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NANNOFOSSIL BIOSTRATIGRAPHY OF THE UTATUR GROUP, TRICHINOPOLY DISTRICT, SOUTH INDIA

CONTENTS

Key words: Early - Middle Cretaceous, Nannofossils, Biostratigraphy, Paleogeography, Utatur Group, South India.

ABSTRACT

The South Indian Cretaceous rocks are exposed on the Coromandel coast. They range from ?Aptian into the Maastrichtian. The Utatur Group is the lowest of the Cretaceous rock units units and represents the oldest exposed marine sequence in the Cauvery basin of the Trichinopoly district. Nannofossils from the sediments of this Group of Early and Middle Cretacoeus age have been studied in detail.

Five nannofossil biozones, viz. *Chiastozygus litterarius* to *Quadrum gartneri* (CC7 to CC11), are used to divide the Late Aptian? to Middle Turonian strata. These are described and significant nannofossil events in the basin recorded. The ammonite and planktonic foraminiferal zones are given for comparison. These zones do not coincide with the zones based on nannofossils.

The nannoflora of the Utatur Group shows a distinctive paleogeografic signature. In Aptian (?) — Albian time it is a high latitude southern flora. This gradually gives way to a temperate/tropical-subtropical flora in Cenomanian to Turonian time. The interpretation confirms the shifting of the position of the Indian Plate from high to temperate latitudes in the Cenomanian — Turonian as postulated by numerous authors based on plate tectonic reconstruction.

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RIASSUNTO

Nell'India meridionale, lungo la costa di Coromandel, affiorano rocce cretacee riferibili all'?Aptiano — Maastrichtiano. L'inferiore delle unità cretacee corrisponde all'Utatur Group e rappresenta la più antica sequenza marina del bacino di Cauvery nel distretto di Trichinopoly. Sono stati studiati in dettaglio i nannofossili di questi sedimenti del Cretaceo inferiore e medio.

Cinque zone a nannofossili, da quella a *Chiastozygus litterarius* a quella a *Quadrum gartneri* (CC7 a CC11), sono state utilizzate per suddividere gli strati dall'Aptiano superiore? al Turoniano medio. Le zone vengono descritte e citati gli eventi a nannofossili più significativi nel bacino. Per correlazione vengono riportate le zonazioni ad ammoniti e a foraminiferi planctonici. Queste zone non coincidono con quelle a nannofossili.

La nannoflora dell'Utatur Group manifesta una chiara impronta paleogeografica. Nell'Aptiano? — Albiano essa è una flora meridionale di alta latitudine. Ad essa gradualmente succede una flora temperato/tropicale — subtropicale dal Cenomaniano al Turoniano. L'interpretazione conferma lo spostamento di posizione della placca indiana da alte a medie latitudini nel Cenomaniano — Turoniano, come postulato da numerosi autori in base alle ricostruzioni della tettonica a placche.

INTRODUCTION

The main aim of this communication is to bring to light a rich nannofossil flora from the Utatur Group of the Cretaceous of South India and establish a biostragraphic classification based on nannofossils. A secondary aim was to examine how useful the nannofossils are in interpreting the palaeogeography of these deposits.

BLANFORD (1862) gave the first comprehensive report on the stratigraphy and structure of these deposits. STOLICZKA (1862-72), KOSSMAT (1895-97) and others have described rich mega invertebrate faunas. SASTRY *et al.* (1986), PHANSALKAR, and KUMAR (1983), AYYASAMI and BANERJI (1984) have presented the ammonite biostratigraphy. NARAYANAN (1977), SASTRY *et al.* (1968) and PHANSALKAR and KUMAR (1983) have presented the planktonic foraminiferal biostratigraphy of the Utatur Group. Integrated biostratigraphy has been presented by PHANSALKAR and KALE (1989).

PANT and MAMGAIN (1969) reported for the first time the presence of some nannofossils namely *Thoracosphaera* cf. *saxea* and *Coccolithus* sp. from the Utatur Group. The present study is the first comprehensive study of calcareous nannofossils from the Utatur Group.

LITHOSTRATIGRAPHY

Table No. 1 gives the general stratigraphic succession in the Cauvery Basin. The Utatur Group with an aggregate thickness of 760 m is the lowest marine unit. The Utatur Group is often observed to be directly overlying the Precambrian gneisses. Wherever such relation is exposed the junction between the two is a band of conglomerate. This conglomerate is exposed at very few places. However, in a few localities (ex-East of Terani), the continental Sivaganga Formation (Neocomian) is present in between the Precambrian gneisses and the Utatur Group, though the contact between the Sivganga Formation and the Utatur Group is not exposed. The Utatur Argillaceous Formation is exposed all along the Western margin of the basin (Fig. 1). Along the Western margin is also a characteristic development of reefoid bodies within the Utatur Argillaceous Formation. These reefoid bodies are disconnected bodies of not very large size and resemble a fringing reef; *eg.* reefoid limestone of Dalmiapuram, Karai, Maravattur, Sittali and Kallai. These reefoid bodies laterally grade into marls and clays with an interfingering relation. At the base of the reefoid body a grey shale is exposed at Dalmiapuram. This has been named as the Dalmiapuram Grey Shale Formation by SUBBARAMAN (1969). BHATIA and JAIN (1969) and BENERJI (1971) have considered it as a part of the Dalmiapuram Formation, along with reefoid limestone, older than the Utatur Group. We, however, feel that, these are part of the Utatur Group. The rest of the Utatur Group is characterized by a thick sequence of finely laminated marls and clays of dominantly white or red colours, while ochre and brown colours are not uncommon. A characteristic feature of the Utatur Argillaceous Formation is the development of clay and marls with phosphatic nodules and gypsiferous clays in them. Glauconite is common in the clays. Sandy intercalations and limestone bands are also present. Some sandy intercalations are ferrugenous and cherry red in colour while others are ochre yellow. At a few places they show evidence of bioturbation but on the whole lamination in these sediments is almost undisturbed. The sediments on the whole, are unindurated but some bands which are calcareous are well cemented.

The uppermost part of Utatur Group is a limestone, which is at places sandy. It is named Kunnam Limestone Formation (PHANSALKAR 1975). The Trichinopoly Group overlies this Formation with an unconformable contact.

METHODS AND TECHNIQUES

SAMPLING

Samples were collected along three traverses (Fig. 2) at an interval of 15 m. At every sampling station sufficient excavation was done to ensure fresh uncontaminated surface. A bulk sample was collected and stored in tough air sealed plastic bags. Implements used at one station were washed before using them at the next.

TECHNIQUES

Techniques suggested by GARTNER (1968) were widely used, though for SEM studies the prepara-

TABLE 1 - Stratigraphy of the Cauvery basin modified after RAMANATHAN (1968) SASTRY *et al.* (1972)

AGE	GROUP	FORMATION	THICKNESS in Meters	LITHOLOGY
PALEOCENE DANIAN	NINIYUR GROUP		200	Variegated clays with bands of nodular limestones and marls, occasional cherts.
MAASTRICHTIAN	ARIYALUR GROUP	KALLAMEDU Fm	150	Medium to Coarse sandstones white, friable, greenish sandstones intercalated with clayey sandstones and purple coloured clay toward the top.
to		OTTAKOVIL Fm	120	Whitish unindurated sands with beds of calcareous sands, fossiliferous at places.
		KALLANKURICHHI Fm	150	Calcareous sandstones and sandy limestones with a prominent carbonate bank made up of organic debris, mostly *Pycnodonte vesicularis*, Inoceramids, Brachiopods etc.
CAMPANIAN		SILLAKUDI Fm	200	Dominantly sandy: whitish sandstones; clayey sandstones; sandstones not well indurated, calcareous, marly etc. Several bands of clays which are bentonitic.
CONIACIAN	TRICHINOPOLY GROUP	KULATUR Fm	100	Dominantly sandy. The uppermost bed of calcareous sandstone with *Peroniceras dravidicum*
		KULKALNATTAM Fm	100	Divisible into upper clay/sand member, middle marl member and lower sandstone member cross-bedded. All the members have phosphatic nodules of moderate size. All members have highly fossiliferous pockets.
		GARUDAMANGALAM SHELL LIMESTONE Fm	150	Shell limestones with conglomeratic bioclasts. Some finely bedded, cross-bedded. Dark coloured micrite matrix. There are at least four bands separated by sandy clays and calcareous sandstones. Conglomerate patches at the base suggesting step up relationship with Kunnam Limestone Fm.
LATE TURONIAN				
MIDDLE TURONIAN	UTATUR GROUP	KUNNAM LIMESTONE Fm	200	Impure clayey limestones associated with unindurated silts, clays and sands, lamination; clays with Gypsum and phosphatic nodules.
		UTATUR ARGILLACEOUS Fm	500	Whitish, yellow orange coloured marls and clays with intervening bands of ferrugenous clayey sandstones, bioclastic limestones; Laminated, prominently make bad lands wherever exposed; Gypsiferous: with Phosphatic nodules of varied sizes.
to		REFOID LIMESTONE Fm	50	Pink to whitish limestone which laterally grades into marls and clays of Utatur Argillaceous Fm. At places developed as Carbonate ram. Full of varied fauna and flora.
? E/M. ALBIAN		DALMIAPURAM GRAY SHALE Fm	10	Thinly bedded, black carbonaceous shale with intercalated black micritic limestone and marls.
NEOCOMIAN		SIVAGANGA Fm	30	Dominantly whitish clays, with minor sandy calcareous bands, yielding Ptilophyllum flora
ARCHAEAN		GNEISSES CHARNOCKITES etc.		Granitic gneisses, banded gneisses, charnockites etc.

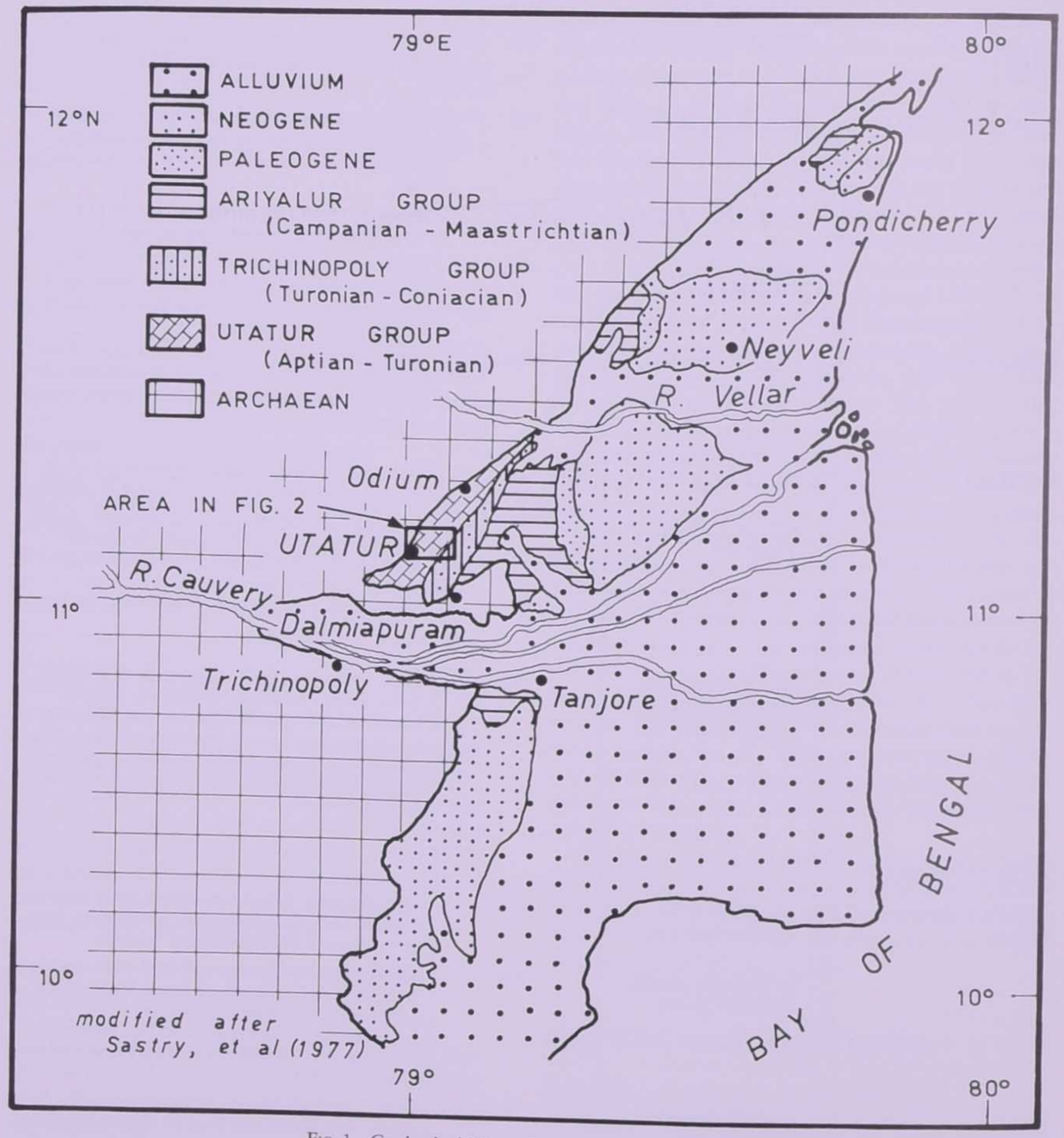

FIG. 1 - Geological Map of the Cauvery basin.

tion was slightly different. Efforts were made to concentrate the nannoflora for SEM studies on the lines suggested by GARTNER (1968). On the basis of LM studies, samples were chosen for SEM studies.

All samples studied under LM were examined for the overall abundance and for the state of preservation of nannofossils.

The relative abundance of the individual species was determined per 300 fields of view on LM. The relative abundance with respect to the abundance of *Watznaueria barnesae* (BLACK,

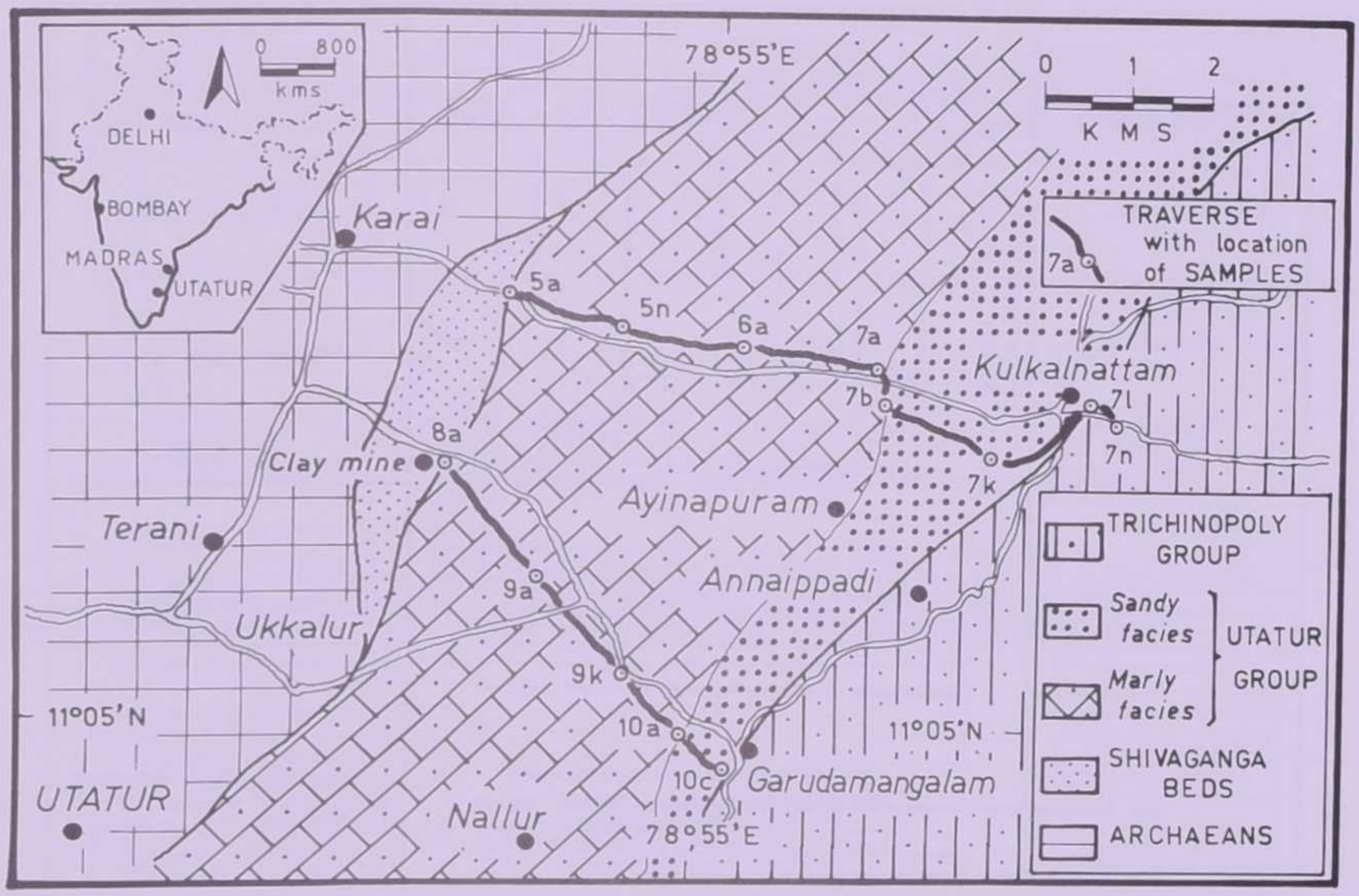

FIG. 2 - Map of sampling traverses across the Utatur Group.

1959) was noted. This serves as a good check for determining the state of preservation.

NANNOFOSSIL BIOSTRATIGRAPHY

The basic framework for the biostratigraphic zonation of the Utatur Group is based upon the scheme adopted by PERCH-NIELSEN (1985). The occurrence of individual species of calcareous nannofossils in each section is presented in weighed distribution charts (Figures 3, 4, and 5).

The following nannofossil zones have been recognized in the three sections studied: a) Karai-Kulkalnattam section b) Terani-Garudamangalam section and c) Kallakudi Quarry at Dalmiapuram.

Chiastozygus litterarius Zone (CC 7)

Definition: FO of *Chiastozygus litterarius* (GORKA, 1957) to FO of *Prediscosphaera columnata* (STOVER, 1966).

Authors: THIERSTEIN (1971), emend. SISSINGH (1977).

Age: Aptian and Early Albian.

Occurrence: In the Terani - Garudamangalam section (Fig. 3) sample numbers IIF/8e - IIF/8i. These are marls in the basal part of the Utatur Argillaceous Formation, which are devoid of megafauna except belemnite guards, though they yield a nannoflora.

Discussion: Presence of *Rhagodiscus angustus* (STRADNER) and *Eprolithus floralis* (STRADNER) along with *Chiastozygus litterarius* (GORKA) warrants placement of these sediments in the *Rhagodiscus angustus* Subzone (CC 7b) of PERCH-NIELSEN (1979). On the basis of this, the age assigned is late Late Aptian (?) to Early Albian. The planktonic foraminifera recovered from these are poor in diversity and do not have any age diagnostic form. The nannoflora is akin to that described by BUKRY (1974c) from sites 260 and 263 of Leg 27 of D.S.D.P. in the Eastern Indian Ocean. The nannoflora is low in diversity as compared to the nannoflora of the Aptian and Albian from the Tethyan and Boreal Provinces describes by MONECHI (1981), ERBA and QUADRIO (1987), JAKUBOWSKI (1987), MUTTERLOSE (1987 and 1989).

Prediscosphaera columnata Zone (CC 8)

Definition: FO of *P. columnata* (STOVER, 1966) to FO of *Eiffellithus turriseiffelii* (DEFLANDRE, 1954).

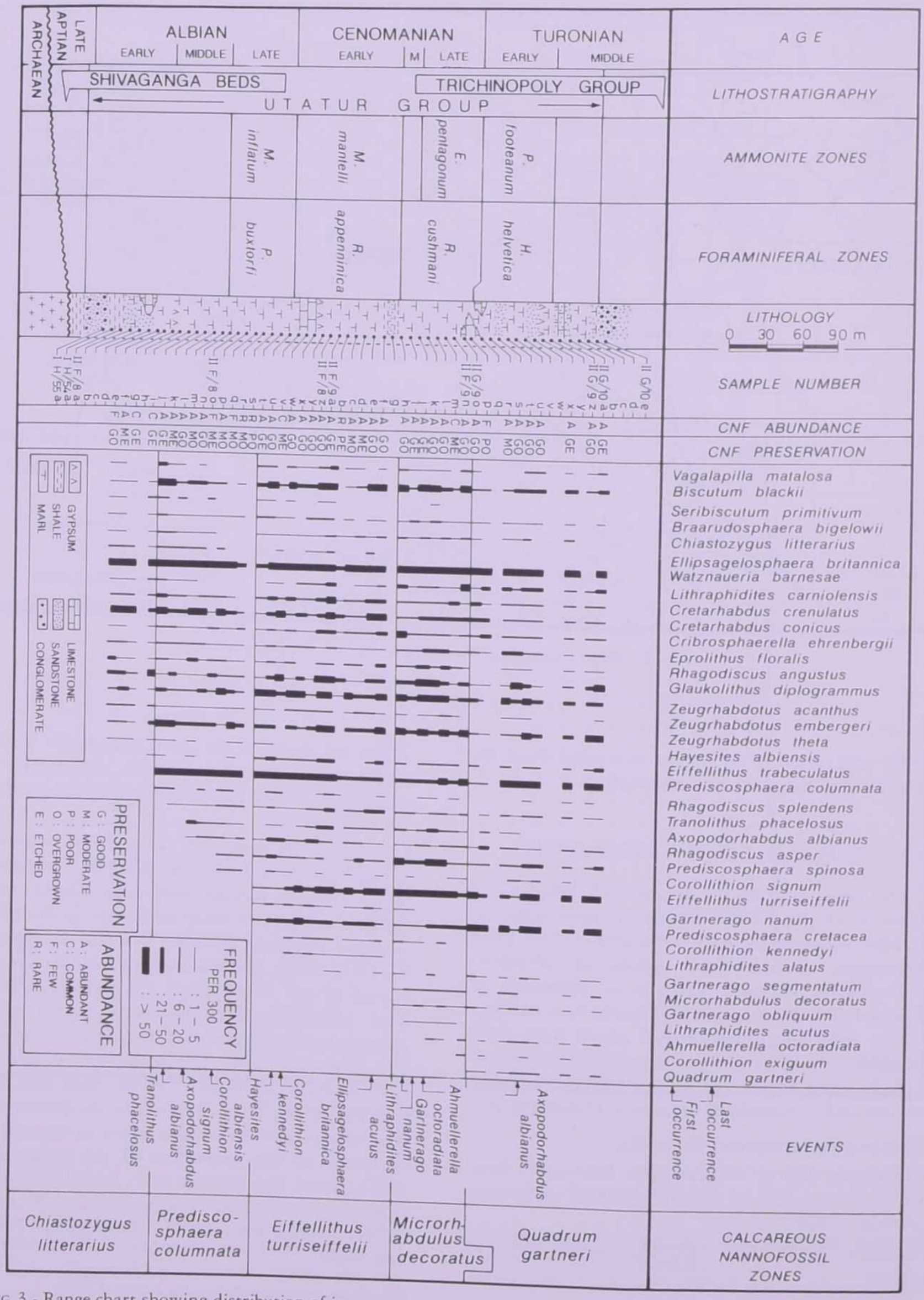

FIG. 3 - Range chart showing distribution of important nannofossil species in the Terani-Garudamangalam section.

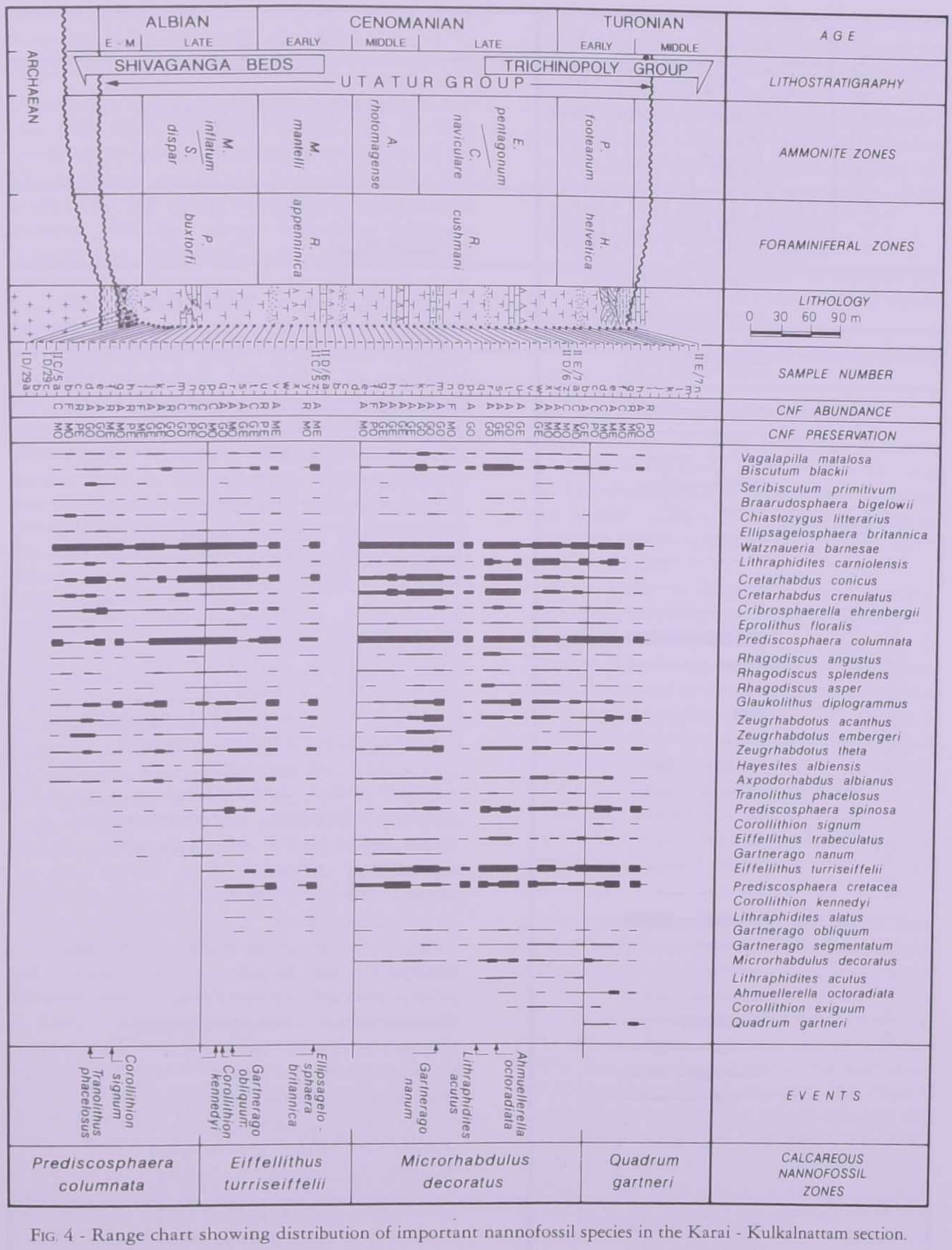

FIG. 4 - Range chart showing distribution of important nannofossil species in the Karai - Kulkalnattam section.

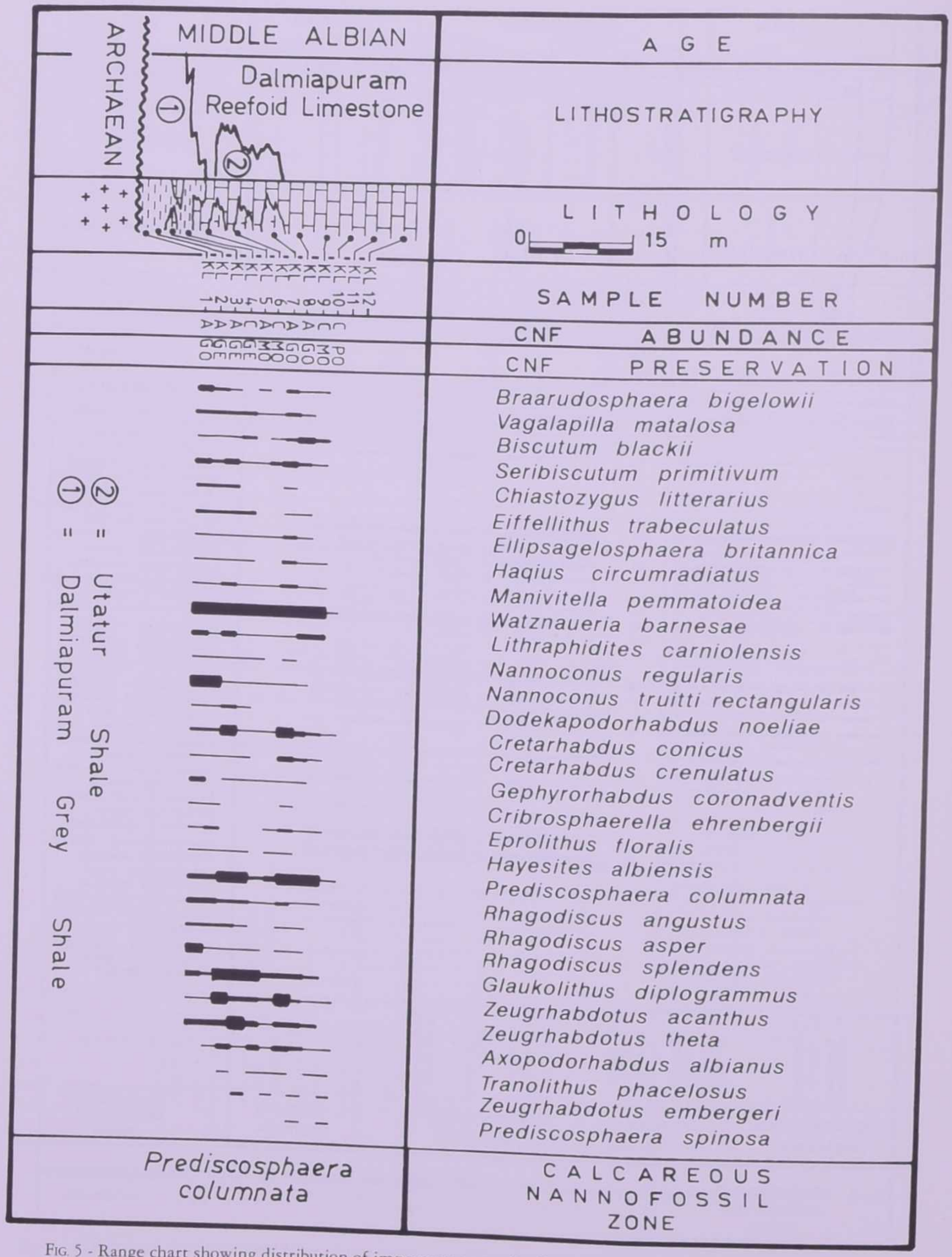

FIG. 5 - Range chart showing distribution of important nannofossil species in the Kallakudi Quarry section.

Authors: THIERSTEIN (1971), nom. corr. MANIVIT *et al.* (1977).

Age: Early Albian to Late Albian.

Occurrence: a) in the Karai - Kulkalnattam section (Fig. 4) *P. columnata* occurs from the first fossiliferous sample (II c/5a) near the base of the Utatur Group *i.e.* at the beginning of the bad lands. The FO of *E. turriseiffelii* is in sample number IIC/5p. *Axopodorhabdus albianus* (BLACK) and *Cribrosphaerella ehrenbergii* (ARKHANGELSKY) also occur in fossiliferous sample. The FO of *Tranolithus phacelosus* STOVER is slightly above the base (sample no IIC/5e). The FO of *Corollithion signum* STRADNER is later than that of *T. phacelosus* (sample no. IIC/5g). b) In the Terani-Garudaman-galam section (Fig. 3) this zone ranges from sample No. IIF/8j to IIf/8s. *C. ehrenbergii* is recorded from the base of the sequence in CC7. The FO of *A. albianus* (IIF/8n) and *C. signum* occur later (IIF/80). c) In the Kallakudi Quarries (Fig. 5), *P. columnata* occurs from the base to top. The FO of *A. albianus* and *T. phacelosus* are above the exposed base of the Grey Shales. *C. signum* is absent.

Discussion: The *P. columnata* Zone records several nannofossil events described earlier. The FO of *A. albianus* (BLACK) has been used by THIERSTEIN (1976) to define a Middle Albian nannofossil zone. PERCH-NIELSEN (1985) has commented upon the report of this species from the Barremian and hence found it unsuitable as a marker and recommends use of first occurrences of *T. phacelosus, C. signum* and the genus *Cribrosphaerella* DEFLANDRE, as significant events. WISE (1983) has used the FO of *T. phacelosus* as a subzone marker in his fourfold division of the *P. columnata* Zone.

During the present study the FO of *A. albianus* and *T. phacelosus* though very near, are found at different levels in the two neighbouring sections of Karai - Kulkalnattam and Terani - Garudamangalam. The interval between these two may represent the transition from the Early to Middle Albian. FO of *C. signum* may represent the transitions from the Middle to Late Albian. In the Karai - Kulkalnattam section the FO of *Mortoniceras (M.) inflatum* (SOWERBY) is observed slightly above the FO of *C. signum. Mortoniceras (M.) inflatum* in the Utatur Group is taken as datum for Late Albian (PHANSALKAR and KUMAR, 1983). The rock matrix from *M.* (*M.*) *inflatum*, on search did not yield any *E. turriseiffelii.* Though forms resembling *Seribiscutum primitivum* (THIERSTEIN) are present in the *C. litterarius* Zone, it becomes abundant only in the *P. columnata* Zone after the first occurrence of *A. albianus* and *T. phacelosus*. It is interesting to note that this species, referred by many to be high latitude Austral, is present in significant numbers in the Dalmiapuram Grey Shale Formation, where it is associated with a strongly paleoecologically controlled nannoflora as described by KALE and PHANSALKAR (1989).

Eiffellithus turriseiffelii Zone (CC 9)

Definition: FO of *Eiffellithus turriseiffelii* (DEFLANDRE, 1954) to FO of *Microrhabdulus decoratus* DEFLANDRE (1959).

Authors: THIERSTEIN (1971) emend. SISSINGH (1977).

Age: Late Albian to Early Cenomanian.

Occurrence: The *E. turriseiffelii* Zone is encountered only in the Karai - Kulkalnattam and Terani - Garudamangalam sections. Karai - Kulkalnattam section: sample Nos - IIC/5p to IID/6d. Terani-Garudamangalam section: sample Nos. - IIF/8t to IIF/9g.

In the Karai - Kulkalnattam section the top of the zone is placed at the FO of *M. decoratus* in sample No. IID/6e. However, sample Nos. II-D/6a to IID/6D are unfossiliferous terrigenous sandy limestones or sandy marls, with intervening layers of gypsiferous marls. The placing of the upper boundary of the *E. turriseiffelii* zone in saample No. IID/6d and the base of *M. decoratus* Zone in sample No. IID/6e is tentative.

Similarly, sample No. IIF/9g is a sandy marl and unfossiliferous. The FO of *M. decoratus* is in sample No. IIF/9h in the Terani - Garudamangalam section.

Discussion: The base of the *E. turriseiffelii* Zone in the Late Albian is probably the best recorded and agreed upon amongst all the mid-cretaceous nannofossil events. In the Utatur Group the base of this zone is observed within the *Mortoniceras (M.) inflatum* Zone.

The first nannofossil event in this zone is the LO of *Hayesites albiensis* MANIVIT. This event is slightly separated from the base of this zone and is taken to mark the late Late Albian. The FO of *Corollithion kennedyi* CRUX in the Karaikulkalnattam section immediately follows the LO of *H. albiensis*. In the Terani-Garudamangalam section they are separated by about 29 m of sediments. The Albian-Cenomanian boundary is placed between these two events. Owing to occurrence of ammonites in pockets, this interval does not afford any evidence from them and it is difficult to differentiate the precise base of the Early Ceno-

manian *Mantelliceras mantelli* (SOWERBY) Zone of PHANSALKAR and KUMAR (1983). The FO of *Gartnerago obliquum* (STRADNER) in the Karai-Kulkalnattam section is in the sample succeding the FO of *C. kennedyi.* However, in the Terani -Garudamangalam section the FO of *G. obliquum* (STRADNER) is with the FO of *M. decoratus,* Preceded by an unfossiliferous interval.

It is due to this separation of the FO of *G. obliquum* in the Utatur Group, that it is not used as a nannofossil event. The LO of *Ellipsagelosphaera britannica* (STRADNER) is toward the top of the *E. turriseiffelii* Zone, though in the Karal-Kulkalnattam section it is succeded by an interval of barren sandy sediments.

Lithraphidites alatus THIERSTEIN is extremely impersistant and extremely rare throughout this zone and hence it is unsatisfactory as a marker.

Microrhabdulus decoratus Zone (CC 10)

Definition: FO of *Microrhabdulus decoratus* DEFLANDRE (1959) to FO of *Quadrum gartneri* PRINS and PERCH-NIELSEN (1977).

Author: SISSINGH (1977).

Age: Middle to Late Cenomanian.

Occurrence:

1. Kara i-Kulkalnattam section. Base: Sample No. IID/6e; Top: Sample No. IIE/7b. 2. Terani - Garudamangalam section. Base: Sample No. IIG/9h; Top: Sample No. IIG/9n.

Discussion: In both the sections studied, the base of the *M. decoratus* zone is preceded by unfossiliferous sandy sediments. The FO of *M. decoratus* and the FO of *Acanthoceras rhotomagense* (BROGNIART) are separated by less than a metre of sediment.This was the only case in which the nannofossil and ammonite zonal boundaries are coincident. The base of both these zones is taken to mark the base of the Middle Cenomanian.

In the Karai-Kulkalnattam section the *M. decoratus* zone is well developed with almost 20 fossiliferous samples representing a sediment thickness of about 200 m. In the Terani-Garudamangalam section this zone is compressed to 60-70m of sediments represented by 7 samples.

The FO of *Lithraphidites acutus* VERBEEK and MANIVIT and *Ahmuellerella octoradiata* (GORKA) and the LO of *Gartnerago nanum* THIERSTEIN are the events recorded in this zone. The LO of *G. nanum* THIERSTEIN is after the FO of *L. acutus* in the Terani - Garudamangalam section, which may be due to the condensed sequence (? lower rate of sedimentation) and possible reworking, as the last observed individuals of *G. nanum* THIERSTEIN appear to be slightly etched and are often broken.

The FO of *A. octoradiata* (GORKA) is observed within the late Late Cenomanian *Eucalycoceras pentagonum* JUKES-BROWNE Zone of PHANSALKAR and KUMAR (1983).

Quadrum gartneri Zone (CC 11)

Definition: FO of *Quadrum gartneri* PRINS and PERCH-NIELSEN (1977) to FO of *Lucianorhabdus maleformis* REINHARDT (1966) or FO of *Eiffellithus eximius* (STOVER, 1966).

Authors: ČEPEK and HAY (1969) emend. SISSINGH (1977), nom. corr. MANIVIT *et al.* (1977).

Age: Early Turonian and Middle Turonian probably including very late Cenomanian.

Occurrence: 1. Karai - Kulkalnattam section. Base: Sample No. IIE/7b; Sample Nos IIE/7i to IIE/7n - unfossiliferous; Top not observed in the Utatur Group. 2. Terani - Garudamangalam section. Base: Sample No. IIG/7a; Sample Nos IIG/10b to IIG/10e unfossiliferous; Top not observed in the Utatur Group.

Discussion: This is the youngest nannofossil zone recognised in the Utatur Group. Its base in both the sections is marked by the FO of *Q. gartneri* which is below the level of FO of either *Inoceramus labiatus* (SCHLOTHEIM) or *Pseudaspidoceras footeanum* (STOLICZKA) which are taken to mark the base of the Turonian in the Utatur Group. BRALOWER (1988) has reported the FO of *Q. gartneri* from the Middle Cenomanian from several sections in the Western Interior of the United States, the Danish-German Basins and the D S D P site 551, south of England. In all these sections the presence of *Q. gartneri* is rare and sporadic in the Middle and Late Cenomanian.

In the present study the FO of *Q. gartneri* is taken to mark the late Late Cenomanian. It would be necessary to redefine the *Q. gartneri* Zone as an acme zone instead of a partial range zone as it is now recognised is further records of *Q. gartneri* in the Middle Cenomanian are established.

The LO of *A. albianus* is noted within a sand dominated part of the Terani-Garudamangalam section. This is well above the FO of *Helvetoglobotruncana helvetica* (BOLLI).

The Early Turonian marker *Whiteinella archaeocretacea* PESSAGNO, has not been recorded from this basin. The LO of *A. albianus* (BLACK) is not recorded in the Karai-Kulkalnattam section.

SIGNIFICANCE OF NANNOFLORA FOR PALAEOGEOGRAPHY

The D.S.D.P. drilled a large numer of sites in several legs. The information brought by this

work and later ODP work has thrown significant light on the stratigraphy of the oceans. BUKRY (1974a), GARTNER (1974), GARTNER *et al.* (1974) in Leg 22; MULLER (1974) in leg 25, THIERSTEIN (1974), BUKRY (1974b) in Leg 26, BUKRY (1974c) and PROTO DECIMA (1974) have studied the nannoflora of the Indian Ocean in the D.S.D.P. ROTH and KRUMBACH (1986) have studied the Mid Cretaceous Biogeography of the Indian Ocean based on calcareous nannoplankton. The oldest marine sediments are Bathonian - Bajocian (VEEVERS and JOHNSTONE, 1974). Late Jurassic marine sediments are present in the Western Indian Ocean, off the coast of Durban (South Africa). These marine Jurassic transgressions mark the initial rupture between Australia-India and Madagascar - Africa (VEEVERS and JOHNSTONE, 1974; SIGAL, 1974).

Large scale marine transgressions are witnessed in the Lower Aptian in the Eastern Indian Ocean, (BOLLI, 1974; VEEVERS and JOHNSTONE, 1974: VEEVERS and HEIRTZLER, 1974) and in the Aptian-Albian in the Western Indian Ocean (SIMPSON *et al.,* 1974). In the Southern Indian Ocean the oldest marine sediments are Middle Albian in age (THIERSTEIN, 1974). A black shale facies is extensively developed in the offshore off Western Australia; in the DSDP site 263 during the Aptian-Albian and in the Albian-Cenomanian in the continental shelf off Western Australia (VEEVERS and JOHNSTONE, 1974).

A hiatus is recorded for the full Cenomanian -Turonian period in the Eastern Indian Ocean (ROBINSON *et al.,* 1974) and Western Indian Ocean (GIRDLEY *et. al.,* (1974) postulate a possible non depositional event for this region, though the evidences for this are not ubiquitous. A Cenomanian-Turonian unconformity is present in the Southern Indian Ocean (THIERSTEIN, 1974).

The flora of the Dalmiapuram Gray Shales, especially the dominance of *W. barnesae*, abundance of *S. primitivum, Nannoconus* spp. *Braarudosphaera bigelowii* (GRAN and BRAARUD), *Rhagodiscus asper* (STRADNER), *Rhagodiscus splendens* (DEFLANDRE), *Lithraphidites carniolensis* DEFLANDRE, *E. turriseiffelii, Cretarhabdus* spp., *Biscutum* spp., is similar to the nannoflora reported from the Albian black shale facies from the Eastern Indian Ocean by PROTO DECIMA (1974). The presence of *Nannoconus* spp. indicates a probable gateway between these two depositional sites.

The high latitude preference of *S. primitivum, R. asper, R. splendens*, and *Biscutum* spp. has been established by ROTH and BOWDLER (1981) and ROTH and KRUMBACH (1986). These species are high in their abundance in the Albian sediments from all over the Indian Ocean and in the Kallakudi section and lower Utatur sediments. These deposits therefore are interpreted as having a high latitude paleogeographic position during the Albian.

Nannoconus, though mostly known from the Tethyan province, is also known from the Southern hemisphere (PROTO DECIMA, 1974; WISE and WIND, 1977; NOEL and MELGUEN, 1978; PROTO DECIMA *et al.,* 1978) from Aptian - Albian black shale facies.

The Cenomanian - Turonian hiatuses in the Indian Ocean and the condensed nature of the Middle Cenomanian in the Cauvery Basin make us believe in a progressive regression of the sea in the Upper Cenomanian - Turonian. This is also substantiated by the increase of the coarse clastics in the Upper Utatur.

The Cenomanian - Turonian nannoflora shows the decreasing dominance of the high latitude species in the Utatur Group. Combined with the absence of the Cenomanian - Turonian sediments in Indian Ocean, this confirms the shifting of the position of the Indian Plate from high to temperate latitudes in this period as postulated by numerous authors based on plate tectonic reconstructions.

CONCLUSIONS

From our studies we can conclude that: 1) The Utatur Group ranges in age from? Late Aptian/Early Albian to Middle Turonian. 2) It is possible to identify five nannofossil zones viz. CC7 to CC11. 3) Nannoflora can be used to interprete the palaeogeography during this period and our interpretation matches with the interpretation based on plate tectonic reconstruction.

ACKNOWLEDGEMENTS

We are thankful to Head of the Department of Geology, University of Poona, for providing necessary facilities of work. Financial assistance to ASK as senior fellowship by C.S.I.R. is gratefully acknowledged. Many thanks to Shirley VAN HECK for critically reading the manuscript in a very thorough way.

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EXPLANATION OF PLATE I

(Magnification: 3600X)
(Figures in brackets are negative numbers of hypotypes
(CPL = Cross Polarised Light)

FIG. 1 - *Ahmuellerella octoradiata* (GORKA, 1957) REINHARDT 1964 Proximal view, CPL, (121191).

FIG. 2 - *Vagalapilla matalosa* (STOVER, 1966).
THIERSTEIN, 1973. Distal view, Phase contrast (131015).

FIG. 3 - *Vagalapilla matalosa* (STOVER, 1966)
THIERSTEIN, 1973. Distal view. Transmitted light (131014).

FIG. 4 - *Gartnerago obliquum* (STRADNER, 1963) REINHARDT, 1970.
Proximal view, CPL, (121314).

FIG. 5 - *Chiastozygus litterarius* (GORKA, 1957) MANIVIT 1971.
Proximal side, CPL, (131090).

FIG. 6 - *Chiastozygus litterarius* (GORKA, 1957) MANIVIT, 1971.
Distal view, CPL, (131090).

FIG. 7 - *Eiffellithus turriseiffelii* (DEFLANDRE, 1954) REINHARDT, 1965. Distal view, CPL, (121200).

FIG. 8 - *Eiffellithus turriseiffelii* (DEFLANDRE, 1954) REINHARDT, 1965. Proximal view, CPL, (121260), 1800x.

FIG. 9 - *Rhagodiscus angustus* (STRADNER, 1963) REINHARDT 1971
Proximal view, CPL, (131099).

FIG. 10 - *Rhagodiscus splendens* (DEFLANDRE, 1953) VERBEEK 1977.
Distal view, CPL, (121336).

FIG. 11 - *Watznaueria barnesae* (BLACK, 1959) PERCH-NIELSEN, 1968 Distal view, CPL, (131013).

FIG. 12 - *Ellipsagelosphaera britannica* (STRADNER, 1963) PERCH-NIELSEN, 1968. Proximal view, CPL, (131041).

FIG. 13 - *Ellipsagelosphaera britannica* (STRADNER, 1963) PERCH-NIELSEN, 1968, same specimen as Fig. 12, Transmitted light, (131042).

FIG. 14 - *Seribiscutum primitivum* (THIERSTEIN, 1974) FILEWICZ *et al.*, 1977. Proximal viev, CPL, (131100).

FIG. 15 - *Braarudosphaera bigelowii* (GRAN and BRAARUD, 1935)
DEFLANDRE, 1947, Proximal view, CPL, (131023).

FIG. 16 - *Corollithion exiguum* STRADNER, 1961.
Axial view, CPL, (121185).

FIG. 17 - *Corollithion kennedyi* CRUX, 1981.
Axial view, CPL, (121357).

FIG. 18 - *Corollithion signum* STRADNER, 1963, overgrown specimen, Axial view, CPL, (121087).

FIG. 19 - *Axopodorhabdus albianus* (BLACK, 1957) WIND & WISE, 1977.
Distal view, CPL, (121249).

FIG. 20 - *Quadrum gartneri* PRINS and PERCH-NIELSEN, 1977.
Axial view, CPL, (121241).

FIG. 21 - *Tranolithus phacelosus* STOVER, 1966.
Distal view, CPL, (121355).

FIG. 22 - *Eprolithus floralis* (STRADNER, 1962) STOVER, 1966,
M. Albian, Axial view, CPL, (121203), 1800x.

FIG. 23 - *Eprolithus floralis* (STRADNER, 1962) STOVER, 1966, E. Cenomanian, Axial view, CPL, (121016).

FIG. 24 - *Eprolithus floralis* (STRADNER, 1962) STOVER, 1966,
L. Cenomanian. Axial view, CPL, (121110).

FIG. 25 - *Eprolithus floralis* (STRADNER, 1962) STOVER, 1966, M. Albian, Side view, CPL, (121084).

FIG. 26 - *Quadrum gartneri* PRINS and PERCH-NIELSEN, 1977.
Axial view, Transmitted light (121227).

FIG. 27 - *Hayesites albiensis* MANIVIT, 1971.
Axial view, CPL, (131080).

FIG. 28 - *Microrhabdulus decoratus* DEFLANDRE, 1959.
CPL, (122307).

FIG. 29 - *Microrhabdulus attenuatus* (DEFLANDRE, 1959)
DEFLANDRE, 1963. CPL, (121373).

FIG. 30 - *Microrhabdulus belgicus* HAY and TOWE, 1963,
CPL, (121364).

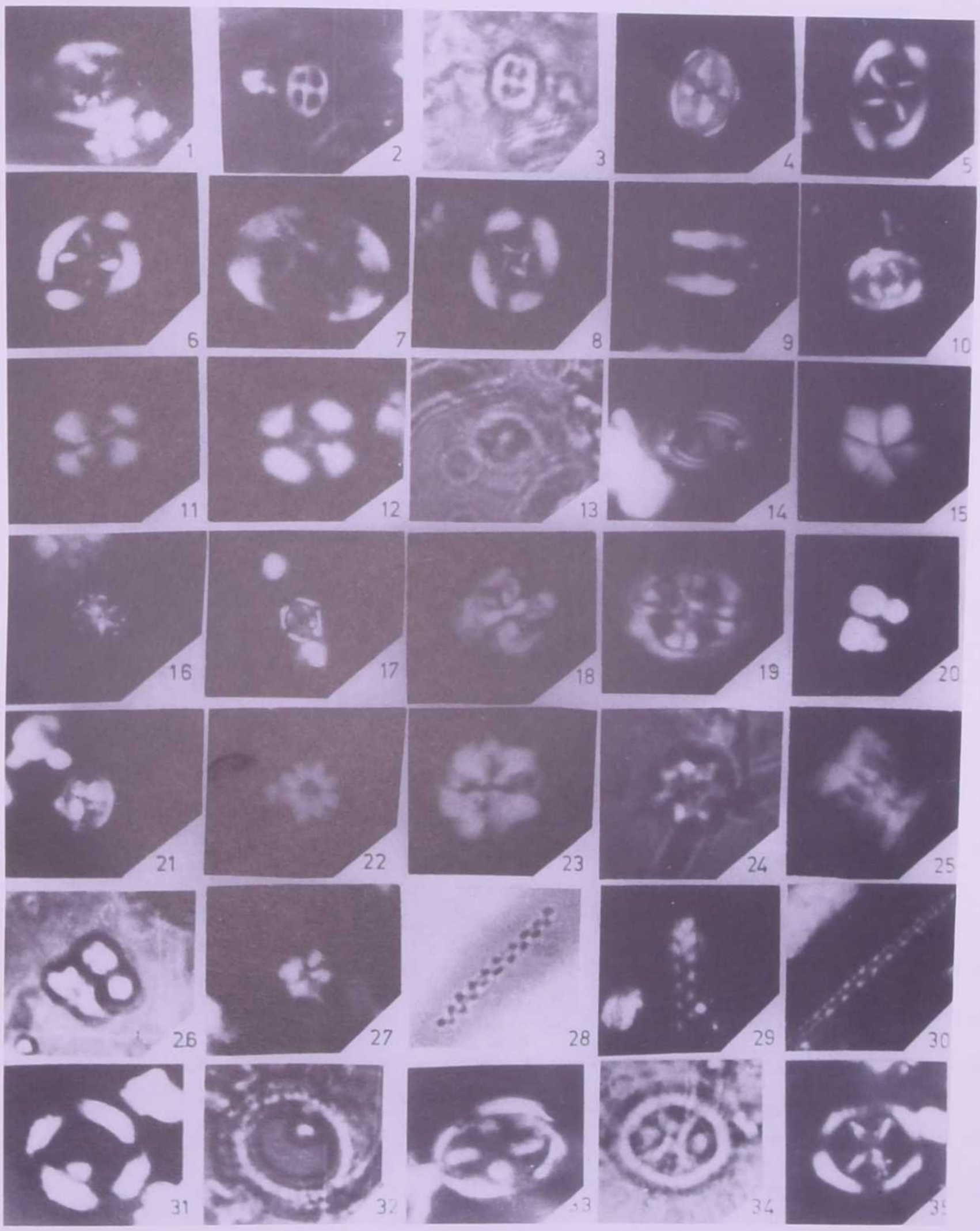
FIG. 31 - *Manivitella pemmatoidea* (DEFLANDRE ex. MANIVIT, 1965),
THIERSTEIN, 1971. Proximal view, CPL, (131097).

FIG. 32 - *Manivitella pemmatoidea* (DEFLANDRE ex. MANIVIT, 1965), THIERSTEIN, 1971, Proximal view. Transmitted light (131095).

FIG. 33 - *Gartnerago striatum* (STRADNER, 1963).
FORCHHEIMER, 1972. Distal view, CPL, (121217).

FIG. 34 - *Gephyrorhabdulus coronadventis* (REINHARDT, 1966),
HILL, 1976. Proximal view. Transmitted light (131027).

FIG. 35 - *Gephyrorhabdulus coronadventis* (REINHARDT, 1966),
HILL, 1976, Proximal view, CPL, (131026).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EXPLANATION OF PLATE II

(Bar = 2 μm)
(Figures in brackets are negative numbers of hypotypes)

FIG. 1 - *Gartnerago obliquum* (STRADNER, 1963) REINHARDT, 1970.
Distal view. (E11477).

FIG. 2 - *Chiastozygus litterarius* (GORKA, 1957) MANIVIT, 1971.
Distal view. (E11037).

FIG. 3 - *Eiffellithus turriseiffelii* (DEFLANDRE, 1954) REINHARDT, 1965. Distal view. (E11470).

FIG. 4 - *Watznaueria barnesae* (BLACK, 1959) PERCH-NIELSEN, 1968.
Distal view. (E111p5).

FIG. 5 - *Ellipsagelosphaera britannica* (STRADNER, 1963) PERCH-NIELSEN, 1968, Overgrown, Distal view. (E11145).

FIG. 6 - *Eprolithus floralis* (STRADNER, 1962) STOVER, 1966.
Axial view. (E11013).

FIG. 7 - *Axopodorhabdus albianus* (BLACK, 1957) WIND and WISE, 1977 Slightly etched, Distal view. (E11053).

FIG. 8 - *Cribrosphaerella ehrenbergii* (ARKHANGELSKY, 1912) DEFLANDRE, 1952. Proximal view. (E11466).

FIG. 9 - *Glaukolithus diplogrammus* (DEFLANDRE, 1954) REINHARDT, 1964 Proximal view. (E11pp5).

FIG. 10 - *Prediscosphaera columnata* (STOVER, 1966) PERCH-NIELSEN, 1984. Albian, Overgrown Distal view. (E11401).

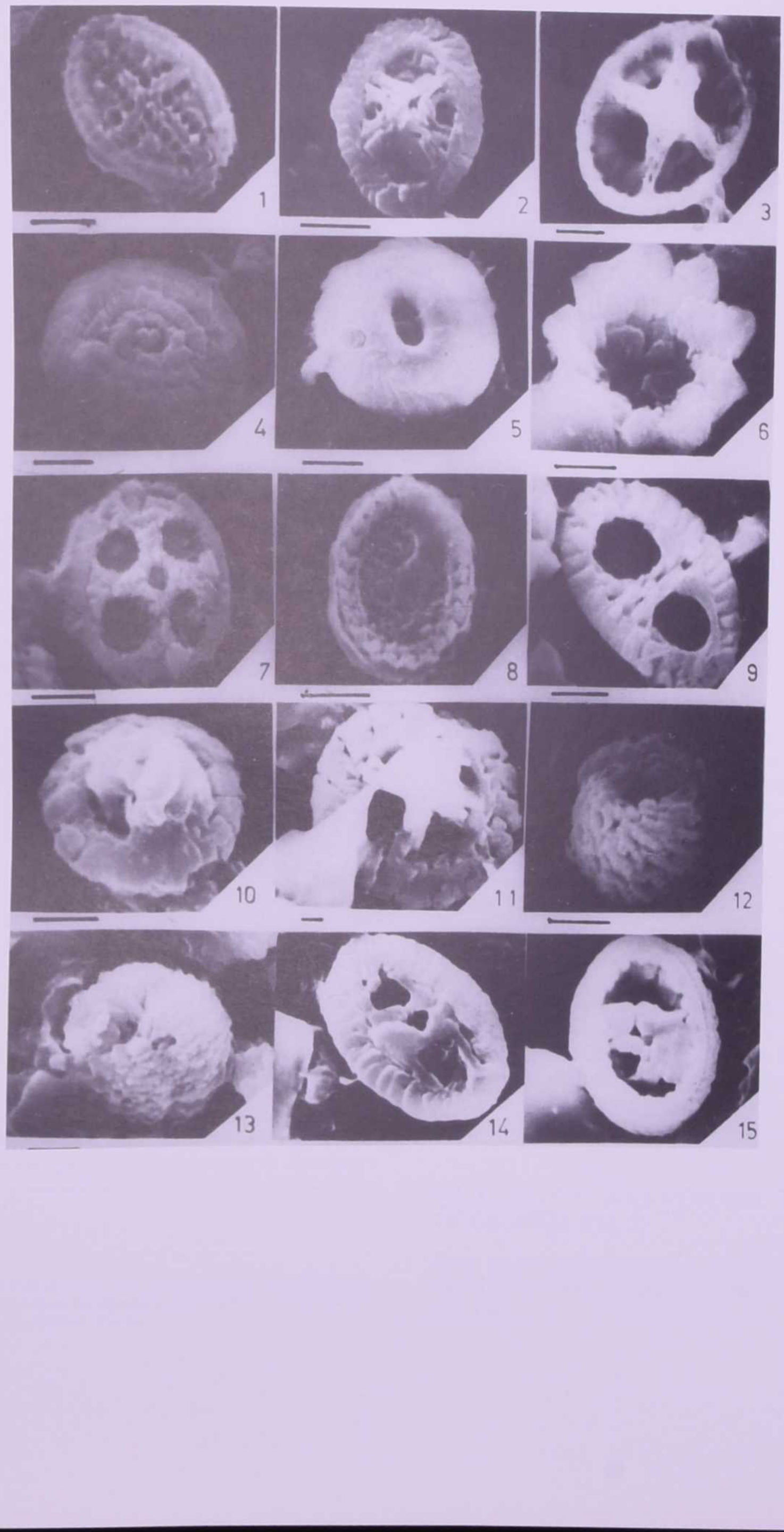
FIG. 11 - *Prediscosphaera columnata* (STOVER, 1966) PERCH-NIELSEN, 1984. Cenomanian, Distal view. (E11441).

FIG. 12 - *Nannoconus truitti rectangularis* DERES and ACHERITEGUY, 1980. Side view. (E11073).

FIG. 13 - *Nannoconus regularis* DERES and ACHERITEGUY, 1980. Side view. (E11063).

FIG. 14 - *Tranolithus phacelosus* STOVER, 1966. Distal view. (E11288).

FIG. 15 - *Tranolithus phacelosus* STOVER, 1966. Proximal view, with two rim cycles. (E11289).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