sea level (Newell, 1962); severe decrease in oceanic fertility (Bramlette, 1965 a, b); periodicity in phytoplankton productivity and its effect on oxygen levels (Tappan, 1968; Tappan and Loeblich, 1970); fluctuations in intensity and direction of the geomagnetic field (Simpson, 1966); release of carbon dioxide during diastrophism (Rutten, 1966); and general astronomical cycles (Worsley, 1970). Other suggestions have ranged from the racial senescence of organisms to the occurrence of great epizootics caused by bacteria or viruses. While some of these explanations are patently insufficient to explain the range of the crisis through various habitats and groups of organisms, the majority have been neither disproved nor strongly supported. It seems clear that environmental changes occurred at the end of Cretaceous time, which affected all or nearly all parts of the biosphere in various ways. Extinction seems to have been particularly severe in the pelagic communities and in the reef setting, less drastic in deeper-water benthos, and rather spotty in terrestrial communities where the dinosaurs were eliminated. The freshwater biotas, according to studies by Bakker (pers. comm.) may have escaped unscathed.

The Cretaceous-Tertiary biotic crisis thus remains one of the great unsolved puzzles in the history of our planet. It has remained unsolved to date because our knowledge of the basic facts remains very generalized.

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The crisis happened some 65 million years ago, and is now generally believed to have occurred at the turn of the Maastrichtian to the Danian stage, but we do not know whether it developed overnight or over a matter of some millions of years; neither do we know whether it affected the various habitats simultaneously or sequentially. The means of more accurate dating and correlation are being developed. Advances in the biostratigraphic zonation of the marine Cretaceous and Paleogene deposits by means of planktonic foraminifera and calcareous nannoplankton now afford more precise correlations in the marine realm, while the emergence of a magnetic stratigraphy (Keating and others, 1975; Fischer and Arthur, in press; Premoli Silva, in press; Roggenthen and Napoleon, in press; Alvarez and others, in press) promises to link continental and oceanic deposits in a more accurate time frame.

At the same time, we must learn more about the crisis itself.

Aims and results of this study. Instead of recognizing only the net effects of the crisis, we must try to resolve it into an historical sequence of biological and physio-chemical events. This can only be done by detailed biostratigraphic investigations in continuously deposited sequences of sediment. Toward this end, Percival (1972) made a microstratigraphical investigation of a sequence of calcareous nannoplankton floras of latest Cretaceous and earliest Cenozoic age. The results of this work are summarized here.

The study was conducted in the sedimentary section exposed in the vicinity of Zumaya, located on the northern coast of Spain between Bilbao and San Sebastian (Fig. 1). This section has become a classical one for pelagic sediments of the late Cretaceous and early Cenozoic, through the work on foraminiferal biostratigraphy by Herm (1965) and v. Hillebrandt (1965). Not only did these investigators find what they believed to be an essentially continuous sequence of foraminiferal faunas, but Herm discovered some deterioration in the foraminiferal community immediately prior to the main crisis proper. Percival undertook a detailed study of the calcareous nannoplankton in this section, concentrating on the record of what we take to be about a million years of history spanning the crisis. While the preservation of coccoliths is not particularly good, due to the compaction and solution welding of the sediment (Fischer, Honjo and Garrison, 1967), 41 taxa could be identified and counted through the 10 meters of section studied. The lowest beds are characterized by a normal Maastrichtian nannoflora. Within this, just prior to and within the basal part of the "Boundary Shale," there appear thoracospheres and braarudospheres, not normal constituents of the open-water biota and here interpreted as taxa mainly associated with ecological instability (disaster forms). Within the lower part of the Boundary Shale, these and a few other long-ranging species essentially replace the normal Maastrichtian flora, simultaneously with the extinction of the last globotruncanid foraminifera. The majority of the Maastrichtian species continue to appear sporadically and in small quantities through the succeeding several meters of sediment; we are uncertain as to whether they continued to survive marginally, or whether these occurrences are the result of resedimentation of Cretaceous sediment, but we suspect the latter. Newly evolved species appeared one by one, but did not begin to be quantitatively important for nearly a million years. This suggests to us that the environmental problems that brought about the crisis are therefore not to be sought in some traumatic but briefly transitory event.

Current work. Since Percival's investigation, the Princeton group has continued to work at Zumaya. A senior thesis by Allen (1975) and examination of samples by Premoli Silva established the presence of the Globigerina eugubina zone, and thus completed the foraminiferal zonal sequence, and have added to our understanding of foraminiferal distributions. While these findings support the general conclusions of the Herm's report of 1965, they are at variance with

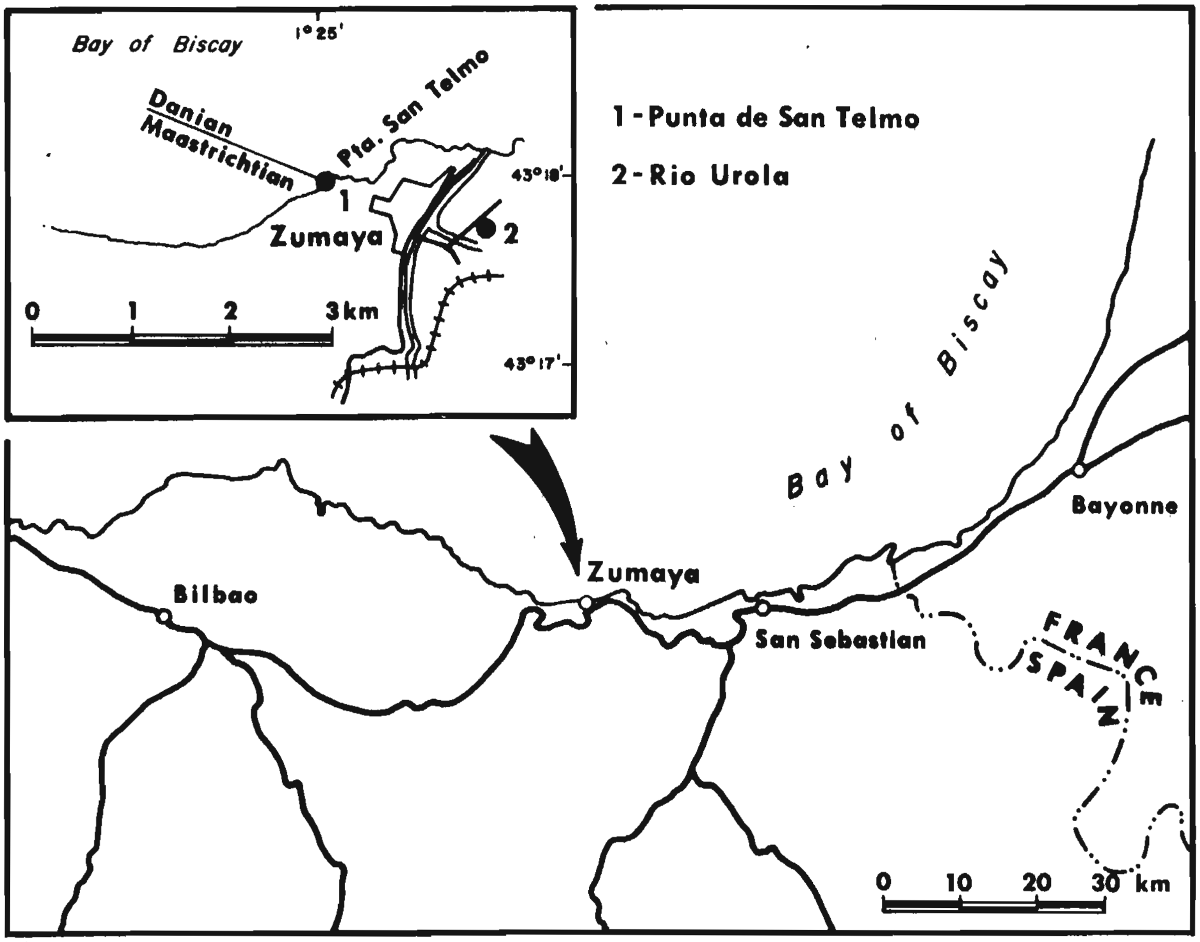

Figure 1. Map showing location of sections at Zumaya, Spain. (Locality map after Herm, 1965).

* * *

it in detail and more work is needed to clarify the foraminiferal distribution patterns. M. Arthur is currently working on sedimentological problems, comparing the Zumaya limestones with the Scaglia Formation at Gubbio, and current work by Roggenthen shows that the Cretaceous-Tertiary boundary at Zumaya, like that at Gubbio, lies within a zone of reversed polarity, defined at Gubbio as Polarity Zone (Roggenthen and Napoleon, in press; Alvarez and others, in press). The present paper presents the main observations of Percival (1972), brought up-to-date in the light of this subsequent work.

Acknowledgments. Percival's study was made possible through financial support from Union Oil Company and from Mobil Research and Development Corporation. The other work at Zumaya, by Fischer and various associates, has been supported by the National Science Foundation. Isabella Premoli Silva of Milano has aided us greatly by identifying foraminiferal zones, as did Layman Allen and Phyllis Hasson at Princeton. To these organizations and individuals we express our sincere thanks.

LATEST MAASTRICHTIAN-EARLY PALEOCENE SEQUENCE AT ZUMAYA

The northern coast of Spain, from the region of Bilbao eastward to and beyond the French border, exposes a thick sequence of Cretaceous (Albian) to Eocene (Cuisian) marine deposits. While several facies are represented in this belt, the portion exposed in and close to the coast itself, from Deva to the French border, is largely in flysch facies, but within this flysch trough the sediment of latest Maastrichtian and early Paleocene (Danian) age represents a quiet interlude during which turbidite deposition was largely interrupted. The flysch facies has received considerable study, but we are here concerned with the non-turbiditic interlude, and specifically with the few meters of the latest Maastrichtian and of the earliest Paleocene, shown in Figs. 2, 3, and 4.

Previous work. Previous studies of this section include a number of geological and paleontological investigations by Gomez de Llarena (1946, 1954, 1956), a study of the Cretaceous foraminifera and biostratigraphy by Herm (1965), a similar study of the Paleogene part of the sequence of v. Hillebrandt (1965), investigations of the trace-fossil fauna by Seilacher (1962) and by Crimes (1972), study of selected limestones by electron microscopy by Fischer, Honjo and Garrison (1967), a detailed study of the changes in nannoplankton in the vicinity of the Maastrichtian-Danian boundary by Percival (1972), and a more general study of the nannoplankton by Kapellos (1974). Some new data on foraminiferal distributions were obtained by Allen (1975). Current studies by the Princeton group include a sedimentological study of the Danian limestones by Arthur, and a paleomagnetic investigation of the Danian sequence by Roggenthen.

The two sections. The latest Cretaceous-earliest Paleocene part of the section is well exposed at Zumaya in two sections (Fig. 1): One, a series of sea cliffs and abraded platforms at the Punta de San Telmo, immediately west of Zumaya's bathing beach. This is here referred to as the Punta de San Telmo section (Figs. 3, 4). The other is a series of artificial cuts just across the river (Rio Urola) from Zumaya--a section here termed the Rio Urola section. Here the outcrop sampled by Percival has since been destroyed by quarrying. The Punta de San Telmo section is normal, though steeply tilted, while the Rio Urola section is overturned. The sections are now only 1.8 km apart, but a major fault intervenes. Several units recognized in both sections show appreciable differences in thickness, suggesting that the two sequences may have been more widely separated at the time of deposition. However that may be, the beds in the vicinity of the Cretaceous-Tertiary boundary are quite similar (Fig. 2).

The uppermost Maastrichtian consists of some 75 meters of reddish purple to greenish gray marlstone "Purple Marls" belonging to the zone of Abathomphalus mayaroensis (Herm, 1965). The Danian consists primarily of the fine-grained "Danian Limestones," in which all of the standard Danian foraminiferal zones are represented (v. Hillebrandt, 1965). The basal 25 cm of these limestones is gray and contains interbeds of sandy limestone. The succeeeding 335 cm at Punta de San Telmo (295 cm at Rio Urola) are likewise gray, and above this the limestones are pink to red, though greenish shales and limestones reappear as interbeds near the top. These limestones are lithified coccolith-globigerinid oozes (Fischer, Honjo and Garrison, 1967). The limestones--particularly the red ones--form planar units in the cm-range, separated by cm-thick interbeds of marl or shale. The limestones are homogeneous and burrow-mottled, and Spirophyton occurs throughout the sequence. A few beds contain fragments of shells, and rare spatangoid echinoids have been noted. Between the Purple Marls and the Danian Limestones lies a gray calcareous shale, here termed the Boundary Shale, 25 cm thick at Punta de San Telmo, and 38 cm thick in the Rio Urola section. The basal portion of this shale is highly pyritic. This shale contains the boundary between the Cretaceous and the Paleocene biotas--foraminifera as well as coccolithophyceans--and corresponds essentially to the biotic crisis.

Foraminiferal zonation. Pelagic foraminifera are abundant through this sequence and were used by Herm (1964) and v. Hillebrandt (1965) for its zonation and correlation. Standard foraminiferal zones and v. Hillebrandt's zonal

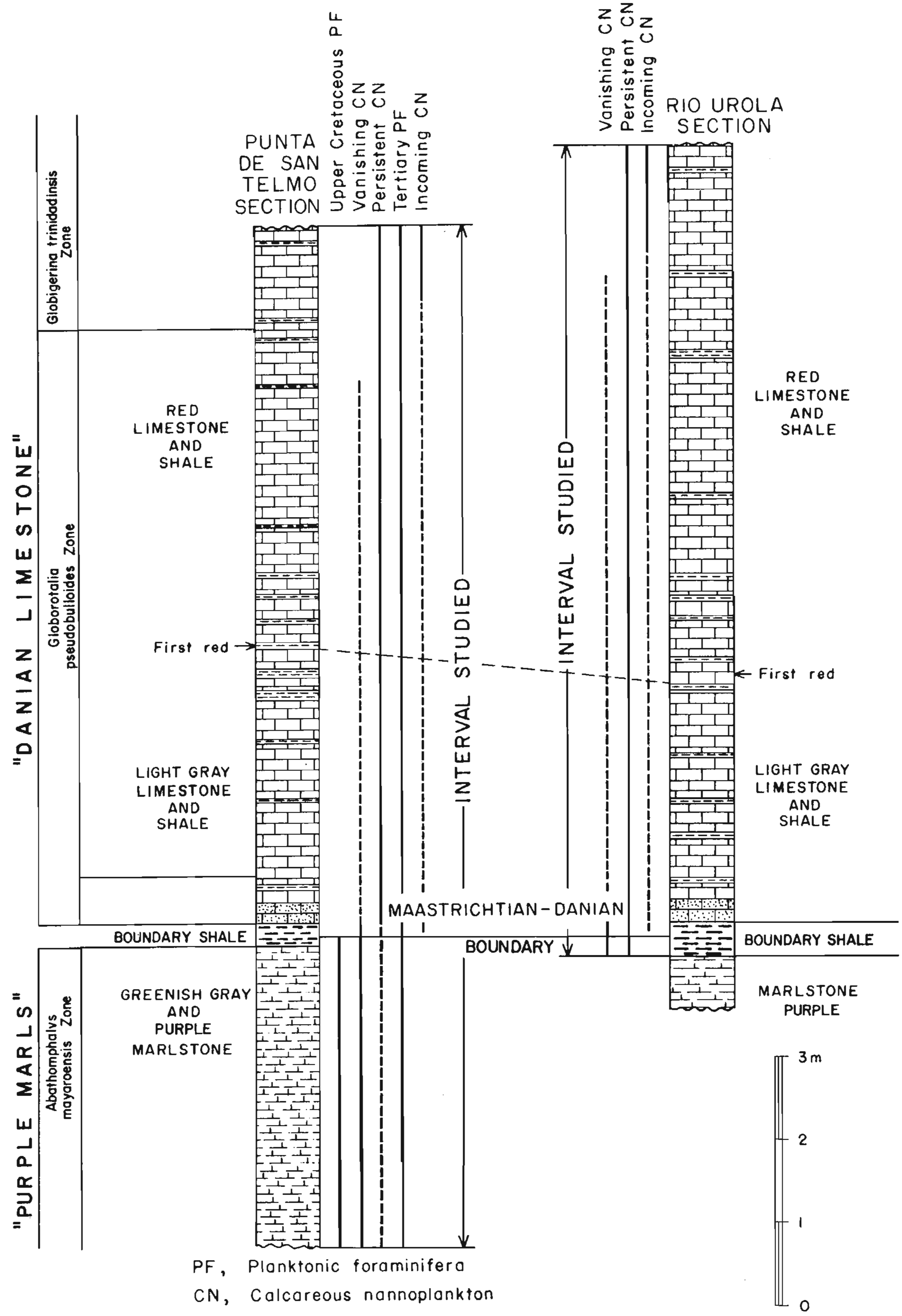

FIGURE 2 General distribution of planktonic Foraminifera and calcareous nannoplankton at the Punta de San Telmo and Rio Urola Sections (Planktonic Foraminifera data from Herm, 1965 and Hillebrandt, 1965)

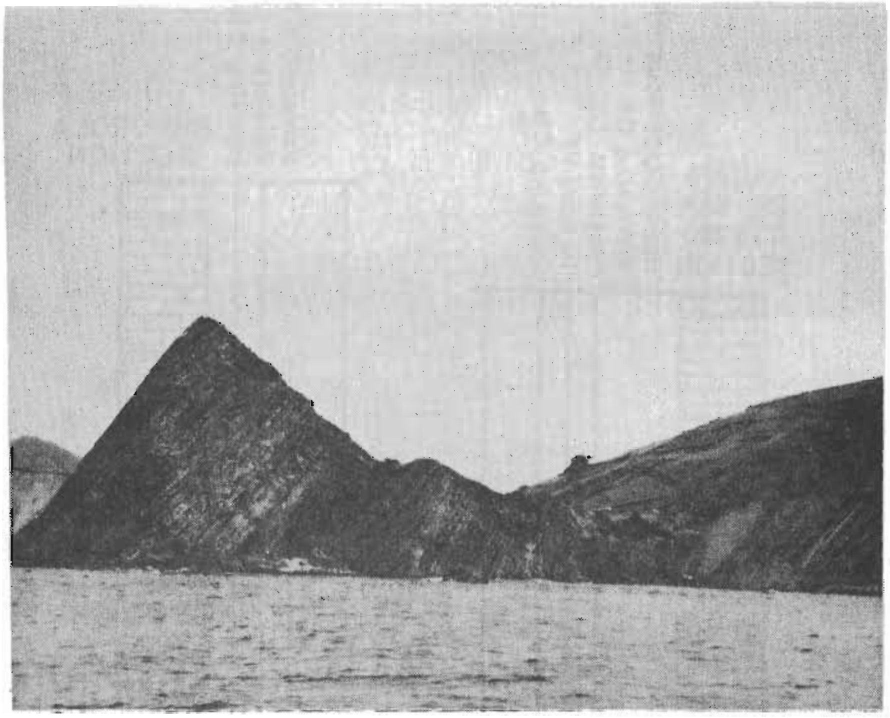

Figure 3. Maastrichtian-Danian beds exposed at the Punta de San Telmo section. Boundary is at left of photograph.

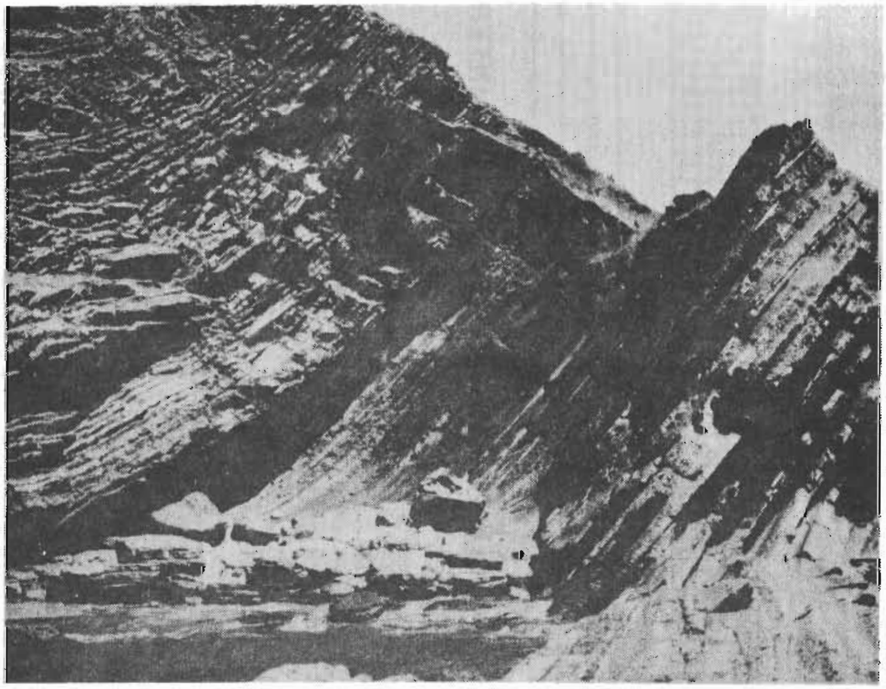

Figure 4. Close-up of the Maastrichtian-Danian boundary at the Punta de San Telmo section. Base of overhang to left marks the top of the Boundary Shale.

terminology are shown in Fig. 5. The Purple Marlstones (plus some 70 meters of gray flysch underlying them) belong to the latest Maastrichtian zone, that of Abathomphalus mayaroensis. The lower 7 meters of the limestones belongs to the lower Danian zone of Globorotalia pseudobulloides (termed by v. Hillebrandt the Globigerina edita subzone), and the succeeding limestone beds to the zone of Globorotalia trinidadensis.

Neither Herm nor v. Hillebrandt recognized the zone of Globigerina eugubina, which had been established by Luterbacher and Premoli Silva (1964) in the section at Gubbio in the Umbrian Appennines, and which has since then been found in distant parts of the world. v. Hillebrandt, however, suggested that it might correspond to the lowest of the limestones.

Subsequent work, as yet unpublished, has yielded a slightly different result. Allen (1975) found the globotruncanids of the Abathomphalus mayaroensis zone to extend into the lower 10 cm of the boundary shale, but to end there, and found the upper two cm of that shale to contain only tiny globigerinids (possibly Globigerina eugubina) and Woodringina cf. hornerstownensis. Premoli Silva, who examined our samples of the boundary shale, failed to find Globigerina eugubina, but also identified Woodringina hornerstownensis. On the basis of these observations, we draw the top of the A. mayaroensis zone 10 cm above the base of the boundary shale, and assign the upper 15 cms of that shale, in the Punta de San Telmo section, to the zone of G. eugubina. Accordingly, we draw the Cretaceous-Tertiary boundary in the middle of the 25-cm shale unit.

The sections at Zumaya thus appear to represent essentially continuous deposition through latest Cretaceous and earliest Paleogene time.

Depositional setting. The Cretaceous-Tertiary sequence of which the Zumaya section is a part, is a flysch representing mainly the floor of a deep trough, fed by turbidity currents. The scarcity or absence of aragonitic fossils (ammonites) but the preservation of calcitic fossils (foraminifera, coccoliths, inoceramids) shows the Maastrichtian sea floor to have lain below the aragonite compensation depth and above the calcite compensation depth. The general scarcity of benthics other than burrowers and total absence of calcareous algae, miliolids, and larger foraminifera (excepting in turbidites) also indicated deposition below the photic zone.

In the latest Maastrichtian--sometime during Abathomphalus mayaroensis time--turbidity currents became excluded from the area under consideration. We suspect that tectonic movements raised these bottoms out of the "abyssal plain" floor of the trough, incorporating them into a part of the basin flank that was not swept by these currents. Yet depositional rates remained high; if we assign a duration of 1.8 m.y. to the A. mayaroensis zone, then the mean depositional rate (compacted) for the 145 meters of beds assigned to that zone is 80 bubnoff units (m/million years), and while the Purple Marlstones which comprise the upper half of the zone were presumably deposited more slowly than the flysch beds of the lower half, still they cannot very well have been deposited at rates below 40 b. Their general character--a predominance of terrigenous clay and silt, with an admixture of coccoliths, pelagic foraminifera, and a few percent of sand--suggests hemipelagic deposits of a basin flank or continental margin. The megafauna--large Spreiten burrows of Spirophyton--seem to fit the same setting.

Shortly after the beginning of Paleocene time, the depositional setting changed again, to one in which terrigenous detritus was largely excluded (excepting for the very fine "red clay" fraction). Pelagic carbonate deposition came to predominate, forming oozes of coccoliths and a variable admixture of planktonic foraminifera (Fischer, Honjo and Garrison, 1967). Spirophyton continued to flourish. Crime's (1973) concept of these beds (which he termed

SYSTEM/STAGE	Stainforth and others (1975)	Hillebrandt (1965) Herm (1965)		Berggren (1969)		
TERTIARY DANIAN	*Globorotalia trinidadensis* Zone	*Globorotalia trinidadensis* - *Globigerina edita* Zone	*Globorotalia trinidadensis* Subzone	P - 1	d	*Globorotalia compressa* /*G. inconstans*/*G. trinidadensis* Zone
	Glorborotalia pseudobulloides		*Globigerina edita* Subzone		c	*Globigerina triloculinoides* Zone
					b	*Globorotalia pseudobulloides* Zone
	Globigerina eugubina Zone		*Globigerina eugubina* Zone ?		a	*Globigerina eugubina* Zone
CRETACEOUS MAASTRICHTIAN	*Abathomphalus mayaroensis* Zone					

Figure 5. Present planktonic foraminiferal zonations.

largely unfossiliferous) as shoalwater limestones reveals a misapprehension of their character and of their position in the middle of (rather than below) a flysch facies.

If we assign to the Globorotalia pseudobulloides zone a time span of one million years, we obtain a depositional rate of about 7 b, a drop by a factor of six. Just why terrigenous detritus did not reach this area during Danian time is not clear, but could have been occasioned either by a change in general influx patterns of terrigenous material into the basin as a whole, or by local tectonism that isolated this particular part of the basin flank, possibly by raising it above the path of sediment transport. Whatever the cause, this interlude was temporary. In the mid-Paleocene the setting reverted to a hemipelagic state, in the Eocene to typical flysch conditions. The accumulation of thick Eocene sediments and the subsequent orogeny converted the underlying carbonate oozes and marls into limestones and marlstones.

METHODS

Sampling. The Punta de San Telmo and Rio Urola sections (Figs. 2,4) were measured in the field to the nearest half centimeter. 67 levels were sampled in the Punta de San Telmo section, and 56 in the Rio Urola section. For purposes of final tallies and of visualization, samples within a given 10 cm interval were averaged (Figs. 6, 7) and all samples, though normally only embracing a few cms of stratigraphic section, were plotted as if they represented a 10 cm interval.

Whenever possible soft shales were sampled in preference to the well indurated shales or limestones. However, in some intervals, especially near the base of the Danian, indurated limestones and hard shales were the only rocks available.

Processing. Samples about one cubic cm in size were gound wet by mortar and pestle and concentrated, using the technique described by Gartner (1968). The sample is placed in a beaker with about 2 cms of distilled water, thoroughly agitated, and allowed to settle for two minutes. The material left in suspension, which contains nearly all of the coccoliths, is then decanted into another beaker. More water is added to bring the depth up to 2 cms and then agitated thoroughly. The liquid is allowed to stand for fifteen minutes, a sufficient time to allow the coccoliths to sink. The water which now contains only clay matter is then decanted. This process is continued until the water above the residue is clear. Smear slides are then made of this residue. The samples are prepared as permanent mounts of Caedex.

Identification and counts. Although electron microscopes are now essential in the description and detailed morphologic study of coccoliths, a high quality optical microscope equipped with facilities for cross polarization and phase contrast microscopy is adequate for recognition of most well described species. Optical microscopy was therefore chosen as the simplest and most efficient means of determining the abundances and precise stratigraphic distribution of a finite number of well established species. Papers used frequently were those by Stradner (1963), Bramlette and Martini (1964), Reinhardt (1966), Hay and Mohler (1967), Gartner (1968), and Perch-Nielsen (1968, 1969 a, 1969 b).

All 123 samples were prepared in this fashion, and their coccolith content identified insofar as possible. In order to obtain a quantitative basis for comparison, 300 specimens were identified from each slide (excepting those in which coccoliths were too scarce). 41 species were recognized in all, and their distribution is shown in Figs. 6 and 7. Contrary to common practice in coccolith stratigraphy, rare occurrences (which might be due to contamination or to reworking) were not ignored, and special precautions (scraping of the

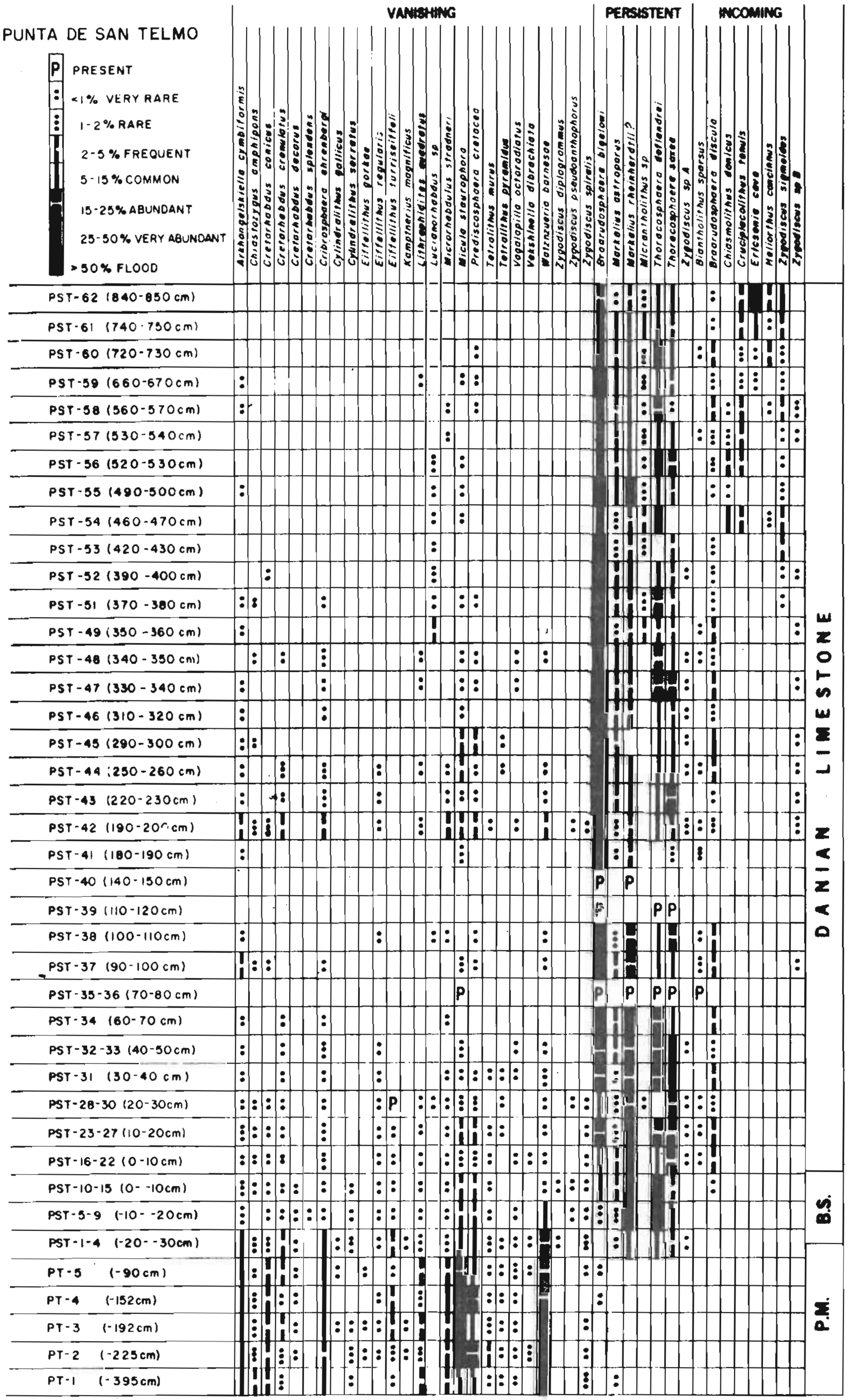

Figure 6. Distribution and frequency of calcareous nannoplankton at the Punta de San Telmo section.

P. M. = Purple Marls;
B.S. = Boundary Shale.

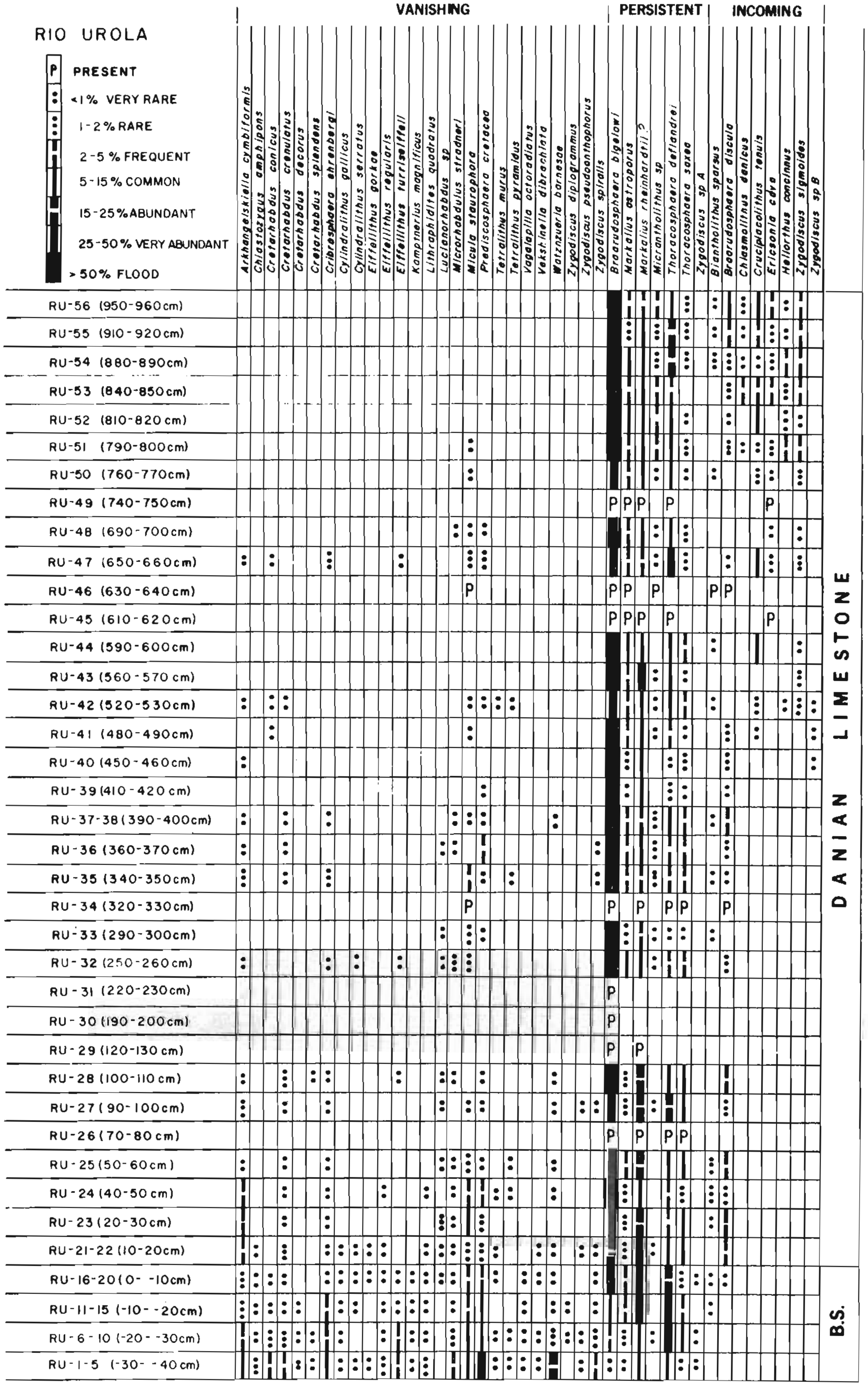

Figure 7. Distribution and frequency of calcareous nannoplankton in the Rio Urola section.

B.S. = Boundary Shale.

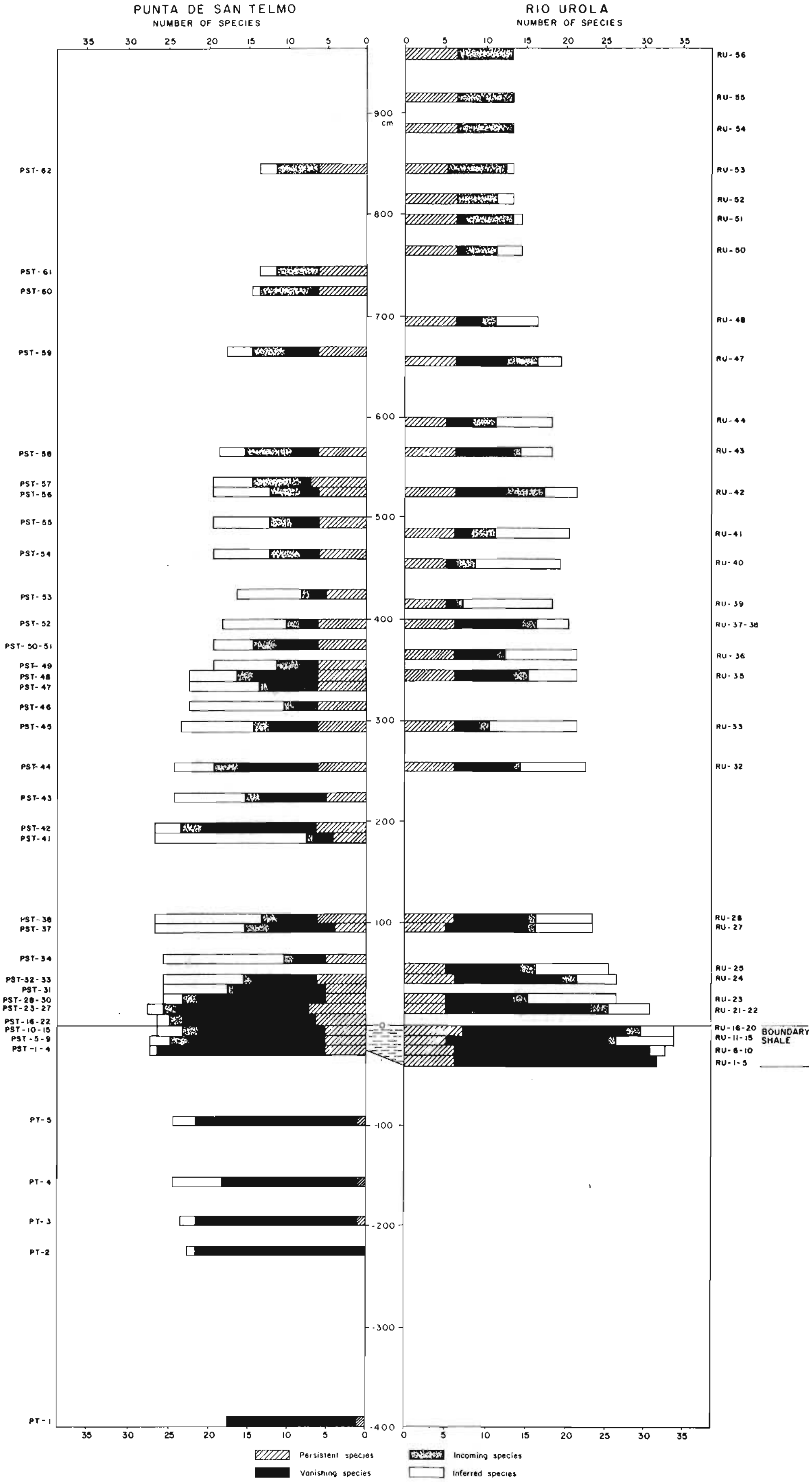

Figure 8. Numbers of calcareous nannoplankton species observed and inferred in the Punta de San Telmo and Rio Urola sections.

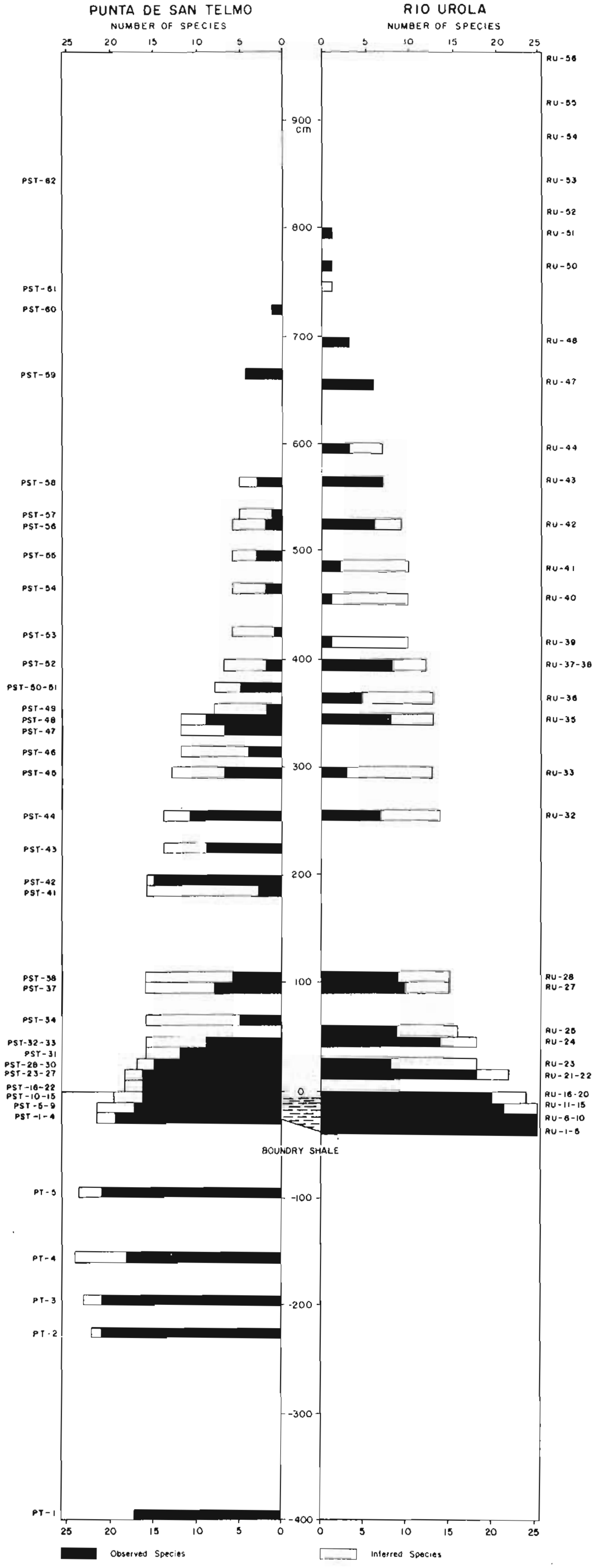

Figure 9 Total Numbers of vanishing species observed and inferred in the Punta de San Telmo and Rio Urola sections.

B.S. = Boundry Shale

original rock samples, acid washing of all preparatory equipment) were taken in order to minimize the dangers of contamination. The object was to assemble an objective record of nannoplankton distribution, and we believe Figs. 6 and 7 to be that.

A few samples yielded only a few, poorly preserved specimens, and for these samples a *P* is entered for the appropriate taxa in Figs. 6 and 7. The great majority of samples yielded long counts of species, and abundance of their species is plotted in terms of seven classes: 1%, very rare; 1-2%, rare; 2-5%, frequent; 5-15%, common; 15-25%, abundant; 25-50%, very abundant; and 50%, floods.

THE NANNOPLANKTON

Groups of species. 41 species were recognized in the course of this investigation, each of them occurring in both sections. The distribution of these species is plotted in Figs. 6 and 7, in 10 cm intervals. The individual species are discussed in an appendix which provides a partial synonymy and notes on occurrence elsewhere. Here we shall be concerned with distribution patterns in the Zumaya sequence, and toward that end we recognize three distinct groups of species, which we term the vanishing species, persistent species, and incoming species.

Vanishing species. The 26 species plotted on the left side of Figs. 6 and 7 are normally regarded as typical of the Cretaceous. In fact, they have been variously reported from basal Cenozoic beds as well, and in the Zumaya sequence various species of this group make sporadic occurrences through the basal 8 meters of the Danian limestones, as shown in Figs. 8, 9, and 14D. The number of species dwindles progressively, and none have been observed above the 800 cm level. Thus, from what has been observed here and elsewhere, it may be concluded that these species became extinct at some time during the roughly one million year time interval here considered. Considerably more information accrues when not only the occurrence of these species but also their abundance is taken into consideration; as shown in Figs. 12 and 14G, this species group dominates the entire flora, almost exclusively, throughout the Purple Marls and in the base of the Boundary Shale, and then drops abruptly to a few percent, with a minor resurgence at 200 cm.

The question that arises is whether any of these species survived beyond the Maastrichtian, whether their sporadic occurrences in later sediments are evidence of short and marginal survival beyond that time or are due to resedimentation of Cretaceous oozes. Most nannoplankton workers have chosen the alternative of reworking, while Worsley (1974) has suggested that *Microrhabdus stradneri*, *Praediscosphaera cretacea*, *Cretarhabdus conicus*, *Eiffellithus regularis* and *Arkhangelskiella cymbiformis*, present in the Danian sediments at the Braggs section in Alabama, survived the crisis for a limited time.

We cannot settle this question with the evidence at hand. However, the observations that the sequence of occurrence in the Danian seems quite irregular, together with Premoli Silva's impression that reworking of foraminifera is not uncommon in this sequence (pers. comm.), and the general likelihood of resedimentation in flysch-type settings, makes reworking seem the more plausible explanation. The matter of reworking is again taken up in the section on limitations.

Persistent species. The six species plotted in the middle of Figs. 6 and 7, in the middle of Fig. 8, and separately in Figs. 10 and 14E are segregated as persistent species. They have all been reported from Cretaceous sediments elsewhere (some only from the Maastrichtian, others from beds as old as Jurassic), and they all persist beyond the interval studied here. *Braarudosphaera bigelowi*--

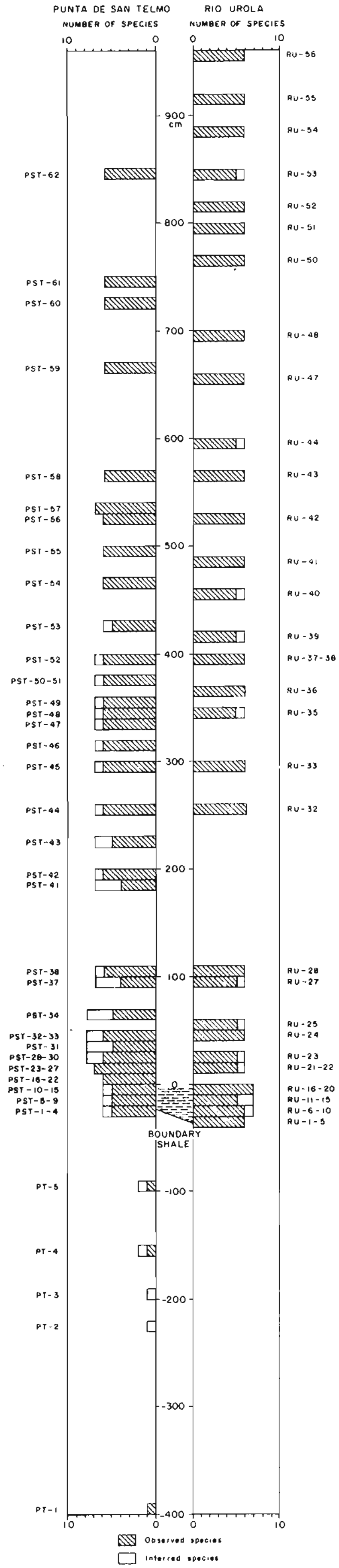

Figure 10. Numbers of persistent species of calcareous nannoplankton observed and inferred in the Punta de San Telmo and Rio Urola sections.

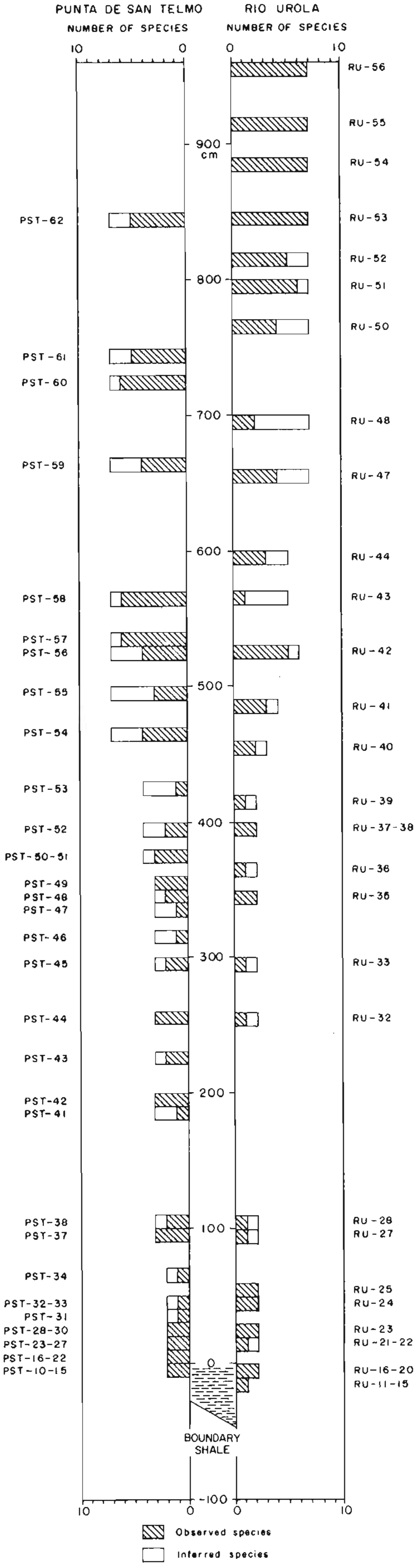

Figure 11. Numbers of incoming species of calcareous nannoplankton observed and inferred in the Punta de San Telmo and Rio Urola sections.

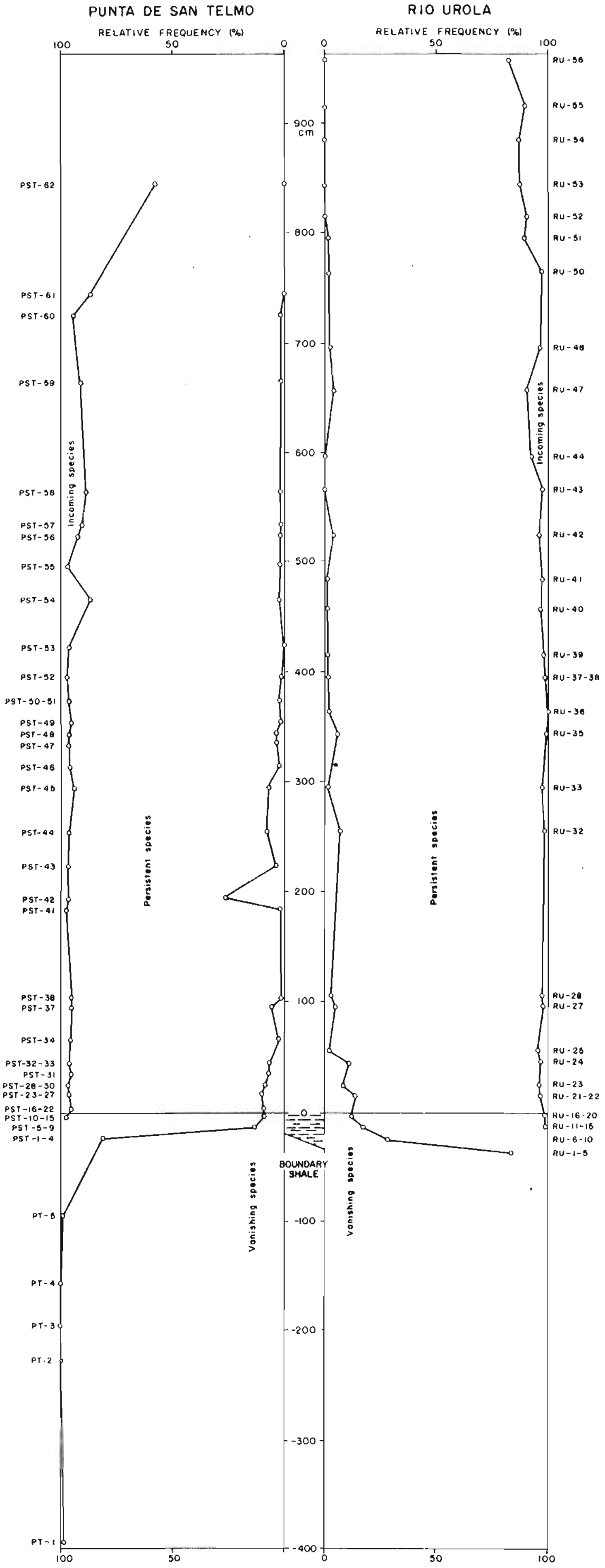

FIGURE 12 Percentage frequency of Vanishing, Persistent, and Incoming species at the Punta de San Telmo and Rio Urola Sections.

the most abundant of them in our sections--ranges from the late Jurassic to the present, and is the most long-lived coccolithophorid taxon known. A majority of these species (Braarudosphaera spp., Thoracosphaera spp.) build strangely massive coccospherss (Fischer, Honjo and Garrison, 1967) that seem more like protective cysts designed to sink and rest on the bottom than like the skeletons of motile phases in the coccolithophore life cycle. Also, Braarudosphaera seems to be generally lacking in normal marine coccolithophycean assemblages, and has been found today mainly in brackish bays. Fischer and Arthur (in press) have called attention to its blooms at what they believe to have been various times of biotic crisis.

The persistent species make sporadic and very rare appearances in the Purple Marls, until thoracospheres appear in somewhat greater abundance immediately below the Boundary Shale. Within the Boundary Shale, they suddenly displace the vanishing species as the dominant floral element, and maintain a dominant position throughout the interval here studied. However, as shown in Fig. 12, they begin to give way to the third species group, the incoming species, above the 700 or 800 cm level.

Incoming species. The nine species plotted at the right side of Figs. 6 and 7, and separately in Figs. 11 and 14F, are species reported to date from the Paleocene only. In the Zumaya sections, also, they make their appearance above the Maastrichtian-Danian boundary, and most of them range beyond the time interval studied here. Three appear in the Boundary Shale, and the rest come in at various higher levels. This group of species represents the root of the flourishing coccolithophorid floras that characterize the later parts of the Paleocene and Eocene. During the time interval here studied, however, they are not only limited in diversity but also in abundance: As shown in Fig. 12, they make up a very small percentage of the specimens in most samples, and become abundant only above the 7m level at the Punta de San Telmo, and above the 8 m level in the Rio Urola section.

Nannoplankton zones. The conventional nannoplankton zonation of the late Maastrichtian and early Paleocene is shown in Fig. 13. The time interval here considered is normally assigned to three zones: The Maastrichtian zone of Tetralithus murus, and the Danian zones of Markalius astroporus and Cruciplacolithus tenuis.

The assemblage zone of Tetralithus murus is essentially that of our vanishing species. Considering the absolute occurrence of species only, this zone cannot be differentiated from the Markalius astroporus zone in the Zumaya sections. By considering abundances, however, as shown in Fig. 12, the top of the T. murus zone can be drawn in the middle of the boundary shale, precisely at the level at which the globotruncanids disappear, and at which the persistent nannoplankton species assume dominance. The the beds between -12 cm and 460 cm come to represent the Markalius astroporus zone. At 460 cm, round about the middle of the foraminiferal zone of Globorotalia pseudobulloides, the appearance of Cruciplacolithus tenuis defines the base of the zone named for it.

LIMITATIONS OF DATA

So far we have presented mainly the facts relating to the stratigraphic distribution of calcareous nannoplankton taxa. Before going on to interpret these as a history of floral change, we must reflect on the limitations and distortions which are inherent in the fossil record, and those which may be introduced in the course of study.

Fossil versus living taxa. The term calcareous nannoplankton is used in paleontology for minute calcitic plates common in pelagic carbonate sediments,

<table>
<tr><th></th><th>BUKRY (1971)</th><th>MARTINI (1971)</th><th>STAINFORTH AND OTHERS (1975)</th><th>HAY & MOHLER (1969)</th></tr>
<tr><td rowspan="11">PALEOCENE</td><td>Heliolithus kleinpellli Zone</td><td>NP-8 Heliolithus kleinpelli Zone</td><td rowspan="4">Globorotalia pusila pusila Zone</td><td rowspan="2">Fasciculithus tympaniformis Zone</td></tr>
<tr><td rowspan="2">Fascicultihus tympaniformis Zone</td><td rowspan="2">NP-5 Fasciculithus tympaniformis Zone</td></tr>
<tr><td rowspan="5">Cruciplacolithus tenuis Zone</td></tr>
<tr><td rowspan="8">Cruciplacolithus tenuis Zone</td><td rowspan="3">NP-4 Ellipsolithus macellus Zone</td></tr>
<tr><td>Globorotalia angulata Zone</td></tr>
<tr><td rowspan="2">Globorotalia trinidadensis Zone</td></tr>
<tr><td rowspan="2">NP-3 Chiasmolithus danicus Zone</td></tr>
<tr><td rowspan="3">Globorotalia pseudobulloides Zone</td><td rowspan="4">Markalius astroporus Zone</td></tr>
<tr><td>NP-2 Cruciplacolithus tenuis Zone</td></tr>
<tr><td rowspan="2">NP-1 Markalius inversus Zone</td></tr>
<tr><td>Globigerina eugubina Zone</td></tr>
<tr><td>MAASTR-ICTIAN</td><td>Micula mura Zone</td><td>Tetralithus murus/ Nephrolithus frequens Zone</td><td>Abathomphalus mayaroensis Zone</td><td></td></tr>
</table>

Figure 13. Calcareous nannoplankton zonations of the Paleocene-Maastrichtian and their correlation with the Paleogene planktonic foraminifera zonation.

but also found in shoalwater deposits. Many of these plates, termed coccoliths and rhabdoliths, are of the general sort which is produced in present-day oceans by a certain class of flagellated algae, the Coccolithophyceae. Included in the general term calcareous nannoplankton are other sorts of plates, such as discoasters, which are quite unlike anything being formed by living organisms, and which may or may not have been produced by coccolithophyceans. However that may be, the living coccolithophyceans give us a basis for comparison, and this shows that fossil and living species are not comparable units.

In the first place, a given cell of a coccolithophycean may have an armor made up of several different kinds of plates (coccoliths). Secondly, living coccolithophyceans have complicated life cycles, in which motile stages alternate with non-motile ones--and these different stages bear distinctive kinds of coccoliths (Parke and Adams, 1960). Yet in the fossil record, in which the plates of a given cell are normally scattered, each kind of plate is given a specific name of its own. The outcome of this is that fossil nannoplankton floras may yield a number of apparent species which is greater than the number of biological species which produced them. Thus, the relative abundance and the diversity of fossil nannoplankton floras cannot be directly compared to diversity patterns in living floras.

Differential solution. Only the upper few hundred meters of present day ocean waters are saturated with respect to calcite; below this level calcareous skeletons tend to be dissolved. The extent of solution depends on the undersaturation of the waters, on the nature of the skeletal particle (size, solubility, protection by organic membranes) and by the length of time for which a given particle is exposed to the circulating waters of the sea before being buried. Various studies of planktonic foraminifera by Berger (1967, 1968, 1970) have shown that solution and preservation can behighly selective.

The same process has been shown to operate on coccoliths by McIntyre and McIntyre (1971), Bukry (1971), Berger (1973), Adelseck and others (1973), and Schneidermann (1973). This process will tend to reduce the apparent diversity of the flora by selective elimination of the more soluble forms.

Reworking. The resedimentation of older sediment and fossils into younger deposits is one of the paleontologist's problems, and one that becomes particularly serious in this case, for two reasons: 1) due to their small size, toughness and resistance to diagenetic alteration, fossil coccoliths are particularly subject to erosion and resedimentation. 2) The problem becomes aggravated when one is trying to carry out a microstratigraphy of the sort attempted here, in which the local shuffling of a few feet of sediment, by a minor landslip or a storm, can introduce serious errors. The occurrence of Cretaceous coccoliths in Recent sediments of the English Channel is easily recognized as a case of reworking, but who is to know whether the last occurrence of a given species in a continuously deposited sequence of sediment records its true time of disappearance from the living flora, or a case of local resedimentation, succeeding the actual extinction of the species by thousands or even millions of years? The relative state of preservation or color, commonly useful in recognizing reworked megafossils, is rarely applicable to nannoplankton, and relative abundance as well as sporadic occurrence remain the most useful criteria--but criteria which are never sure. We have already broached this problem in connection with the continued recurrence of the vanishing species--generally considered as Cretaceous forms--in the Danian limestone sequence.

Burrow-mixing. A special case of reworking, to which the slowly deposited pelagic sediments are particularly susceptible, is that of burrow-mixing or bioturbation. Most of the limestones in the Danian, for example, have become quite thoroughly stirred by random burrowers of the cut-and-fill variety. The problem of burrow-mixing in sediments of this type has been discussed at some length by Arthur and Fischer (in press). Random burrowers have probably blended most of the sediments of the section here studied to the nearest 10 cm, though the sharp contacts of the Boundary Shale and the notable changes in the biota within it show that such mixing is not universal. Locally, Spirophyton burrows have introduced younger sediment more deeply into older beds.

Biases in preparation. Finally, we must concede that sampling is always imperfect, that contamination can occur despite such precautions as washing of preparatory equipment with acid, and that preparatory methods as grinding may leave some taxa more recognizable than others.

Bearing on the Zumaya study. While a paleontological study of this sort does not yield floristic data comparable to those based on millipore-filter samples of a living population, it should yield data that are internally comparable and consistent. Utmost care was taken to avoid contamination. Burrow-mixing is likely to limit the resolving power of microstratigraphy to something on the order of one or several tens of thousands of years. That may seem crude to the ecologist studying current changes in living communities, but it is detailed from the standpoint of a paleontologist whose normal time resolution is one of millions. Besides, burrow-mixing seems to have been minor at the very time of the crisis.

The problem of more extensive reworking has been discussed. We have no definite answer to the continued rare occurrence of Maastrichtian species in Danian rocks, but suggest that reworking is a likely cause. That differential solution is not the cause of the general change observed at Zumaya is shown by the fact that these general changes are world-wide (see discussion of individual taxa in appendix). The scarcity of calcareous nannoplankton in certain samples may indeed be due to times of excessive dissolution on the sea floor; such intervals as those at 70-80 cm, 110-120 cm and 140-150 cm at Punta de San Telmo, and 70-80 cm, 120-130 cm, 190-200 cm, 220-230 cm, 320-330 cm and 610-620 cm, 630-640cm and 740-750 cm in the Rio Urola section may be explained by such a cause; alternatively they may be due to subsequent pressure solution under load or under tectonic stress. We conclude, therefore, that these limiting factors limit but do not invalidate the biological interpretation of the data.

INTERPRETATION

The history of a million years, plus or minus, from shortly before the Cretaceous-Tertiary crisis into early Danian time, seems to show five phases of floral development, as follows:

Phase 1, normal late Maastrichtian Tetralithus murus flora. This is a diverse flora showing little dominance, and containing few or no representatives of the long-ranging species that came to make up the succeeding group. According to Herm, planktonic foraminifera were growing smaller (Fig. 14C), globotruncanid species were becoming extinct (Fig. 14B), and the ratio of globigerinids to benthonic foraminifera was changing in favor of the latter (Fig. 14A), while the Tetralithus murus flora was still flourishing (Figs. 14D, G).

Phase 2, entrance of disaster species. In phase 2, commencing in the last few centimeters of the Purple Marls, and continuing through the lower half of the Boundary Shale, we find a mixture of the Tetralithus murus flora and the species of the persistant type.

In theory, the mixture could be due to burrow-mixing, but this seems unlikely in view of the fact that it crosses a sharp lithic boundary. We have discussed the peculiar morphology of the majority of the species,above, and have pointed out that the most common one, Braarudosphaera bigelowi, is today not a normal member of the open-sea biota, but flourishes in bays in various

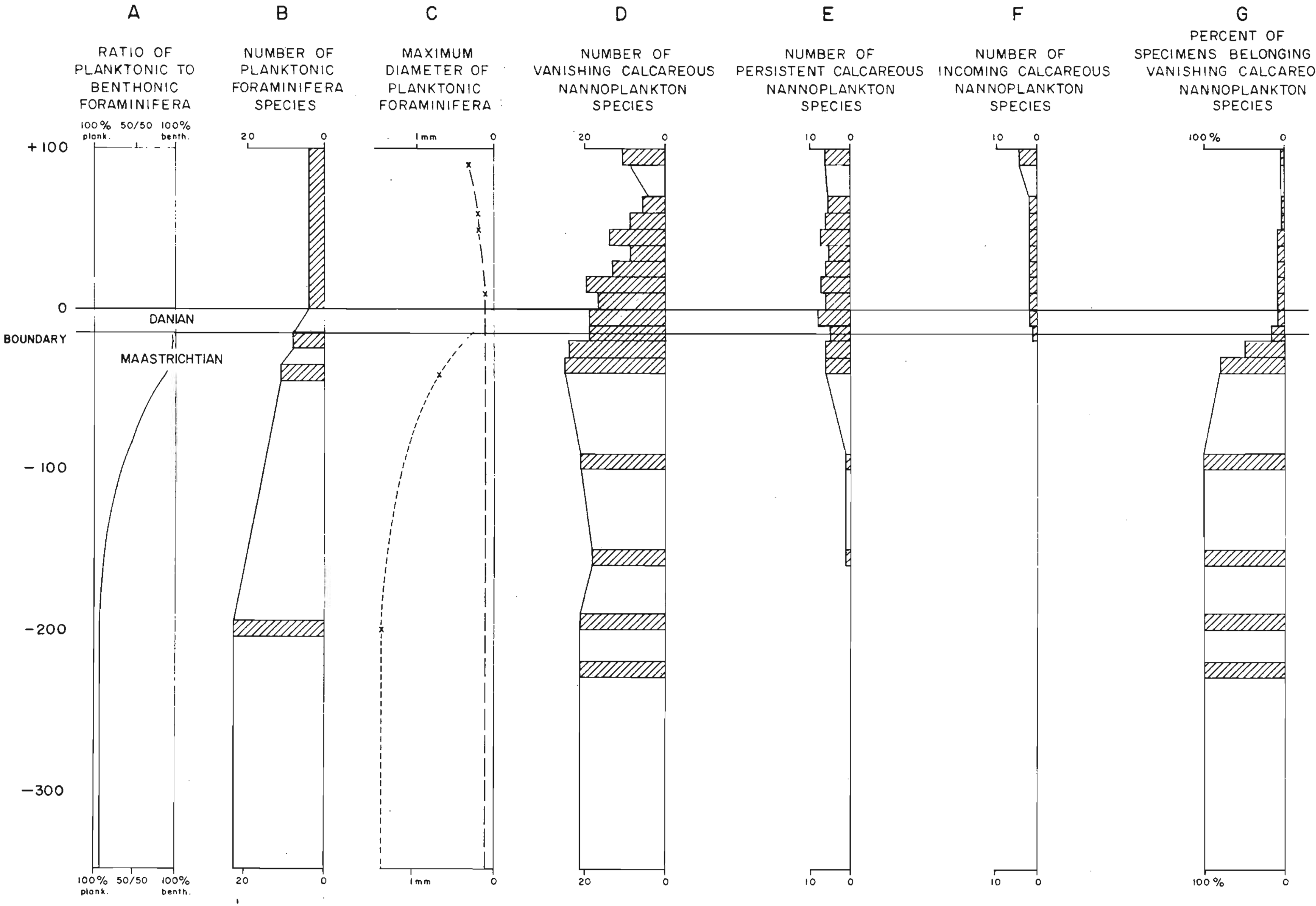

Figure 14. Summary of distribution of planktonic foraminifera and calcareous nannoplankton at the San Telmo and Rio Urola sections. (A, B, and C modified after Herm, 1965, and v. Hillebrandt, 1965).

parts of the world. We advance two possible alternatives for the ecology of the persistent species.

One is that the persistent species are opportunists in the sense of Mac Arthur (1955) and of Levinton (1970): generalistic species, able to make a living under harsh and variable environments but excluded from the more stable habitats by more efficient specialists. In that case, their sudden appearance amidst the normal biota suggests that the environment had become sufficiently unstable to exclude the specialists at least temporarily, and to allow these opportunists to bloom.

The second possibility is that some of these persistent species--specifically the braarudospheres and thoracospheres--are not normal motile stages but cysts developed under times of ecological stress. In this case, too, their appearance indicates that the environment was undergoing changes. Their appearance coincides, according to Herm, with the complete inversion of the ratio of planktonic to benthonic foraminifera, and with the disappearance of the globotruncanids, but we have found globotruncanids to be still present in fair numbers in the basal part of the Boundary Shale (Allen, 1975).

Third phase, disaster forms dominant. In the third phase, beginning in the middle of the Boundary Shale, the persistent species assumed dominance. The vanishing species of the Cretaceous dwindled to a trickle of individuals that may represent either marginal survival or, more likely, reworking after the species had become extinct. The first elements of the group of incoming species made their appearance, as rare forms, one by one. This phase lasted through about six meters of sediment, presumably nearly a million years.

Fourth phase, emergence of a new flora. In the fourth phase of development, following the appearance of _Cruciplacolithus tenuis_, the incoming species expanded at the expense of the persistent forms, but had not yet reached an abundance of 50% at the top of the interval here investigated.

This pattern suggests to us that stresses felt by the foraminifera, but not reflected in the coccolithophycean flora, began some ten thousand years before the end of Maastrichtian time, and turned more severe a few thousand years before that magic time line, admitting the first waves of disaster forms--the opportunistic or cyst-producing "persistent species". Then the full crisis developed, leading to extinction of the globotruncanids, dominance of benthonic forms in the foraminiferal faunas, and the virtual or more likely complete extermination of the "vanishing species" of nannoplankton. New species of nannoplankton evolved, but their rarity and gradual appearance suggests to us that the environmental conditions that brought about the biotic crisis at the end of Maastrichtian time did not abate rapidly, but continued to hold the nannoplankton biota severely in check for nearly a million years, and had not fully relented at the end of the time span covered by this study.

This, in turn, suggests that the cause of the crisis is not to be sought in some very transitory event such as the explosion of a supernova, but in some more subtle but long-lasting modification of the biosphere.

Much remains to be learned, at Zumaya and in any other sedimentary sequence that spans the Cretaceous-Tertiary boundary. The distinction of the Boundary Shale, which essentially coincides with the biotic crisis, from the overlying and underlying beds may afford significant clues to that historical event--but clues which we have not unravelled. It seems noteworthy that the Fish Clay, which occupies a similar position in Denmark, also has a pyritic base. Further, the clay which occupies the boundary position at Gubbio in the Italian (Umbrian) Appennines has a reduced base, and beneath it the latest of the pink Maastrichtian limestone beds has had its upper part bleached. These observations, seemingly contradictory to the previous paragraph, suggest that after some environmental deterioration, the main crisis was initiated or accompanied by some fairly drastic physical-chemical event.

APPENDIX

Notes on Species

A complete synonymy of taxa is not given because all forms are well documented in the literature of calcareous nannoplankton. Therefore, only the original work is cited, plus a few of the more recent significant works. No photographs are included in this study because the species are well illustrated in the literature and also because preservation of species is at best fair. The authors have used an alphabetical listing of species rather than separating species into family and order groups, since these groups are completely artificial.

Genus ARKHANGELSKIELLA Vekshina, 1959
Arkhangelskiella cymbiformis Vekshina

"Coccoliths of uncertain affinity," ARKHANGELSKY, 1912, pl. 6, fig. 24. Arkhangelskiella cymbiformis VEKSHINA, 1959, p. 66, pl. 2, fig. 3. ________ BRAMLETTE & MARTINI, 1964, p. 297, pl. 1, figs. 3-9. ________ GARTNER, 1968, p. 38, pl. 1, figs. 1-6; pl. 4, figs. 1-4; pl. 6, fig. 1. ________ PERCH-NIELSEN, 1968, p. 57, text-figs. 24-25, pl. 19, figs. 1-2; pl. 20, figs. 3-8.

Occurrences. Reported from the Late Cenomanian to Maastrichtian. It has been found in the Maastrichtian of Holland, Denmark, France, Alabama, Arkansas, and Texas. Worsley (1974) recorded this species as in situ in the Lower Danian of Alabama. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the upper part of the Danian Globorotalia pseudobulloides zone, but the range into the Danian may represent reworking.

Genus BIANTHOLITHUS Bramlette & Martini, 1964
Biantholithus sparsus Bramlette & Martini

Biantholithus sparsus BRAMLETTE & MARTINI, 1964, p. 305, pl. 4, figs. 21-25. ________ HAY & MOHLER, 1967, p. 1535. ________ PERCH-NIELSEN, 1969 b, p. 56, pl. 6, figs. 1-2; pl. 7, figs. 3-10.

Occurrences: Reported from the Danian of Denmark, France, and Alabama. In the Zumaya sections, it has been observed from the Danian portion of the Boundary Shale to the top of the sections studied. The extinction level of this species is younger than the studied sections.

Genus BRAARUDOSPHAERA Deflandre, 1947
Braarudosphaera bigelowi (Gran & Braarud)

Pontosphaera bigelowi GRAN & BRAARUD, 1935, p. 338, fig. 67. Braarudosphaera bigelowi (Gran & Braarud), DEFLANDRE, 1947, p. 439, text-figs. 1-5. ________ HAY & MOHLER, 1967, p. 1535, pl. 202, figs. 12, 16, 20.

Occurrences: Reported from sediments ranging in age from Jurassic to Recent. It has been found in the Maastrichtian of Holland, Denmark, Tunisia, and Alabama; also, from the Danian of Denmark, Tunisia, Alabama, and France. In the Zumaya section, it has been found from the Upper Maastrichtian to the top of the sections studied.

Braarudosphaera discula Bramlette & Riedel

Braarudosphaera discula BRAMLETTE & REIDEL, 1954, p. 394, pl. 38, fig. 7. ________ HAY & MOHLER, 1967, p. 1535, pl. 202, figs. 13-15. ________ PERCH-NIELSEN, 1969 b, p. 57, pl. 7, figs. 1-2.

Occurrences: Reported from Paleocene of France; Paleocene, Lower and Middle Eocene of California; and Danian of Denmark. In the Zumaya sections, it has been observed from the Danian portion of the Boundary Shale to the top of the sections studied. The extinction of this species is younger than sections studied.

Genus CHIASMOLITHUS Hay, Mohler & Wade, 1966

Chiasmolithus danicus (Brotzen)

Cribrosphaerella danica BROTZEN, 1959, p. 25, text-fig. 9, 3-6

Coccolithus danicus (Brotzen), BRAMLETTE & MARTINI, 1964, p. 298, pl. 1, figs. 15-16.

Chiasmolithus danicus (Brotzen), HAY & MOHLER, 1967, p. 1526, pl. 196, figs. 16, 21, 22; pl. 198, figs. 8, 12, 13. ________ PERCH-NIELSEN, 1969 a, p. 321, pl. 33, figs. 1-2. ________ PERCH-NIELSEN, 1969 b, p. 58, pl. 1, figs. 1-4; pl. 7, figs. 11-12.

Occurrences: Reported from the Danian of Denmark, Tunisia, France, and Alabama. In the Zumaya sections, it has been observed from the middle part of the Danian *Globorotalia pseudobulloides* Zone to the top of the section studied at Punta de San Telmo section and from the upper part of the Danian *Globorotalia pseudobulloides* Zone to the top of the section at the Rio Urola section. The discrepancy in the ranges between the two Spanish localities may be the result of rarity of specimens. The extinction level of this species is younger than the sections studied.

Genus CHIASTOZYGUS Gartner, 1968

Chiastozygus amphipons (Bramlette & Martini)

Zygodiscus? amphipons BRAMLETTE & MARTINI, 1964, p. 302, pl. 4, figs. 9-10.

Chiastozygus amphipons (Bramlette & Martini), GARTNER, 1968, p. 26, pl. 8, figs. 11-14; pl. 11, fig. 9; pl. 22, figs. 1-11.

Occurrences: Reported from Santonian to Maastrichtian. It has been found in the Maastrichtian of Holland, Denmark, France, Tunisia, Alabama, Arkansas, and Texas. In the Zumaya sections, it has been observed from Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the lower part of the *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range into the Danian may represent reworking.

Genus CRETARHABDUS Bramlette & Martini, 1964

Cretarhabdus conicus Bramlette & Martini

Cretarhabdus conicus BRAMLETTE & MARTINI, 1964, p. 299, pl. 3, figs. 5-8. ________ GARTNER, 1968, (partim) p. 21, pl. 1, fig. 11; pl. 3, fig. 5; pl. 6, fig. 3; pl. 11, fig. 12; pl. 20, fig. 8-9; pl. 22, fig. 20-21. ________ PERCH-NIELSEN, 1968, p. 51, pl. 12, figs. 1-4.

Occurrences: Reported from the Berriasian to Maastrichtian. Found in the Maastrichtian of Denmark, France, Tunisia, Alabama, Arkansas, and Texas. This species has been recorded from Danian of Alabama as *in situ* by Worsley (1974). In the Zumaya sections, it has been found from the Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the upper part of the *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences of this species in the Danian may represent reworking.

Cretarhabdus crenulatus Bramlette & Martini

Cretarhabdus crenulatus BRAMLETTE & MARTINI, 1964, p. 300, pl. 21, figs. 21-24. ________ GARTNER, 1968, (partim) p. 22, pl. 1, fig. 9; pl. 6, fig. 6; pl. 19, fig. 11; pl. 20, figs. 10-11.

Cretarhabdus conicus Bramlette & Martini , GARTNER, 1968, (partim) p. 21, pl. 1, fig. 10; pl. 14, figs. 7-9; pl. 16, figs. 12-14; pl. 17, fig. 10; pl. 25, figs. 3-4.

Polypodorhabdus crenulatus (Bramlette & Martini), PERCH-NIELSEN, 1968, p. 48, fig. 18; pl. 11, figs. 2-5.

Occurrences: Reported from the Berriasian to Maastrichtian. It has been found in the Maastrichtian of Holland, Denmark, France, Tunisia, Alabama, and Arkansas.

In the Zumaya sections, it has been observed from the Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone of the Punta de San Telmo section and from the Upper Maastrichtian to the upper part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Cretarhadbus decorus (Deflandre)

Rhabdolithus decorus DEFLANDRE, in Deflandre & Fert, 1954, p. 159, pl. 13, fig. 4-6; text-fig. 87.
Cretarhabdus decorus (Deflandre), BRAMLETTE & MARTINI, 1964, p. 300, pl. 3, figs. 9-12.
Cretarhabdus? decorus (Deflandre), GARTNER, 1968, p. 22, pl. 4, figs. 15-16; pl. 8, figs. 23-25; pl. 11, figs. 13-14.
Occurrences: Reported from the Campanian of Texas and from the Maastrichtian of Holland, France, Tunisia, Siberia, and Alabama. In the Zumaya sections, it it has been found only in the Upper Maastrichtian.

Cretarhabdus splendens (Deflandre)

Rhabdolithus splendens DEFLANDRE, 1953, p. 1786, figs. 4-6.
Cretarhabdus splendens (Deflandre), BRAMLETTE & MARTINI, 1964, p. 300, pl. 3, figs. 13-16.
Actinozygus splendens (Deflandre), GARTNER, 1968, p. 25, pl. 5, figs. 15-16; pl. 7, figs. 1-2; pl. 10, fig. 1; pl. 11, fig. 15.
Occurrences: Reported from the Campanian of Texas and the Maastrichtian of France, Tunisia, Alabama, Arkansas, and Texas. In the Zumaya sections, it has been observed only from the Upper Maastrichtian at the Punta de San Telmo section and from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences in the Danian may represent reworking.

Genus CRIBROSPHAERA Arkhangelsky, 1912

Cribrosphaera ehrenbergi

Cribrosphaera ehrenbergi ARKHANGELSKY, 1912, p. 412, pl. 6, figs. 19-20.
Discolithina cf. *D. numerosa* (Gorka), BRAMLETTE & MARTINI, 1964, p. 301, pl. 1, figs. 23-24.
Cribrosphaerella ehrenbergi (Arkhangelsky), GARTNER, 1968, p. 40, pl. 1, figs. 14-15; pl. 3, fig. 2; pl. 6, fig. 7; pl. 12, fig. 2; pl. 15, fig. 11.
________ PERCH-NIELSEN, 1968, p. 54, text-fig. 21, pl. 17, figs. 1-8.
Cribrosphaerella linea GARTNER, 1968, p. 40, pl. 1, fig. 16; pl. 3, fig. 4a-d; pl. 11, fig. 16a-c.
Occurrences: Reported from Albian to Maastrichtian and has been found in the Maastrichtian of Denmark, Holland, France, Tunisia, Alabama, Texas and Arkansas. In the Zumaya sections, it has been observed from Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the upper part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Genus CRUCIPLACOLITHUS Hay & Mohler, 1967

Cruciplacolithus tenuis (Stradner)

Heliorthus tenuis STRADNER, 1961, p. 84, text-figs. 64-65.
Coccolithus helis STRADNER, in Gohrbandt et al., 1963, p. 74, pl. 8, fig. 16; pl. 9, figs. 1-2. ________ BRAMLETTE & MARTINI, 1964, (partim) p. 298, pl. 1, figs. 10-12; (non pl. 7, figs. 5-6).
Cruciplacolithus tenuis (Stradner), HAY & MOHLER, 1967, p. 1527, pl. 196, figs. 29-31; pl. 198, figs. 1, 17. ________PERCH-NIELSEN, 1969 b, p. 59, pl. 1, figs. 7-8.

Occurrences: Reported from the Danian of Denmark, Tunisia, Alabama, France, New Zealand, and Austria. In the Zumaya sections, it has been observed from the middle part of the Danian *Globorotalia pseudobulloides* Zone to the top of sections studied. The extinction level of this species is younger than the sections studied.

Genus CYLINDRALITHUS Bramlette & Sullivan, 1961

Cylindralithus gallicus (Stradner)

Coccolithus gallicus STRADNER, 1963, p. 10, pl. 1, figs. 8-8a.
Cylindralithus? gallicus (Stradner), GARTNER, 1968, (partim) p. 46, pl. 1, fig. 20; (non pl. 6, fig. 11).

Occurrences: Reported from the Maastrichtian of Holland, France, Tunisia, Alabama, and Texas. In the Zumaya sections, this species is restricted to the Upper Maastrichtian at the Punta de San Telmo section and has been found from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences of this species in the Danian may represent reworking.

Cylindralithus serratus Bramlette & Martini

Cylindralithus serratus BRAMLETTE & MARTINI, 1964, p. 310, pl. 5, figs. 18-20.
________ GARTNER, 1968, p. 47, pl. 10, fig. 9.

Occurrences: Reported from the Campanian of Texas and the Maastrichtian of Holland, Tunisia, and Alabama. In the Zumaya sections, this species is restricted to the Upper Maastrichtian at the Punta de San Telmo section and has been observed from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Genus EIFFELLITHUS Reinhardt, 1965

Eiffellithus gorkae Reinhardt

Eiffellithus gorkae REINHARDT, 1965, p. 36, fig. 6; pl. 2, fig. 2. ________ PERCH-NIELSEN, 1968, p. 29, fig. 7, pl. 3, figs. 11-13.

Occurrences: Reported from the Lower Maastrichtian and Upper Cretaceous of Denmark. In the Zumaya sections, it is restricted to the Upper Maastrichtian at the Punta de San Telmo section and has been found from Upper Maastrichtian to the lower part of *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences of this species into the Danian may represent reworking.

Eiffellithus regularis (Gorka)

Tremalithus regularis GORKA, 1957, p. 246, pl. 2, fig. 4.
Actinozygus regularis (Gorka), GARTNER, 1968, p. 23, pl. 3, fig. 12; pl. 5, figs. 17-18; pl. 6, figs. 17-18; pl. 12, fig. 11.
Eiffellithus regularis (Gorka), PERCH-NIELSEN, 1968, p. 30, pl. 37, figs. 8-9.

Occurrences: Reported from the Maastrichtian of Poland, Denmark, Arkansas and Texas. This species has been reported as *in situ* in the Lower Danian of Alabama by Worsley (1974). In the Zumaya section, it has been observed from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zones, but the occurrences of this species in the Danian may represent reworking.

Eiffellithus turriseiffeli (Deflandre)

Zygolithus turriseifelli DEFLANDRE, in Deflandre & Fert, 1954, p. 149, text-fig. 65, pl. 13, figs. 15-16.
Zygohablithus? turriseiffeli (Deflandre), BRAMLETTE & MARTINI, 1964, p. 304, pl. 3, figs. 18-21; pl. 4, figs. 1-2.
Eiffellithus turriseiffeli (Deflandre), REINHARDT, 1966, p. 38. ________ GARTNER, 1968, p. 26, pl. 2, figs. 22-23; pl. 3, figs. 13a-c; pl. 5, fig. 19; pl. 7, figs. 5a-c; pl. 9, figs. 5-9; pl. 13, figs. 1-2; pl. 16, figs. 1-2;

pl. 17, figs. 13a-d; pl. 18, fig. 8; pl. 22, fig. 4; pl. 23, fig. 7; pl. 24, figs. 1a-c; pl. 25, figs. 15-16; pl. 26, figs. 3-4. ________ PERCH-NIELSEN, 1968, p. 28, text-fig. 8; pl. 3, figs. 1-7.

Occurrences: This species has been reported from many parts of the world from early Aptian through Maastrichtian. In the Maastrichtian, it has been found in Denmark, France, Belgium, Tunisia, Algeria, Alabama, Arkansas, Texas, and Poland. In the Zumaya sections, it has been found from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the upper part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Genus ERICSONIA Black, 1964

Ericsonia cava (Hay & Mohler)

Coccolithus cavus HAY & MOHLER, 1967, p. 1524, pl. 196, figs. 1-3; pl. 197, figs. 5 & 7.

Ericsonia cava (Hay & Mohler), PERCH-NIELSEN, 1969b, p. 61, pl. 2, figs. 7 & 8.

Occurrences: Reported from the Danian of Denmark and Alabama. In the Zumaya sections it has been observed from the upper part of the Danian *Globorotalia pseudobulloides* Zone to the top of the sections studied. The extinction level of this species is younger than the interval studied.

Genus HELIORTHUS Bronnimann & Stradner, 1960

Heliorthus concinnus (Martini)

Zygolithus concinnus MARTINI, 1961, p. 18, pl. 3, fig. 35; pl. 5, fig. 54.

Zygolithus concinnus Martini, BRAMLETTE & MARTINI, 1964, p. 304, pl. 4, figs. 13-14; pl. 7, fig. 3.

Heliorthus concinnus (Martini) HAY & MOHLER, 1967, p. 1533, pl. 199, figs. 16-18; pl. 201, figs. 6-7, 10. ________ PERCH-NIELSEN, 1969b, p. 62, pl. 5, figs. 6-8.

Occurrences: Reported from the Danian of Denmark, Alabama, and France. In the Zumaya sections, it has been found from the upper part of the Danian *Globorotalia pseudobulloides* Zone to the top of the sections studied. The extinction level is stratigraphically younger than the sections studied.

Genus KAMPTNERIUS Deflandre, 1959

Kamptnerius magnificus

Kamptnerius magnificus DEFLANDRE, 1959, p. 135, pl. 1, figs. 1-4. ________ BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, figs. 1-3. ________ GARTNER, 1968, p. 39, pl. 2, figs. 1-2; pl. 3, fig. 7; pl. 12, fig. 9; pl. 14, figs. 11-12; pl. 15, fig. 10; pl. 16, figs. 17-19; pl. 17, figs. 11-12; pl. 21, fig. 12. ________ PERCH-NIELSEN, 1968, p. 41, fig. 16; pl. 6, figs. 1-3, 5.

Occurrences: Recorded from the Coniacian to the Maastrichtian. It has been found in the Maastrichtian of Holland, Denmark, France, Tunisia, Alabama, Arkansas, and Texas. In the Zumaya sections, this form has not been observed above the Upper Maastrichtian.

Genus LITHRAPHIDITES Deflandre, 1963

Lithraphidites quadratus Bramlette & Martini

Lithraphidites quadratus BRAMLETTE & MARTINI, 1964, p. 310, pl. 6, figs. 16-17; pl. 7, fig. 8. ________ GARTNER, 1968, p. 43, pl. 2, fig. 3; pl. 3, fig. 3; pl. 5, figs. 1-2; pl. 6, fig. 9. ________ PERCH-NIELSEN, 1968, p. 84, pl. 25, figs. 8-9.

Occurrences: Reported from Maastrichtian of Holland, Denmark, France, Tunisia, Alabama, and Texas. In the Zumaya sections, it has been found in the Upper Maastrichtian to the upper part of the Danian *Globorotalia pseudobulloides*

Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences into the Danian may represent reworking.

Genus LUCIANORHABDUS Deflandre, 1959

Lucianorhabdus sp

Remarks: The specimens of this species require more study.

Occurrences: In the Zumaya sections, it has been observed from the lower to middle part of the Danian *Globorotalia pseudobulloides* Zone of the Punta de San Telmo section and from the Danian portion of the Boundary Shale to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section. This species belongs to a Cretaceous genus and probably represents reworking. Therefore, it is placed with the vanishing species.

Genus MARKALIUS Bramlette & Martini, 1964

Markalius astroporus (Stradner)

Cyclococcolithus leptoporus Murray & Blackman var. *inversus* DEFLANDRE, in Deflandre & Fert, 1954, (partim) p. 150, pl. 9, figs. 4-5, (non figs. 6-7).

Cyclococcolithus astroporus STRADNER, in Gohrbandt et al., 1963, p. 75, pl. 9, figs. 5-7; text-fig. 3, 2a-b.

Markalius inversus (Deflandre) BRAMLETTE & MARTINI, 1964, (partim), p. 302, pl. 2, figs. 4-9, (non pl. 7, figs. 2a-b).

Cyclococcolithus inversus Deflandre, HAY & MOHLER, in Hay et al., 1967, p. 389, pl. 7, fig. 2.

Markalius astroporus (Stradner), HAY & MOHLER, 1967, p. 1528, pl. 196, figs. 32-35; pl. 198, figs. 2,6.

Cylindralithus gallicus (Bramlette & Martini), GARTNER, 1968, (partim) p. 46, pl. 6, fig. 11; (non pl. 1, fig. 20).

Markalius inversus (Deflandre), PERCH-NIELSEN, 1968, p. 72, pl. 24, figs. 1-8; pl. 25, fig. 1; text-figs. 34a, 35. ________ PERCH-NIELSEN, 1969b, p. 63, pl. 3, figs. 5-6.

Occurrences: Reported from the Maastrichtian of Denmark, Texas, and Alabama. Also reported from the Danian of Denmark, France, Austria, and Alabama. In the Zumaya section, it has been found from Upper Maastrichtian to the top of the sections studied. The extinction level of this form is younger than the sections studied.

Markalius reinhardtii? Perch-Nielsen

Tergestiella barnesae (Black), REINHARDT, 1966, (partim) pl. 1, figs. 1-2; text-fig. 2.

Markalius reinhardtii PERCH-NIELSEN, 1968, p. 76, pl. 23, figs. 6-8; text-figs. 34 & 38. ________ PERCH-NIELSEN, 1969b, p. 63, pl. 3, figs. 2-4; pl. 7, figs. 13-14.

Remarks: The specimens observed closely resemble the figures of Perch-Nielsen; however, her figures are of poorly preserved specimens so that positive identification cannot be made.

Occurrences: Reported from the Maastrichtian and Danian of Denmark. In the Zumaya sections, it has been observed from the Upper Maastrichtian into the top of the sections studied. The extinction level of this form is younger than the sections studied.

Genus MICRANTHOLITHUS Deflandre, 1950

Micrantholithus sp

Remarks: This species closely resembles the species depicted by Hay & Mohler (1967); however, the specimens are not as well preserved.

Occurrences: In the Zumaya sections, it has been found from the lower part of the Danian *Globorotalia pseudobulloides* Zone to the top of the section studied at the Punta de San Telmo section and from the Upper Maastrichtian to the top of the section studied at the Rio Urola section. The extinction level of this species is younger than the sections studied.

Genus MICRORHABDULUS Deflandre, 1959

Microrhabdulus stradneri Bramlette & Martini

Microrhabdulus stradneri BRAMLETTE & MARTINI, 1964, p. 316, pl. 6, figs. 3-4. ________ GARTNER, 1968, p. 44, pl. 12, fig. 4.

Occurrences: Reported from the Maastrichtian of Denmark, Tunisia, Alabama, Arkansas, and Texas. Also, it has been reported as in situ in the Danian of Alabama by Worsley (1974). In the Zumaya sections, it has been observed from the Upper Maastrichtian to the upper part of the Danian Globorotalia pseudobulloides Zone, but the range into the Danian may represent reworking.

Genus MICULA Vekshina, 1959

Micula staurophora (Gardet)

Discoaster staurophorus GARDET, 1955, p. 534, pl. 10, fig. 96.

Micula staurophora (Gardet), STRADNER, 1963, p. 13, fig. 12. ________ BRAMLETTE & MARTINI, 1964, p. 318, pl. 6, figs. 7-11.

Micula decussata Vekshina, GARTNER, 1968, (partim) p. 47, pl. 2, figs. 5 & 8; pl. 4, fig. 17; pl. 9, fig. 18; pl. 14, fig. 13; pl. 18, fig. 7; pl. 20, fig. 15.

Micula staurophora (Gardet), PERCH-NIELSEN, 1968, p. 86, fig. 43; pl. 31, figs. 1-5.

Occurrences: Reported from Turonian to Maastrichtian. This species has been found in the Maastrichtian of Denmark, France, Germany, Tunisia, New Zealand, Australia, Alabama, Arkansas, and Texas. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the upper part of the Danian Globorotalia pseudobulloides Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the lower part of the Danian Globorotalia trinidadensis Zone at the Rio Urola section, but the occurrences into the Danian may represent reworking.

Genus PREDISCOSPHAERA Vekshina, 1959

Prediscosphaera cretacea

Coccolithophora cretacea ARKHANGELSKY, 1912, p. 410, pl. 6, figs. 12-13.

Deflandrius cretaceus (Arkhangelsky), BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, figs. 11-12.

Deflandrius intercisus (Deflandre), BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, figs. 13-16. ________ MANIVIT, 1965, p. 193, pl. 1, fig. 7.

Prediscosphaera cretacea (Arkhangelsky), GARTNER, 1968, p. 19, pl. 2, figs. 10-14; pl. 3, fig. 8; pl. 4, figs. 19-24; pl. 6, figs. 14-15; pl. 9, figs. 1-4; pl. 12, fig. 1; pl. 14, figs. 20-22; pl. 18, fig. 8; pl. 22, figs. 1-3; pl. 23, figs. 4-6; pl. 25, figs. 12-14; pl. 26, fig. 2.

Deflandrius cretaceus (Arkhangelsky), PERCH-NIELSEN, 1968, p. 63, figs. 29-31; pl. 13, figs. 1-6; pl. 14, figs. 1-2; pl. 15; pl. 16, figs. 1-5.

Occurrences: Reported from Albian to Maastrichtian. This species has been found in the Maastrichtian of Denmark, Holland, France, Tunisia, Alabama, and Arkansas. Worsley (1974) recorded this species as in situ from the Danian of Alabama. In the Zumaya sections, it has been found from the Upper Maastrichtian to the lower part of the Danian Globorotalia trinidadensis Zone, but the range of this species into the Danian may represent reworking.

Genus TETRALITHUS Gardet, 1955

Tetralithus murus Martini

Tetralithus murus MARTINI, 1961, p. 4, pl. 1, fig. 6; pl. 4, fig. 42. ________ BRAMLETTE & MARTINI, 1964, p. 320, pl. 6, figs. 18-21.

Occurrences: Recorded from the Upper Maastrichtian of France, Tunisia, Alabama and Trinidad. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the upper part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the occurrences of this species into the Danian may represent reworking.

Tetralithus pyramidus? Gardet

Tetralithus pyramidus GARDET, 1955, p. 571, pl. 7, fig. 66.
Occurrences: Recorded from Turonian to Campanian. In the Zumaya sections, it has been found from the Upper Maastrichtian to the lower part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Genus THORACOSPHAERA Kamptner, 1927

Thoracosphaera deflandrei Kamptner

Thoracosphaera deflandrei KAMPTNER, 1956, p. 448, text-figs. 1-4.
Thoracosphaera operculata BRAMLETTE & MARTINI, 1964, p. 305, pl. 5, figs. 3-7.
Thoracosphaera deflandrei Kamptner, HAY & MOHLER, 1962, p. 1534, pl. 203, fig. 8.
Occurrences: Reported from the Maastrichtian of Tunisia and Alabama. Also it has been reported from the Danian of Denmark, France, Tunisia and Alabama. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the top of the sections studied. The extinction level of this species is younger than the sections studied.

Thoracosphaera saxea Stradner

Thoracosphaera saxea STRADNER, 1961, pl. 84, text-fig. 71. ________ STRANDER, 1963, p. 9, pl. 3, fig. 3; ________ STRADNER, 1963, in Gohrbandt et al., p. 18, pl. 10, fig. 8.
Thoracosphaera cf. *T. imperforata* Kamptner, BRAMLETTE & MARTINI, 1964, p. 305, pl. 5, figs. 1-2.
Thoracosphaera saxea Stradner, HAY & MOHLER, 1967, p. 1534, pl. 203, fig. 5.
Occurrences: Reported from the Maastrichtian of Arkansas and also from the Danian of Denmark, Alabama, and France. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the lower part of the *Globorotalia trinidadensis* Zone. The extinction level of this species is younger than the sections studied.

Genus VAGALAPILLA Bukry, 1969

Vagalapilla octoradiata (Gorka)

Discolithus octoradiatus GORKA, 1957, p. 259, pl. 4, fig. 10.
Zygolithus? *octoradiatus* (Gorka), BRAMLETTE & MARTINI, 1964, p. 304, pl. 4, figs. 15-16.
Eiffellithus octoradiatus (Gorka), GARTNER, 1968, p. 25, pl. 2, fig. 17-21; pl. 3, fig. 11; pl. 5, fig. 20; pl. 12, fig. 10.
Ahmulerella octoradiata (Gorka), PERCH-NIELSEN, 1968, p. 23, text-fig. 3; pl. 2, fig. 1, 2, 12-15.
Vagalapilla octoradiata (Gorka), BUKRY, 1969, p. 58, pl. 33, figs. 5-7.
Occurrences: Reported from Middle Turonian to Maastrichtian. It has been found from the Maastrichtian of Poland, Texas, Arkansas, and Denmark. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the middle of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the Danian portion of the Boundary Shale at the Rio Urola section, but the range of this species into the Danian may represent reworking.

Genus VEKSHINELLA Loeblich & Tappan, 1963
Vekshinella dibrachiata Gartner

Vekshinella dibrachiata GARTNER, 1968, p. 30, pl. 5, figs. 23-24; pl. 7, fig. 8; pl. 9, fig. 15; pl. 19, fig. 8; pl. 22, fig. 8.

Occurrences: Reported from Coniacian to Maastrichtian of Texas. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the lower part of the Danian Globorotalia pseudobulloides Zone at the Punta de San Telmo section and from the Upper Maastrichtian at the Rio Urola section, but the occurrences into the Danian may represent reworking.

Genus WATZNAUERIA Reinhardt, 1964
Watznaueria barnesae (Black)

Tremalithus barnesae BLACK, in Black & Barnes, 1959, p. 325, pl. 9, figs. 1-2.

Coccolithus cf. C. barnesae (Black), BRAMLETTE & MARTINI, 1964, pl. 1, figs. 13-14.

Coccolithus barnesae (Black), GARTNER, 1968, p. 17, pl. 1, fig. 12; pl. 4, figs. 6-7; pl. 8, figs. 18-22; pl. 11, fig. 11; pl. 14, figs. 4-5; pl. 15, fig. 8; pl. 16, figs. 15-16; pl. 19, fig. 12; pl. 20, figs. 12-13; pl. 22, figs. 16-17; pl. 24, fig. 8; pl. 25, figs. 1-2.

Watznaueria barnesae (Black), PERCH-NIELSEN, 1968, p. 69, text-fig. 32, pl. 22, figs. 1-7; pl. 23, figs. 1, 4, 5, 16. ________ BURKY, 1969, p. 31, pl. 10, figs. 1-7.

Occurrences: Reported from the Oxfordian to the Maastrichtian. It has been found in the Maastrichtian of France, Holland, Denmark, Tunisia, Algeria, Texas, Arkansas, and Alabama. In the Zumaya sections, it has been found from the Upper Maastrichtian to the middle part of the Danian Globorotalia pseudobulloides Zone, but the range of this species into the Danian may represent reworking.

Genus ZYGODISCUS Bramlette & Sullivan, 1961
Zygodiscus diplogrammus (Deflandre)

Zygolithus diplogrammus DEFLANDRE, in Deflandre & Fert, 1954, p. 148, pl. 10, fig. 7, text-fig. 57. ________ BRAMLETTE & MARTINI, 1964, p. 304, pl. 4, figs. 11-12.

Zygodiscus diplogrammus (Deflandre), GARTNER, 1968, p. 32, pl. 14, fig. 18; pl. 17, fig. 4; pl. 19, fig. 3; pl. 21, fig. 2; pl. 22, fig. 7; pl 23, fig. 12-14; pl. 24, fig. 6; pl. 25, fig. 17-18. ________ BURKY, 1969, p. 59, pl. 34, figs. 3-5.

Occurrences: Recorded from the Maastrichtian of France, Tunisia, Holland, Alabama and Texas. In the Zumaya sections, it has been observed from the Upper Maastrichtian to the Danian portion of the Boundary Shale at the Punta de San Telmo sections and from the Upper Maastrichtian to the lower part of the Danian Globorotalia pseudobulloides Zone at the Rio Urola Zone, but the range into the Danian may represent reworking.

Zygodiscus pseudoanthophorus Bramlette & Martini

Zygodiscus? pseudoanthophorus BRAMLETTE & MARTINI, 1964, p. 303, pl. 3, fig. 17; pl. 4, figs. 17-18.

Zygodiscus pseudoanthophorus Bramlette & Martini, GARTNER, 1968, p. 33, pl. 2, figs. 25-26; pl. 3, fig. 14; pl. 13, figs. 6-7.

Occurrences: Reported from the Maastrichtian of Alabama, Holland, Denmark, France. In the Zumaya sections, it has been found from the Upper Maastrichtian to the lower part of the Danian Globorotalia pseudobulloides Zone, but the occurrences into the Danian may represent reworking.

Zygodiscus sigmoides Bramlette & Sullivan

Zygodiscus sigmoides BRAMLETTE & SULLIVAN, 1961, p. 149, pl. 4, fig. 11.

Zygodiscus sigmoides Bramlette & Sullivan, HAY & MOHLER, 1967, p. 1532, pl. 199, figs. 12-14. ________ PERCH-NIELSEN, 1969b, p. 65, pl. 5, figs. 1-2.

Occurrences: Reported from the Danian of Denmark, Tunisia, and Alabama. Also it has been found in the Paleocene of California. In the Zumaya sections, it has been observed from the middle part of the Danian *Globorotalia pseudobulloides* Zone to the top of the section studied at the Punta de San Telmo section and from the upper part of the Danian *Globorotalia pseudobulloides* Zone to the top of the section studied at the Rio Urola section. The discrepancy in ranges between the two Spanish localities may be the result of rarity of specimens. The extinction level of this species is younger than the sections studied.

Zygodiscus spiralis Bramlette & Martini

Zygodiscus spiralis BRAMLETTE & MARTINI, 1964, p. 303, pl. 4, figs. 6-8. ________ GARTNER, 1968, p. 35, pl. 5, figs. 21-22; pl. 7 fig. 3. ________ PERCH-NIELSEN, 1968, p. 89, pl. 29, figs. 7-13.

Occurrences: Reported from the Maastrichtian of Holland, Denmark, France, Tunisia, Alabama, Arkansas, and Texas. In the Zumaya sections, it has been found from the Upper Maastrichtian to the middle of the Danian *Globorotalia pseudobulloides* Zone, but the occurrences into the Danian represent reworking.

Zygodiscus sp A

Remarks: This species needs further study.

Occurrences: In the Zumaya sections, it has been observed from the Upper Maastrichtian to the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the Upper Maastrichtian to the Danian of the Boundary Shale at the Rio Urola section. The discrepancy in ranges between the two Spanish sections may be the result of rarity of specimens.

Zygodiscus sp B

Remarks: This species needs further study.

Occurrences: In the Zumaya sections, it has been found from the lower part to the upper part of the Danian *Globorotalia pseudobulloides* Zone at the Punta de San Telmo section and from the middle part of the Danian *Globorotalia pseudobulloides* Zone at the Rio Urola section. The discrepancy in ranges between the Spanish sections may be the result of rarity of specimens.

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