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PLANKTONIC FORAMINIFERA AND CALCAREOUS NANNOFOSSILS AT THE CRETACEOUS-TERTIARY CONTACT IN ZULULAND

by

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ABSTRACT

Assemblages of planktonic foraminifera and calcareous nannofossils for the Maestrichtian and Danian of Zululand are listed and illustrated. The *Globotruncana gansseri* and *G. mayorensis* foraminiferal zones are present in the Maestrichtian. The *Globigerina triloculinoides* and *Globorotalia compressa* foraminiferal subzones are present in the Danian. The Maestrichtian in this area cannot be subdivided on the basis of calcareous nannofossils. Danian nannofossil zones present are those of *Cruciplacolithus tenuis* and *Chiasmolithus danicus*. The Cretaceous-Tertiary faunal extinctions are briefly discussed and it is concluded that lowered temperatures were a factor in this extinction.

INTRODUCTION

The presence of lowermost Tertiary sediments in Zululand was first noted by Orr and Chapman (1974) who reported early Paleocene planktonic foraminifera from an excavation at Richards Bay. Maud and Orr (in press) described the subsurface stratigraphy of the Richards Bay area and listed some of the more important species of planktonic foraminifera present in the uppermost Cretaceous and lowermost Tertiary. Numerous test boreholes have since revealed that a narrow belt of early Paleocene sediments is present in the subsurface parallel to the coast. Several of these boreholes passed through the Cretaceous-Tertiary (Maestrichtian-Danian) contact and from two of these boreholes (see location map, Fig. 1), a continuous sequence of core was recovered.

This is the only known area on land in southern Africa where the Maestrichtian-Danian contact occurs although similar contacts have been extensively studied in other parts of the world. The purpose of this paper is to document the assemblages of the two most important microfossil groups — the planktonic foraminifera and the calcareous nannofossils — within this interval in Zululand.

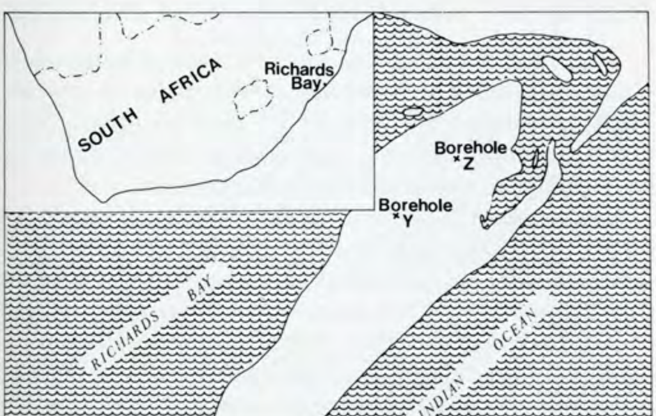

Fig. 1. Location map.

ZONATION

Postuma (1971) erected a threefold division for the Maestrichtian based on planktonic foraminifera. For the Danian, he recognized a single zone of *Globigerina daubjergensis*. Berggren (1969) subdivided the *G. daubjergensis* zone into three subzones.

There is as yet no satisfactory nannofossil zonation for the Maestrichtian. Martini's (1970) nannofossil zonation is used for the Danian. The zonations are shown in Fig. 2. Original zone names are used although the species *Globotruncana mayorensis*

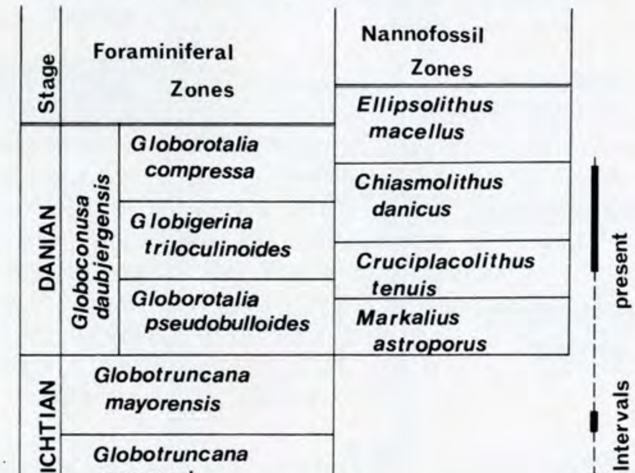

Fig. 2. Planktonic foraminiferal and calcareous nannofossil zonations for the Maestrichtian and Danian.

is usually placed in the genus *Abathomphalus* and *Markalius astroporus* is considered to be a junior synonym of *M. inversus*.

Borehole Z was sampled at one metre intervals and Borehole Y at three metre intervals. Borehole Z had a collar elevation of 4 m above sea level with first sample recovered at 18 m and total depth of 92 m. Borehole Y with a collar elevation of 5 m above sea level was drilled to 103 m with top samples at a depth of 30 m. The zones encountered and their depths are shown in Fig. 3.

Both boreholes bottomed in the middle Maestrichtian foraminiferal zone of *Globotruncana gansseri* which extended upward to 67 m in Borehole Z and 58 m in Borehole Y. The presence of *Globotruncana fornicata* and *G. stuarti* throughout this interval indicates that only the lower portion of the zone is present. Above the *G. gansseri* zone, there was a 1 m thick interval in both boreholes containing a microfauna of the uppermost Maestrichtian zone of *Globotruncana mayorensis*. A few specimens of *Globotruncana arca* were present, suggesting that the interval falls into the lower portion of the zone.

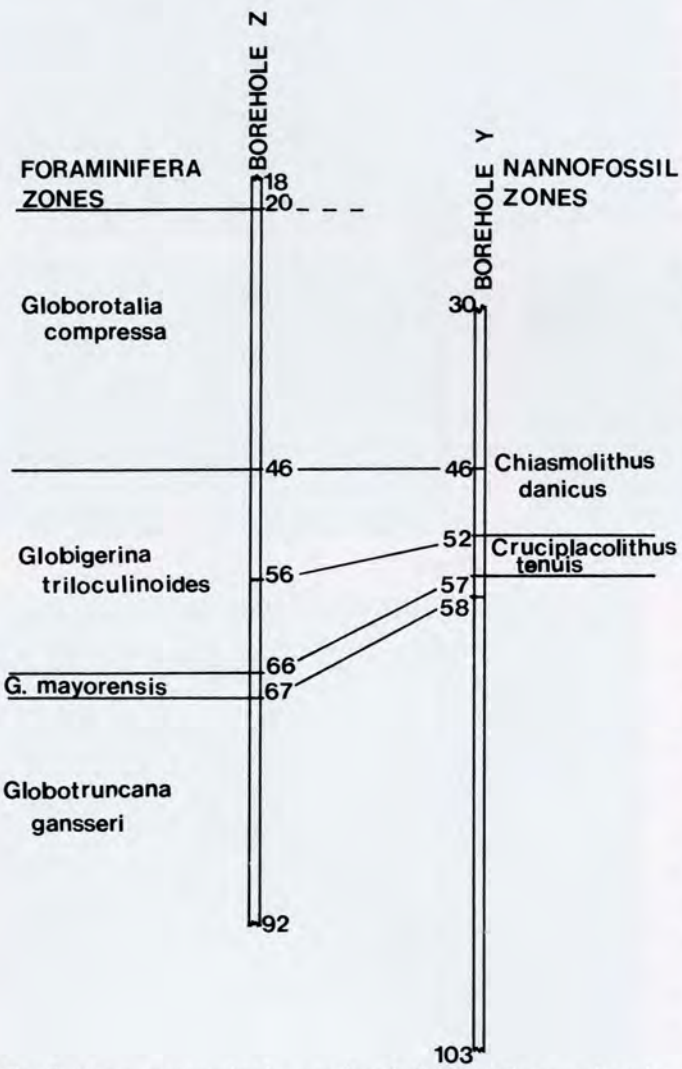

Fig. 3. Zones present in the two boreholes. Depths are given in metres.

Nannofossils in both foraminiferal zones were virtually identical. *Tetralithus pyramidus* and *Zygolithus rhombicus* were present in the *G. gansseri* zone but not in the *G. mayorensis* zone. However, both species were extremely rare and their presence or absence cannot be considered significant.

Above the Maestrichtian, the middle Danian foraminiferal subzone of *Globigerina triloculinoides* was present to 46 m in both boreholes. The *Globorotalia compressa* subzone extended from 46 m to the uppermost sample at 30 m in Borehole Y and to 20 m in Borehole Z. In the latter borehole, a few metres of unfossiliferous sand occur above the Danian.

The lowermost Danian samples (66 m in Borehole Z and 57 m in Borehole Y) were within the *Cruciplacolithus tenuis* nannofossil zone which extended upward to 56 m in Borehole Z and 52 m in Borehole Y. Above this, all Danian material was within the *Chiasmolithus danicus* zone.

Deposition during the Danian appears to have been continuous. There are no abrupt changes in assemblages to suggest hiati.

The hiatus at the Maestrichtian-Danian contact extends from within the *G. mayorensis* zone, through the *Globorotalia pseudobulloides* subzone and into the *Globigerina triloculinoides* subzone. The absence of the *Globorotalia pseudobulloides* foraminiferal subzone is confirmed by the absence of the nannofossil zone of *Markalius astroporus*.

The absence of the upper portion of the *Globotruncana gansseri* zone indicates a second hiatus between that zone and the overlying zone of *G. mayorensis*. Although neither borehole penetrates below the *G. gansseri* zone, the absence of the lowermost Maestrichtian zone of *G. stuarti* elsewhere in Zululand suggests that there may be a third hiatus lower in the succession.

The persistence of the thin *G. mayorensis* zone throughout the area suggests that the hiati are depositional rather than erosional.

NOTES ON NANNOFOSSIL OCCURRENCES

There are a number of known cases of anomalous chronological distributions of nannofossil species. Such anomalies are caused by provincialism, local environmental factors, reworking, faulty observation and inadequate stratigraphic control.

Chiasmolithus bidens and *Toweius craticulus* were present in the *Chiasmolithus danicus* zone although both Gartner (1971) and Perch-Nielsen (1972) indicate that the species do not occur until the overlying zone of *Ellipsolithus macellus*. Perch-Nielsen (1972) indicates *Braarudosphaera discula* as restricted to Danian or younger, but the species was common in the Maestrichtian of Zululand. *Micula staurophora* has been reported throughout the Tertiary but such reports are generally considered to be examples of reworking. The species was present in the Zululand

Danian, even in samples which contained no other Cretaceous species, and it is possible that it does extend into the Tertiary.

The uniformity of the nannofossil assemblages in the upper two Maestrichtian foraminiferal zones indicates that these zones cannot be separated on a nannofossil basis in this area. Characteristic early Maestrichtian species such as *Arkhangelskiella parca, Microrhabdulus decoratus* and *Tetralithus obscurus* were not seen in the *Globotruncana gansseri* zone.

ASSEMBLAGES

No new species were seen and the author would be sceptical of the existence of undescribed species in a portion of the section which has been so frequently studied. Perhaps more significant is the absence of many characteristic Maestrichtian species: *Globotruncana conica, G. falsostuarti, Rugoglobigerina rotundata, Kamptnerius magnificus, Ceratolithoides kamptneri* and *Tetralithus* spp. The species present are listed in Tables 1 and 2 and are illustrated in the plates.

Worsley (1974) used the presence of *Abathomphalus mayorensis* and *Racemiguembelina fructicosa* together as an indicator of the tropical zone. Other planktonic foraminifera and the calcareous nannofossils in the Maestrichtian are consistent with this interpretation. This would place the southern boundary of the tropical zone somewhat farther south than indicated by Worsley. Danian assemblages are fairly uniform from the tropics into the temperate zone and little can be said of Danian water temperatures. The relative abundance of both groups in the borehole samples indicates normal marine conditions, probably inner to middle neritic.

Table 1
Species of planktonic foraminifera present.

ZONES				
G. gansseri	*G. mayorensis*	*G. triloculinoides*	*G. compressa*	
+				*Globotruncana fornicata* Plummer
+				*Globotruncana marginata* (Reuss)
+				*Globotruncana stuartiformis* Dalbiez
+				*Globotruncana tilevi* (Brönnimann & Brown)
+				*Heterohelix plummerae* (Loetterle)
+				*Heterohelix pulchra* (Brotzen)
+	+			*Globigerinelloides aspera* (Ehrenberg)
+	+			*Globigerinelloides messinae* (Brönnimann)
+	+			*Globigerinelloides subpetaloidea* (Gandolfi)
+	+			*Globotruncana arca* (Cushman)
+	+			*Globotruncana contusa* (Cushman)
+	+			*Globotruncana gagnebini* Tilev
+	+			*Globotruncana gansseri* Bolli
+	+			*Globotruncana leupoldi* Bolli
+	+			*Globotruncana rosetta* (Carsey)
+	+			*Globotruncana stuarti* (de Lapparent)
+	+			*Heterohelix carseyae* (Plummer)
+	+			*Heterohelix glabrans* (Cushman)
+	+			*Heterohelix globulosa* (Ehrenberg)
+	+			*Heterohelix ornatissima* (Cushman & Church)
+	+			*Heterohelix striata* (Ehrenberg)
+	+			*Planoglobulina acervulinoides* (Egger)
+	+			*Rugoglobigerina macrocephela* Brönnimann
+	+			*Rugoglobigerina rugosa* (Plummer)
	+			*Abathomphalus mayorensis* (Bolli)
	+			*Globigerinelloides subcarinata* (Brönnimann)
	+			*Racemiguembelina fructicosa* (Egger)
	+			*Trinitella scotti* (Brönnimann)
		+	+	*Globigerina triloculinoides* Plummer
		+	+	*Globoconusa daubjergensis* (Brönnimann)
		+	+	*Globorotalia pseudobulloides* (Plummer)
			+	*Globorotalia compressa* (Plummer)
			+	*Chiloguembelina morsei* (Kline)

Table 2
Species of calcareous nannofossil present.

ZONES				
G. gansseri	*G. mayorensis*	*C. tenuis*	*C. danicus*	
+				*Tetralithus pyramidus* Gardet
+				*Zygolithus rhombicus* Stradner & Adamiker
+	+			*Actinozygus splendens* (Deflandre)
+	+			*Ahmuellerella octoradiata* (Gorka)
+	+			*Arkhangelskiella cymbiformis* Vershina
+	+			*Corollithion exiguum* Stradner
+	+			*Cretarhabdus conicus* Bramlette & Martini
+	+			*Cretarhabdus decorus* (Deflandre)
+	+			*Cribrosphaerella ehrenbergi* (Arkhangelsky)
+	+			*Cylindralithus gallicus* (Stradner)
+	+			*Deflandrius cretaceus* (Arkhangelsky)
+	+			*Deflandrius intercisus* (Deflandre)
+	+			*Deflandrius spinosus* Bramlette & Martini
+	+			*Eiffellithus turriseiffeli* (Deflandre)
+	+			*Lithraphidites quadratus* Bramlette & Martini
+	+			*Markalius circumradiatus* (Stover)
+	+			*Microrhabdulus attenuatus* (Deflandre)
+	+			*Microrhabdulus nodosus* Stradner
+	+			*Nephrolithus frequens* Gorka
+	+			*Polypodorhabdus crenulatus* (Bramlette & Martini)
+	+			*Reinhardtites anthophorus* (Deflandre)
+	+			*Staurolithites mielnicensis* (Gorka)
+	+			*Stephanolithion laffittei* Noël
+	+			*Thoracosphaera operculata* Bramlette & Martini
+	+			*Watznaueria barnesae* (Black)
+	+			*Zygodiscus spiralis* Bramlette & Martini
+	+			*Zygolithus dubius* Deflandre
+	+	+	+	*Braarudosphaera bigelowi* (Gran & Braarud)
+	+	+	+	*Braarudosphaera discula* Bramlette & Riedel
+	+	+	+	*Markalius inversus* (Deflandre)
+	+	+	+	*Micula staurophora* (Gardet)
		+	+	*Cruciplacolithus tenuis* (Stradner)
		+	+	*Micrantholithus attenuatus* Bramlette & Sullivan
		+	+	*Micrantholithus pinguis* Bramlette & Sullivan
			+	*Chiasmolithus bidens* (Bramlette & Sullivan)
			+	*Chiasmolithus danicus* (Brotzen)
			+	*Coccolithus pelagicua* (Wallich)
			+	*Cruciplacolithus staurion* (Bramlette & Sullivan)
			+	*Heliorthus concinnus* (Martini)
			+	*Toweius craticulus* Hay & Mohler
			+	*Zygodiscus plectopons* Bramlette & Sullivan
			+	*Zygodiscus sigmoides* Bramlette & Sullivan

THE CRETACEOUS-TERTIARY EXTINCTION

Numerous fossil groups became extinct at the end of the Cretaceous. In some cases, this extinction was gradual, lasting throughout the later Cretaceous; in other cases, the extinction was incomplete with some species persisting well into the Tertiary. Among the calcareous nannofossils and the planktonic foraminifera, however, a massive and abrupt extinction took place between the end of the Maestrichtian and the beginning of the Danian. Nearly forty species from each group disappeared. No species of Maestrichtian planktonic foraminifera and only a few species of calcareous nannofossils persisted into the Danian.

The time interval during which the extinction took place is unknown since there is an hiatus at all known contacts, even those in the deep ocean basins.

Numerous explanations have been offered for extinctions at system boundaries. Most of these are discussed and criticised by Rhodes (1967). One of the more plausible explanations, first advanced by Bramlette (1965), postulated a crisis in the nutrient cycle. Tappan (1968) suggested that the critical nutrient was carbonate, depleted by massive phytoplankton blooms, and Worsley (1974) proposed a model in which the carbonate compensation depth was elevated into the photic zone.

There is no firm evidence for such a crisis. The end of the Cretaceous was a period of active orogeny with increasing sedimentation. Even if, as Bramlette suggested, most sedimentation took place in non-marine basins, the soluble nutrients should still have been carried out to sea. All evidence points to shrinking tropical regions at the end of the Cretaceous which should have produced an increase in vertical mixing and replenishment from the deep basins. Massive phytoplankton blooms would be ephemeral, with immediate destruction of the blooms and stabilization. Worsley's model for an elevated carbonate compensation depth was not borne out by later drilling (Anonymous, 1975; van Andel, 1975). Finally, such hypotheses do not explain why meroplanktonic groups such as the benthonic foraminifera were largely unaffected.

The only major ecological factor for which evidence is available is temperature and most evidence points to the latest Cretaceous as a period of cooling with a minimum occurring late in the Maestrichtian or early in the Danian. By the end of the Cretaceous, the tropical zone had shrunk to within the 30° parallels (Bandy, 1967; Worsley, 1974). Although this reduction in living area, along with possible lowered surface water temperatures, may have been the critical factor, it is possible that some asylum areas with higher temperatures would have persisted. However, lowered temperatures and a reduced living area may have produced critical conditions under which some other factor or factors could have operated to produce the extinction.

It is perhaps significant that Danian planktonic foraminifera are forms whose morphology suggests a cold-water environment and that the few calcareous nannofossil species which persisted into the Tertiary are either cold-water forms such as *Markalius inversus* or tolerant forms such as *Braarudosphaera* spp. The earliest new species of calcareous nannofossil to appear in the Danian, *Biantholithus sparsus,* is a cold-water form.

SUMMARY AND CONCLUSIONS

Assemblages of calcareous nannofossils and planktonic foraminifera from the Maestrichtian and Danian of Zululand show no major divergences from assemblages reported for the same stages in other parts of the world. The Zululand assemblages are somewhat smaller than usual and some common species were not seen. At least two and possibly three hiati are present in the Zululand Maestrichtian. The hiatus at the Maestrichtian-Danian contact is relatively long.

The assemblages indicate that this area was within the tropical zone during the Maestrichtian. It is suggested that shrinkage of the tropical zone in the Danian produced conditions which resulted in the Cretaceous-Tertiary extinctions.

ACKNOWLEDGEMENTS

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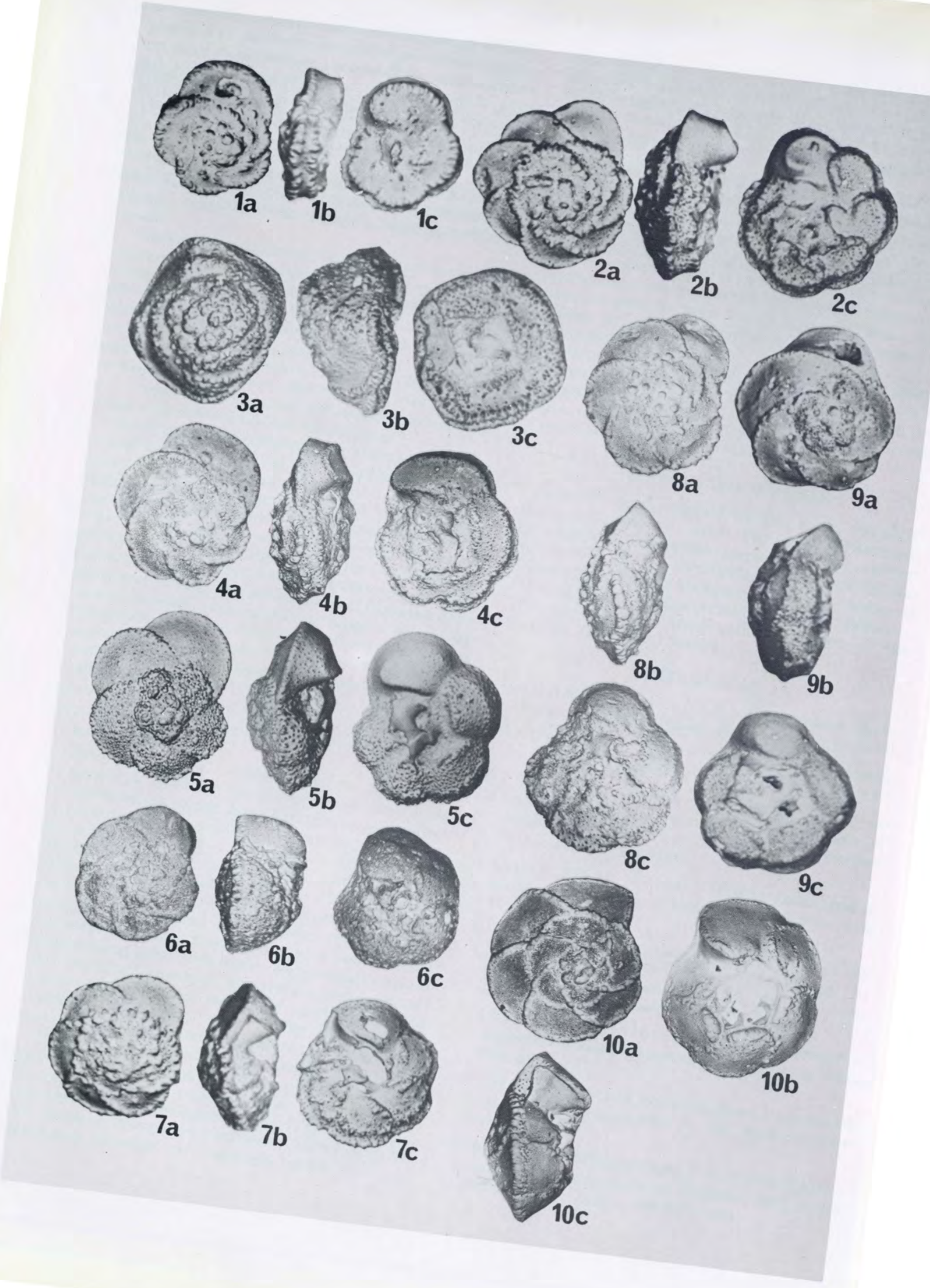
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PLATE I

Fig. 1a—c. *Abathomphalus mayorensis* (Bolli), X60.
Fig. 2a—c. *Globotruncana arca* (Cushman), X60.
Fig. 3a—c. *Globotruncana contusa* (Cushman), X50.
Fig. 4a—c. *Globotruncana fornicata* Plummer, X75.
Fig. 5a—c. *Globotruncana gagnebini* Tilev, X100.
Fig. 6a—c. *Globotruncana gansseri* Bolli, X50.
Fig. 7a—c. *Globotruncana leupoldi* Bolli, X60.
Fig. 8a—c. *Globotruncana marginata* (Reuss), X75
Fig. 9a—c. *Globotruncana rosetta* (Carsey), X60.
Fig. 10a—c. *Globotruncana stuarti* (de Lapparent), X50.

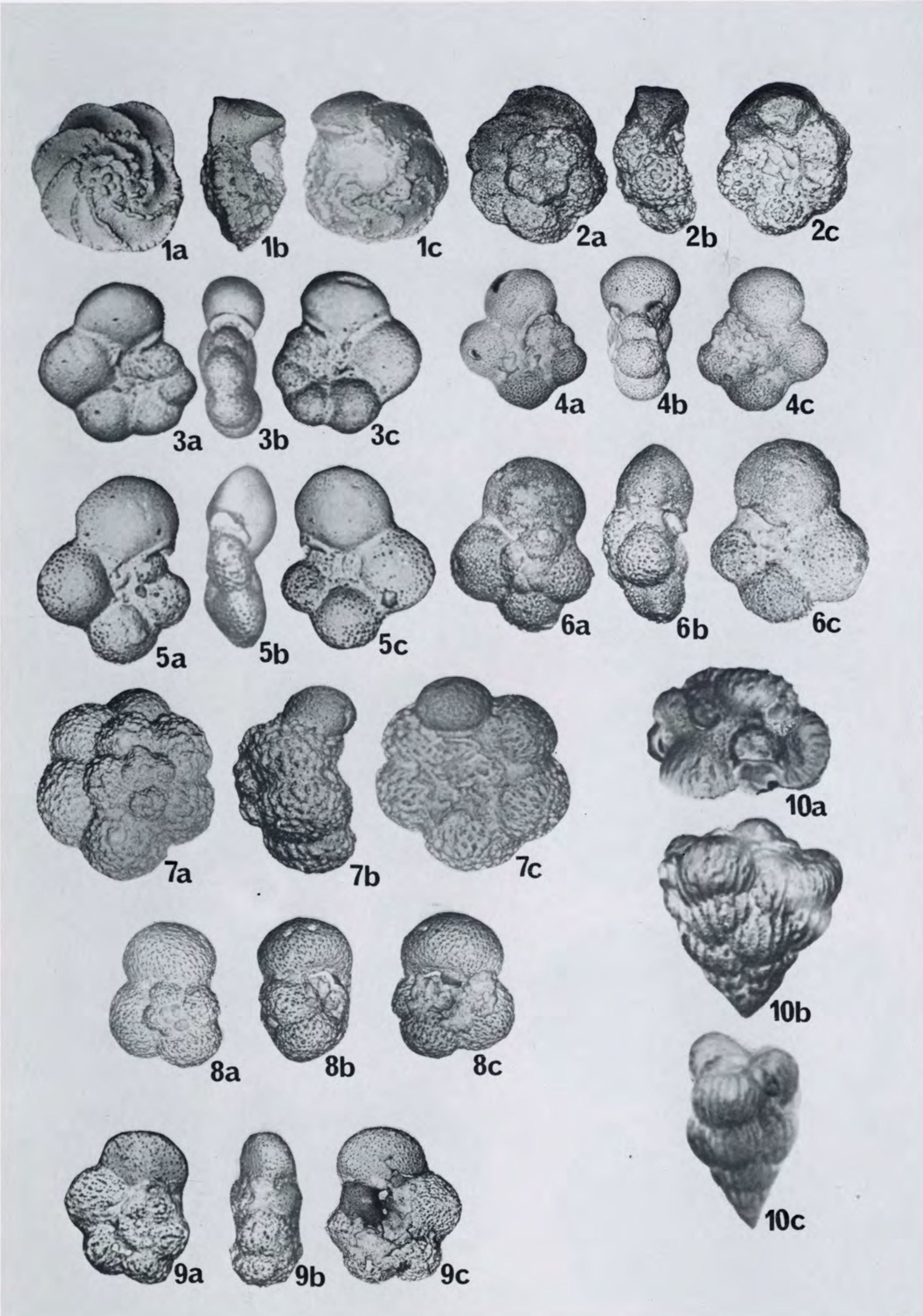
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PLATE II

Fig. 1a—c. *Globotruncana stuartiformis* Dalbiez, X50.
Fig. 2a—c. *Globotruncana tilevi* (Brönnimann and Brown), X100.
Fig. 3a—c. *Globigerinelloides aspera* (Ehrenberg), X100.
Fig. 4a—c. *Globigerinelloides messinae* (Brönnimann), X75.
Fig. 5a—c. *Globigerinelloides subcarinata* (Brönnimann), X100.
Fig. 6a—c. *Globigerinelloides subpetaloidea* (Gandolfi), X100.
Fig. 7a—c. *Rugoglobigerina rugosa* (Plummer), X75.
Fig. 8a—c. *Rugoglobigerina macrocephela* Brönnimann, X75.
Fig. 9a—c. *Trinitella scotti* (Brönnimann), X75.
Fig 10a—c. *Racemiguembelina fructicosa* (Egger), X60.

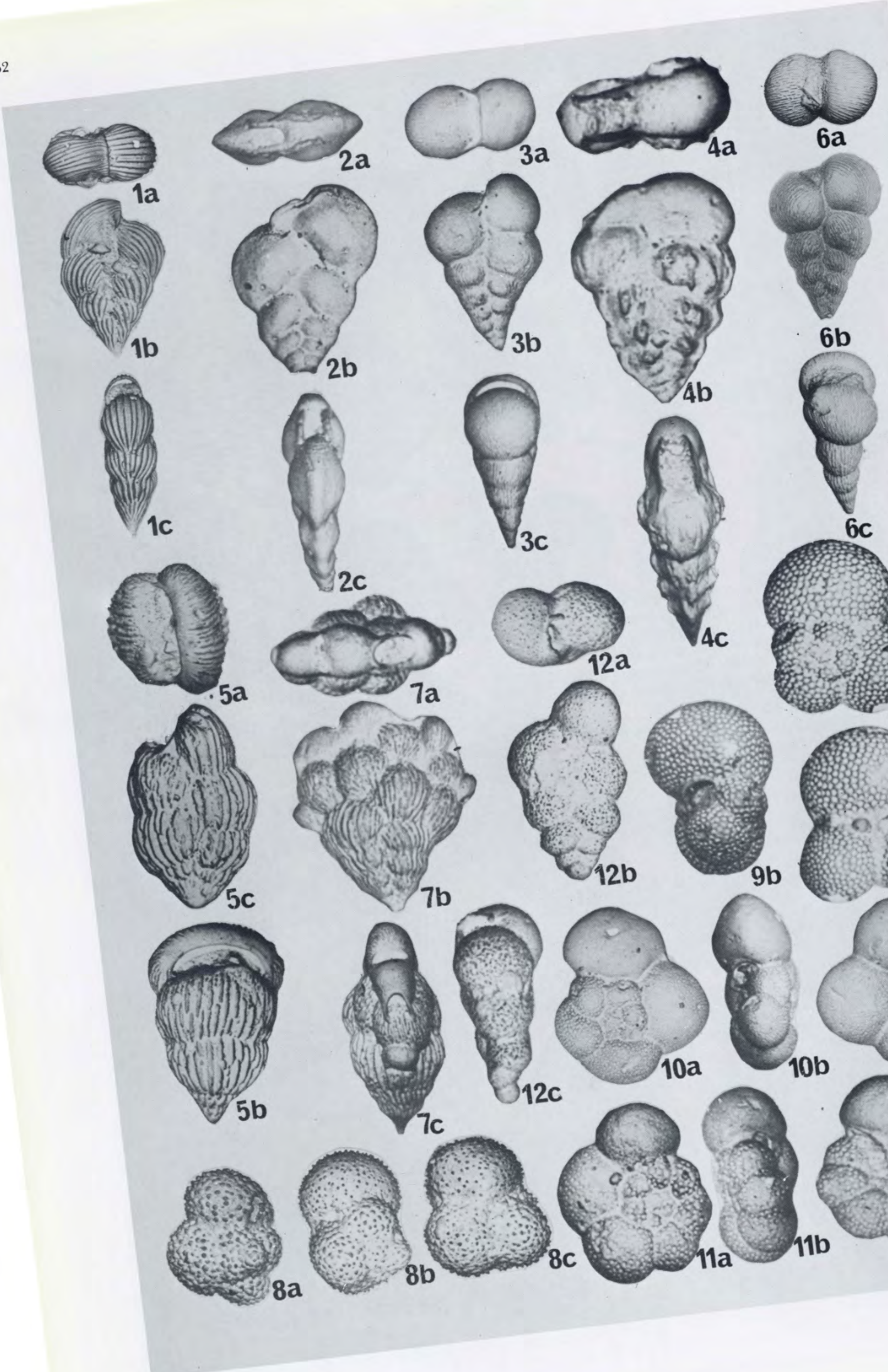
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PLATE III

Fig. 1a—c. *Heterohelix carseyae* (Plummer), X100.
Fig. 2a—c. *Heterohelix glabrans* (Cushman), X100.
Fig. 3a—c. *Heterohelix globulosa* (Ehrenberg), X100.
Fig. 4a—c. *Heterohelix ornatissima* (Cushman and Church), X100.
Fig. 5a—c. *Heterohelix plummerae* (Loetterle), X75.
Fig. 6a—c. *Heterohelix striata* (Ehrenberg), X100.
Fig. 7a—c. *Planoglobulina acervulinoides* (Egger), X60.
Fig. 8a—c. *Globoconusa daubjergensis* (Brönnimann), X150.
Fig. 9a—c. *Globigerina triloculinoides* Plummer, X100.
Fig. 10a—c. *Globorotalia compressa* (Plummer), X75.
Fig. 11a—c. *Globorotalia pseudobulloides* (Plummer), X100.
Fig. 12a—c. *Chiloguembelina morsei* (Kline), X90.

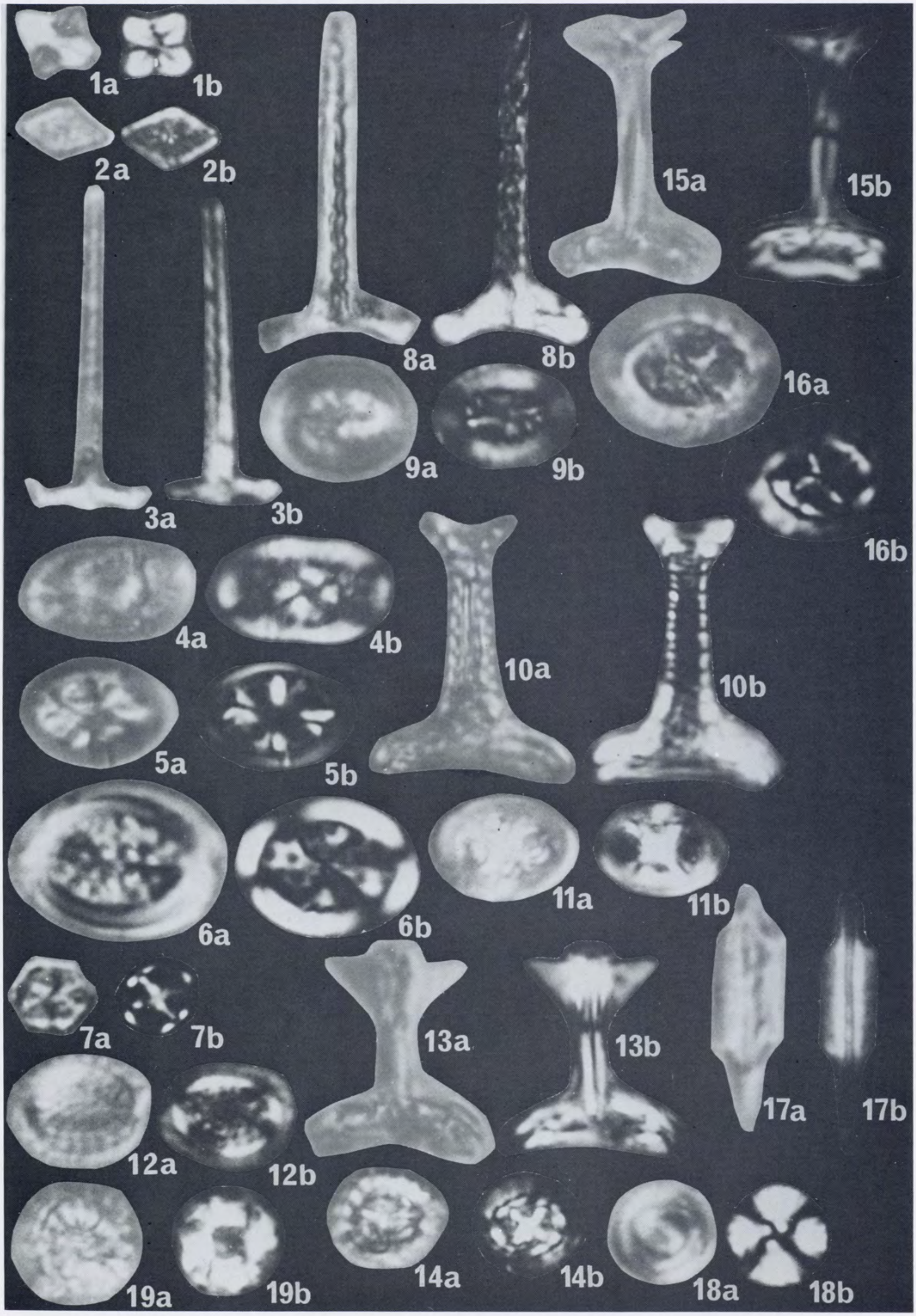
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PLATE IV

All figures X3 500. Figures 'a' are under interference contrast; figures 'b' under crossed polarizers.

Fig. 1a—b. *Tetralithus pyramidus* Gardet.
Fig. 2a—b. *Zygolithus rhombicus* Stradner and Adamiker.
Fig. 3a—b. *Actinozygus splendens* (Deflandre), spine.
Fig. 4a—b. *Actinozygus splendens* (Deflandre), base.
Fig. 5a—b. *Ahmuellerella octoradiata* (Gorka).
Fig. 6a—b. *Arkhangelskiella cymbiformis* Vershina.
Fig. 7a—b. *Corollithion exiguum* Stradner.
Fig. 8a—b. *Cretarhabdus conicus* Bramlette and Martini, spine.
Fig. 9a—b. *Cretarhabdus conicus* Bramlette and Martini, base.
Fig. 10a—b. *Cretarhabdus decorus* (Deflandre), spine.
Fig. 11a—b. *Cretarhabdus decorus* (Deflandre), base.
Fig. 12a—b. *Cribrosphaerella ehrenbergi* Arkhangelsky.
Fig. 13a—b. *Deflandrius cretaceus* (Arkhangelsky), spine.
Fig. 14a—b. *Deflandrius cretaceus* (Arkhangelsky), base.
Fig. 15a—b. *Deflandrius intercisus* (Deflandre), spine.
Fig. 16a—b. *Deflandrius intercisus* (Deflandre), base.
Fig. 17a—b. *Lithraphidites quadratus* Bramlette and Martini.
Fig. 18a—b. *Markalius circumradiatus* (Stover).
Fig. 19a—b. *Cylindralithus gallicus* (Stradner).

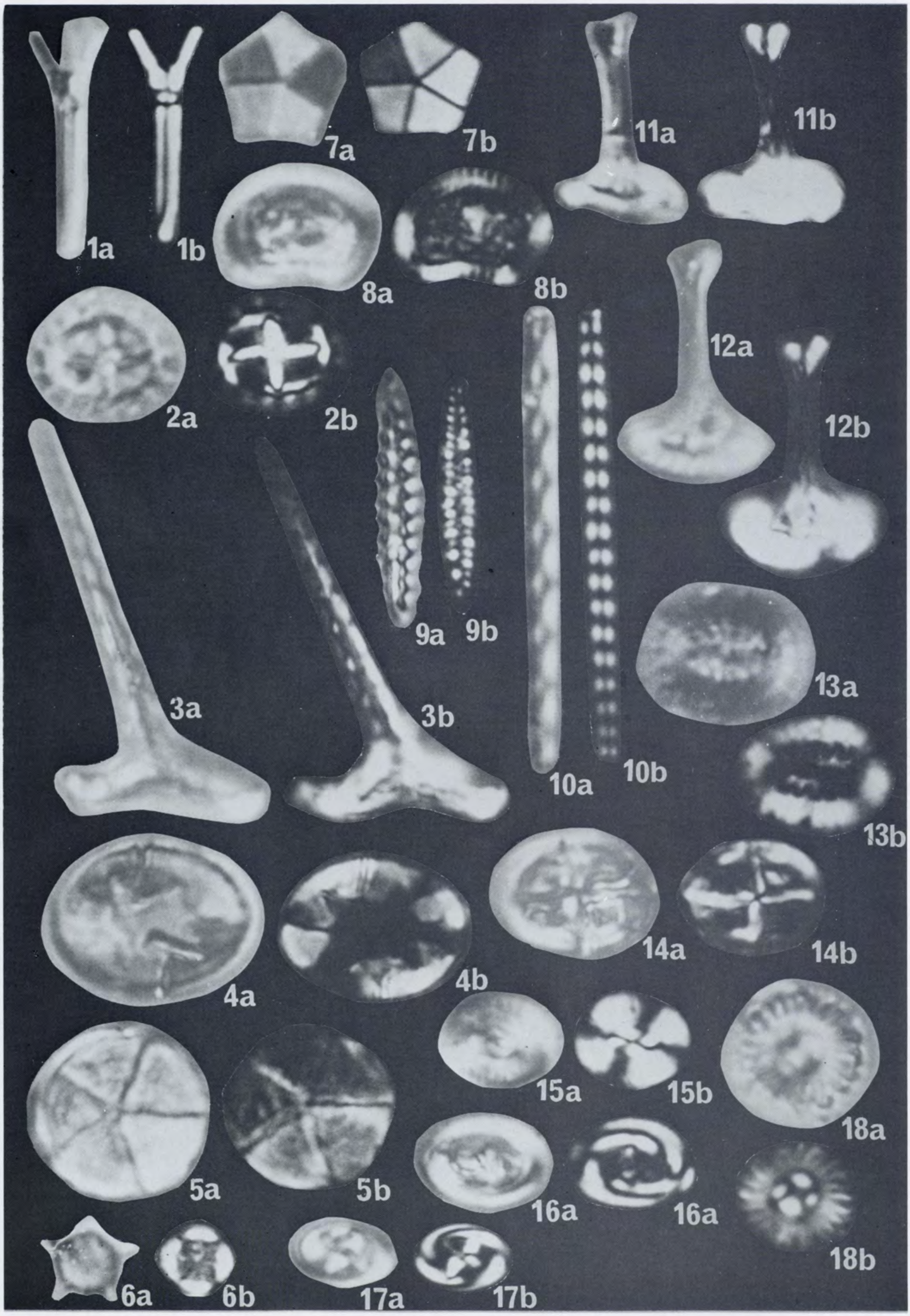
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PLATE V

All figures X3 500. Figures 'a' are under interference contrast; figures 'b' under crossed polarizers.

Fig. 1a—b. *Deflandrius spinosus* Bramlette and Martini, spine.
Fig. 2a—b. *Deflandrius spinosus* Bramlette and Martini, base.
Fig. 3a—b. *Eiffellithus turriseiffeli* (Deflandre), spine.
Fig. 4a—b. *Effellithus turriseiffeli* (Deflandre), base.
Fig. 5a—b. *Braarudosphaera discula* Bramlette and Riedel.
Fig. 6a—b. *Stephanolithion laffittei* Noël.
Fig. 7a—b. *Braarudosphaera bigelowi* (Gran and Braarud).
Fig. 8a—b. *Nephrolithus frequens* Gorka.
Fig. 9a—b. *Microrhabdulus nodosus* Stradner.
Fig. 10a—b. *Microrhabdulus attenuatus* (Deflandre).
Fig. 11a—b. *Reinhardtites anthophorus* (Deflandre).
Fig. 12a—b. *Polypodorhabdus crenulatus* (Bramlette and Martini), spine.
Fig. 13a—b. *Polypodorhabdus crenulatus* (Bramlette and Martini), base.
Fig. 14a—b. *Staurolithites mielnicensis* (Gorka).
Fig. 15a—b. *Watznaueria barnesae* (Black).
Fig. 16a—b. *Zygodiscus spiralis* Bramlette and Martini.
Fig. 17a—b. *Zygolithus dubius* Deflandre.
Fig. 18a—b. *Markalius inversus* (Deflandre).

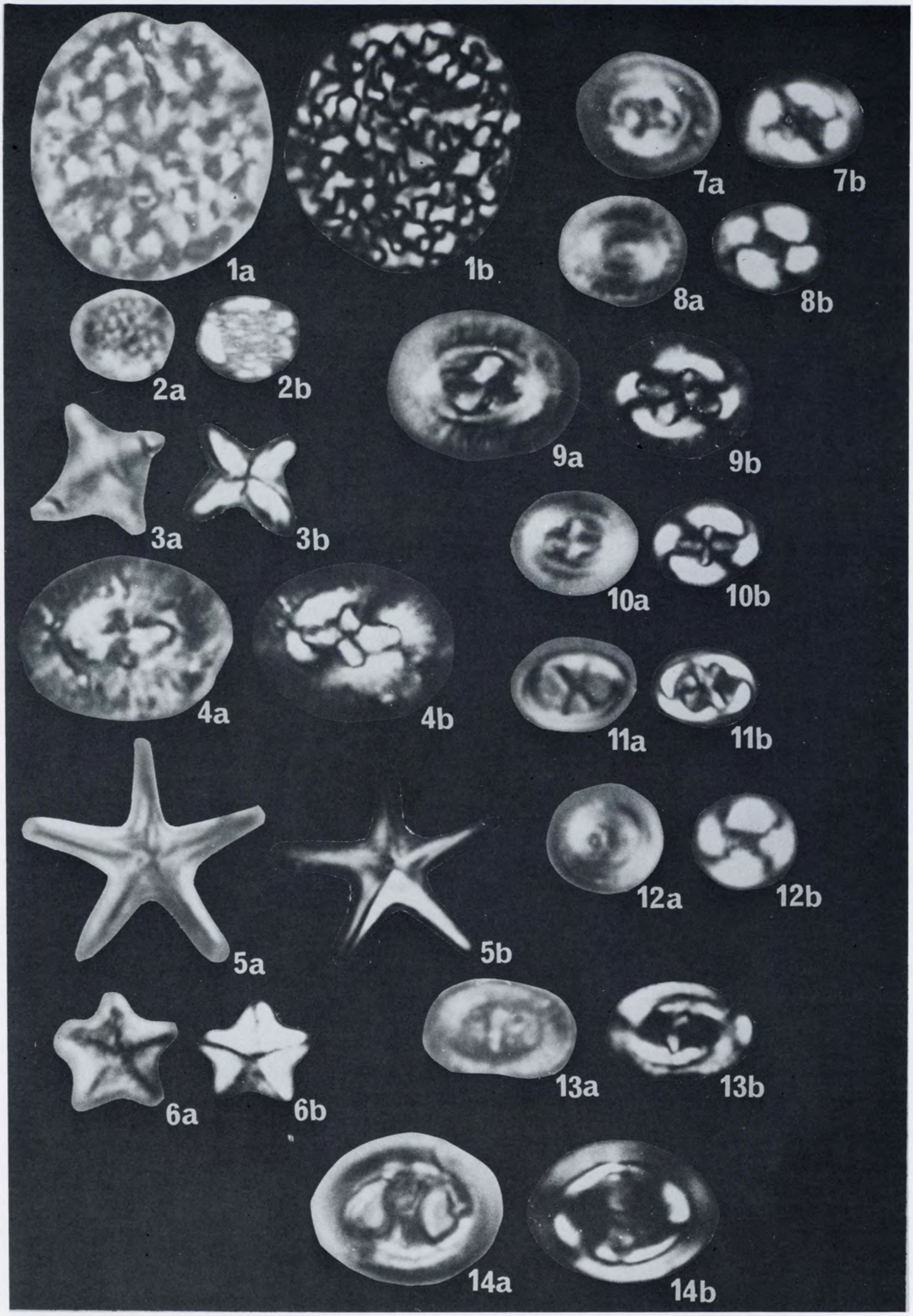
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PLATE VI

All figures X3 500. Figures 'a' are under interference contrast; figures 'b' under crossed polarizers.

Fig. 1a—b. *Thoracosphaera operculata* Bramlette and Martini.
Fig. 2a—b. *Thoracosphaera operculata* Bramlette and Martini, operculum.
Fig. 3a—b. *Micula staurophora* (Gardet).
Fig. 4a—b. *Cruciplacolithus tenuis* (Stradner).
Fig. 5a—b. *Micrantholithus attenuatus* Bramlette and Sullivan.
Fig. 6a—b. *Micrantholithus pinguis* Bramlette and Sullivan.
Fig. 7a—b. *Chiasmolithus danicus* (Brotzen).
Fig. 8a—b. *Coccolithus pelagicus* (Wallich).
Fig. 9a—b. *Chiasmolithus bidens* (Bramlette and Sullivan).
Fig. 10a—b. *Cruciplacolithus staurion* (Bramlette and Sullivan).
Fig. 11a—b. *Heliorthus concinnus* (Martini).
Fig. 12a—b. *Toweius craticulus* Hay and Mohler.
Fig. 13a—b. *Zygodiscus sigmoides* Bramlette and Sullivan.
Fig. 14a—b. *Zygodiscus plectopons* Bramlette and Sullivan.