JOURNAL OF THE PALAEONTOLOGICAL SOCIETY OF INDIA
VOL. 27, 1982, pp. 17—30.

NANNOPLANKTON EVIDENCE OF TURONIAN TRANSGRESSION ALONG NARMADA VALLEY, INDIA, AND TURONIAN—CONIACIAN BOUNDARY PROBLEM

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ABSTRACT

The marine Cretaceous rocks of Narmada Valley are synchronous facies equivalents of a single stroke and short lived transgressive event of late Turonian age, which coincided with late Cretaceous spread of epicontinental seas on a global scale. Critical evaluation of age diagnostic Vertebrate-, Invertebrate-and Microfossils earlier reported from different levels support an age not younger or older than Turonian.

31 species of Calcareous Nannoplankton are recorded from the upper calcareous part of Nimar Formation exposed in sections about 100 Km. apart viz. Chikli and Sitapuri. Turonian-Coniacian Stage Stratotypes are discussed in the context of integrated Planktonic Foram—Nannoplankton datum levels ; in view of virtually barren nature of type Coniacian, a Hypostratotype for recognizing Turonian-Coniacian boundary should be chosen, preferably in continuous Dyr El Kef section of Tunesia ; it is suggested to demarcate the base of Coniacian by the first appearance of cosmopolitan Nannoplankton *Marthasterites furcatus*. The Nannoplankton assemblage of Nimar Sandstone can be assigned to *Eiffellithus eximius* zone of Manivit *et al.*, (1977), which is of Late Turonian to early Coniacian in age ; however, in view of the suggestion proposed herein, a precise late Turonian age is demonstrated.

The high diversity and low frequency of recorded Nannoplankton taxa can be partly ascribed to bad preservation, but mainly to the ecological stress of an estuarine complex, in which the sediments were laid.

INTRODUCTION

The late Cretaceous sedimentaries scattered along Narmada suture line and extending from parts of Saurashtra in western India into about 1200 Km. deep into the heart of central India beyond Jabalpur, reflect one of the significant transgressive events (Fig. 1). Traditionally, these sedimentaries in ascending order comprise Nimar, Bagh and Lameta Formations and have been studied for nearly a century (Bose, 1884). The Nimar Formation is a sandy facies consisting of conglomerates, coarse sandstones and shales, the latter gradually merge into dominantly calcareous facies of Bagh Formation, which contain subordinate sandstones and shales ; the Lameta Formation represents cherty limestones, sandstones and shales and are well developed in upper Narmada Valley. Strikingly, these sedimentaries attain a thickness of only couple of meters and rest directly upon a variety of basements with or without a visible break, such as Vindhyan, Precambrian crystallines and fluviatile upper Gondwana. The major area of these sedimentaries is concealed under Deccan Traps—an effusive rock believed to be of late Maastrichtian to Palaeocene age ; wherever these are overlain by Traps, the contact is never so distinct to suggest a possible hiauts (Wadia, 1966, p. 290). Consideration of this factor becomes inevitable for age interpretation of these rocks based upon the evaluation of containing fauna and flora.

Raiverman (1975), based upon data in Gujarat area, declares that Nimar, Bagh and Lameta Formations are synchronous facies equivalents of a single marine transgressive event ; hence, the traditional view of Nimar being older than Bagh and Lameta being youngest lithostratigraphic unit becomes questionable. Chiplonkar & Borkar (1975) found a close resemblance in the faunal elements of Wadhwan Sandstone of Saurashtra to that of Bagh Formation, thereby implying, that the two represent facies variants of a single transgressive event. I. B. Singh (1981b) on the basis of sedimentologic and Trace Fossil community evidence of the Lameta Formation in Jabalpur area, considers them to be deposits of marine origin ; I. B. Singh (1981b) proposed an estuarine complex model for the deposition of late Cretaceous rocks of Narmada Valley ; S. K. Singh & Srivastava (1981) demonstrated a close similarity in the trace fossil assemblage of Bagh and Lameta formations and also emphasized lithostratigraphic similarity between the two.

FOSSIL RECORDS FROM THE CRETACEOUS ROCKS OF NARMADA VALLEY

It is beyond the scope of this paper to enumerate a variety of Vertebrate, Invertebrate and Microfossil remains reported from the Cretaceous rocks of Narmada Valley during the last several decades. An important monograph on fossil invertebrates of Bagh sediments by Dassarma

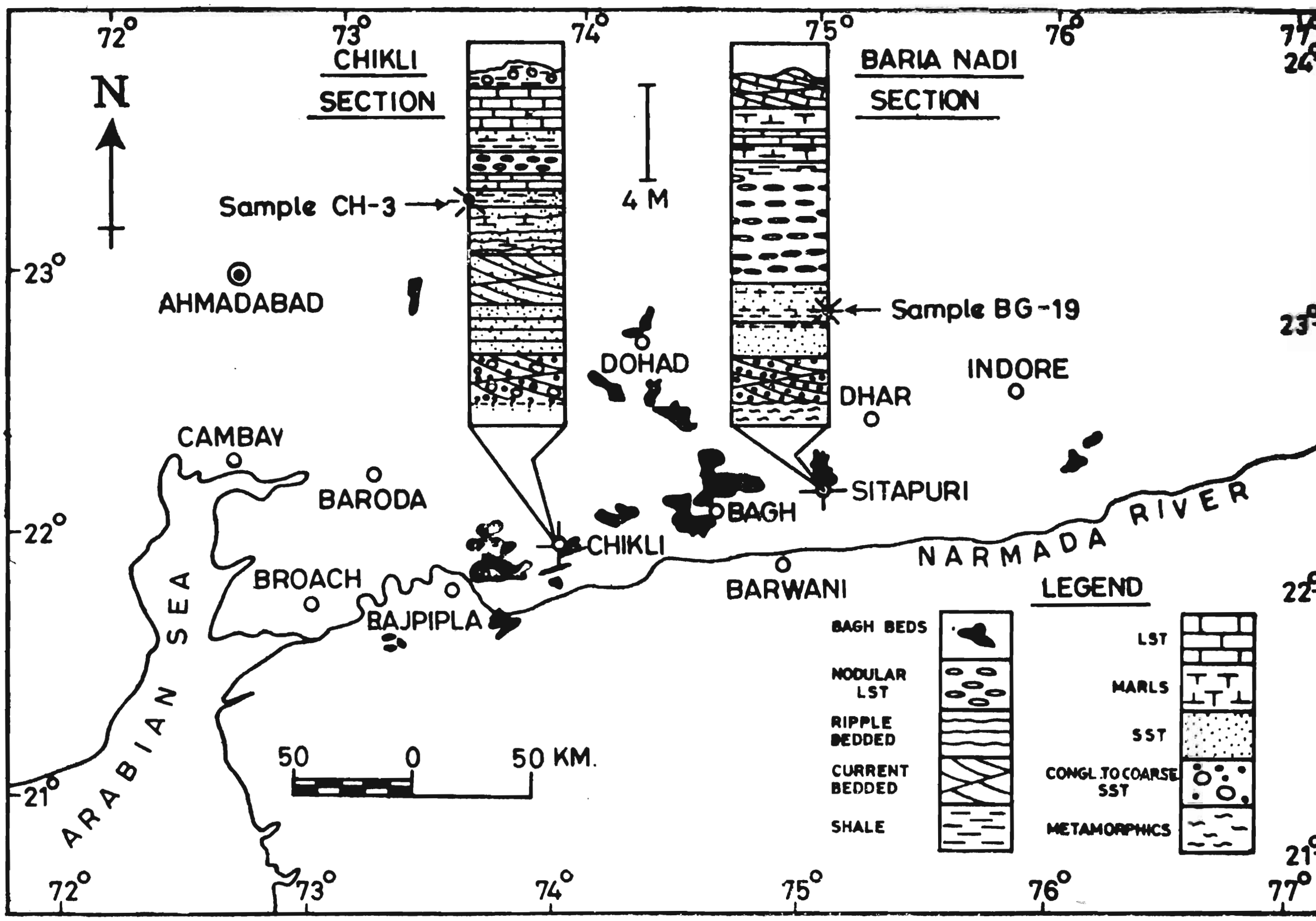


Fig. 1. Showing the distribution of Bagh beds in Lower Narmada Valley and the sampling loclaities. Lithologs display the position of samples yielding Calcareous Nannoplankton. The lithologs are redrawn using basic data of S. K. Singh and Srivastava (1981).

& Sinha (1975) is worth consulting ; a useful summary of fossil records in cretaceous of Narmada Valley is provided by Chiplonkar (1980). Except for rare records of terrestrial elements like dinosaur remains, fresh water molluscs, wood pieces etc., typical fossil plant impressions or Pollens and spores remain completely unrecorded (pers. Comm. Pramod Kumar, BSIP, Lucknow). The maximum yield of marine fossils is from Bagh Formation and followed by Nimar and Lameta Formations, the latter contain scarce body fossils, hence its marine nature is determinable only on the basis of typical bioturbated horizons, presence of mineral Glauconite and other sedimentologic parameters (Chanda, 1963 ; Kumar and Tandon, 1977, I. B. Singh (1981b).

Based upon fossil evidence of various groups recovered from different levels of Bagh Formation, Chiplonkar (1980) suggests rather broad age for each group ; Echinoids-Cenomanian ; Bivalves=Cenomanian-Turonian ; Ammonoids=Turonian-Coniacian ; Bryozoans =Cenomanian-Turonian ; Gastropods=late Cretaceous ; Brachiopods=Albian-Cenomanian ; Polychaeta=Turonian-Lower Senonian. Summing up the evidence of voluminous megainvertebrates, Chiplonhkar (1980) assigns Albian-Turonian age for the Bagh Formation, though reasons for doing so are not clear.

A recent record of *Halimeda* algae from the upper part of Nimar Sandstone is extremely interesting and of Palaeoecologic significance (Badve & Nayak, 1981).

The remains of Microfossils, especially the planktonic forms enjoy the reputation of serving as valuable index fossils for global correlation. Jain (1975) documented several species of Ostracodes from Bagh beds and indicated Coniacian age for the assemblage, though concrete evidence for this age assignment is lacking. In two short papers, the remains of Algae and Planktonic Forams were reported from the Bagh beds (S. N. Singh, 1950 ; Jain, 1961) ; however, none of these authors provided documentation of the Planktonic forams. Sharma (1976) published Camera-lucida drawings of rather ill-preserved assemblage of Planktonic forams from Bagh beds and suggested late Cenomanian to early Turonian age.

The remains of Calcareous Nannoplankton are being reported for the first time from the Narmada Group of sediments. Although several samples of Nimar, Bagh and Lameta Formations were studied, only two samples from sections situated about 100 Km. apart (Fig. 1) and representing the calcareous shales in the upper part of Nimar Sandstone proved productive ; their absence in other samples may either be due to the absence of plankton in that area or due to the diagenetic overgrowth of the finest matrix of rock material. Further search for favourable lithologies are likely to yield positive results.

Calcareous Nannoplankton are fragmentary remains of golden-brown algae, dominantly marine phytoplankton (Coccolithophorids), barely a few microns in size and thus the tiniest of known planktonic groups employed for global correlation ; these have been recorded from sediments of late Triassic to Recent in age and on account of their rapid origination—extinction rates, astronomical abundance in a small lump of soft material, quick preparation techniques and compact Lab. requirements, serve as an efficient tool for dating and correlation of Mesozoic-Cenozoic marine sediments derived from deep sea coring and land profiles.

SECTIONS AND SAMPLES

The samples from Bagh and Lameta beds were made available through the courtesy of Dr. S. K. Singh and Dr. I. B. Singh respectively of the Geology Department, Lucknow University. Samples of Lameta beds proved barren in Calcareous Nannoplankton. About 15 samples representing soft lithologies and taken from different levels of Bagh and Nimar beds were examined and only two proved productive. The location of the two sections, yielding productive samples is indicated in Fig. 1. The Barianadi section at Sitapuri Village, yielded one productive sample (BG-19) ; the upper part of the Nimar Sandstone contain dirty-yellow sandy marls underlain by an Oyster bed. The same bed contains characteristic trace fossil *Bergaueria* Prantl, (S. K. Singh, 1982, this volume) and yielded Nannoplankton. At Chikli Village, cream coloured marls overlying current bedded Nimars, yielded Nannoplankton (CH-3). The lithological field data is provided by S. K. Singh. Most of the samples were silicified and the Nannofossils were diagenetically deformed to escape recognition under high power polarizing research microscope.

METHODS

Conventional methods currently employed for making permanent slides for light microscopic work was followed. About 1 gm. of freshly scratched material from the rock was soaked for some time in distilled but neutral water and later crushed with cleaned finger tips to generate cloudy suspension. A few drops of turbid suspension was drawn by a dropper and evenly spread on a glass slide and allowed to completely dry up on a hotplate. Later, it was covered with a drop of Canada Balsam or Caedex (Merck, Germany) and boiled for a while ; air bubbles were removed by putting a coverslip and gently pressing it at the corners. After cooling the permanent slide was ready for observation. Precaution was taken to scratch only freshly broken and non-weathered portion of the rock sample and to avoid lab. contamination.

The Nannofossils were observed and documented under crossed polarized illumination by using oil immersion objective. Research microscope of AMPLIVAL type of East German make was used. The specimens were photographed on slow speed Black and White film by employing semi-automatic exposure device. The illustrated micrographs represent final magnification of 2000 X.

TAXONOMY

31 species of Calcareous Nannofossils are recorded and most of them are documented in this paper. All the forms are amply documented in the literature, hence a synonymy list is avoided. However, significant features including their stratigraphic worth is discussed under remarks of each species.

Ahmuellerella octoradiata (GÓRKA, 1957) REINHARDT, 1966. (Plate I—13, 14).

Remarks : Originally described from Maastrichtian of Poland ; description by Górka is based upon a solitary schematic sketch, showing an elliptic coccolith spanned by a cross with diamond shaped central area and bifurcated arms of the cross. The four pairs of elements arch up toward the center to support a small spine. This is a fairly distinctive species under crossed polarized light; the rim and each pair of arms remain bright, the latter show characteristic broadening toward the rim.

This is sufficiently documented both under the light and Electron-microscopes ; globally distributed and the earliest occurrence in upper Turonian serves as an useful datum marker ; search of material older than late Turonian failed to yield this (author's unpublished data on European material). This is a cosmopolitan form being equally distributed in both hemipelagic and oceanic realms and becomes abundant with increasing Palaeolatitude (THIERSTEIN, 1976). Younger occurrences show gradual increase in the size of coccolith. Together with host of other taxa, it becomes extinct at the great Maastrichtian-Danian boundary event.

Braarudosphaera bigelowi (GRAN & BRAARUD, 1935) DEFLANDRE 1947

Remarks : Originally described from recent plankton ; the isolated pentaliths of this readily recognizible form are common in hemipelagic sediments and the earliest record dates back to Tithonian. Exceptionally recorded in oceanic realm but abounds in modern and ancient near-shore sediments. Lower salinities tend to favour smaller forms, such as in Bagh area.

Broinsonia enormis (SHUMENKO, 1968) MANIVIT, 1971

Remarks : Under crossed polarized light this characteristic small elliptic coccolith compares well with the figures of MANIVIT (1971, pl. I, figs. 18-20). Known to range from Late Albian to Maastrichtian.

Chiastozygus litterarius (GÓRKA, 1957) MANIVIT, 1971
(Plate I—32)

Remarks : The original description by Górka is based upon a solitary sketch showing a broadly elliptic coccolith with a narrow rim and spanned by a X-shaped cross displaying a rectangular central area. Recent work, both with the light and Electron-microscopy fails to fully satisfy the original description of the species, more so in regard to the width and the nature of the rim, the steeply arching of the four arms meeting in the center with or without rectangular central area. Under crossed nicols, the single cycled rim and the arms remain bright, the latter are longitudinally divided into two rather unequal parts by a dark and twisted extinction line. In its earliest occurrences, both the small and large forms occur together in lower Aptian. Detailed studies would show several useful taxa, so far broadly included within this taxon. It has a cosmopolitan distribution and the earliest occurrence marks Barremian/Aptian boundary and becomes extinct at the end of Maastrichtian.

Corollithion signum STRADNER, 1963
(Plate I—27)

Remarks : Originally described from upper Turonian (Emscherian) of Austria. This is a small and delicate species having a thin rim of hexagonal outline and spanned by an offset central cross (usually broken). Under crossed nicols, the rim area is bright and traversed by four thin and dark extinction lines. Well documented under light and electron microscopes (see Hill, 1976). Being small and rare, it is of no stratigraphic value. Known to range from Late Albian to Campanian.

Cretarhabdus crenulatus BRAMLETTE AND MARTINI, 1964
(Plate I—12, 35)

Remarks : Originally described from the late Maastrichtian of France. Two closely appressed elliptic shields are surmounted by a spine displaying spirally arranged elements. Under crossed nicols, the distinct crenulated outline of the central area is diagnostic ; Bagh forms show moderately coarse to fine crenulations.

The earliest occurrence of this species is somewhat disputed ; Thierstein (1973) employs the initial appearance of this species to mark upper Berriasian, but these forms are smaller and distinct from *C. crenulatus* sensu stricto. Becomes extinct at Maastrichtian-Danian boundary.

Eiffellithus eximius (STOVER, 1966) PERCH-NIELSEN, 1968

Remarks : This is closely related to *E. turriseiffeli*, but for accurate determination of this species, only Stover's figures 16a-b on plate 2 are relevant. The arms of the central cross of this elliptic coccolith are arranged parallel to the long and short axes of the coccolith. The bars meet at the center of an eiffelithid shield to support a hollow spine, which tapers distally. In certain forms, the axial alignment of the bars may be slightly offset. The distinction of such forms from *E. turriseiffeli* may be difficult.

At its initial appearance in late Turonian, the forms of this species are smaller and the tips of the central cross are pointed or display only faint bifurcations ; at younger Senonian level, the size of both *E. turriseiffeli* and *E. eximius* increases and together with conservative forms the new variants exhibit broader arms with distinct bifurcating tips.

The initial appearance of *E. eximius* in late Turonian is a valuable marker event. It becomes extinct in lower Campanian ; this event was used by several authors to erect *E. eximius* zone in Campanian, but due to common reworking of material, this may not serve as reliable marker.

Eiffellithus trabeculatus (GÓRKA, 1957) REINHARDT & GÓRKA, 1967

Remarks : This is a fairly distinctive species and well documented in the literature. *Discolithus disgregatus* Stover, 1966 is referable to this taxon. The initial appearance of this species in Middle Albian is valuable and the extinction occurs at the end of Maastrichtian.

Eiffellithus turriseiffeli (DEFLANDRE, 1954) REINHARDT, 1965
(Plate I—8, 25)

Remarks : This is a common element of Cretaceous nannoflora and can be readily determined. The morphological variations are similar to those displayed by *E. eximius*. Bagh specimens are comparatively smaller in size and show either pointed (fig. 8). or faintly bifurcating tips of the arms (fig. 25). The specimens of *E. eximius* display axial alignment of the central arms otherwise similar to the form of this species illustrated as fig. 25.

The initial appearance is a useful marker to recognize upper Albian and the extinction occurs at the end of Maastrichtian.

Gartnerago obliquum (STRADNER, 1963) REINHARDT, 1970
(Plate I—1, 2, 3, 4)

Remarks : Originally described from upper Turonian of Austria and the range was erroneously given as Cenomanian-Coniacian by Stradner : the elliptic coccolith showed a thin rim, the large central area was perforated by varying number of pores and the central area showed a distinct cross, the shorter arm being obliquely aligned to the short axis of the coccolith. The modern taxonomic assignment of this species to Genus *Gartnerago* is on the basis of ultrastructural details made available through Electronmicroscopy. However, other significant features observable under crossed nicols are rather neglected. Detection of the number of pores in the central area of the coccolith may prove futile as most of the assemblage contain specimens overgrown with excess calcite ; even in such badly preserved material this species can be readily determined under crossed polarized light; under crossed nicols, extremely thin rim area remains bright, the central area reveals four bright and curved arms (sinistral or dextral), and rest of the area remains dark. For complete synonymy, Roth (1973) may be consulted.

Extensive search of material older than Turonian level failed to yield this species. In Turonian, comparatively smaller forms occur which gradually attain larger size in younger Senonian strata. In upper Turonian, this is quite a frequent member of Nannoflora on a global scale. However, certain small elliptic coccoliths like *Broinsonia gammation* (Hill, 1976) occurring in Albian-Cenomanian do mimic this species, but differ in nature and relative brightness of rim and axial figure under crossed nicols ; electronmicroscopy of such forms is needed. Initial appearance in Turonian is useful and the extinction occurs in late Maastrichtian.

Lithastrinus floralis STRADNER, 1962
(Plate I—23, 24)

Remarks : Originally described from higher Senonian level. In side views, typical forms exhibit H-shaped profile. In plan view, flower like appearance is characteristic ; in certain forms, the elements show gently curved to pointed margins or may be just smooth, the latter appear as quadrate shaped plates in side views. Under crossed nicols and in plan view, a dark extinction cross is visible in the central area. Variants showing pointed and protruding elements are usually confused with *Lithastrinus grilli* Stradner, the typical forms of which are never found at Turonian level but appear in lower Coniacian (see Lectotype designations by Bukry 1969). All the variants are detected in Bagh material and in spite of general scarcity of Nannoflora this together with *G. obliquum* is the most frequent member present. The genera *Eprolithus* and *Radiolithus* of Stover (1966) must be considered as synonyms of *Lithastrinus* Stradner.

The initial appearance of *L. floralis* coincides with that of *Rhagodiscus angustus* (Stradner) and marks upper Aptian level and survives up to end of Coniacian. General abundance at Turonian level is noteworthy. Younger occurrences in Santonian-Campanian not well established. This is a typical form of Tethyan province and scarce to absent in Pacific (see Thierstein 1976).

Lithraphidites helicoideus (DEFLANDRE, 1959) DEFLANDRE 1963

Remarks : Rod shaped Nannofossils tapering at both the ends and displaying helicoid arrangement of fine elongated elements are referable to this taxon. Well documented from Senonian level. Rare specimens of Bagh are probably the oldest record but has no stratigraphic value.

Loxolithus armilla (BLACK *et* BARNES, 1959) NÖEL, 1965

Remarks : These are simple ring like elliptic coccoliths, exhibiting smooth inner and outer margins and curved extinction gyres under crossed nicols. This species is fairly common at Cenomanian-Turonian level, but has no stratigraphic worth.

Lucianorhabdus cayeuxii DEFLANDRE, 1959
(Plate I—9)

Remarks : The Nannofossils of this type are fairly common in Senonian rocks, though the lower and upper limits of its occurrence is disputed. These are closely related to *Tetralithus obscurus*—*Tetralithus ovalis* lineage. Detailed work has lately demonstrated this species to consist of uniformly shaped tiny calcite rhombohedra (Holococcoliths) ; this was earlier pointed out by the author (Jafar, 1977) and later well documented by Wind & Wise (1978). Sissingh (1977) suggested *L. compactus*—*L. maleformis*—*L. cayeuxii* evolutionary lineage, which may be hard to recognize in the assemblages ; the first two are characterized by the presence of a plug at the terminal end of the rod, while *L. cayeuxii* is irregular in outline and lacks a central canal.

Earliest occurrence of *L. cayeuxii* was indicated as Santonian by Sissingh (1977) and Coniacian by Thierstein (1976). The discovery of the present form suggests that the initial appearance may lie in late Turonian. *L. compactus* and *L. maleformis* appear in lower Cenomanian and upper Turonian respectively (fide Sissingh, *op. cit.*). The choice of *Lucianorhabdus* species does not seem to be good markers. *L. cayeuxii* is quite abundant till lower Maastrichtian, but becomes scarce to absent in late Maastrichtian (=*L. quadratus* and *M. mura/N. frequens* zones). This observation is in agreement with that of Bramlette and Martini, 1964.

Markalius circumradiatus (STOVER, 1966) PERCH-NIELSEN, 1968

Remarks : Circular coccoliths with faintly striate margin and showing extinction cross under crossed nicols. The specimens are referable to the illustrations of Stover (1966) and Manivit (1971). The assignment of this form to genus *Markalius* Bramlette and Martini, 1964 is tentative and this form may ultimately prove to belong elsewhere. The lower and upper limits of its occurrence are not precisely known but distributed in sediments of Albian-Turonian age.

Microrhabdulus belgicus HAY AND TOWE, 1962

Remarks : This tiny and fusiform nannofossil is distinctive under crossed nicols. Known to occur from Turonian to Lower Maastrichtian.

Parhabdolithus bitraversus STOVER, 1966
(Plate I—16, 17, 18, 31)

Remarks : Original description stipulates an elliptic coccolith with a thick rim and the minor axis traversed by a double row of bars meeting at the center to support a spine. Under crossed nicols, the diagonally opposite bars remain bright and characteristically broaden toward the rim ; the central area supports a short spine, which yield four tiny bright points in plan view. This may be easily confused with *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen, which otherwise lacks double row of bars and supports a thicker stem of characteristic appearance under crossed nicols. Sissingh (1977) indicates lower Santonian as the first appearance of *R. anthophorus*, whereas *P. bitraversus* commonly occurs in sediments of Albian-Turonian age, but may also have extended range. The form illustrated by Roth (1973 ; pl. 22, figs. 4a-c) and determined as *R. anthophorus* looks like belonging to this species.

Podorhabdus albianus BLACK, 1967
(Plate I—34)

Remarks : This distinctive species was originally described from the Lower Gault (Middle Albian) of England under Electron Microscope. Under light microscope, the elliptic rim surrounds a cross, surmounted by a hollow cylindrical spine ; each bar of the central cross broadens towards the rim, resulting in four large windows. Under crossed nicols, the broadened part of the arms and the rim remains bright, the former show a pair of bright elements. This species differs from closely related *P. dietzmanni* (Reinhardt, 1965) in possessing elliptic rather than quadrate outline. *P. albianus* is short ranging, but the extinction level is disputed. Thierstein (1976) supports Middle Albian to lower Turonian range and uses the initial appearance to mark Middle Albian in Europe, Indian and Pacific ocean sites. It is fairly common element of Nannoflora in Upper Albian-Cenomanian deposits of Europe (author's unpublished data). The presence of this species in Bagh samples would now extend its range up to upper Turonian. The range of Middle Albian to Campanian given by Hill (1976) is misleading, moreover this species is extremely rare in upper Turonian of Europe.

Prediscosphaera columnata (STOVER, 1966) Bukry, 1972

Remarks : Several authors have described this under *P. cretacea*, however, both under the light and electron-microscopes, it can be set apart, specially at its initial appearance level in lower Albian when typical *P. cretacea* is absent. *P. columnata* is well illustrated by Stover (1966). This is a small species with circular to nearly circular outline in plan view. In side view the basal plate exhibits more curvature than in *P. cretacea*. Under crossed nicols and side views, the short and robust stem displays simple parallel pair of elements without 'scissor like" character and the stem may or may not contain one or two rings of wing like extensions (synonym=*Deflandrius cantabrigensis* Black, 1967). Accordingly, fig. 10 on plate 6 of Stover, should belong to *P. cretacea*. In plan view alone, except for its small size, it would be difficult to distinguish it from *P. cretacea*.

The initial appearance of *P. columnata* or genus *Prediscosphaera* itself, is an important marker for lower Albian. *P. columnata* continues up and joined by bigger and distinct *P. cretacea*, which finally attains 3-4 times its original size at younger Senonian level before becoming extinct at the end of Maastrichtian.

Prediscosphaera cretacea (ARKHANGELSKY, 1912) GARTNER, 1968
(Plate I—10, 11, 33)

Remarks : In plan view subcircular to elliptical. Tilted specimens may display circular outline. The rim consists of quadrate shaped elements enclosing a ring of smaller elements. Center of coccolith spanned by an arched cross surmounted by spine displaying winglike extensions at the distal end. Under Crossed nicols and plan view the appearance is characteristic ; in side views, the stem if intact shows typical "scissor like" merging of elongate elements. Typical specimens are found in Cenomanian and becomes extinct at Maastrichtian-Danian boundary.

Prediscosphaera spinosa (BRAMLETTE AND MARTINI, 1964) GARTNER, 1968

Remarks : It can be readily distinguished from *P. cretacea* and *P. columnata*. Under crossed nicols and in plan view, central area is compact and accupied by a central cross with its arms aligned with the axes of elliptic coccolith ; moreover, the long slender spine looks divided into two long slender elements terminated by bifurcating tips at the distal end.

The initial appearance of this species is somewhere in Cenomanian and may prove to be an important marker, as it has not been found in association with *P. columnata* alone. Extinction occurs at the end of Maastrichtian.

Quadrum gartneri PRINS AND PERCH-NIELSEN, 1977 (Plate I—15)

Remarks : The author agrees with the diagnosis and descriptions of this species as given by Prins and Perch-Nielsen in Manivit *et al.*, (1977). This is the only species of "*Tetralithus*" forms occurring in Turonian. Typical *Micula staurophora* (Gardet) event in middle Turonian, as suggested by Thierstein (1976) does not appear to be realistic. The initial appearance *Q. gartneri* is in lower Turonian and the upper limit is still subjective.

Scapholithus fossilis DECLANDRE, 1954 (Plate I—26)

Remarks : This tiny form of acute rhombic or boatlike shape is extremely rare and has no stratigraphic worth. Initially appears in Albian and for the living forms a different name *Calciosolenia* Gran is in use.

Tranolithus exiguus Stover, 1966 (Plate I—19, 29, 30)

Remarks : Contrary to the view of Thierstein (1976), this species is kept apart from *T. orionatus* Stover, as both the species were observed together in well preserved as well as overgrown samples. *T. exiguus* is a characteristic species of elliptic outline and a pair of bars, broadest near the rim gradually thin out and nearly meet at the center. In the same sample, the specimens of *T. exiguus* are broadly elliptical than narrowly elliptical *T. orionatus*.

Earliest occurrence in upper Albian and becomes extinct in Maastrichtian.

Tranolithus orionatus (REINHARDT, 1966) PERCH-NIELSEN, 1968 (Plate I—20, 21)

Remarks : Like *T. exiguus*, but the central area of narrowly elliptic coccolith is spanned by four large elements, which nearly close the central part. *T. phacelosus* Stover, 1966, should be considered as synonym of this species. Exact range not known, but probably ranges from Albian to Maastrichtian.

Vagalapilla matalosa (STOVER, 1966) THIERSTEIN, 1973

Remarks : Only the holotype of Stover (1966, pl. 2, figs. 1a-c) is relevant for the accurate determination of this species, which is quite distinctive under crossed polarized light illumination and cannot be confused with similar smaller species of *Broinsonia* as claimed by several authors. Under crossed nicols, fairly thick rim remains bright and traversed by distinct extinction gyres. The bars of the central cross are longitudinally divided by dark extinction lines. Except for quadrant openings, no other perforations are discernable. These features are absent in species of *Broinsonia*.

V. matalosa appears in early Aptian and continues through Campanian (fide Thierstein, 1976).

Watznaueria barnesae (BLACK, 1959) PERCH-NIELSEN, 1968 (Plate I—1, 5, 6, 7)

Remarks : This species often dominates the Nannofloral assemblage of Cretaceous and can be readily determined. Within a single sample variations in size, ellipticity, relative width of rim and central area can be observed. Detailed work might help in splitting taxa of potential stratigraphic value. Ranges from upper Jurassic to Maastrichtian.

Watznaueria ovata BUKRY, 1969

Remarks : This is a small species having a large and open central area without any dividing bar. Under crossed nicols, the extinction gyres are similar to those of other *Watznaueria* species. On account of its rarity and sporadic occurrence, it has no stratigraphic significance. Ranges from upper Jurassic to Maastrichtian.

Zygodiscus diplogrammus (DEFLANDRE, 1954) GARTNER, 1968 (Plate I—28)

Remarks : Elliptic coccolith with a broad rim and spanned by double bridge accross minor axis and does not support a spine. Fairly common element of Cretaceous Nannoflora. Ranges from Valanginian to Maastrichtian.

Zygodiscus spiralis BRAMLETTE AND MARTINI, 1964 (Plate I—36)

Remarks : This is a comparatively small species and the minor axis of the elliptic coccolith is spanned by a bridge supporting a spine. Under crossed nicols, the extinction gyres in the rim area are distinctly spiral. A tiny variant of this species survives the Maastrichtian—Danian boundary event in Europe and flourishes into Palaeocene (authors unpublished data). It is known to range from Albian to Palaeocene and at certain levels shows either low or high frequency of occurrence.

Zygodiscus xenotus (Stover, 1966) Hill, 1976
(Plate 1—22)

Remarks : Robust elliptic forms somewhat resembling *Z. diplogrammus*, but differ in possessing a central spine supported by bars. Specimens overgrown with calcite are difficult to differentiate. Known range Albian to Turonian.

CRITICAL EVALUATION OF PLANKTONIC MICROFOSSIL RECORDS

Sharma (1976) recorded rather poorly preserved forms from the marly layers of Bagh Formation exposed around Deola and Chirakhan villages. The following brief comment of these forms is based upon the critical examination of illustrations only :

Ten species of Planktonic Forams were described, and illustrated by Camera-lucida drawings ; though sufficient magnification was provided the side views were presented for only a few forms (Sharma, 1976). *Heterohelix globulosa* (Ehrenberg) was described as commonly occurring in the assemblage but typical striate forms are apparently absent. *Heterohelix* cf. *reussi* (Cushman) and *Heterohelix* sp., also lack striations. Possibility is not altogether dismissed, that the absence of striations be an artifact of preservation, as the appearance of this feature is characteristic of Cenomanian-Turonian boundary event.

The genus *Hedbergella* is represented by maximum number of species at Turonian level and together with species of *Heterohelix* dominates the warm water assemblages at a global scale. Due to morphologic gradations among known species and provincialism, the exact determination is always full of pitfalls. Transitional forms exist between *H. amabilis* Loeblich and Tappan and *H. delrioensis* (Carsey), hence the illustration of the former species (Sharma, 1976, pl. 1, figs. 1-2) looks more like *H. delrioensis* (Carsey), which is confined to upper Cenomanian to Turonian. The forms actually identified as *H. delrioensis* (pl. 1, figs. 3-6) are difficult to interpret. The identification of *H. bornholmensis* Douglas and Rankin, looks genuine (pl. 1, figs. 7-8). The form determined as *H. kingi* (Trujillo) on pl. 1, figs. 9-10, looks like *H. praehelvetica* (Trujillo) Douglas and Slitter, 1966, an important species lying between two extreme lineage members viz. *H. delrioensis* and *Praeglobotruncana helvetica* Bolli. *H. praehelvetica* (Trujillo) has a short range and confined to Turonian level only. The forms determined as sp. A and sp. B (pl. 1, figs. 15-17 and 18-20 respectively) of genus *Ticinella* Reichel, show resemblance to assigned genus in possessing concavo-convex test ; the true generic identity, however, remains obscured. Similarily, the form determined as *Rugoglobigerina* sp., remains indeterminate (pl. 1, figs. 21-22).

Since the recovered Nannoplankton do not suggest any reworking from older levels, the Planktonic Foram assemblage also reflects natural cocurrence and the presence of youngest element suggest Turonian rather than late Cenomanian-lower Turonian as suggested by Sharma (1976).

STATUS OF MID-CRETACEOUS STRATOTYPES IN CONTEXT OF INTEGRATED NANNOPLANKTON-PLANKTONIC FORAM BIOSTRATIGRAPHY

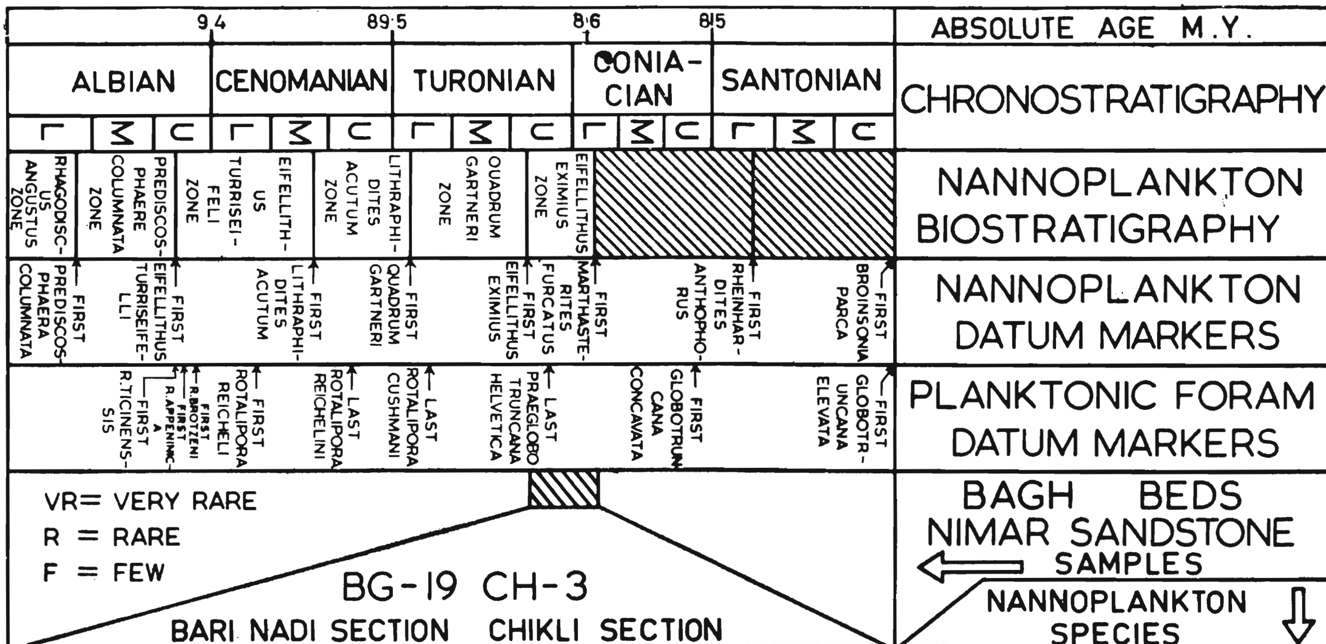
On account of the discovery of widespread sapropelic facies development in deep sea and marginal land areas during Mid-Cretaceous period (Albian-Turonian), considerable economic importance is being attached to the precise biozonation and global correlation of marine sequences for this time slice. Special working group of IGCP is entrusted to work toward this goal (Manivit *et al.*, 1977).

For Cretaceous period, the classical stratotypes in Europe are being worked upon for Planktonic microfossils for over a decade. Still the results are not entirely satisfactory, mainly due to the fact, that either a particular stage is not completely exposed in a single section or the taxonomic group in question is badly preserved or missing altogether. The problems concerning the nomenclature of Stratotypes and varying taxonomic criteria used by different workers for marker species of a certain fossil group further complicate the matter.

Still some refined picture is emerging, as the datum levels defined by the appearance or disappearance of Planktonic Foram-Nannoplankton species are more confidently established, chiefly owing to the widespread coring activity of Deep Sea Drilling Project during the last two decades (Thierstein, 1976). Sissingh (1977) provided a biozonation scheme for Cretaceous and a useful chart comparing the biozonation schemes proposed since 1963 is given ; Calcareous Nannoplankton from European stage stratotypes are investigated and supplemented with better preserved nannoflora from continuous sections exposed in Dyr el Kef of western Tunesia. Integrated biostratigraphy employing Planktonic Forams, Nannoplankton and Calpionellids from stage-Stratotypes of European Cretaceous is discussed and supported by data of Tunesian Cretaceous in a separate publication of Sissingh (1978).

For the age interpretation of Bagh sedimentaries, the integrated Planktonic Foram-Nannoplankton biohorizons proposed by IGCP working group is adopted with minor modification (Table 1) ; this scheme is slightly different than proposed by Sissingh (1978). The Ceno-

Table 1. Showing the frequency of occurrence of calcareous Nannoplankton taxa in the productive samples. Integrated Nannoplankton—Planktonic Foraminifera Zonation scheme for the Mid-Cretaceous after Manvit *et al.*, (1977). Absolute ages after Ernst & Kreuzer (1976)—unpublished report.



NANNOPLANKTON SPECIES	BG-19 (BARI NADI SECTION)	CH-3 (CHIKLI SECTION)
AHMUELLERELLA OCTORADIATA	R	VR
BRAARUDOSPHAERA BIGELOWI		VR
BROINSONIA ENORMIS	VR	
CHIASTOZYGUS LITTERARIUS	R	R
COROLLITHION SIGNUM	VR	VR
CRETARHABDUS CRENULATUS	R	R
EIFFELITHUS EXIMIUS	R	R
EIFFELITHUS TRABECULATUS	VR	
EIFFELITHUS TURRISEIFELLI	F	F
GARTNERAGO OBLIQUUM		F
LITHASTRINUS FLORALIS	F	VR
LITHRAPHIDITES HELICOIDEUS	VR	
LOXOLITHUS ARMILLA	VR	
LUCIANORABDUS CAYEUXII	R	VR
MARKALIUS CIRCUMRADIATUS	VR	
MICRORHABDULUS BELGICUS	VR	
PARHABDOLITHUS BITRAVERSUS	R	F
PODORHABDUS ALBIANUS	VR	
PREDISCOSPHAERA COLUMNATA	R	R
PREDISCOSPHAERA CRETACEA	F	F
PREDISCOSPHAERA SPINOSA	R	R
QUADRUM GARTNERI		VR
SCAPHOLITHUS FOSSILIS	VR	VR
TRANOLITHUS EXIGUUS	R	R
TRANOLITHUS ORIONATUS	F	R
VAGALAPILLA MATALOSA	VR	
WATZNAUERIA BARNESAE	F	F
WATZNAUERIA OVATA	VR	
ZYGODISCUS DIPLOGRAMMUS	R	R
ZYGODISCUS SPIRALIS	F	
ZYGODISCUS XENOTUS		R

manian and Turonian Stratotypes in terms of planktonic and molluscan stratigraphy are discussed and data summarized by Marks (1977), who indicates an overlap between the top of Cenomanian Stratotype and base of type Turonian. The Cenomanian—Turonian and Turonian—Coniacian boundaries in the type area cannot be demarcated by Planktonic Foram or Nannoplankton ; However, extinction of Nannoplankton species like *Hayesites albiensis* and the appearance of *Gartnerago obliquum* and *Quadrum gartneri* (=*Tetralithus pyramidus, Micula decussata, Micula staurophora*) may ultimately prove helpful in recognizing Cenomanian-Turonian boundary. Similarly, the appearance of *Lithastrinus grilli*, *Arkhangelskiella specillata* and *Marthasterites furcatus* should help in recognizing Turonian-Coniacian boundary. It is here proposed to use the initial appearance of *Marthasterites furcatus* to recognize the Turonian-Coniacian boundary on a worldwide basis (author's unpublished data on European material).

AGE INTERPRETATION BASED UPON MEGA-, MICRO- AND NANNOFOSSIL DATA

MEGAFOSSILS

For long range correlations, only the species of Ammonites and *Inoceramus* (*Mytiloides*) can be used with some confidence. In an exhaustive review of invertebrate fauna of the Narmada Valley Cretaceous rocks (Chiplonkar, 1980), the critical ammonite species are not recorded. Moreover, Turonian-Coniacian age deduced from Ammonite assemblage is not supported by index species or tied to universally accepted biozonation scheme (Van Hinte, 1976).

At least 34 species of *Inoceramus* (*Mytiloides*) are claimed to have been identified from Cretaceous rocks of Narmada Valley (Chiplonkar and Bhadve, 1976 ; Dassarma and Sinha, 1975 ; Chiplonkar, 1980), but it is rather disappointing to note, that this valuable group has not been fully exploited to recognize precise biohorizons. However, *I. labiatus* and *I. crippsi* is reported from Bagh sediments ; these species belong to a lineage *I. crippsi—I. pictus—I. labiatus* and universally mark Turonian level (Marks, 1977).

Among vertebrate remains, those of dionosaurs in upper Narmada Valley (Lameta Formation) are significant and were assigned Turonian age by Huene and Matley (1933) and later supported by more recent work (reviewed by I. B. Singh, 1981b).

MICROFOSSILS

The age diagnostic planktonic microfossils are already discussed. As the first order correlation exists between Planktonic Foram-Nannofossil biohorizons, the Planktonic Forams described by Sharma (1976) should be supplemented with species like *Praeglobotruncana helvetica* Bolli and *Globotruncana sigali* Reichel, which would confirm late Turonian level. The benthonic Forams are yet to be documented from Bagh beds, though passing references are made by Dassarma and Sinha (1975) and Sharma (1976).

Nannofossils :

For interpreting the age of the assemblage, the biozonation scheme of Manivit, *et al.*, (1977) prepared under the auspices of IGCP is followed here (Table 1) ; the assemblage can be assigned to *Eiffellithus eximius* Zone, which is of late Turonian to early Coniacian in age.

Eiffellithus eximius Zone ; Author : Verbeek (1976) emended Manivit *et al.*, 1977.

Definition : Interval from the first occurrence of *Eiffellithus eximius* s. l. to the first occurrence of *Marthasterites furcatus* Deflandre.

DISCUSSION

E. eximius Zone should not be confused with *E. eximius* Zone of Roth (1973) and others, which is of Campanian age and moreover its base is defined by the extinction of *E. eximius*. *E. eximius* Zone was created by Verbeek (1976) from upper Cretaceous section of Dyr el Kef, Tunesia and defined as : Interval from the first occurrence of *E. eximius* to that of *Arkhangelskiella specillata* Vekshina. The next younger zone was named *Arkhangelskiella specillata* Zone, which was defined as : Interval from the entry of *A. specillata* to the appearance of *Marthasterites furcatus* Deflandre ; Manivit *et al.*, (1977) have not recognized this zone, accordingly, *E. eximius* Zone as emended by these authors included Turonian-Coniacian boundary (Table 1).

The critical and cosmopolitan *M. furcatus* is a tiny triradiate form with simple terminations of arms at its initial appearance, but there is a gradual increase in size and in higher Coniacian level, forms with bifurcating or trifurcating arm tips dominate over the ones with simple arm tips (authors unpublished data from Cretaceous of Gosau, northern Calcareous Alps). Several authors record this species at a higher level than Turonian-Coniacian boundary (Čepek and Hay, 1969 ; Manivit, 1971). Others, like Martini (1975), Roth (1973), Thierstein (1976) and Sissingh (1977) record this practically at Turonian-Coniacian boundary. Lately, Manivit (1979) modifies her earlier view and proposes the initial appearance of *M. furcatus* in late Turonian ; this is not acceptable as the initial appearance of this species can best be recognized as coinciding with Turonian-Coniacian boundary, and a consensus must be sought on this score.

In view of the discusssions presented above and virtually barren nature of Coniacian Stratotype at Cognac, a Hypostratotype section should preferably be chosen in Dyr El Kaf section of Tunesia and the Turonian-Coniacian boundary should be recognized by the first apperance of cosmopolitan *Marthasterites furcatus* Deflandre. Other species, which should be carefully recorded to recognize Coniacian level are : first appearance of *Arhangelskiella specillata* and *Lithastrinus grilli* (should not be confused with variants of *Lithastrinus floralis* exhibiting protruding elements in plan view). In view of the emendation proposed here, a precise late Turonian age can be established for the recovered Nannoplankton assemblage.

The above critical evaluation of published records of mega- and microfossil records from different lithunits of Bagh sedimentaries coupled with Nannoplankton data suggest an age neither older nor younger than Turonian level.

PALAEOECOLOGY OF NANNOPLANKTON ASSEMBLAGE

The exclusion of several Nannoplankton taxa in Bagh area can be ascribed to the bad preservation of yielding samples, though ecologic and geographic factors may also have played a role. Taxa like *Watznaueria communis, Stephanolithion laffitei, Lithraphidites carniolensis, Parhabdolithus angustus, Parhabdolithus embergeri, Corollithion exiguum* and [1]*Nannoconus* spp., which otherwise frequently occur in Turonian level elsewhere are absent in Bagh area.

Compared to the present day distribution of Nannoplankton, which show distinct assemblages in Tropical, sub-Tropical and Boreal-Austral realms, such differentiation is not so well marked during Cretaceous period, as the globe experienced fairly uniform climate. However, interesting palaeoecologic interpretations are emerging for individual taxa as well as assemblages of cretaceous, which permit recognition of Hemipelagic/Oceanic as well as high and low latitude assemblages (Thierstein, 1976). I.B. Singh (1981b) advocates an estuarine complex model for the deposition of Cretaceous rocks of Narmada Valley ; he stipulates the influx of fresh water in the upper Narmada Valley (Lameta Formation), which may explain the general absence or scarcity of megafossils and microplankton in these sediments. In contrast, westwardly lying sedimentaries of lower Narmada Valley (Nimar and Bagh Formations) supported a rich invertebrate and microplankton community ; the water depth may not have exceeded a couple of meters.

The distributional behaviour of recorded Nannoplankton coupled with their high diversity (31 species are identified) and low frequency suggests distinct sedimentation history for lower and upper Narmada Valley sedimentaries during a short lived transgressive event. However, the occurrence of Planktonic Forams and Nannoplankton would demand appreciable water depth to effectively command the circulation of currents, which would guarantee continued exchange of plankton crop from the open sea. The occurrence of diverse Nannoflora in Cretaceous rocks of Narmada Valley, extending far deep into the heart of Peninsular India, would, nevertheless, serve as an interesting model of Nannoplankton occurrence in an estuarine complex.

The frequency of occurrence of Nannoplankton taxa, plotted as Few, Rare, and Very Rare (Table 1), would elsewhere show Abundant, Common and Rare occurrences respectively, in material free from the diagenetic overgrowith of calcite in the finest matrix of rock.

By comparing the Nannoplankton assemblage of Chikli Section (Sample CH-3) and Baria Nadi Section (Sample Bg-19), the absence of *Gartnerago obliquum* in eastwardly lying sample Bg-19, seems significant. This does not reflect any stratigraphic gap between the levels of the two samples, as the age diagnostic forms are common to both, but may indicate exclusion of this species by local ecologic factor like reduced salinity induced by the debouching of small riverulets in the main estuarine flat. Similarly, *Zygodiscus spiralis* is "Few" in sample Bg-19 and absent in sample CH-3. *Lithastrinus floralis*, a characteristic species, is "Few" in sample Bg-19 and "Very Rare" in sample CH-3. Striking behaviour of these three taxa in localities barely 100 Km. apart, can be ascribed to local ecologic factor, such as reduced salinity.

Disregarding the ecological stress of estuarine complex, to some extent influencing the Nannoplankton assemblage, most of the taxa described herein are cosmopolitan and serve as useful datum markers in Mid-Cretaceous of both hemipelagic and pelagic sedimentary sequences of Tropical to sub-Tropical palaeolatitudes.

PALAEOGEOGRAPHY OF INDIA DURING TURONIAN TRANSGRESSIVE EVENT AND THE HYDROCARBON PROPSECTS

Turonian period witnessed rapid Sea Floor spreading activity on a global scale; during this time Africa and South American connections were severed, resulting in North-South Atlantic faunal exchange (Berggern and Hollister, 1974) ; the eastern and western coast of India experienced free exchange of fauna and plankton mixing both via main Tethys in the north and a narrow southern sea separating India from Antarctica and Australia. From its Turonian latitudinal position of about 30 deg. South, the site of Narmada Valley has migrated to occupy present day position of nearly 30 deg. North.

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1 The genus *Nannoconus* which was earlier presumed to be absent in Indian continent, is represented by at least one species viz. *Nannoconus truittii* Brönnimann in Dalmiapuram Grey Shale member of South India (Tentative age : Late Aptian Earliest Albian ; author's unpublished data).

The east-west trending Narmada Valley lineament represents Rift Valley like structure and witnessed a single stroke short lived late Turonian transgression, which may have lasted for less than a million year in terms of absolute age calibration (Ca. 87 m.y. BP). Till we have evidence to the contrary, the entire Senonian period was a time of non-deposition, till the effusive rocks of Deccan Traps (Late Maastrichtian-Palaeocene) covered most of the exposed Cretaceous rocks of Narmada Valley.

Apart from short lived transgression along Narmada Valley, the marine sedimentation continued with some minor breaks since Neocomian on the east coast of India and since Jurassic in the NW part of Rajasthan. The area of Kachchh, which witnessed continuous sedimentation since at least Bajocian times, experienced regression during Albian, the renewed Turonian transgression along Narmada Valley, surprisingly did not reach Kachchh area. Parallel histories of marine transgressive events along Narmada Valley and Subathu-Dogadda lineament of Lesser Himalaya was pointed out by I. B. Singh (1981a) ; according to him, rocks of lower Permian, late Cretaceous and Palaeocene-Eocene ages should occur in a parallel fashion along two rift valley like structures of Indian shield. Though this hypothesis sounds attractive, a more pragmatic approach to this should seek to clarify :

(i) As to why the rocks of Palaeocene-Eocene age are confined to the westernmost area of Lower Narmada Valley ?

(ii) The equivalent rocks of late Turonian age in Narmada Valley, are probably represented in Subathu-Dogadda Zone of Lesser Himalaya by a single known hard Limestone band (Nilkanth Formation of I. B. Singh 1981a). The lateral facies equivalents of this late Cretaceous transgressive event surprisingly remain undiscovered so far in lesser Himalaya.

The E-W trending Cretaceous rocks of Narmada Valley exhibit much aerial extent, though a major part seems to be concealed beneath Deccan Traps ; the dominant lithologies viz. carbonates and sands with subordinate clays containing rich marine elements in the western part could serve as good source rock for hydrocarbons. However, the lack of sufficient burial, hence reduced geothermal maturity and oxidation of organic matter both at primary and secondary stage seems to have destroyed the traces of hydrocarbons ; hence from hydrocarbon exploration viewpoint, the Cretaceous rocks of Narmada Valley do not look attractive.

CONCLUSIONS

I. The Cretaceous rocks of Narmada Valley are considered as synchronous facies equivalents of a single stroke transgressive event of late Turonian age, extending deep into the heart of Peninsular India along the present limits of Narmada Valley lineament.

II. Available data on Vertebrates, Invertebrates (specially age diagnostic Ammonites and Inoceramus) and Microfossils earlier described from different lithostratigraphic units tend to support a Turonian age for Bagh and Lameta sediments. More significant Microplankton, like Planktonic Foraminifera must be reassessed on the basis of fresh collections.

III. An assemblage of Nannoplankton from upper calcareous part of Nimar Sandstone comprising 31 species can be assigned to *Eiffellithus eximius* Zone of Manivit *et al.*, (1977), which is considered to be of late Turonian to early Coniacian age.

IV. Critical review of literature dealing with the Mid-Cretaceous Stage Stratotypes of Europe suggests, that the Type Section of Coniacian at Cognac, France is practically barren in the remains of fossils. As such the Turonian-Coniacian boundary should be recognized in a Hypostratotype section, such as Dyr el Kef of western Tunesia, which offers a continuous sequence of some importance. It is suggested to use the initial appearance of cosmopolitan Nannoplankton species *Marthasterites furcatus* Deflandre to define Turonian-Coniacian boundary; accordingly, precise late Turonian age is indicated for the Nannoplankton assemblage of Nimar Sandstone.

V. The Nannoplankton assemblage of Bagh area is characterized by fairly high diversity and low frequency of taxa ; this is largely ascribed to diagenetically induced excess calcite in the finest carbonate matrix of the rock. The strained ecologic conditions of estuarine complex, may also have reduced the frequency and excluded some common taxa occurring elsewhere in Turonian level.

VI. Three Nannoplankton species viz. *Gartnerago obliquum*, *Lithastrinus floralis* and *Zygodiscus spiralis* are recognized as ecologically sensitive species.

VII. The contact of Cretaceous rocks with the overlying Deccan Basalt (presumably of late Maastrichtian to Palaeocene age) has to be more critically examined to explain the time gap (Senonian) involved between the retreat of Turonian sea and the initiation of Trap activity.

VIII. The single stroke late Turonian Transgression along Narmada Valley was in response to general spread of epicontinental seas on a global scale during late Cretaceous times, and may have lasted for less than a million year. A parallel probably coeval event took place along Subathu-Dogadda lineament of Lesser Himalaya ; efforts must be made to trace the lateral facies equivalents of the Nilkanth Formation in Lesser Himalaya.

ACKNOWLEDGEMENT

The author is greatly indebted to Dr. S. K. Singh of the Department of Geology, Lucknow University, for a variety of discussions relating to the Geology of Narmada Valley and for supplying the material and lithologs, which forms the basis of this paper. Valuable assistance in the form of material, discussions and encouragement was offered by Dr. I. B. Singh, Department of Geology, Lucknow University. Thanks are due to late Dr. R. P. Sharma for help rendered during the photodocumentation of the material (Geology Department, Lucknow University). Mr. P. K. Bajpai (Birbal Sahni Institute of Palaeobotany, Lucknow) helped in the drawing of sketches.

Grateful acknowledgement is extended to the Director, Birbal Sahni Institute of Palaeobotany, Lucknow, for working facilities and for according premission to publish this paper.

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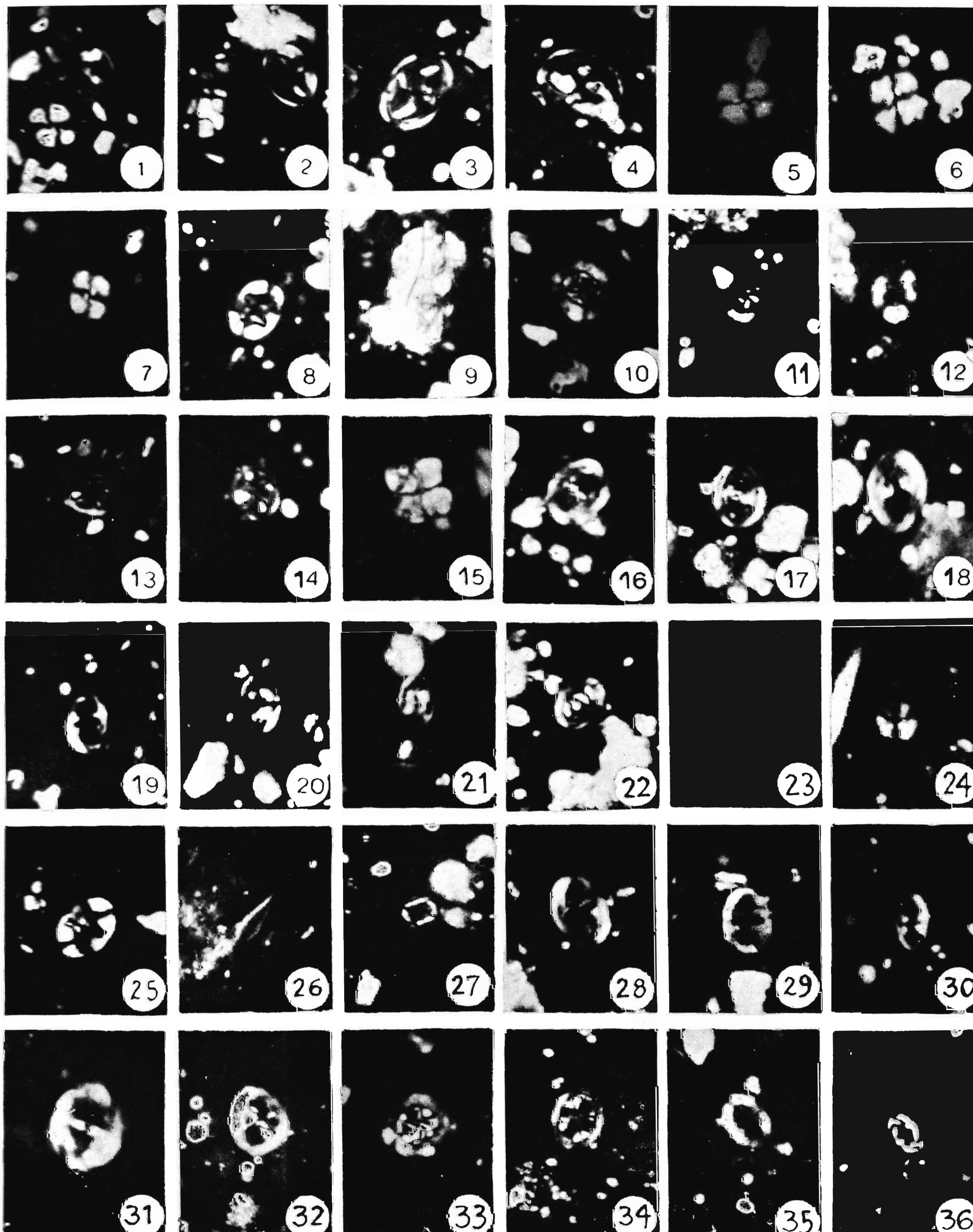
EXPLANATION OF PLATE

PLATE I

All figures ×2000 and taken under crossed polarized light. The specimens are printed in the same orientation as they were observed and photographed under the microscope. Specimens figured as 1-22 were recovered from sample CH-3 of Chikli Section and as 23-36 from sample Bg-19 of Baria Nadi Section.

1 *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970. *Watznaueria barnesae* (Black, 1959) Perch-Nielsen, 1968 in SW corner.
2—4 *Gartnerago obliquum* (Stradner, 1963) Reinhardt, 1970.
5—7 *Watznaueria barnesae* (Black, 1959) Perch-Nielsen, 1968.
8 *Eiffellithus turriseiffeli* (Deflandre, 1954) Reinhardt, 1965.
9 *Lucianorhabdus cayeuxii* Deflandre, 1959.
10—11 *Prediscosphaera cretacea* (Arkhangelsky, 1912) Gartner, 1968.
12 *Cretarhabdus crenulatus* Bramlette & Martini, 1964.,
13—14 *Ahmuellerella octoradiata* (Górka, 1957) Reinhardt, 1966.
15 *Quadrum gartneri* Prins & Perch-Nielsen, 1977.
16—18 *Parhabdolithus bitraversus* Stover, 1966.
19 *Tranolithus exiguus* Stover, 1966.
20—21 *Tranolithus orionatus* (Reinhardt, 1966) Perch-Nielsen, 1968.
22 *Zygodiscus xenotus* (Stover, 1966) Hill, 1976.
23—24 *Lithastrinus floralis* Stradner, 1962.
25 *Eiffellithus turriseiffeli* (Deflandre, 1954) Reinhardt, 1965.
26 *Scapholithus fossilis* Deflandre, 1954.
27 *Corollithion signum* Stradner, 1963.
28 *Zygodiscucs diplogrammus* (Deflandre, 1954) Gartner, 1968.
29—30 *Tranolithus exiguus* Stover, 1966.
31 *Parhabdolithus bitraversus* Stover, 1966.
32 *Chiastozygus litterarius* (Górka, 1957) Manivit, 1971.
33 *Prediscosphaera cretacea* (Arkhangelsky, 1912) Gartner, 1968.
34 *Podorhabdus albianus* Black, 1967.
35 *Cretarhabdus crenulatus* Bramlette & Martini, 1964.
36 *Zygodiscus spiralis* Bramlette & Martini, 1964.

PLATE I



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