DISCOVERY OF ALBIAN NANNOFLORA FROM TYPE DALMIAPURAM FORMATION, CAUVERY BASIN, INDIA—PALEOCEANOGRAPHIC REMARKS

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ABSTRACT

Based on the primary evidence of nannoplankton, the lower part of a few meters of Dalmiapuram grey shales exposed in type section of Kallakkudi quarry II, is assigned to the uppermost part of *Chiastozygus litterarius* CC7 zone of Early Albian age, and the upper part to *Prediscosphaera columnata* CC8 zone of Middle Albian age. Distinct variations in the frequency of terrestrial and marine palynofossils, suggest blooms of dinoflagellates and nannoplankton producing organic and carbonate-rich laminae in the lower and upper part of the shales, respectively. Anoxic/kenoxic bottom conditions, probably related to global mid-Cretaceous event, supported only microbenthos. Waning phase of anoxity is characterized by coastal upwelling coupled with bloom of siliceous plankton during Late Albian basal Uttatur Formation.

INTRODUCTION

FOSSIL calcareous nannoplankton are most abundant on earth and have assumed worldwide importance during the last two decades enabling high resolution dating and paleoceanographic modelling of marine Mesozoic–Cenozoic sediments. Dalmiapuram Formation encompassing the grey shales[1] or including the unconformably overlying reefoidal limestone[2], is important for supporting hydrocarbon[3] and cement[4] industries in the Cauvery Basin (figure 1A–C).

Dalmiapuram grey shales lack datable ammonites and planktonic foraminifera, which otherwise contain fragmentary remains of nektonic ammonites, bivalves and drift wood[4,5], besides a low oxygen-tolerant ichnogenus *Chondrites*[6]. Small benthic foraminifera[2,7] and ostracodes[1] suggested Aptian–Albian affinity. Rich assemblage of terrestrial and marine palynofossils were used to interpret age and environment of deposition[8–13], suggesting slightly different ages for the grey shales but within a span of Aptian–Albian. The recovery of nannoplankton from grey shales permits a more precise dating. Though late Cretaceous nannoplankton are known[14–16], this is the first record of early Cretaceous assemblage from the Indian region (figure 1A, B).

The study is based upon three productive samples (KL-10, KL-9 and DAL-1) representing the lower part of the grey shales exposed in Kallakkudi quarry II (figure 1D), which have also yielded rich terrestrial and marine palynofossil assemblage[12].

Conventional smear slides were prepared for nannoflora and studied under the light microscope using the oil immersion objective. Rare and smaller forms demanding electron microscopy are not considered in this paper. Taxonomic concepts are largely taken from Perch-Nielsen[17] and Hill[18].

NANNOFLORAL ASSEMBLAGE

**Biscutum constans* (Górka 1957) Black 1959; *B. supracretaceum* (Reinhardt 1965) Perch-Nielsen 1968; *Ceratolithina* sp.; **Chiastozygus platyrhethum* Hill 1976; **Ch. litterarius* (Górka 1957) Manivit 1971; *Ch.* cf. *Ch. tetragonothyrus* Hill 1976; *Chiastozygus* sp. 1; *Chiastozygus* sp. 2; **Ellipsagelosphaera communis* (Reinhardt 1964) Perch-Nielsen 1968; *E. fossacincta* Black 1971; *Ellipsagelosphaera* sp.; **Eprolithus floralis* (Stradner 1962) Stover 1966; **Gartnerago striatum* (Stradner 1963) Forchheimer 1972; *Glaukolithus diplogrammus* (Deflandre 1954) Reinhardt 1964; *Grantarhabdus meddii* Black 1971; **Gephyrorhabdus coronadventis* (Reinhardt 1966) Hill 1976; *G. decorus* (Deflandre and Fert 1954) Hill 1976; **Lithraphidites pseudoquadratus* Crux 1981; *Lithraphidites* sp.; *Loxolithus armilla* (Black 1959) Nöel 1965; *Manivitella pemmatoidea* (Deflandre 1965) Thierstein 1971; **Nannoconus truitti* Brönnimann 1955; *Placozygus fibuliformis* (Reinhardt 1964) Hoffmann 1970 *Perissocyclus* sp.; **Prediscosphaera columnata* (Stover 1966) Perch-Nielsen 1984; *Prediscosphaera* cf. *P.*

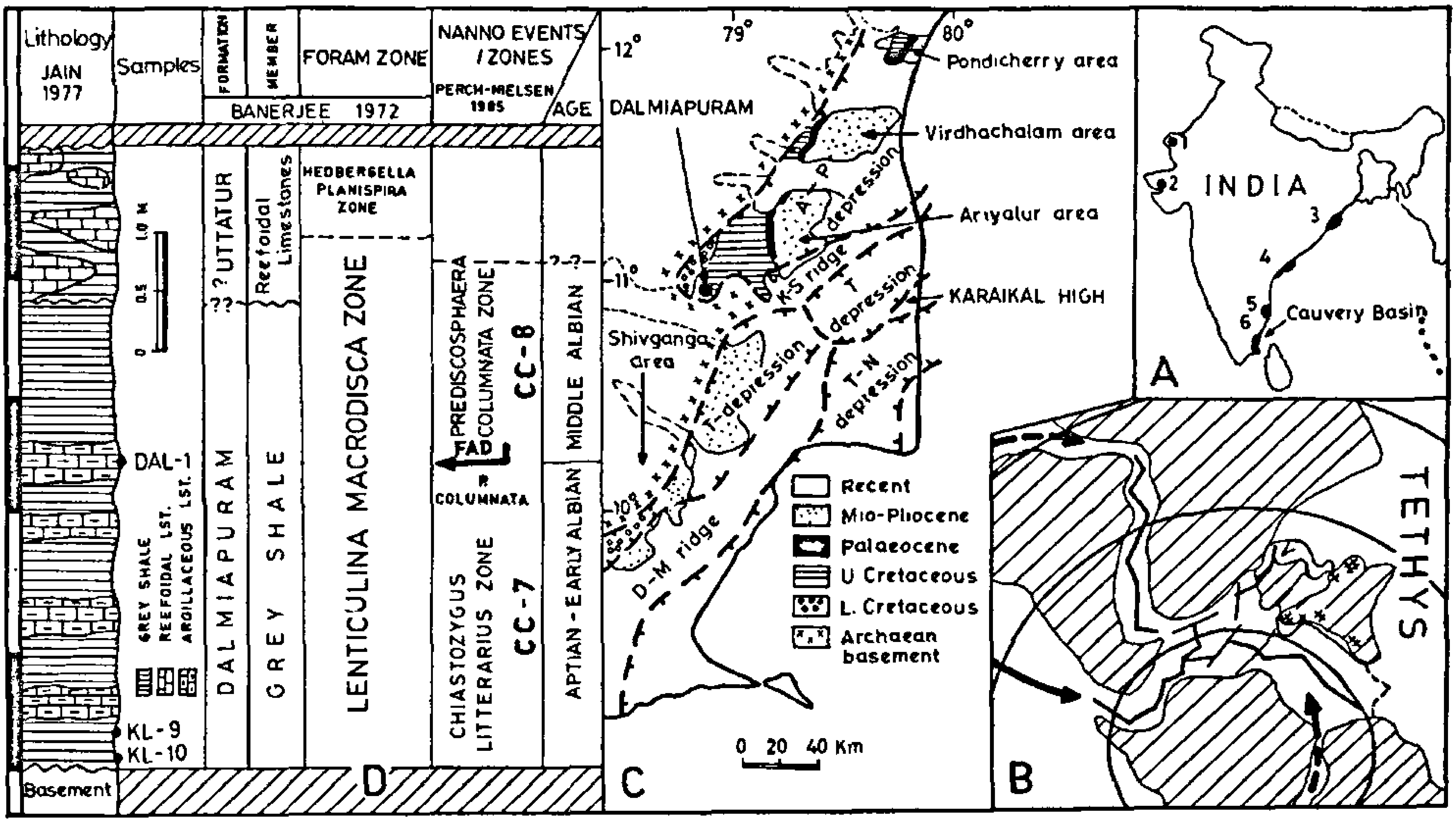


Figure 1A–D. A. Map showing distribution of known Early Cretaceous marine sediments in pericratonic basins of India: 1. Jaisalmer, 2. Kutch, 3. Mahanadi, 4. Krishna–Godavari, 5. Palar, 6. Cauvery; **B.** Reconstruction at about 100 myr. (Albian) displaying juvenile Indian Ocean with possible routes (broken arrow) and established route (solid arrow) of oceanic currents affecting nannoplankton crop fertility and genesis of grey shales (simplified after Barron and Harrison[21]); **C.** Geological map of Cauvery basin showing major outcrops and the position of Dalmiapuram (after Venkatachala *et al*[9]), and **D.** Chart showing lithology of Kallakuddi Limestone Quarry II, sampling points, foraminiferal and inferred nannoplankton zones (after Banerji[2], Jain[12] and Perch-Nielsen[17]).

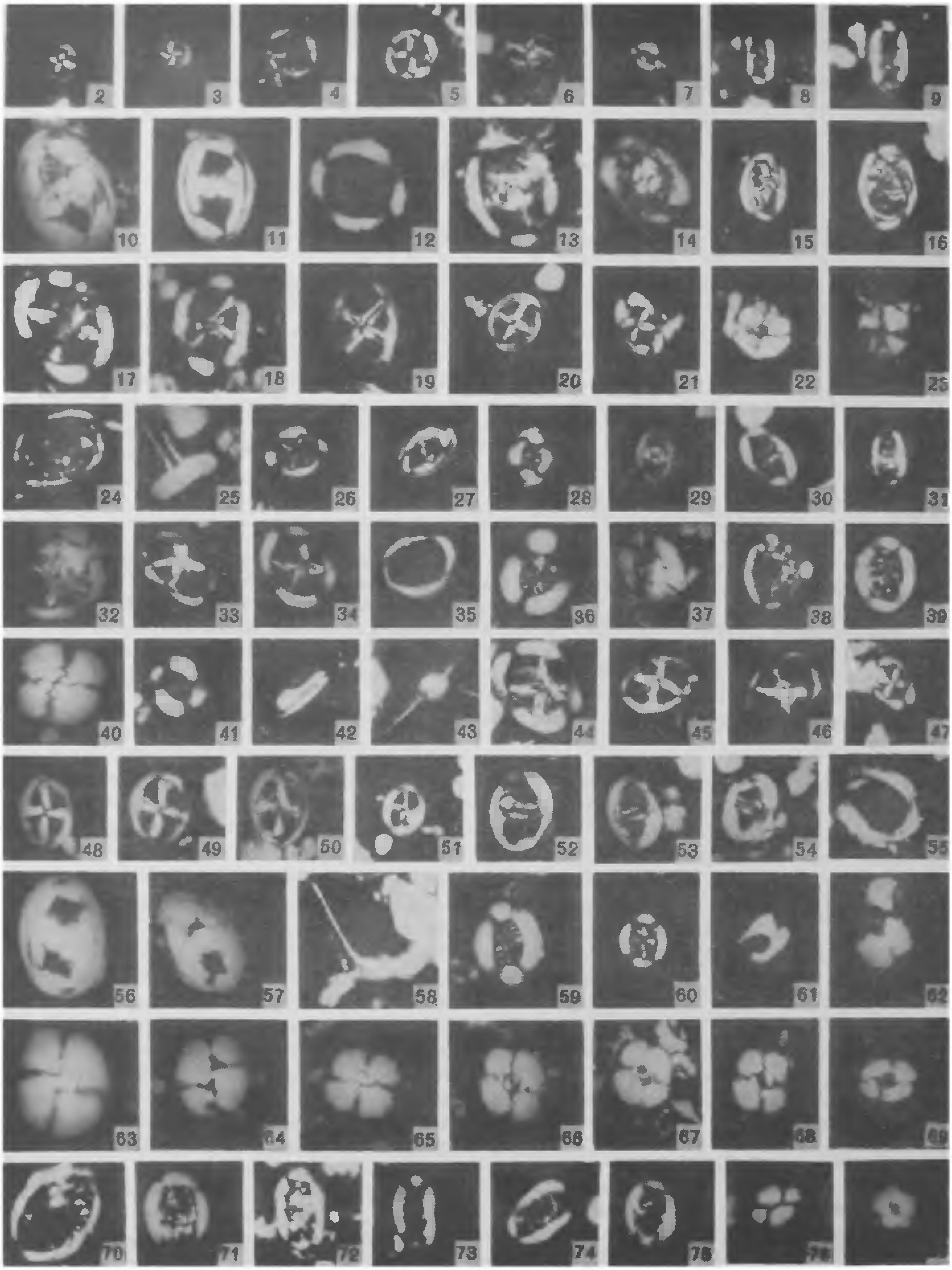
spinosa (Bramlette and Martini 1964) Gartner 1968; **Radiolithus planus* Stover 1966; **Rhagodiscus angustus* (Stradner 1963) Reinhardt 1971; *R. asper* (Stradner 1963) Reinhardt 1967; **R. splendens* (Deflandre 1953) Verbeek 1977; *Rhagodiscus* sp. *Retecapsa* sp. 1; *Retecapsa* sp. 2; **Stoverius baldiae* (Stradner and Adamiker 1966) Perch-Nielsen 1984; **Stradneria crenulata* Reinhardt 1964; **Vagalapilla gausorhethium* Hill 1976; *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968; *W. biporata* Bukry 1969; *W. ovata* Bukry 1969; *Watznaueria* sp.; **Zeugrhabdotus embergeri* (Nöel 1959) Perch-Nielsen 1984; *Zygodiscus* sp. 1; *Zygodiscus* sp. 2.

Note: Potential or known stratigraphic markers are shown by an asterisk.

DISCUSSION

Age of Dalmiapuram Grey Shales

Ramanathan and Rao[3] were perhaps the earliest workers to report on rich assemblage of microbenthic foraminifera, terrestrial and marine palynofossils from Dalmiapuram grey shales, suggesting broad Neocomian–Albian age[8]. Apparently unaware of this work and unable to find datable marine megafossils, Subbaraman[4] assigned "Pre-Uttatur" age on field relations for grey shales, indicating much greater thickness in subsurface. Due to absence of typical Late Cretaceous elements, later workers agreed on Early Cretaceous date based on low diversity but abundant microbenthos, viz. ostracodes[1], foraminifera[2,7] and common terrestrial and marine palynofossils[8–13,19], suggesting slightly different ages but within the time slice of Aptian–Albian. Most of these reports were based on samples collected from Kallakkudi quarry II, but the number of samples and sampling gaps was not indicated, except by Jain[12]. All three samples (KL-10, KL-9 and DAL-1) from the lower part of the grey shales (figure 1D) yielded rich nannoflora (figures 2–77)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corresponding to palynological assemblage B of Jain[12]. The nannoflora is suggestive of warm, nearshore environment with open ocean connection and dominated by species of *Ellipsagelosphaera*, *Watznaueria* and *Rhagodiscus*. The topmost sample (DAL-1) is characterized by a general increase in the size of coccoliths and enhanced frequency of *R. asper*, *Ellipsagelosphaera* spp. and *Watznaueria* spp. Typical specimens of *P. columnata* (small dark variants; figures 2, 3), *R. planus* (figures 22, 23), *S. baldiae* (figures 4, 5) and *R. splendens* (figures 13, 14), make their first appearance in sample DAL-1. The assemblage is further characterized by the absence of Braarudospharaceae and younger stratigraphic marker *Eiffellithus turriseiffeli*, and by the presence of extremely rare Nannoconids.

The basal part of the grey shales below the first appearance datum (FAD) of *P. columnata*, can be assigned to *Ch. litterarius* CC7 zone of Aptian–Early Albian age[17]; however, further refinement in dating is indicated by the presence of *E. floralis* (figure 77) and typical small specimens of *R. angustus* (figures 8, 31), suggesting upper part of CC7b zone of Early Albian age[17].

Aptian–Albian boundary could not be resolved by palynofossils and plankton including nannoplankton; however, there are strong indications that typically small specimens of nannoplankton *R. angustus* with narrowly elliptic outline and parallel sides with distinct central area (figures 8, 31) may be globally used to demarcate this boundary. This implies that grey shales of Aptian age are not exposed in Kallakkudi quarry, but may be found in the subsurface.

The upper part of grey shales matching palynological assemblage A of Jain[12] can be assigned to *Prediscosphaera columnata* CC8 zone (figure 1D). Despite difference of opinion prevalent among plankton stratigraphers in drawing boundary in two-fold or three-fold subdivision of Albian, and following latter, a Middle Albian age is favoured for the upper part of grey shales, owing to the presence of this zone in the stratotype. Since samples from upper part of grey shales and reefoidal limestone were not available, Middle–Late Albian boundary could not be recognized and the age assignment of younger sequence is, therefore, less certain and based on indirect evidences. Failure to recognize subtle differences in lithology and field relations of reefoidal limestone and basal Uttatur Formation with the underlying grey shales, resulted in divergent views, whether to include reefoidal limestone in Dalmiapuram Formation[2] or whether due to its distinct unconformable contact with the grey shales, be altogether excluded[1]. Reefoidal limestone is characterized by scarcity or absence of ammonites, belemnites, inoceramus and siliceous plankton, which are well represented in basal Uttatur, Limestone–Phosphorite–Evaporite sequence containing fauna of *Mortoniceras* (*M.*) *inflatum* ammonite zone of Late Albian age[5]. However, the presence of *Praeglobotruncana*, though not illustrated, seem to suggest Late Albian age for *Hedbergella planispira* zone of Banerji[2] recognized within reefoidal limestone (figure 1D). Based on field relations and fossil content, the reefoidal limestone, thus appears to be partly or complete lateral facies variant of basal Uttatur Formation, and therefore, should not be included in the definition of Dalmiapuram Formation.

Paleoceanographic remarks

The Dalmiapuram black shales in the Cauvery Basin, probably attaining the character of "oil shales" in the subsurface, developed in response to global sea level rise during Aptian Albian and

Figures 2–77. **2–3.** *P. columnata*; **4, 5.** *S. baldiae*; **6.** *Prediscosphaera* cf. *P. spinosa*; **7.** *B. constans*; **8.** *R. angustus*; **9.** *Rhagodiscus* sp.; **10, 11.** *Z. embergeri*; **12.** *M. pemmatoidea*; **13, 14.** *R. splendens*; **15, 16.** *R. asper*; **17, 18.** *G. coronadventis*; **19.** *Ch. platyrhethum*; **20.** *V. gausorhethium*; **21.** *G. meddii*; **22, 23.** *R. planus*; **24.** *Perissocyclus* sp.; **25.** *G. decorus*; **26.** *Chiastozygus* sp. 1; **27.** *P. fibuliformis*; **28.** *Zygodiscus* sp. 1; **29.** *Zygodiscus* sp. 2; **30.** *G. diplorgrammus*; **31.** *R. angustus*; **32–34.** *Ch. litterarius*; **35.** *L. armilla*; **36, 37.** *S. crenulata*; **38.** *R. asper*; **39.** *Retecapsa* sp. 1; **40.** *W. barnesae*; **41.** *W. ovata*; **42.** *Lithraphidites* sp.; **43.** *L. pseudoquadratus*; **44.** *G. coronadventis*; **45.** *Chiastozygus* sp. 2; **46.** *Chiastozygus* cf. *Ch. tetragonothyrus*; **47.** *G. meddii*; **48–51.** *V. gausorhethum*; **52–54.** *G. diplogrammus*; **55.** *M. pemmatoidea*; **56, 57.** *Z. embergeri*; **58.** *S. crenulata*; **59.** *G. striatum*; **60.** *Retecapsa* sp. 2; **61.** *Ceratolithina* sp.; **62.** *N. truttii*; **63.** *Watznaueria* sp.; **64.** *W. biporata*, **65.** *W. barnesae*; **66, 67.** *E. communis*; **68.** *Ellipsagelosphaera* sp; **69.** *F. fossacincta*, **70–75.** *R. asper*, **76.** *B. supracretaceum*, and **77.** *E. floralis*. [Note: Figures 2–26 from DAL-1, 27–43 from KL-9 and 44–77 from KL-10. Light micrographs under crossed polarized light. × 1500] appear to be a part of mid-Cretaceous anoxic event widely observed in north-south Atlantic and Indian ocean sectors[20]. Though, locally black shales can develop at any stratigraphic level, the magnitude of mid-Cretaceous black shales is unparalleled and seem to be related to the geometry of landmasses restricting oceanic circulation. Palaeogeographic reconstruction (figure 1A,B) reveals a solitary route through a channel between Antarctica-S. American landmasses (indicated by solid arrow) permitting juvenile Indian Ocean to exchange water masses with the Pacific. Less certain routes are shown by broken arrows (figure 1B). More significant, is however, the lack of connection between growing Indian Ocean and Tethys either via northwestern or northeastern sector of India[16,21], inducing large scale stagnant bottom conditions in Indian Ocean and elsewhere.

Finely laminated grey shales with cyclicity of dark-pale laminae lacking bioturbation, containing pyrite–marcasite granules with upward increase in grain size and micritic carbonate[4], suggest deposition in offshore mud facies with bathymetry of about 200 m, under regressive pulsations. Anoxic with intermittent kenoxic (partly oxygen-depleted) bottom conditions model would explain complete absence of megabenthos, except rare occurrence of low oxygen-tolerant ichnogenus *Chondrites*[6], and abundant microbenthos adapted to low oxygen and stress conditions permitting low diversity, viz. ostracodes[1] and benthic foraminifera[2,7]. This microfauna is expected to lie within millimeter thin layers laid down under kenoxic cyclic conditions. Nektonic and pseudoplanktonic megafauna together with carbonized drift wood, is represented by a few ammonite and other molluscan fragments, with no report so far of fish and reptile remains[2,4,5].

Although detailed geochemical work on Dalmiapuram shales from surface and subsurface sections is awaited, stable isotope data coupled with vertical fluctuations in Dinoflagellates–acritarchs, nannoplankton and terrestrial palynofossils in black shale sequences elsewhere[22,23], suggest climate-controlled cyclicity. Dinoflagellate blooms were favoured by slightly warmer waters, contributing organic rich laminae in the lower part of the shales under offshore conditions as evidenced by the negligible number of trilete spores[12,23]. High percentage of trilete spores coupled with reduced dinoflagellate population but enhanced nannoplankton blooms in the upper part, suggest inshore and cooler waters[23]. Nannoplankton blooms added much carbonate layers imparting paler colour to shales in the younger part.

No physical barrier model would explain the genesis of shales and observed vertical changes in the abundance and diversity of phytoplankton. Culmination of anoxic phase with further shallowing of the basin is characterized by restricted development of reefoidal facies and spectacular deposits of Limestone–Phosphorite–Evaporite sequence during Late Albian basal Uttatur Formation signifying coastal upwelling of nutrient rich water-inducing radiolarian blooms[24]. This unit is important for the yield of Diatomaceous plankton which remain undiscovered so far. Ventilation of bottom waters promoted rich and diverse micro- and megabenthos, nektonic ammonites and belemnites became important, while the cropping pressure of zooplankton probably added to the diversity of nannoplankton[20].

CONCLUSIONS

(i) Based on primary evidence of nannoplankton, the lower part of the shales exposed in Kallakkudi quarry II, is assigned an Early Albian and upper part a Middle Albian age. Grey shales of Aptian age are not exposed in the quarry, but could be found in the subsurface.

(ii) Reefoidal limestone is recognized as local facies variant of basal Uttatur Formation containing Limestone–Phosphorite–Evaporite suite, signifying waning phase of anoxity with coastal upwelling triggering bloom of siliceous plankton.

(iii) Grey shales probably developed in response to global sealevel rise during Aptian–Albian, with strong possibility of Aptian age grey shales in subsurface attaining the character of "oil shales", being attributed to peculiar geometry of landmasses restricting oceanic circulation during mid-Cretaceous anoxic event.

(iv) Anoxic with intermittent kenoxic bottom condition model is evoked to explain the absence of megabenthos and the presence of low diversity but common microbenthic ostracodes and foraminifera. Dramatic vertical variations in the frequency of dinoflagellate, nannoplankton and terrestrial palynofossils, signify increased blooms of dinoflagellates in warmer and offshore waters, inducing organic-rich laminae in the lower part of grey shales. Increased nannoplankton blooms were favoured by relatively cooler and inshore waters, inducing carbonate-rich laminae imparting paler colour to the upper part of grey shales. Physical barrier model would not explain the observed relative abundance of marine phytoplankton in grey shales, which seem to display dominantly climatic controlled cyclicity.

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1. Bhatia, S. B. and Jain, S. P., *Bull. Indian Geol. Assoc.*, 1969, **2**, 105.
2. Banerji, R. K., *J. Palaeontol. Soc. India*, 1972, **15**, 32.
3. Ramanathan, S. and Rao, V. R., *Proc. 3rd. Symp. Dev. Pet. Res. Asia Far East. Tokyo*, 1965.
4. Subbaraman, J. V., *Mem. Geol. Soc. India*, 1968, **2**, 92.
5. Phansalkar, V. G. and Kumar, M. K., In: *Proc. Symp. Cretaceous of India. Ind. Assoc. Palynostratigraphers, Lucknow*, 1983, p. 120.
6. Chiplonkar, G. W. and Tapaswi, P. M., *Curr. Sci.*, 1975, **44**, 123.
7. Bhatia, S. B. and Jain, S.' P., *Bull. Indian Geol. Assoc.*, 1972, **5**, 45.
8. Rao, V. R. and Venkatachala, B. S., *Ann. Geol. Dept. A. M. U., Aligarh*, 1971, **5** and **6**, 353.
9. Venkatachala, B. S., Rawat, M. S., Sharma, K. D. and Jain, A. K., *Proc. IV Int. Palynol. Conf. Lucknow (1976–1977)*, 1980, **2**, 396.
10. Jain, K. P. and Subbaraman, J. V., *Curr. Sci.*, 1969, **38**, 549.
11. Jain, K. P. and Taugourdeau-Lantz, J., *Geophytology*, 1973, **3**, 52.
12. Jain, K. P., *The Palaeobotanist*, 1977, **24**, 170.
13. Venkatachala, B. S. and Kumar, A., *J. Palaeontol. Soc. India*, 1980, **23** and **24**, 92.
14. Jafar, S. A., *J. Palaeontol. Soc. India*, 1982, **27**, 17.
15. Jafar, S. A., *Curr. Sci.*, 1985, **54**, 170.
16. Jafar, S. A. and Kapoor, P. N., *The Palaeobotanist*, 1988, (in press).
17. Perch-Nielsen, K., In: *Plankton stratigraphy*, (eds) H. M. Bolli, J. B. Saunders and K. Perch-Nielsen, Cambridge University Press, 1985, p. 329.
18. Hill, M. E., *Palaeontographica*, 1976, **156**, 103.
19. Venkatachala, B. S., Sharma, K. D. and Jain, A. K., *Proc. Sem. Palaeopalynol. Ind. Strat. Calcutta*, 1972, p. 172.
20. Roth, P. H., *Proc. IV Int. Palynol. Conf. Lucknow (1976–1977)*, 1979, **2**, 22.
21. Barron, E. J. and Harrison, C. G: A., In: *Mechanisms of continental drift and plate tectonic*, (eds) P. A. Davies and S. K. Runcorn, Academic Press, New York, 1980, p. 89.
22. DeBoer, P. L., In: *Cyclic and event stratification*, (eds) G. Einsele and A. Seilacher, Springer-Verlag, Berlin 1982, p. 456.
23. Mutterlose, J. and Harding, I., *Abh. Geol. B.-A.*, 1987, **39**, 177.
24. Garg, R. and Jain, K. P., *Biol. Mem.*, 1979, **3**, 131.

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