

Late Maastrichtian-Danian nannoplankton from basal Subathu of Dharampur, Simla Himalaya, India— Palaeogeographic implications

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The discovery of Danian calcareous nannoplankton of combined NP3-NP4: *Chiasmolithus danicus*/*Ellipsolithus macellus* zones from apparently unproductive Subathu of Dharampur, offers new scope for high resolution dating; reworked nannofloral elements of Late Maastrichtian (*Micula mura* Zone of low-mid latitudes) demand the fixing of lower age limit of Subathu Formation straddling K/T boundary. This may signify an event permitting the entry of Assam-Arakan sea along lesser Himalayan rift via Arunachal during Late Maastrichtian.

Key-words—Calcareous nannoplankton, Palaeogeography, Cretaceous, Simla Hills (India).

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सारांश

शिमला हिमालय (भारत) में धरमपुर के आधारी सुबाथु से अर्न्तम मास्ट्रिक्शियन-डेनियन परासूक्ष्मप्लवक-पुराभौगोलिक महत्व

सैय्यद अब्बास जाफ़र एवं पुष्कर नाथ कपूर

धरमपुर के स्पष्टतया अधारक सुबाथु से सयोजित एन-पी० 3- एन-पी० 4—चिआसमोलियस डेनिकस/एलिप्सोलियस मेसिलस नामक मंडलों के डेनियन युगीन चूनामय परासूक्ष्मप्लवकों के अन्वेषण से इनके पुनः कालनिर्धारण के नये अवसर बढ़ गये हैं। अर्न्तम मास्ट्रिक्शियन (निम्न-मध्य अक्षांशों का मिकुला मुरा मंडल) के पुनरीक्षित परासूक्ष्मवनस्पतिजातीय अवयवों के कारण सुबाथु की अभी तक अनिश्चित क्रीटेशी/तृतीयक सीमा की अधर आयु को सुनिश्चित करने की आवश्यकता है। इससे अर्न्तम मास्ट्रिक्शियन काल में अरुणाचल से होकर लघु हिमालय श्रृंखला के संग-संग असम-अराकन समुद्र के प्रवेश की घटना व्यक्त हो सकती है।

WELL-KNOWN Subathu-Dagshai-Kasauli sequence of rocks (Map 1A-C), established over a century ago (Medlicott, 1864), represents the last waning phase of marine sedimentation in lesser Himalaya, bearing the imprint of tectonic history prior to collision of Indian-Asiatic plates (Powell, 1979; Ray & Acharyya, 1976; Acharyya & Ray, 1982). Open tidal sea of Subathu changing to estuarine and complete withdrawal of sea during Kasauli sedimentation (Singh, 1978) is characterised by intermittent influx of terrestrial elements, viz., bone beds, shell layers, etc. These mostly contain broadly datable elements, like larger foraminifera, dinoflagellates, spores and pollen. Planktonic foraminifera and

nannoplankton permitting high resolution dating are rather scarce and concentrated in thin horizons that often lack any other fossil. The present discovery of late Maastrichtian-Danian nannoplankton is extremely important from the viewpoint of palaeogeography, as no authentic and documented reports of coeval age are known from western Indian sections, Pakistan (Haq, 1971) and western Himalaya (Mathur, 1983). In contrast, the eastern sector of India contains datable plankton of nearly complete Cretaceous succession including rich suite of *Globotruncana* matching *A. mayaroensis* Zone of Late Maastrichtian in Assam-Arakan Basin (Rangarao, 1983).

MATERIAL AND METHODS

Collections were made from two profiles, about 1 km apart on Dharampur-Dagshai road (Map 1B). Finely laminated grey to olive-green claystone-siltstone interbedded with a few centimeter thick Oyster shell-beds, failed to yield any other mega- or micro-fossil for age determination. Basement was concealed in both the profiles and the entire sequence matches olive-green shale facies recognised within Subathu (Singh, 1978). Samples were drilled with sharp needle to release powder from partially recrystallised fine matrix of calcareous shales; conventional smear slides were prepared with Caedax mounts. Out of 10 samples, two proved productive (Map 1B; samples DD1, DD4), while DD1 revealing better preservation yielded most of the forms documented here. Abundant fine carbonate grains acted as background noise in recognition and identification of rather ill-preserved and scarce but datable nannoplankton under the light microscope (Pl. 1, figs 1-41).

RECORDED NANNOPLANKTON TAXA

Reworked Late Maastrichtian (*Micula mura* Zone) Assemblage

- Watznaueria barnesae* (Black) Perch-Nielsen 1968
- Micula mura* (Martini) Bukry 1973
- Micula decussata* Vekshina 1959
- Micula* sp.
- Tetralithus?* sp.
- Cretarhabdus crenulatus* Bramlette & Martini 1964
- Cretarhabdus?* sp.
- Glaukolithus compactus* (Bukry) Perch-Nielsen 1984
- Lithraphidites quadratus* Bramlette & Martini 1964
- Lithraphidites helicoideus* (Deflandre) Deflandre 1963
- Eiffellithus gorkae* Reinhardt 1965
- Octolithus?* spp.
- Zygodiscus spiralis* Bramlette & Martini 1964

Early Palaeocene = Late Danian-combined NP3-NP4 (*Ch. danicus*-*E. macellus* zone) Assemblage

- Sphenolithus* sp.
- Pontosphaera plana* (Bramlette & Sullivan) Haq 1971
- Micrantholithus* sp.
- Braarudosphaera bigelowii* (Gran & Braarud) Deflandre 1947
- Braarudosphaera* sp.

- Thoracosphaera operculata* Bramlette & Martini 1964
- Thoracosphaera saxea* Stradner 1961
- Markalius inversus* (Deflandre) Bramlette & Martini 1964
- Biantholithus sparsus* Bramlette & Martini 1964
- Prinsius bisulcus* (Stradner) Hay & Mohler 1967
- Ericsonia cava* (Hay & Mohler) Perch-Nielsen 1969
- Ericsonia subpertusa* Hay & Mohler 1967
- Cruciplacolithus tenuis* (Stradner) Hay & Mohler 1967
- Neochiastozygus concinnus* (Martini) Perch Nielsen 1971
- Neochiastozygus modestus* Perch-Nielsen 1971
- Neochiastozygus imbrei* Haq & Lohmann 1976
- Placozygus sigmoides* (Bramlette & Sullivan) Romein 1979
- Hornibrookina?* spp.

DISCUSSION

The checklist of taxa and the interpretation of the data have been slightly modified than published earlier as abstract on the same set of samples (Jafar & Kapoor, 1984). The assemblage suggests precise Late Danian age corresponding to combined NP3-NP4: *Chiasmolithus danicus*-*Ellipsolithus macellus* zones, despite the absence of both these markers (Martini, 1971). Tiny species of *Neochiastozygus* and large *Biscutum*-like elements identified as *Hornibrookina?* spp. acted as substitute markers (Perch-Nielsen, 1979, 1981). The absence of species belonging to typical Late Palaeocene genera: *Bomolitus*, *Fasciculithus*, *Heliolithus* and *Discoaster*, lends further support to this dating. However, outcropping sections in Pondicherry (Cauvery Basin) yielded typical nannoplankton assemblage of NP4: *E. macellus* Zone, including the marker (authors unpublished data). *Hornibrookina?* sp. with peculiar rhomboidal outline (Pl. 1, figs 3a-c) and oval outlines (Pl. 1, figs 6a, b; 7a, b) displays extinction pattern quite unlike large *Biscutum* (Perch-Nielsen, 1985) but shows affinity with *H. edwardsii* and *H. teuriensis* typically known from Early Palaeocene of middle to high latitudes, e.g., New Zealand, Atlantic and Mediterranean belt. Dharampur forms, except for their large size, closely resemble primitive and small *Biscutum?* *romeini* (Perch-Nielsen, 1981).

Careful empirical observations backed by Iridium and stable isotope data on some rare hiatus and bioturbated free K/T boundary pelagic sediments both on land and deep sea suggest that

unlike several communities suffering "Catastrophic" extinction, the terminal Cretaceous nannoflora did survive for a while in basal Danian (Perch-Nielsen, McKenzie & He, 1982). However, for practical purposes these survivors vanished before the dawn of NP3 and occur in a few centimeters of basal Danian sediments. As such the Cretaceous nannoplankton of Dharampur associated with younger sediments (NP3-NP4) must be interpreted as reworked and can be assigned to low-middle latitude *Micula mura* Zone of Late Maastrichtian age. Further, this implies widespread existence of calcareous shales of comparable age below the conventional Subathu.

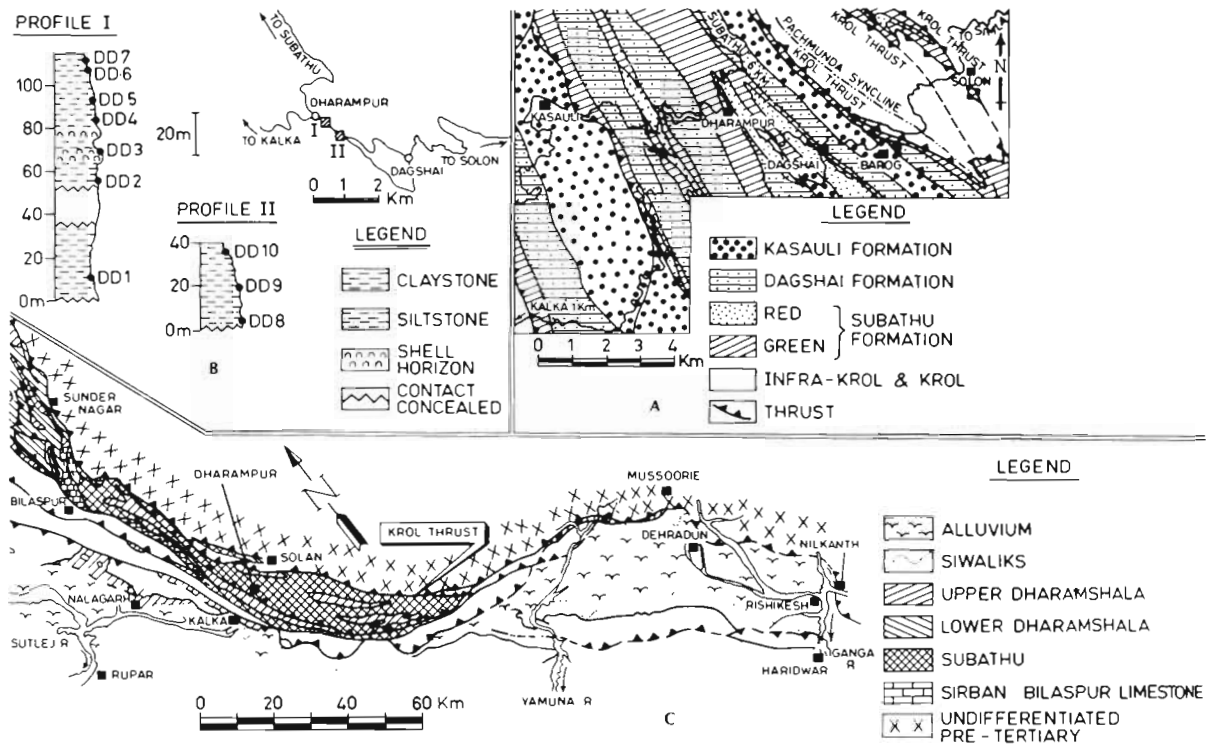
Out of the two earlier reports of nannoplankton from the so-called "Krol" of lesser Himalaya, that of Tewari (1969) deserves rejection owing to poor documentation, while that of Sinha (1975) assumes renewed significance in view of the present discovery of Dharampur nannoplankton. A critical assessment of this paper, however, revealed inorganic crystals besides two determinable species indicating broad Late Cretaceous age (Jafar, 1980; Singh, 1981). About 15 meters of calcareous shales yielding these species, as would normally be expected, appear to be sandwiched between different Krol units as tectonic slices. Due to general paucity of megafossils it may readily be confused with various Precambrian shales (Acharyya, 1983). Detailed mapping would reveal more frequent occurrence of such shales as tectonic wedge between Precambrian rocks and may prove to be of Late Maastrichtian age.

From palaeoceanographic viewpoint, the Dharampur succession reflects low energy, rather shallow embayment with access to open sea current system, permitting flourishing of nannoplankton crop of low but normal diversity, distinctly controlled by subdued salinities. In view of facies and tectonics, one should never expect a high frequency and excellent preservation of nannoflora as observed elsewhere in pericratonic basins of India. The shell beds (Map 1B) were formed by reworking, sorting and concentration of only low salinity tolerant and sturdy Oyster communities inhabiting coastal margins by periodic storms (Singh, 1978).

The most likely high energy equivalent of Late Maastrichtian coccolith bearing shales are the so-called Shell Limestone or Upper Tal Limestone known from widespread localities of lesser Himalaya (Bhatia, 1980). Such facies is not expected to yield datable plankton including coccoliths, except from diagenesis-free marly intercalations. As such this important lithounit after generating heated controversies in lesser Himalayan biostratigraphy, is

nevertheless enjoying by widespread consensus a broad Maastrichtian-Danian dating based on rich invertebrate fossils (Bhatia, 1980; Singh, 1981). Several workers have attempted to date this unit on the basis of "planktonic foraminifera" recognizable only in thin sections. Unless one is dealing with hard indurated pelagic limestone containing common plankton, extreme caution is needed to date the unit alone on the basis of a few sporadic and fragmentary specimens (Singh, 1980). A detailed work on invertebrate fossils, excluding planktonic elements, is likely to furnish more precise date for Shell Limestone than now available, and some sections may contain Late Maastrichtian or Danian exclusively or encompass K/T boundary. Singh and Rai (1983), upon the strength of facies and other evidences, suggested Precambrian to Early Cambrian age for the Blaini-Infra Krol-Krol-Tal sequence of rocks with explicit exclusion of this Shell Limestone unit from classic concept of Tal Formation (Bhatia, 1980; Singh, 1979). While lower contact of Shell Limestone has been recognised as unconformable with varying lithounits, the upper contact, if at all seen, is considered transitional with Subathu, such as in Garhwal area. Considering this, the concept of marine cycle and limited thickness of Shell Limestone observed all over, it would be reasonable to include it in Subathu Formation with distinct and mappable member rank splitting (Rupke, 1974). This concept would have added advantage of recognising Late Maastrichtian transgressive event, with entire Triassic, Jurassic and Cretaceous except terminal Late Maastrichtian part, signifying a period of non-deposition of marine sediments in lesser Himalaya.

Marine sediments of Danian age were hitherto unknown in lesser Himalaya, whereas, definite Late Palaeocene corresponding to Kakra Series (Srikantia & Bhargava, 1967) is firmly established, largely on the basis of index larger foraminifera (Datta & Banerji, 1966; Tewari & Singh, 1976) and palynofossils (Singh, Khanna & Sah, 1978; Mathur & Venkatachala, 1979). None of the data published so far is convincing enough for the presence of Middle to Late Eocene marine sediments in Subathu, being supported by long ranging species of foraminifera, ostracode and palynofossils. This needs to be more critically evaluated to determine the last phases of marine influences in the Himalaya subsequent to collision of India-Eurasia land masses. In fact, marine Subathu-Dagshai with exclusion of fluvialite Kasauli, most probably encompass Late Maastrichtian-Early Eocene time slice. These signify a single marine cycle starting with Late Maastrichtian transgressive event along lesser Himalayan rift, probably triggered due to widespread Deccan Trap



Map 1—A, Simplified geological map displaying structure and outcrop pattern around Dharampur (after Raiverman, 1976); **B,** Two profiles showing sampling points on Dharampur-Dagshai Road Section; and **C,** Simplified geological map showing structural units and outcrops in Simla Himalaya and adjoining regions (after Karunakaran & Rao, 1976).

activity on the Indian craton. Besides, extensive terrestrial outpouring of lava, both east and west coast bear evidence of extrusion in coastal marine milieu, being characteristically interbedded with *Globotruncana* bearing sediments of Late Maastrichtian age (Mehrotra & Biswas, 1986; Govindan, 1981). This, coupled with significant findings of Courtillot *et al.* (1986), strongly suggests the initiation of Trap activity in Late Maastrichtian throughout Indian craton and continuing up to basal Danian, thereby containing K/T boundary. Disputed, however, is cessation time of trap activity, which may have lasted a little longer than suggested by Courtillot *et al.* (1986). An event of such a magnitude can not span several million years as presumed earlier, mainly due to the fact, that a wealth of flora and fauna published from the Intertrappean beds display monotonous assemblage of similar age. Moreover, plate stratigraphers can not reconcile with the assumption that during rapid northward flight India can contain hot spot for several million years.

REMARKS ON CRETACEOUS PALAEOCEANOGRAPHY AND ENTRY OF SUBATHU SEA

In order to grasp the geotectonic evolution of India, it is instructive to briefly review a few critical models proposed for Cretaceous time slice. Such models proposed within recent years, despite their shortcomings, are based on a wealth of data generated by Deep Sea Drilling Project alone, data based on Indian basins alone or a combination of both (McGowran, 1978; Powell, 1979; Barron & Harrison, 1980; Biswas, 1982; Datta *et al.*, 1983; Sahni, 1984). The earliest Mesozoic marine sediments on Indian craton are curiously confined to northwestern basins of Kutch and Jaisalmer and signify a typical epicontinental Tethyan facies developed in response to a Middle Jurassic (Bajocian) transgressive event followed by Early Cretaceous regressive event. The latter characterized by paucity of marine mega- and micro-fossils and preponderance of terrestrial plant fossils and

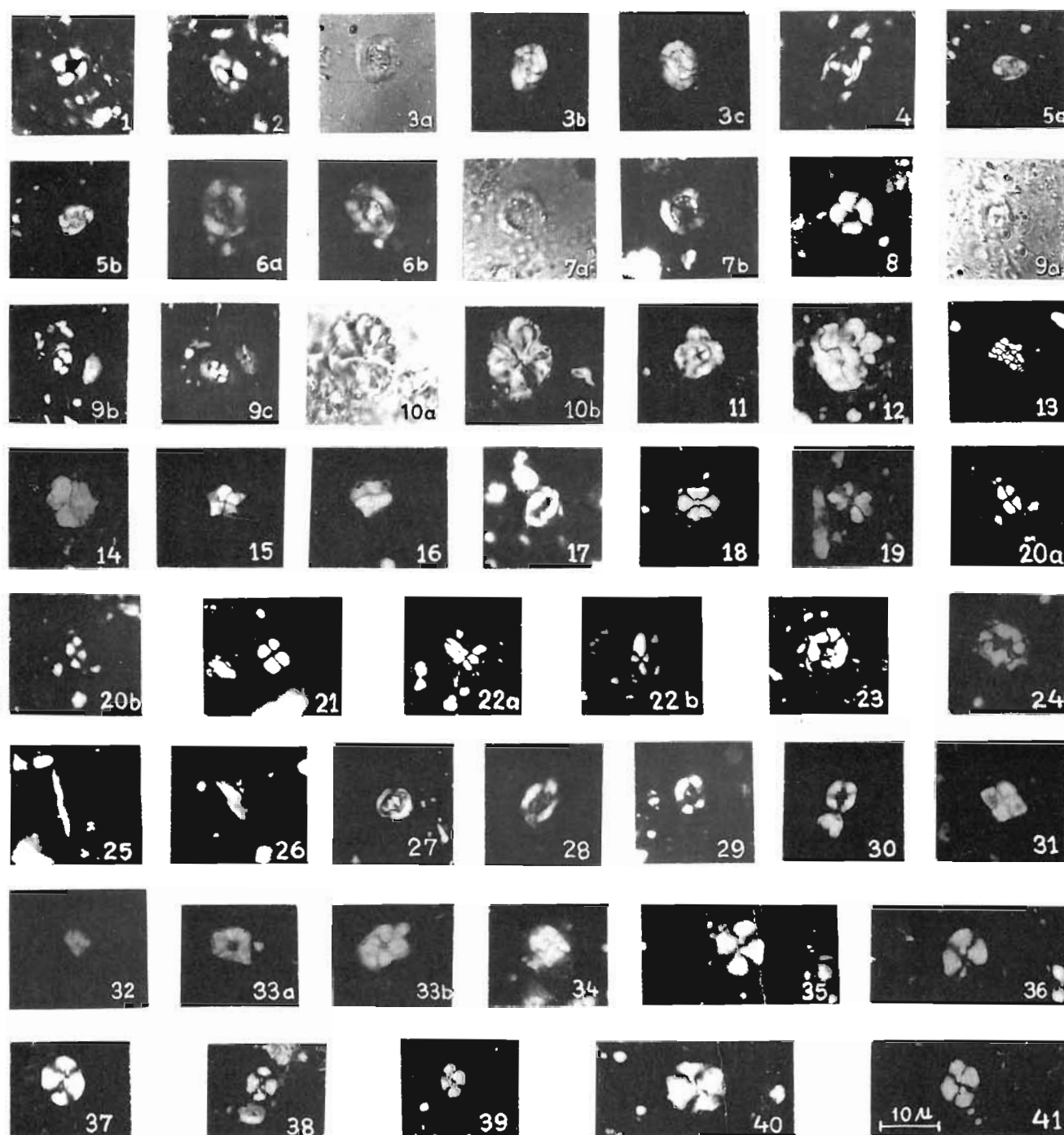


PLATE 1

(Figures 3a, 9a and 10a were photographed under single Polarizer, the rest were taken under crossed polarized illumination.
Scale bar in Figure 41)

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|--|---------------------------------------|--|
| 1, 2. <i>Ericsonia cava</i> | 12. <i>Thoracosphaera saxea</i> | 25. <i>Lithrhapidites belicoideus</i> |
| 3a-c. <i>Hornibrookina</i> ? sp. 1 | 13. <i>Thoracosphaera operculata</i> | 26. <i>Lithrhapidites quadratus</i> |
| 4. <i>Placozygus sigmoides</i> | 14. <i>Braarudosphaera bigelowii</i> | 27. <i>Glaukolithus compactus</i> |
| 5a, b. <i>Neochiastozygus modestus</i> | 15. <i>Braarudosphaera</i> sp. | 28. <i>Cretarhabdus</i> ? sp. |
| 6a, b. <i>Hornibrookina</i> ? sp. 2 | 16. <i>Micrantholithus</i> sp. | 29, 30. <i>Cretarhabdus crenulatus</i> |
| 7a, b. <i>Hornibrookina</i> ? sp. 3 | 17. <i>Zygodiscus spiralis</i> | 31. <i>Tetralithus</i> ? sp. |
| 8. <i>Ericsonia subpertusa</i> | 18, 19. <i>Octolithus</i> ? spp. | 32. <i>Micula</i> sp. |
| 9a-c. <i>Prinsius bisulcus</i> | 20a, b, 21. <i>Pontosphaera plana</i> | 33a, b. <i>Micula decussata</i> |
| 10a, b. <i>Biantholithus sparsus</i> | 22a, b. <i>Sphenolithus</i> sp. | 34. <i>Micula mura</i> |
| 11. <i>Markalius inversus</i> | 23, 24. <i>Eiffellithus gorkae</i> | 35-41. <i>Watznaueria barnesae</i> |

palynoflora and tempted classic workers to brand them as "non-marine coastal Gondwanas." In view of recent findings these must now be considered fully marine, with intermittent condensation horizons, intraformational conglomerates and increasing deltaic influence during Neocomian to Albian. The concomitant change in the coastal geometry restricted the entry of organic-walled plankton and calcareous nannoplankton (Jaikrishna *et al.*, 1983; Jaikrishna, 1983). The onset of Early Cretaceous regressive phase in epicontinental Tethyan domain of Kutch and Jaisalmer appears to be intimately connected with the growth of juvenile Indian Ocean (see 120 Ma and 100 Ma reconstructions of Barron & Harrison, 1980). Madagascar-Seychelles-India landmass was separated from East Africa by a narrow spreading channel, which became dormant and later shifted to a position between Madagascar and Seychelles-India, finally between Seychelles and India to impart independent status to Indian craton during terminal Cretaceous. With regressive phase operating in Tethyan area and the shores of juvenile Indian Ocean lying too far, the possibility of an Early Cretaceous transgressive event must be ruled out in the western sector of Indian craton, specially along intracratonic set up of Cambay and Narmada and Son grabens, containing Dhrangadhara-Wadhwan and Nimar Sandstone formations, respectively, and erroneously interpreted as fluvio-deltaic sediments of Early Cretaceous transgression (Biswas, 1982, 1983).

It must be emphasized that during the Early Cretaceous time slice and even later the growing Indian Ocean failed to establish any connection with retreating shores of Tethyan Ocean, either via northwestern or northeastern sectors of Indian craton, therefore left blank or connection questionably depicted in several published reconstructions including those of Dietz and Holden (1970) and Barron and Harrison (1980). The juvenile Indian Ocean was fed by current system operating via channels between South America and Antarctica landmasses and as recently demonstrated by Veevers (1986), also via channel between Antarctica and Australian landmasses during Aptian-Albian. Lack of connection between juvenile Indian Ocean and Tethyan Ocean would explain widespread stagnant bottom conditions prevailing in juvenile Indian Ocean-South Atlantic sector and the entire North Atlantic sector, resulting in spectacular development of Black shale facies of extraordinary magnitude during middle-Cretaceous (Roth, 1979).

In contrast to Early Cretaceous marine sediments of northwestern part of Indian craton

representing regressive facies and genetically related to middle Jurassic epicontinental Tethys, another set of Early Cretaceous marine sediments developed along east coast of India in response to rifting, vulcanism and possibly eastward reversal of drainage of Indian craton for regions lying south of Narmada-Son lineament (Datta *et al.*, 1983). This significant reversal of drainage which had maintained westerly course during Gondwana sedimentation, is supported by paralic sediment packages developed in Mahanadi, Krishna-Godavari, Palar and southernmost Cauvery basins. Coarse clastics with preponderance of plant megafossils and palynofossils and scarcity of marine mega- and microfossils including plankton, prompted earlier workers to brand them as "non-marine coastal Gondwana" of Late Jurassic to Early Cretaceous age. Recent work has, however, demonstrated (Jaikrishna *et al.*, 1983; Venkatachala & Rajanikanth, 1988) that these sediment packages were formed during Neocomian with gradual increase of pelagic sedimentation toward southern basins, thereby permitting finer resolution in dating by phytoplankton. Rapid fluctuations in shoreline and offshore enrichment of plankton make them attractive from viewpoint of hydrocarbon exploration. Black shale facies, though developed in restricted way in southernmost Cauvery Basin (Dalmiapuram Formation), should display wider development farther offshore as per stagnant bottom water model cited for Middle Cretaceous of juvenile Indian Ocean (Roth, 1979).

The palaeogeography of India during Early Cretaceous, as backed by deep sea data and cratonic basins of India, permits recognition of two distinct regions, viz., northwest regressive epicontinental Tethys of Kutch and Jaisalmer and transgressive Neocomian epicontinental sea stretching from Mahanadi to Cauvery basins on the east coast of India. The entire cratonic region including Cambay and Narmada grabens on the west coast, northeastern regions of Meghalaya, Bengal and Assam including lesser Himalayan belt must be shown as positive area. Palaeocurrent data of coeval fresh water sediments developed in Rewa, Satpura and Godavari basins (Datta *et al.*, 1983) is needed to understand the nature of drainage reversal caused due to significant Neocomian rifting and Rajmahal-Sylhet vulcanism on the eastern sector of India.

Late Cretaceous palaeogeography of India was controlled by rapid growth of plates leading to fast growth of juvenile Indian Ocean coupled with activation of pre-existing rifts on Indian craton (see 80 Ma and 60 Ma reconstructions of Barron & Harrison, 1980). Most significant was establishment

of north-south Atlantic connection, thereby shortest entry to Tethyan current system into juvenile Indian Ocean, as more direct connections to Tethys via northwest and northeast sectors of the Indian craton are not confidently known. Activation of prominent rift grabens of Cambay and Narmada, which had maintained N-S and E-W palaeodrainage, respectively, despite eastward reversal of drainage during Neocomian rifting on the east coast, attracted a solitary and shortlived marine transgression during Turonian (Jafar, 1982). Failure to achieve at least stage level dating, had resulted in broad "Late Cretaceous" dating of Narmada Valley sediments and their correlation with lesser Himalayan Cretaceous based on a few long ranging invertebrate species common to both, resulting in erroneous palaeogeographic reconstructions (Singh, 1979, 1981; Singh, 1980). It must be emphasized that Turonian dating of Narmada Valley Cretaceous was not only based upon recovery of datable nannoplankton assemblage from Nimar Sandstone, but also took critical note of a wealth of data published on vertebrates, invertebrates and microfossils coupled with facies succession Sandstone-Nodular Limestone-Coralline Limestone of reduced thickness, without evidence of this sedimentary package being of condensed nature. Therefore, a shortlived marine transgression emanating from westward lying juvenile Indian Ocean must be envisaged. Further work on largely concealed pretrappean sediments of Saurashtra (Wadhwan-Dhrangadhara formations) is likely to yield Turonian age for Wadhwan against Early Cretaceous age suggested by Biswas (1982, 1983), especially in view of close faunal similarity with Narmada Cretaceous (Chiplonkar & Borkar, 1975) and geometry of the basins.

Two important events characterize rapid growth of juvenile Indian Ocean on the eastern sector of India. Firstly, the paralic sedimentation ceased on the coastal basins of Mahanadi to Cauvery with dominance of pelagic sedimentation in offshore areas. The southernmost Cauvery Basin displays nearly complete succession of Cretaceous sediments with minor hiatuses and evidence of significant coastal upwelling during Late Albian basal Uttatur sediments that contain phosphate influx with bloom of plankton including appearance of radiolaria (Garg & Jain, 1979). The oldest oceanic crust, close to the passive eastern margin of India has not been encountered and dated, though deep sea data suggest Early Campanian age for large areas in Bay of Bengal, including oceanic Islands of Andamans, which have yielded Campanian age for the oldest sediments associated with ophiolites (Jafar, 1985). Thus, the birth of proto-Bay of Bengal must remain

speculative, which may have come into existence anytime between Aptian to Campanian. Secondly, renewed spreading events during Campanian-Maastrichtian resulted in inundation of cratonic areas with epicontinental sea emanating from growing Indian Ocean, with no sign whatsoever of Tethyan connection. Thus the areas which remained positive during Early Cretaceous, viz., Meghalaya, Bengal, Assam and lesser Himalaya were successively invaded by "northward" shifting marine pulses during Campanian-Maastrichtian time slice.

Despite structural complexities induced by tectonics of collision between north-east segment of the Indian and Asiatic plates, one should not lose sight of the fact that intensive exploration activities during recent years support existence of broad Late Cretaceous sediments and penetration of marine influences deep into the vicinity of Arunachal area (Rangarao, 1983; Datta *et al.*, 1983) via Assam-Arakan Basin. The oldest marine sediments overlying Precambrian crystallines in Meghalaya, and Sylhet traps and partially oceanic crust in Bengal Basin, suggest Campanian age. Lower Disang and Dergaon formations, including ophiolites of Manipur and Nagaland, suggest Maastrichtian or Late Maastrichtian age, basically backed by species of critical *Globotruncana* found in association with long ranging benthonics (Rangarao, 1983).

Terminal part of Cretaceous encompassing Late Maastrichtian-Danian was probably the most significant phase in the northward drift of the Indian craton when Seychelles separated from India in response to rifting and pronounced Deccan trap activity affecting western to eastern sectors of India. New data generated on timings and duration of Deccan traps, based on widely separated areas and filtering out erroneous dates, suggest Late Maastrichtian-Danian outpouring around K/T boundary (Courtillet *et al.*, 1986). This is further strengthened by the findings of *Globotruncana*-bearing Intertrappeans both on the western (Mehrotra & Biswas, 1986) and eastern offshore regions (Govindan, 1981). These suggest a possible correlation with Deccan Trap vulcanism of extraordinary magnitude (McLean, 1985) and Maastrichtian transgressions affecting north-east sector of India. It must be emphasized that western sector of India under the influence of rifting, vulcanism and uplift would not permit the entry of sea along Narmada-Son Graben, as suggested in "Trans Deccan Strait" model of Sahni (1984). This model based on broad "Late Cretaceous" time slice largely backed by dating of marine benthonics and terrestrial vertebrates, is no more tenable. Curiously enough, the entire western sector of India shows absence of Late Maastrichtian-Danian marine

sediments in Laki, Sulaiman and Salt ranges in Pakistan (Powell, 1979; Haq, 1971) and western Himalayan ranges (Mathur, 1983), which otherwise contain prolific Late Palaeocene plankton including nannoplankton (Haq, 1971). Similarly, lack of convincing Maastrichtian-Danian marine sediments in western Indian sections (Jafar, 1986) suggests a positive area. Irrespective of the fact, as to whether the marine sediments during Late Maastrichtian-Danian were deposited by Tethyan or Indian Ocean, a positive area is suggested in both the regions.

Lesser Himalayan rift or Subathu-Dogadda rift (Singh, 1979) bears striking resemblance to prominent rift zones of the eastern peninsular India in terms of facies, stratigraphic record, which prompted classic workers to brand it as "Peninsular Himalayas", though tectonic slicing has drastically modified its geometry. In several reconstructions, Indian craton is depicted as an Island with Tethys in the "North" and growing Indian Ocean in the "South" (see 60 Ma reconstruction of Barron & Harrison, 1980), with gaps on north-west and north-east sectors showing no confident connections between contracting Tethys and expanding Indian Ocean. Future studies would probably fill these gaps with microcontinents (Powell, 1979). Nevertheless, under this set up and considering the crustal shortening involved due to collision and rise of Himalayas, the prominent rift grabens on the eastern sector, viz., Subathu, Damodar, Mahanadi and Godavari are suited to receive marine incursions during Late Maastrichtian-Danian, probably triggered due to Deccan trap activity. Palaeobotanical evidence tends to suggest marine estuarine complex extending deep into Godavari Graben during trap activity. It could be an event of short duration, but can have no connection with Narmada Valley Cretaceous, which is of Turonian age and emanated from a westerly incursion, thereby challenging the "Trans Deccan Strait" model of Sahni (1984). From Damodar and Mahanadi grabens, no evidence of coeval marine incursion has come to light so far, but the possibility cannot be ruled out.

The classic discovery of marine invertebrates of Cretaceous age, notably Belemnites by Middlemiss (1885) and nannoplankton by Sinha (1975) and the present discovery of Late Maastrichtian-Danian nannoplankton from lesser Himalaya, need more critical assessment, despite the fact that beside this data, no other conclusive evidence of Cretaceous age has come to light. Rich fauna of Shell Limestone has not yet been resolved into distinctly Cretaceous and Danian. Moreover, throughout the belt stretching from Jammu-Murree to Arunachal area, critical Late Maastrichtian or Lower/Upper Palaeocene plankton markers remains undiscovered. Despite severe

tectonic slicing, metamorphism and facies affecting ready recovery of microfossils, the recent find of Early Eocene Subathu sediments in Arunachal area, earlier believed to be absent in regions east of Nepal (Tripathi & Mamgain, 1986), offers strong possibility of Late Maastrichtian-Palaeocene marine sediments to be discovered throughout Subathu belt. The absence of marine elements in western sector during Late Maastrichtian-Danian and their presence throughout north-east regions of Meghalaya, Bengal, Assam-Arakan including oceanic Andaman Islands, as discussed earlier, offers compelling reasons to postulate the entry of Assam-Arakan sea via Arunachal during Late Maastrichtian transgressive event. Planktonic foraminifera coupled with high Iridium anomaly, possibly suggesting K/T boundary are recently reported from Meghalaya outcrops (Bhandari *et al.*, 1987), which may also be present in Andamans (Jafar, 1985) and Lower Disang and Dergaon formations. Radiometric-stable isotope and magnetic datings of fossil poor facies and sustained field work is likely to yield K/T boundary throughout lesser Himalayan belt with possibilities of minor local hiatuses.

CONCLUSIONS

1. The discovery of Late Maastrichtian-Danian nannofloral elements in hitherto undatable Subathu shales of Simla Himalaya suggests a Late Maastrichtian transgressive event along lesser Himalayan rift zone, possibly triggered due to widespread and coeval Deccan Trap vulcanism on Indian craton and matching the rapid spreading events recorded in the growth of juvenile Indian Ocean.
2. Since absence of Late Maastrichtian-Danian marine sediments in western India-Pakistan sections suggest positive area, but well-developed in northeastern Assam-Arakan Basin, one might postulate the entry of Late Maastrichtian Assam-Arakan sea via Arunachal and terminating at Jammu-Murree with retreat by the end of Early Eocene, as published Middle to Late Eocene microfossils and palynological records from lesser Himalaya need critical revaluation.
3. Despite constraints of plate tectonics model, well-defined transgressive events are recognised on the eastern and western sectors of Indian craton and Cretaceous palaeogeography is critically reassessed.
4. The lower age limits of Subathu-Dagshai needs to be pushed down to coincide with Late Maastrichtian transgressive event; coeval marine incursions should be expected along other rift

zones of India, viz., Damodar and Mahanadi and more vigorous search must be made in Godavari, which already bears fragmentary evidences of such an incursion.

5. Adverse facies and large scale tectonic slicing in lesser Himalaya pose severe problems, but careful mapping and recovery of plankton from calcareous shales would help in demonstrating the presence of Late Maastrichtian-Early Palaeocene marine sediments in other areas including Arunachal and a link between Subathu and Assam-Arakan sea. Radiometric-, stable isotope- and magnetic datings would further help in tracing Late Maastrichtian event containing K/T boundary all through the route with minor local hiatuses.

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