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Pliensbachian nannofossils from Kachchh: Implications on the earliest Jurassic transgressive event on the western Indian margin

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Abstract

The oldest rocks within the Kachchh Basin belong to the sediments of Kaladongar Formation exposed in Kuar Bet, Pachchham Island (western India). The Formation's lowest unit, the Dingi Hill Member has yielded a moderately diversified calcareous nannofossil assemblage that includes the marker species of *Lotharingius contractus* and *Triscutum sullivanii* of late Early Aalenian age associated with reworked species of *Biscutum finchii*, *Bussonius prinsii*, *Crucirhabdus primulus*, *Crepidolithus pliensbachensis*, *Discorhabdus criotus* and *D. striatus* suggesting an age spanning NJ4a to NJ7 Zones (Early Pliensbachian, Tethyan ammonite Jamesoni Zone to Middle Toarcian, Variabilis Zone). Additionally, samples from four other Kachchh domal localities (Kachchh Mainland: Jara, Jumara and Habo and the Island belt, Waagad) have also yielded reworked Pliensbachian-Toarcian age (~183 Ma) nannotaxa viz. *Crepidolithus granulatus*, *Diductius constans*, *Mazaganella protensa*, *Mitrolithus elegans*, *Parhabdolithus liasicus*, *Similiscutum orbiculus*, and *Triscutum tiziense*. This nannotaxa age is much earlier than the ammonite-based Earliest Bajocian date (~171.6 Ma) based on the presence of ammonite *Calliphylloceras heterophylloides* (Oppel). Additional reworked assemblages have been studied from the Callovian sediments at Jara, the Bathonian-Callovian sediments at Jumara, the Callovian sediments at Habo and the Oxfordian-Kimmeridgian sediments at Wagad. The present data, thus, indicates the presence of a marine connection at least since the Pliensbachian in Kachchh. It is proposed that both global eustatic rise and local tectonics were responsible for this Pliensbachian inundation of the Kachchh Basin. Similar record of Late Pliensbachian age reworked nannofossils have also come from the Masirah Island of the Sultanate of Oman and of ?Aalenian-Bajocian age nannofossils from Kuwait, lending credence to our findings and of the presence of at least Pliensbachian-Toarcian age sediments in Kachchh.

Key words: Calcareous nannofossils, Pliensbachian, Toarcian, Aalenian, Kuar Bet, Pachchham Island, Kachchh, western India

Zusammenfassung

Die ältesten Sedimente des Kachchh Beckens gehören zur Kaladongar Formation und sind in Kuar Bet, Pachchham (West-Indien), aufgeschlossen. Aus der untersten Einheit dieser Formation (Dingi Hill Member) konnte eine relativ diverse Vergesellschaftung kalkiger Nannofossilien gewonnen werden, die u.A. die Marker-Taxa *Lotharingius contractus* und *Triscutum sullivanii* (oberes unteres Aalenium) enthält sowie umgearbeitete Exemplare von *Biscutum finchii*, *Bussonius prinsii*, *Crucirhabdus primulus*, *Crepidolithus pliensbachensis*, *Discorhabdus criotus* und *D. striatus*, welche eine Zuordnung der Sedimente zwischen NJ4a und NJ7 indizieren (unteres Pliensbachium, Tethys Ammoniten Jamesoni Zone bis mittleres Toarcium, Variabilis Zone). Darüber hinaus wurden in vier andere Lokalitäten des Kachchh Beckens (Kachchh Festland: Jara, Jumara und Habo sowie Inselgürtel, Waagad) ebenfalls umgearbeitete Nannofossilien aus dem Pliensbachium-Toarcium (~183 Ma) gefunden, nämlich *Crepidolithus granulatus*, *Diductius constans*, *Mazaganella protensa*, *Mitrolithus elegans*, *Parhabdolithus liasicus*, *Similiscutum orbiculus*, und *Triscutum tiziense*. Die Nannofossilien indizieren ein höheres Alter der Sedimente, als die Datierung mit Ammoniten, welche auf der Basis des Vorkommens von *Calliphylloceras heterophylloides* (Oppel) die Sedimente in das unterste Bajocium (~171.6 Ma) stellt. Um das ungewöhnliche Vorkommen von Nannotaxa aus dem Pliensbachium-Toarcium in Kachchh zu überprüfen, wurden fünf weitere Lokalitäten erfolgreich auf Nannofossilien hin untersucht. Diese Proben stammen aus Sedimenten des Calloviums von Jara und des Bathoniums-Calloviums von Jumara, aus dem Callovium von Habo sowie aus dem Oxfordium-Kimmeridgium von Wagad. Unsere Ergebnisse lassen den Schluss zu, dass in Kachchh mindestens seit dem Pliensbachium eine marine Verbindung existierte. Es ist wahrscheinlich, dass sowohl der weltweite eustatische Anstieg des Meeresspiegels als auch lokale tektonische Aktivitäten für die Überflutung des Kachchh Beckens im Pliensbachium verwantwortlich waren. Ähnliche Vorkommen von umgearbeiteten Nannofossilien aus jungen Pliensbachium sind auch vonder Insel Masirah, Sultanat Oman bekannt. Nannofossilien aus dem ?Aalenium-Bajocium kennt man aus Kuwait. Beide Vorkommen stützen unsere Ergebnisse und bestätigen das Vorkommen von

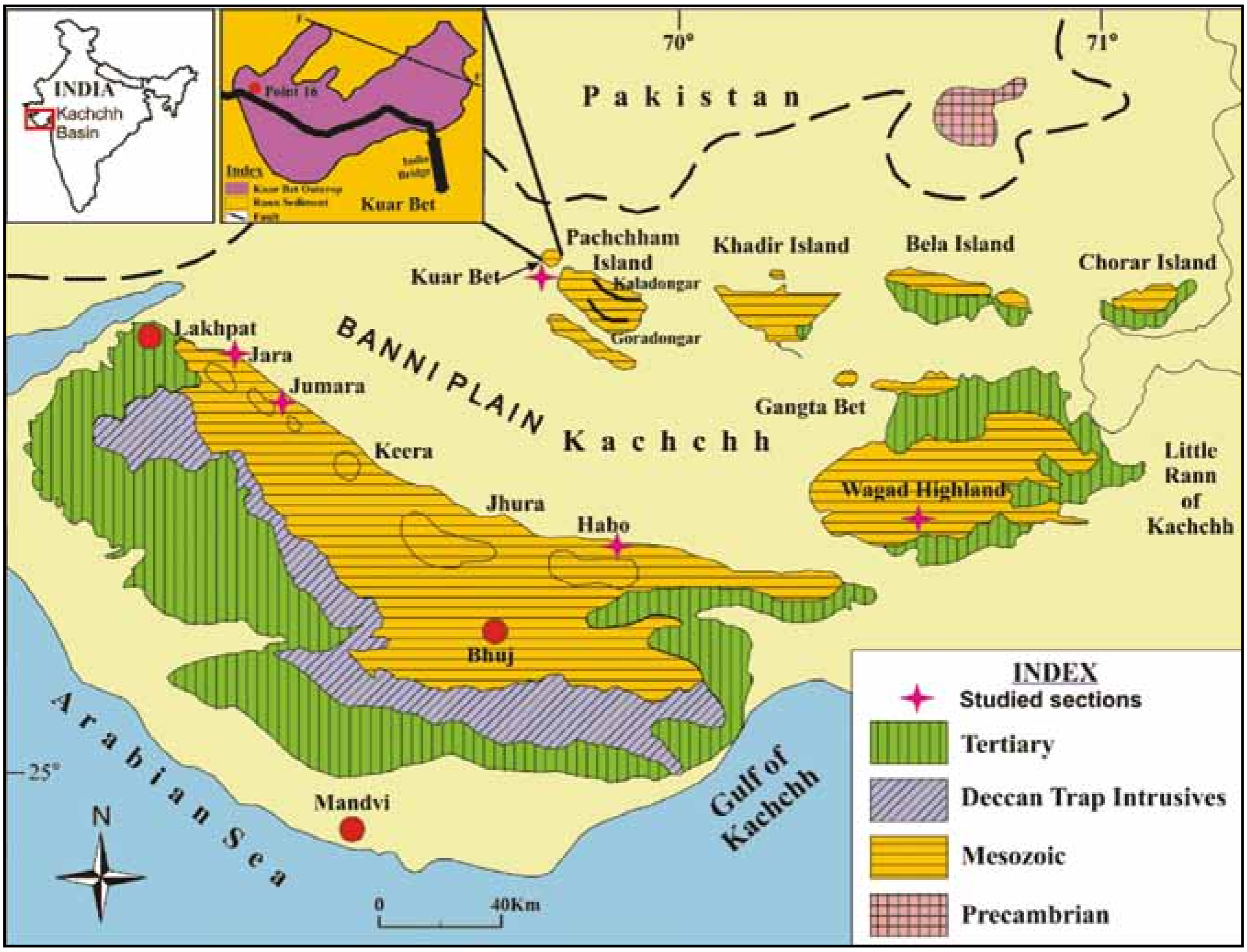
Sedimenten mindestens aus dem Pliensbachium-Toarcium im Kachchh Becken.

Schlüsselwörter: kalkige Nannofossilien, Pliensbachium, Toarcium, Aalenium, Kuar Bet, Pachchham Island, Kachchh, West-Indien

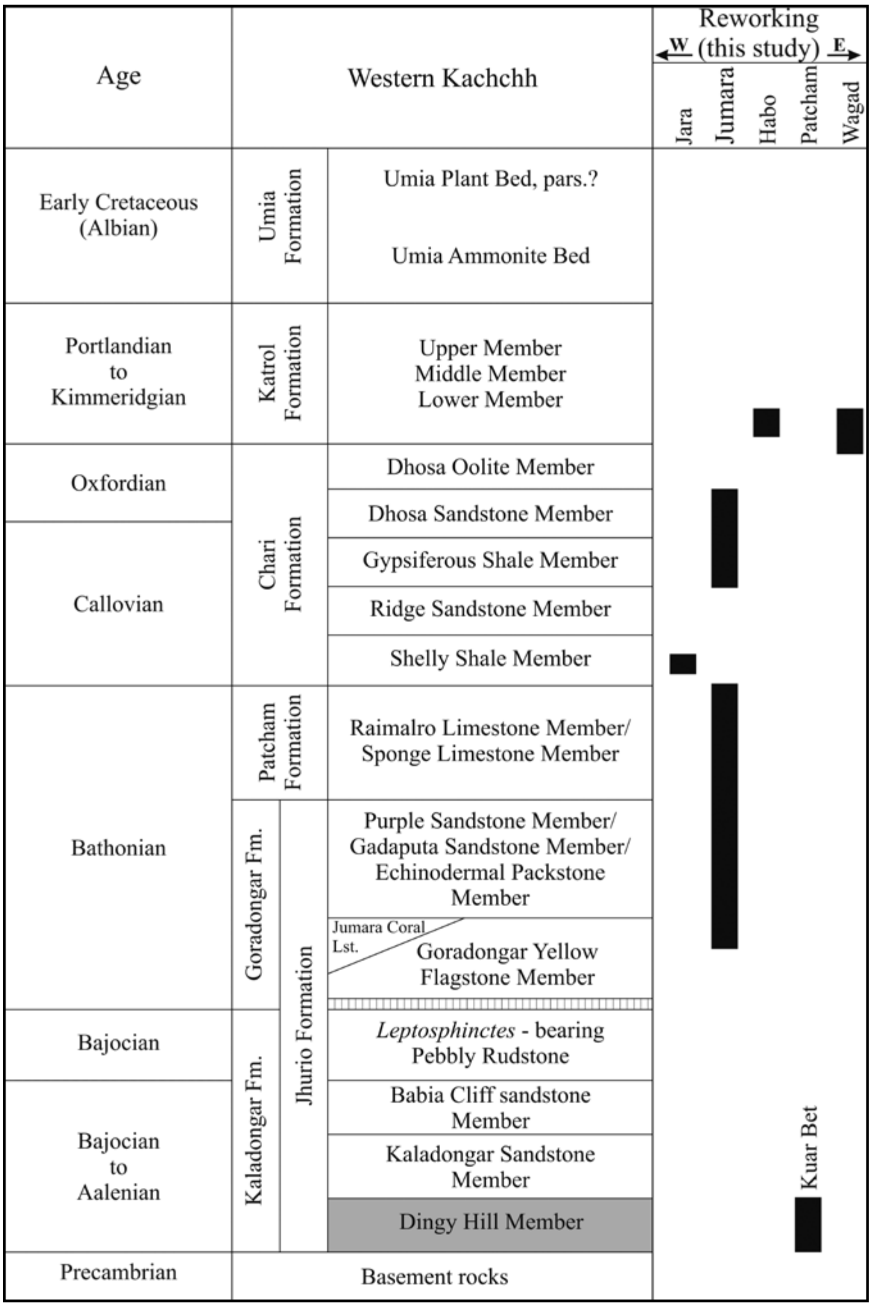
1. Introduction

Calcareous nannofossils from the oldest marine sediments exposed in Kuar Bet area of Pachchham Island, Kachchh Basin, are studied to decipher the earliest epeiric transgressive event in western India in response to the opening of the Ethiopian gulf. The Kachchh Basin (Textfig. 1) is a small sedimentary basin situated on the eastern fringe of the southern extension of the Neotethys at a palaeo-latitude of around 33° S during Early-Middle Jurassic times (Dercourt et al. 2000). Current reports indicate that after a phase of terrestrial sedimentation in Late Triassic (Koshal 1984), marine sedimentation started during the Early Jurassic (Earliest Bajocian) in response to the opening of the Arabian Sea. This date is based on the earliest ammonite record of *Calliphylloceras heterophylloides* from the ?Earliest Bajocian (~171.6 Ma; Pandey et al. 2013), recorded from the Dingy Hill Member (Pachchham Island; Textfig. 2).

We report here a moderately diversified late Early Aalenian age calcareous nannofossil assemblage with reworked Early Jurassic Pliensbachian-Toarcian interval nannotaxa from the middle part of the Dingi Hill Member of Kaladongar Formation exposed at Point 16 hillock at Kuar Bet in Pachchham Island (Textfig. 1). This assemblage includes the marker species *Lotharingius contractus* and *Triscutum sullivanii* of late Early Aalenian age which co-occurs with reworked nannotaxa of *Biscutum finchii*, *Bussonius prinsii*, *Crepidolithus granulatus*, *C. pliensbachensis*, *Discorhabdus criotus*, *D. striatus* and *Mitrolithus elegans* (Pl. 3) of Pliensbachian-Toarcian interval. Rai (2007) and Rai & Jain (2012) have also previously reported Pliensbachian-Toarcian (Early Jurassic) interval reworded nannofossils from the Pachchham Island of Kachchh.



Textfigure 1: Kachchh Locality map showing the sampling localities at Pachchham, Jara, Jumara, Habo and Wagad. Inset is the detailed map of Kuar Bet showing Point 16, the sampling locality of the oldest beds in Kachchh.



Textfigure 2: Stratigraphy of the Jurassic sediments of Kachchh and the presence of reworked nannotaxa recorded from Jurassic localities of Pachchham (Kuar Bet), Jara, Jumara, Habo and Wagad.

2. Geological setting

The Mesozoic rocks exposed in Kachchh Basin range in age from Aalenian with no datable elements (Middle Jurassic; 178 Ma) to Albian (Early Cretaceous; 98.9 Ma) (Biswas 1991; Rai 2006). These Mesozoic rocks are exposed in six localities viz. Kachchh Mainland, Wagad, Pachchham, Khadir, Bela “Islands” and Chorad Hill (Textfig. 1) and are separated by vast spans of arid Banni Plains or grassland. The western-most island belt of Pachchham comprises two main island parts: the Pachchham and the Kuar Bet (Textfig. 1). The geological sequence exposed in the Pachchham Island comprises the shallow, lower Kaladongar Formation and the overlying relatively deeper Goradongar Formation (Textfig. 2).

The Kaladongar Formation is a ~472 m thick sequence of conglomerates, sandstones and shales exposed at Kaladongar (Textfig. 1) constituting the oldest stratigraphic unit in Kachchh (Textfig. 2) assigned to ?Aalenian-Early Bajocian (Biswas 1991). On the basis of its lithological attributes, the formation is divisible into three informal Members: upper Babia Cliff Sandstone, middle Kaladongar Sandstone and lowest Dingi Hill (from where the nannofossil record described in this study comes). On the other hand, the ~152 m thick Goradongar Formation is exposed on the southern flank of Modar Hill at the easternmost point of the Goradongar Range. Its lower part is predominantly shales with thin flaggy fossiliferous calcareous bands and the upper part is dominated by sandstones with minor shales.

The nannofossil-yielding middle part of the Dingi Hill Member of the Kaladongar Formation (Fürsich et al. 2001) exposed at Point 16 hillock at Kuar Bet in the Pachchham Island (Textfig. 1), ~10 m heigh, contains broadly alternating sandy fossiliferous limestones and calcareous sandstones with planar and concurrent stratification and flaser bedding and well preserved ichnotaxa viz. *Thalassinoides, Rhizocorallium,* and *Diplocriterion* (Textfig. 3). Near the top of this unit is a shell-hash deposit with small sized bivalves and rare gastropods. The base is marked by a conglomerate. The calcareous sandstone level shows prominent bedding fissility and one such level represented by sample number PAT–2 (GPS location: 23° 59′ 40″ N: 69° 42′ 28″ E; Textfig. 3) has yielded datable calcareous nannofossils of moderate diversity (Pls 1, 2).

3. Age controversy: Kuar Bet in Pachchham Island

The Kuar Bet beds of Kaladongar Formation contain alternating sandy limestones, conglomerates, red-green sandstones, and occasional shales; the upper part has yellow massive sandstones with calcareous bands (Textfig. 2). For these Kuar Bet beds palaeontological evidences favour a Middle Jurassic age (Wynne 1872; Waagen 1875; Rajnath 1932, 1942; Pandey & Dave 1993; Satyanarayana et al. 1999), whereas palaeobotanical and palynological evidence suggests an Early Cretaceous age (Mathur 1972). Biswas (1977) suggested a Bathonian age but later revised the same down to Bajocian and/or Lias (Biswas 2002). Both Wynne (1872) and Waagen (1875) considered these units as being Bathonian in age, whereas Rajnath (1932, 1942) gave an age range from Bathonian to Early Callovian. Singh et al. (1982) used the marker ammonite *Leptosphinctes* from the overlying Goradongar Formation to date the stata as latest Bajocian. Mathur (1972), who studied plant megafossils, reported the occurrence of the Early Cretaceous marker taxon *Onychiopsis* cf. *psilotoides*. However, a re-analysis (Jana & Hilton 2007) of the same sediments yielded a broad Middle Jurassic age. Satyanarayana et al. (1999) recorded fossil vertebrae and limb elements of a dinosaur along with petrified tree trunks and suggested an Aalenian-Bathonian age.

The nannofossils assemblage described in this paper, containing *Lotharingius contractus* and *Triscutum sullivanii* from Kuar Bet, now permits a more precise dating of the sediments as late Early Aalenian (Pls 1, 2). The assemblage also contains reworked Pliensbachian-Toarcian interval nannotaxa, including *Axopodorhabdus cylindratus*, *Biscutum finchii*, *Bussonius prinsii*, *Crucirhabdus primulus*, *Crepidolithus pliensbachensis*, *Discorhabdus criotus, D. striatus, Lotharingius contractus,* and *Triscutum sullivanii* (Pl. 3).

Four additional localities were studied to ascertain the anomalous occurrence of Pliensbachian-Toarcian nannotaxa in Kachchh, and all have produced essentially the same results (Pl. 4), strongly suggesting that the timing of the oldest epeiric transgressive event in the Kachchh Basin (western India) occurred at least during the Pliensbachian. These other asemblages of reworked nannofossils come from Jara (in Callovian sediments; Rai 2006; Textfig. 1), Jumara (in Bathonian-Callovian sediments), Habo (in Callovian sediments) and Wagad (in Oxfordian-Kimmeridgian sediments) (Pl. 4, Fig. 2).

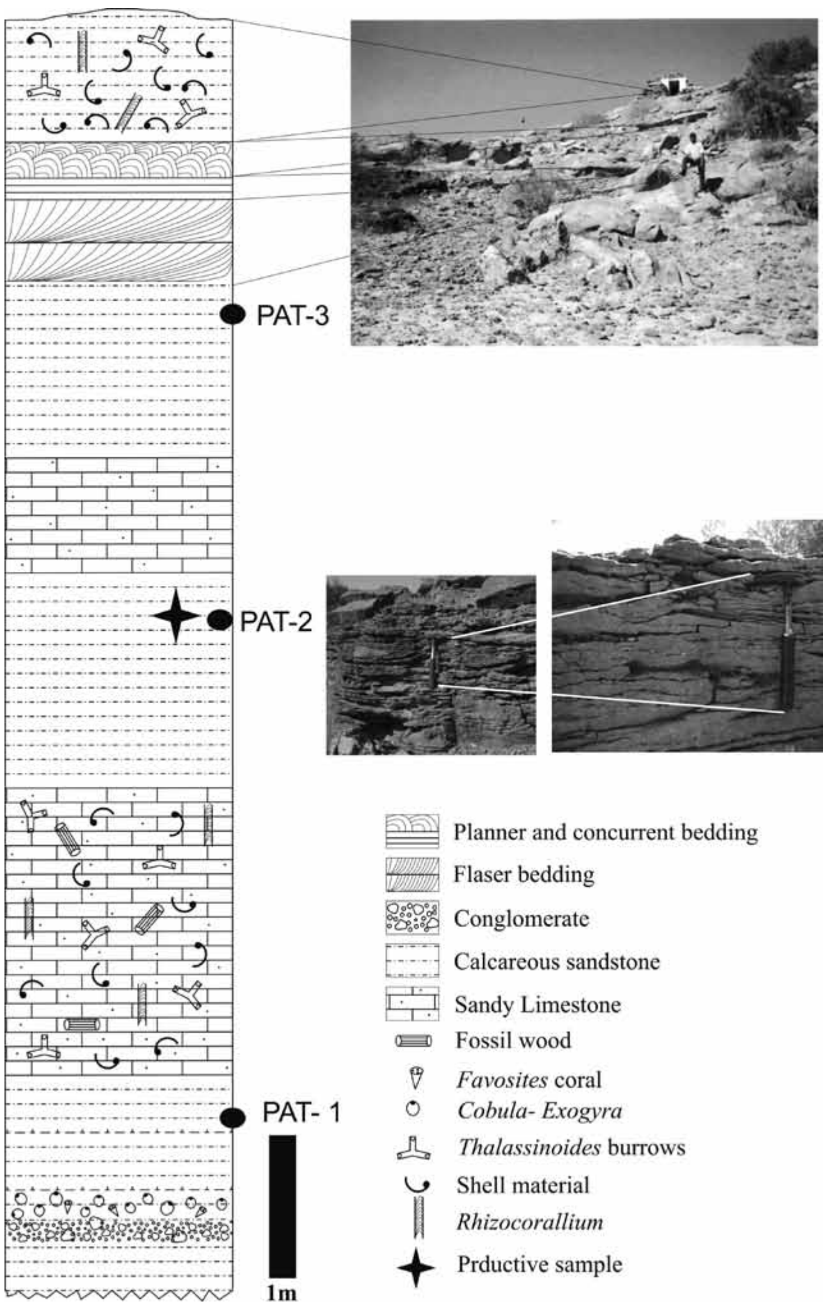
4. Material and methods

Permanent duplicate slides, one containing comparatively coarser and the other having finer fraction of the samples for nannofossil productivity and study were prepared using the usual preparation technique described in Bown & Young (1998). These slides were examined under Leitz polarizing microscope (LM) with 10x (magnification) or 12.5x occulars and microphotographs were taken under 100x oil immersion objective. The recovered nannofossils were compared with global marker charts (Bown 1998; Mattioli & Erba 1999; Sandoval et al. 2012).

5. New nannofossil record

The nannotaxa recovered from the sediments studied include the following species (Pls 1, 2): *Axopodorhabdus cylindratus* (Noël, 1965) Wind & Wise in Wise & Wind, 1977, *Biscutum finchii* Crux, 1984, *B. novum* (Goy *in* Goy et al., 1979) Bown, 1987, *Biscutum* sp., *Bussonius prinsii* (Noël, 1973) Goy, 1979, *Crepidolithus crassus* (Deflandre in Deflandre & Fert, 1954) Noël, 1965, *C. granulatus* Bown, 1987, *C. pliensbachensis* Crux, 1985, *Crucirhabdus primulus* Rood et al., 1973, *Diazmatolithus lehmanii* Noël, 1965, *Discorhabdus* cf. *D. criotus* Bown, 1987, *Discorhabdus striatus* Moshkovitz & Ehrlich, 1976, *Ethmorhabdus gallicus* Noël, 1965, *Lotharingius contractus* Bown & Cooper, 1989*, Micula staurophora* (Gardet, 1955) Stradner, 1963, *Mitrolithus elegans* Deflandre in Deflandre & Fert, 1954, *Octopodorhabdus* sp., *Parhabdolithus liasicus* Deflandre in Grassé, 1952, *Schizosphaerella* sp., *Triscutum sullivanii* de Kaenel & Bergen, 1993, *Tubirhabdus patulus* Rood et al., 1973, *Watznaueria barnesae* (Black in Black & Barnes, 1959) Perch-Nielsen, 1968 and *W. fossacincta* (Black, 1971) Bown in Bown & Cooper, 1998.

The Pliensbachian-Aalenian age reworked nannofossils (Pl. 4) have been also found in the Bathonian-



Textfigure 3: Sampling location from the middle part of the Dingi Hill Member of the Kaladongar Formation exposed at the Point 16 hillock (23° 59′ 40″ N: 69° 42′ 28″ E) at Kuar Bet in the Pachchham Island.

Callovian sediments of the three Mainland domes (i.e. Jara, Jumara and Habo), as well as in the Oxfordian-Kimmeridgian sediments of Wagad. All strongly suggest that the timing of the oldest epeiric transgressive event in the Kachchh Basin (western India) occurred at least during the Pliensbachian.

6. Ammonite data

Ammonites in general provide precise dates. However, the Early Jurassic basal sediments of the Kachchh Basin lack ammonite fossils. Hence, to better appreciate this early duration, it is imperative to look beyond Kachchh, and into the Indian subcontinental region and neighboring ammonite yielding localities such as the Himalayas (Nepal, Tibet and Spiti), Pakistan and Madagascar to assign a comparative age for the basal sediments of Kachchh (Tab. 1). The Pliensbachian and Aalenian are devoid of ammonites from the Indian subcontinent, whereas early Toarcian sediments are quite rich in ammonites. Higher sea level (Textfig. 4) might explain this rich record that not only provided newer niches but also made the previously unavailable land areas available to aquatic animals. However, the available

Plate 1: Calcareous nannofossil assemblage identified from sample number PAT–2, middle part of the Dingi Hill Member of Kaladongar Formation exposed at Point 16 hillock (23° 59′ 40″ N: 69° 42′ 28″ E) at Kuar Bet in the Pachchham Island; all forms magnified at 1200x.

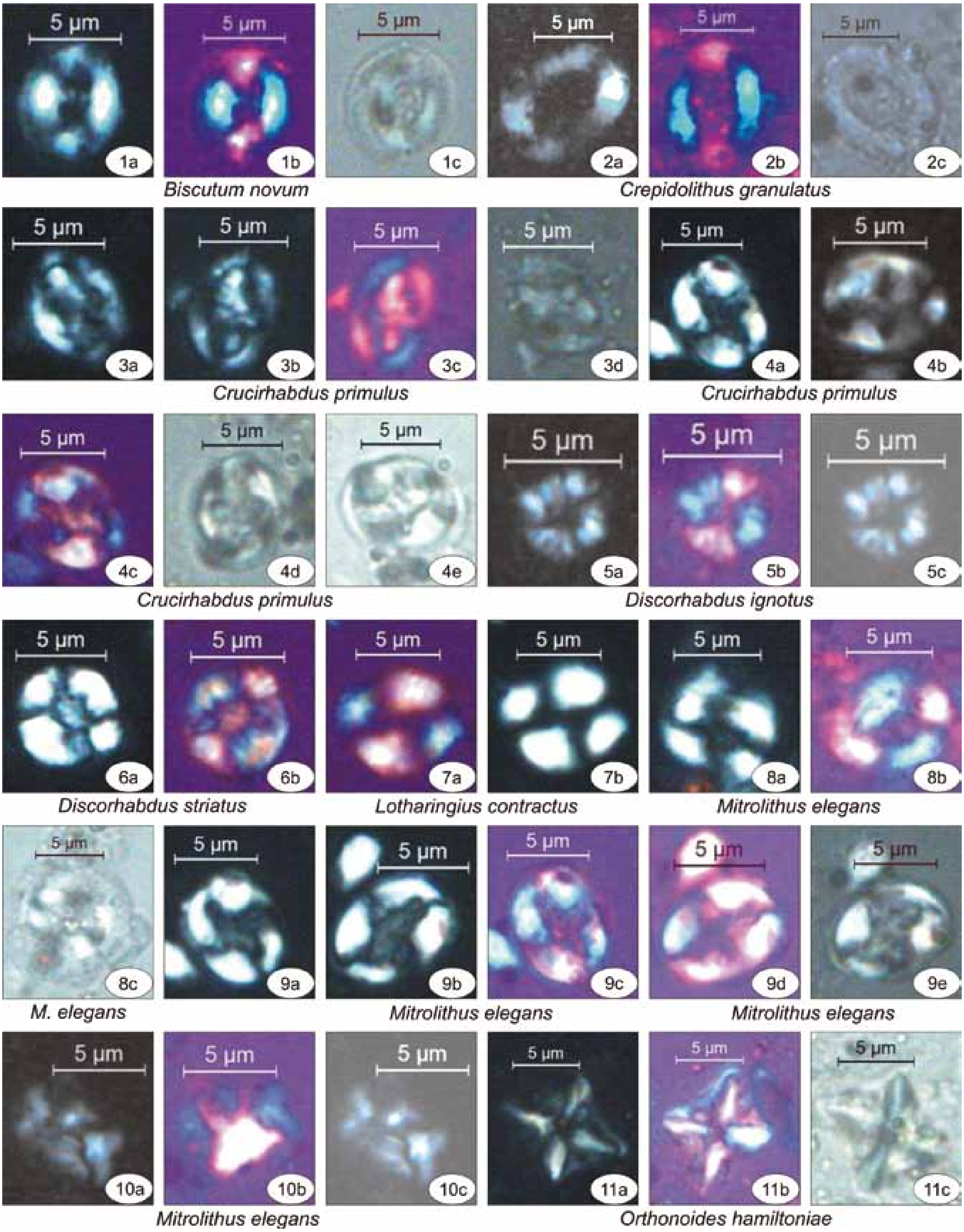


Plate 2: Calcareous nannofossil assemblage identified from sample number PAT–2, middle part of the Dingi Hill Member of Kaladongar Formation exposed at Point 16 hillock (23° 59′ 40″ N: 69° 42′ 28″ E) at Kuar Bet in the Pachchham Island; all forms magnified at 1200x.

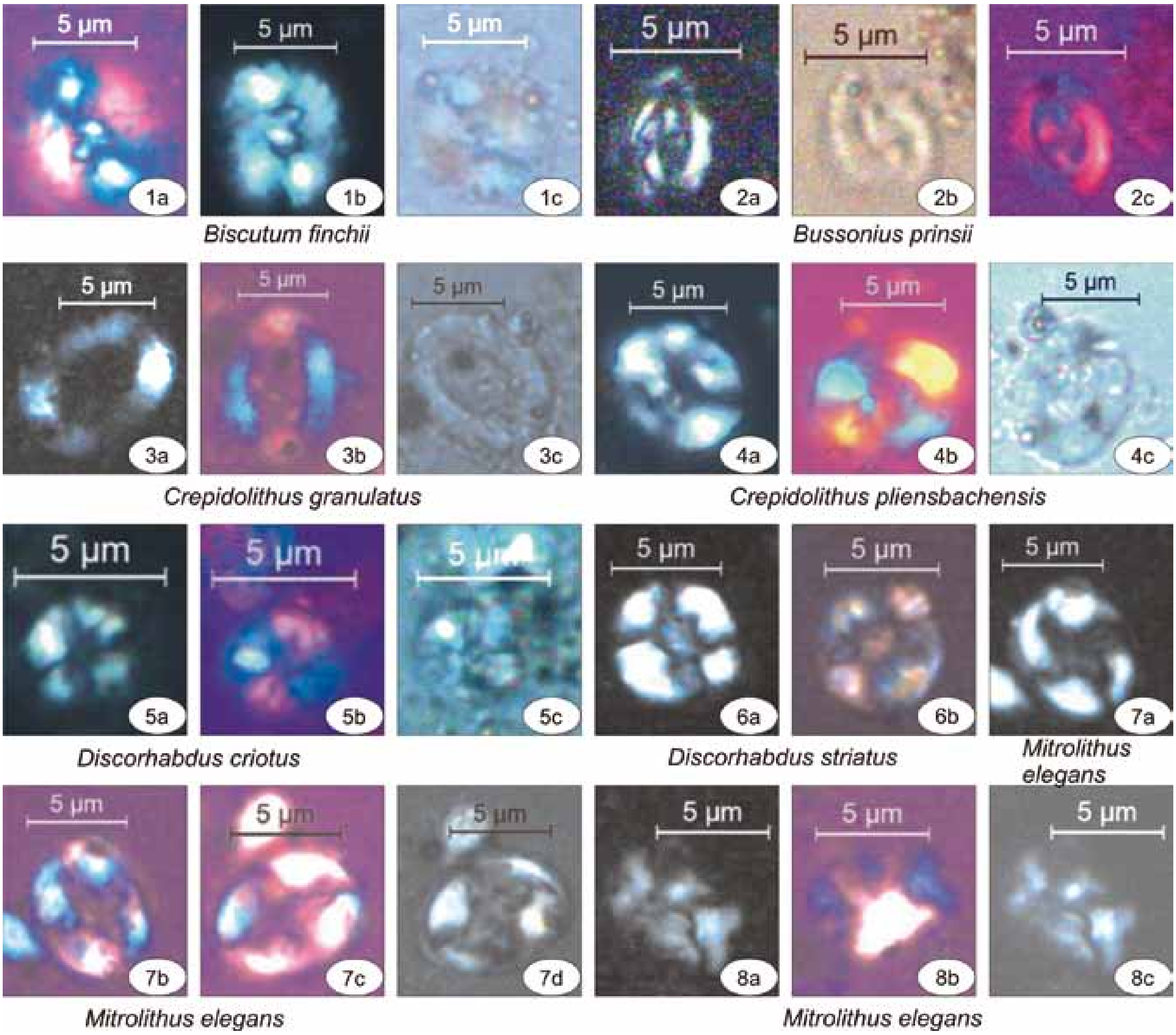


Plate 3: Marker calcareous nannofossil species identified from sample number PAT–2, middle part of the Dingi Hill Member of Kaladongar Formation exposed at Point 16 hillock (23° 59′ 40″ N: 69° 42′ 28″ E) at Kuar Bet in the Pachchham Island; all forms magnified at 1200x.

ammonite data do not help in dating the basal sediments of Kachchh, but it is intriguing to ponder as to why Pliensbachian ammonites are not recorded from Kachchh, whereas other body fossils (pelecypods, gastropods and corals) and microfossils (nannofossils) are profuse. Closer and careful sampling might yield Pliensbachian and Aalenian ammonites from Kachchh.

7. Discussion

7.1 Biostratigraphy

There is little consensus amongst Early Jurassic nannofossil workers concerning the ranges of marker species (de Kaenel & Bergen 1993; de Kaenel et al. 1996; Mattioli & Erba 1999; Perilli & Duarte 2006; Veiga de Oliveira et al. 2007). Hence, for now, we have followed the most commonly used stratigraphic ranges put forward by Mattioli & Erba (1999; see Tab. 2).

The presence of *Lotharingius contractus* Bown & Cooper (FAD at base of NJ8b) and *Triscutum sullivanii* (FAD NJ8b) suggests that the lowest sediments of Kuar Bet Island are late Early Aalenian in age (Tab. 2). The assemblage of *B. prinsii* (FAD NJ4 and LAD NJ8b), *Biscutum finchii* (FAD at NJ4b and LAD at NJ6), *Crepidolithus granulatus* (FAD NJ4a and LAD NJ4b) *C. pliensbachensis* (LAD base of NJ4b), *Crucirhabdus primulus* (LAD NJ5a), *Discorhabdus criotus* (FAD base of NJ7), *D. striatus* (FAD straddling the NJ6 and NJ7), and *Mitrolithus elegans* (FAD NJ2a and LAD Upper Pliensbachian) can be placed between the NJ4a and NJ7 Zones of Early Pliensbachian to Middle Toarcian age, and are here considered to be reworked into the Aalenian (Pls 1–3). This assemblage equates with the Tethyan ammonite in-

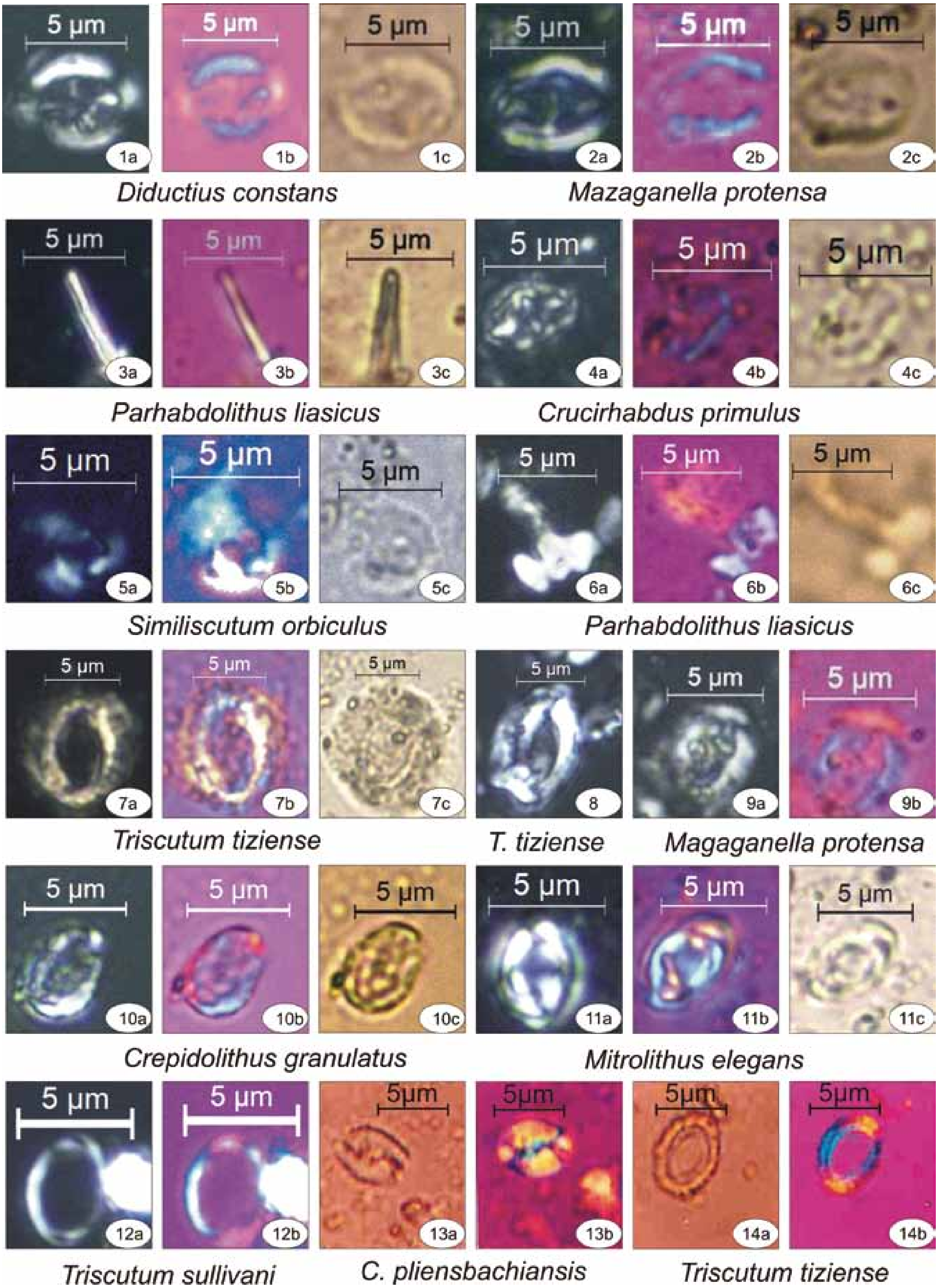


Plate 4: Pliensbachian-Toarcian age reworked nannofossils from Wagad (1–4), Jumara (5–11), Habo (12) and Jara (13–14) domes (Kachchh).

Table 1: Ammonite records from the Indian subcontinental region and neighboring areas such as Ladakh Himalaya, Nepal, Pakistan and Madagascar.

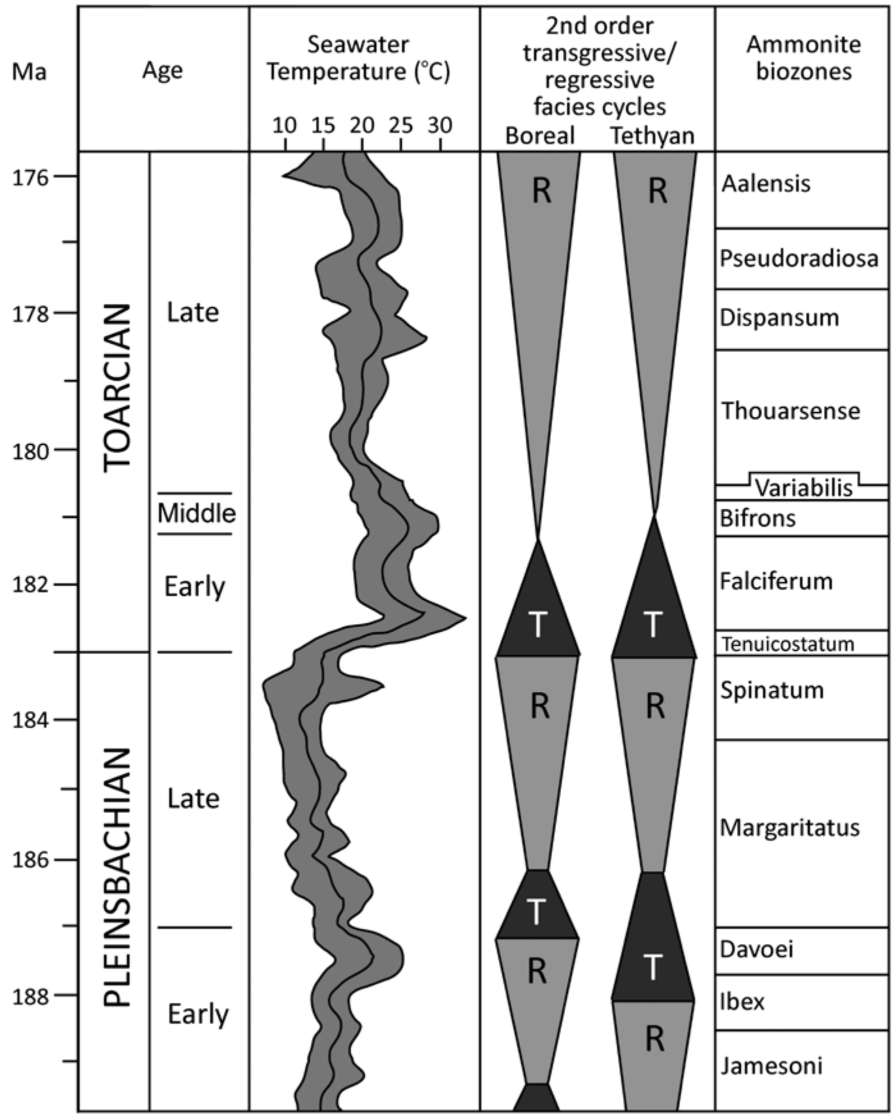
Age	Ammonite species	Locality	Reference
Bajocian	*Calliphylloceras heterophylloides*	Sadhara Dome, Goradongar	Pandey et al. (2013)
	Leptosphinctes sp.	Kaladongar, Kachchh	Singh et al. (1982)
	Dorstensia, Emileia, Sonninia and *Witchellia*	Central Nepal	Bordet et al. (1971); Gradstein et al. (1989)
	Stephanoceras, Witcheillia and *Fontanessia*	South Tibet	Hayden (1907); Westermann & Wang (1988)
Aelanian is devoid of ammonites from the Indian subcontinent			
Early Toarcian	*Alocolytoceras*	Spiti	Stoliczka (1866)
	Associated with *Alocolytoceras* are *Paltarpites, Dactylioceras, Fuciniceras, Peronoceras, Protogrammoceras, Sphenarpites, Harpoceras* and *Hildoceras*	Madagascar and Pakistan	Holland (1909)
	Bouleiceras sp.		Arkell (1956); Fatmi (1972, 1986); Fatmi et al. (1986); Shah (1978)
Pliensbachian is devoid of ammonites from the Indian subcontinent			
Late Sinemurian (Oxynotum Zone)	*Sulciferites* and *Gleviceras*	South Tibet	Holland (1909); Shah (1978); Wignall et al. (2006)
Early Sinemurian (Bucklandi Zone)	*Arietites, Coroniceras* and *Oxynoticeras*	Baluchistan	
Earliest Hettangian (Planorbis Zone)	*Psiloceras* gr. *planorbis*	Ladakh Himalaya (Lama Yuru Formation)	Krishna et al. (1997)

terval between the Early Pliensbachian Jamesoni to the Middle Toarcian Variabilis (Gradstein et al. 2004) zones not yet recorded from India.

All data gathered to date suggest that the age of the present nannofossil assemblage from the Dingi Hill Member of the Kaladongar Formation represents a 9 Ma interval span (~189–180 Ma) and that the earliest marine sediments in Kachchh date back to the Early Pliensbachian NJ4a nannofossil Zone and within the Tethyan ammonite Jamesoni Zone (Textfig. 4).

7.2 Palaeogeography

The recorded assemblage has wider palaeogeographical implications. Based on this new record, it appears that after faulting of the Indian plate in its western margin, the transgressive event within the Kachchh basin took place at least during the Pliensbachian. As a result, this early transgression is ~11 Ma older than the previously proposed Early Bajocian ammonite-based date (Pandey et al. 2013). In this context, the record of coeval Late Pliensbachian nannofossils from the Masirah Island (Sultanate of Oman, Arabia; Von Salis & Immenhauser 1997) and



Textfigure 4: Sea level at the Pliensbachian-Toarcian boundary interval (modified after Dera et al. 2009) and the corresponding Tethyan ammonite Zones.

?Aalenian-Bajocian (NJ8b Zone) age nannofossils from Kuwait (Kadar et al. 2012) further strengthens the present record (Textfig. 5). Additionally, reworked Pliensbachian-Aalenian age nannofossils (*Crepidolithus granulatus*, *Diductius constans*, *Mazaganella protensa*, *Mitrolithus elegans*, *Parhabdolithus liasicus*, *Similiscutum orbiculus* and *Triscutum tiziense*) have also been recovered from Jara (in Callovian sediments; Rai 2006; Textfig. 1), Jumara (in Bathonian-Callovian sediments), Habo (in Callovian sediments) and Wagad (in Oxfordian-Kimmeridgian sediments) (Pl. 4, Fig. 2). These findings attest to the presence of marine conditions in the Kachchh Basin at least since the Pliensbachian (see also Rai 2007; Rai & Jain 2012). In this context, it is very interesting to note that from the sub-surface sediments in a well in Banni south of Pachchham (Textfig. 1), Rheatian-Liassic (Latest Triassic-Earliest Jurassic) palynoflora have also been recorded (Koshal 1975).

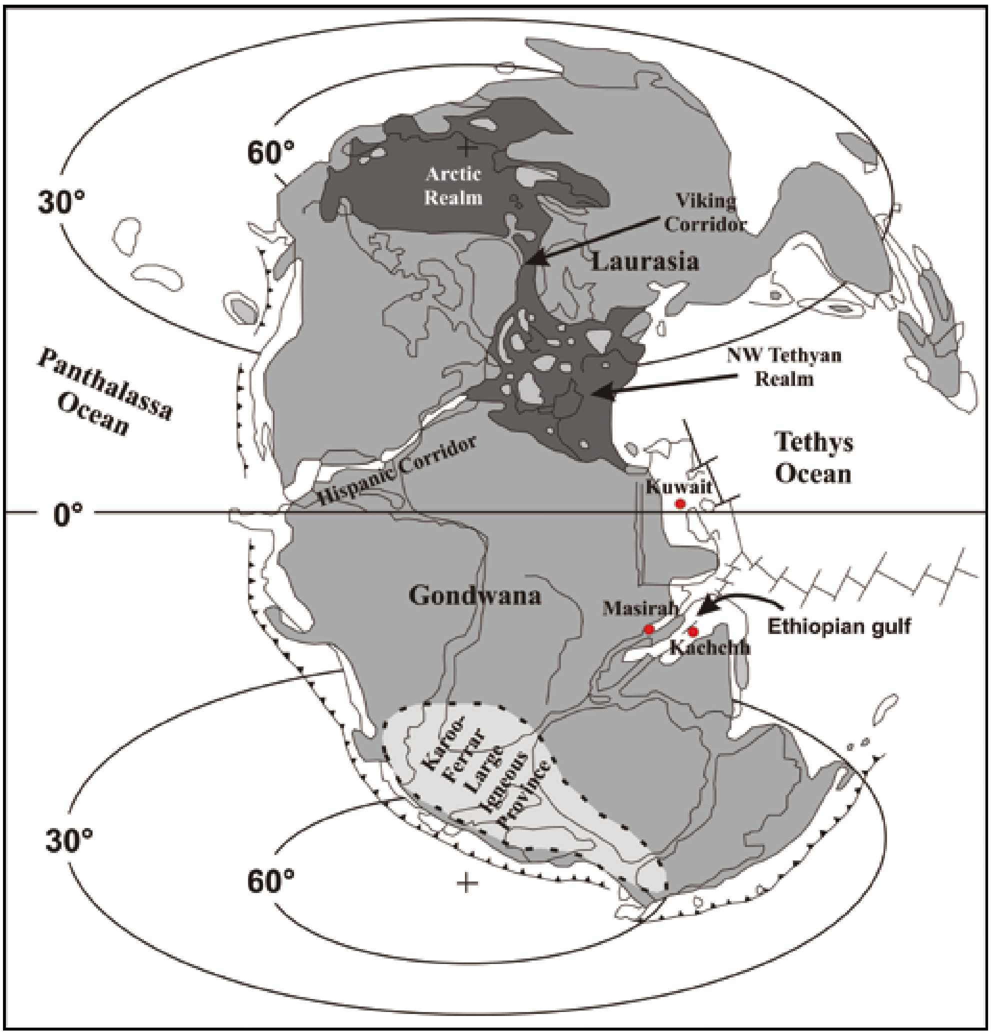
It is proposed that both global eustatic rise (Textfig. 4) coupled with local tectonics during the Pliensbachian-Toarcian boundary interval led to the early introduction of this new nannofossil assemblage marking the presence of marine conditions within the Kachchh Basin, for the first time.

Table 2 lists the presence of global marker species recorded from Kachchh.

8. Conclusions

The oldest rocks exposed in Kuar Bet (Pachchham Island) are of marine origin and are of late Early Aalenian age containing reworked Pliensbachian-Toarcian age nannotaxa. This nannofossil assemblage is of low diversity with moderate preservation.

Based on the presence of *Lotharingius contractus* (FAD at base of NJ8b) and *Triscutum sullivanii* (FAD NJ8b), the lowest sediments of the Dingi Hill Member (Kaladongar Formation) in Kuar Bet (Pachchham Island) are assigned an early Late Aalenian age. The presence of *Biscutum finchii* (FAD NJ5, LAD NJ6),



Textfigure 5: Palaeogeographical map of Pliensbachian-Toarcian time (~190–185 Ma) and Early-Middle Jurassic nannofossil record localities mentioned in the text (modified after Dera et al. 2010; Sandoval et al. 2012).

Bussonius prinsii (NJ5B), *Crepidolithus granulatus* (FAD NJ4a and LAD NJ4b), *Crucirhabdus primulus* (NJ5B), *Discorhabdus criotus* (FAD NJ7) and *Mitrolithus elegans* (FAD NJ2a and LAD Upper Pliensbachian) in this assemblage suggests an age between NJ4a–NJ7 nannofossil Zones, straddling the Pliensbachian-Toarcian boundary interval.

Reworked Pliensbachian-Toarcian age nannofossils have also been found from Bathonian-Oxfordian sediments of Jara, Jumara and Habo domes (Kachchh Mainland) and in the Oxfordian-Kimmeridgian sediments of Wagad.

Based on a data set of five sampling localities covering the entire Kachchh basin, the earliest transgressive event in the Kachchh basin occurred ~11 Ma prior to the previously proposed ammonite-inferred [*Calliphylloceras heterophylloides* (Oppel)] Earliest Bajocian age.

It is proposed that the global eustatic rise coupled with local tectonics were responsible for this Pliensbachian-Toarcian age nannofossil introduction in the Kachchh Basin Record of Pliensbachian-Toarcian age nannofossils from Masirah Island of Sultanate of Oman and? Aalenian-Bajocian (NJ8b Zone) age nannofossils from Kuwait respectively supports this contention.

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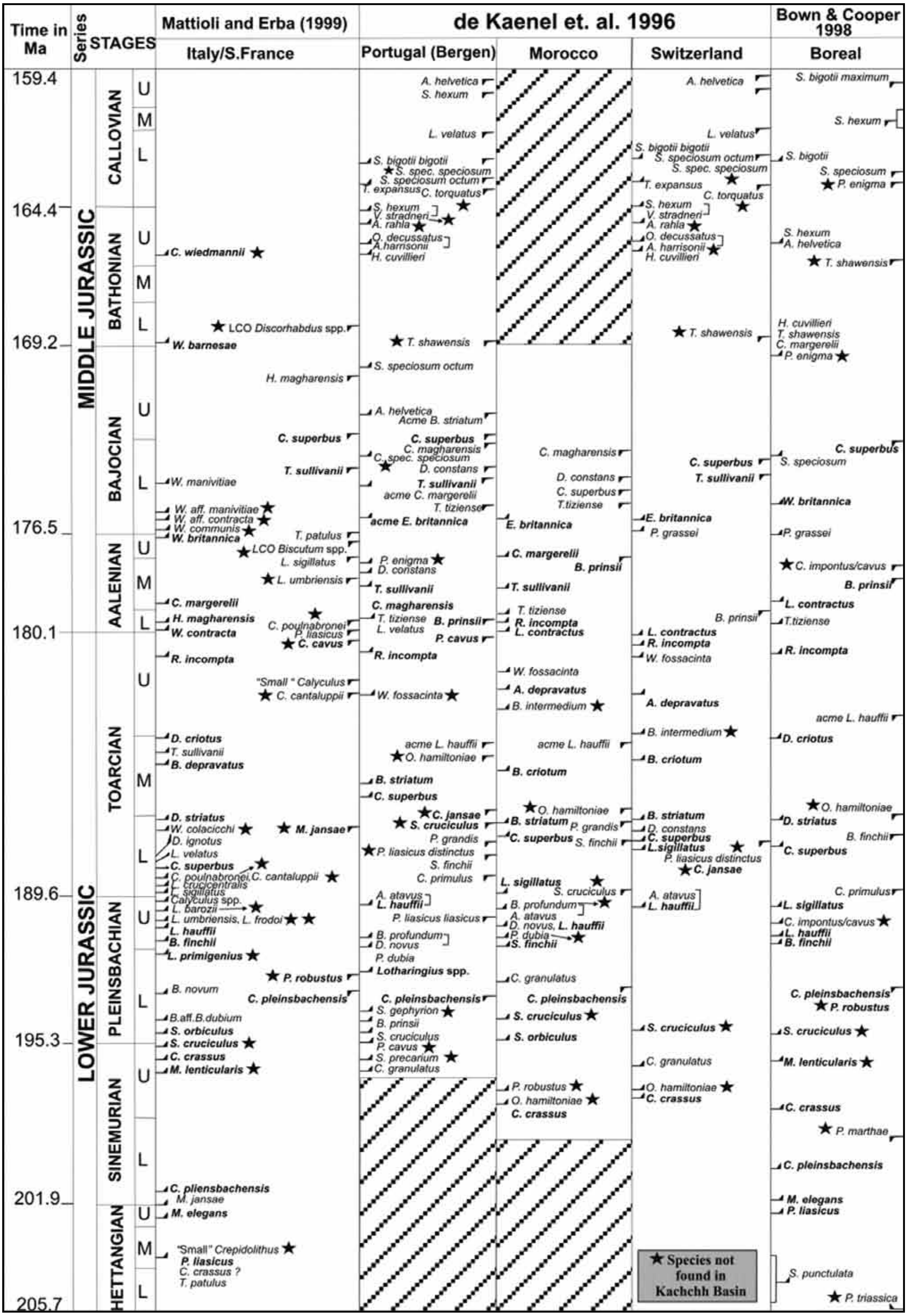
Table 2: Global marker species (in bold). Those not recorded from Kachchh are marked by an asterisk.



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Appendix: Index of calcareous nannofossils identified in the present study.

1. *Axopodorhabdus atavus* (Grün et al., 1974) Bown, 1987
2. *Axopodorhabdus cylindratus* (Noël, 1965) Wind & Wise in Wise & Wind, 1977
3. *Biscutum* finchii Crux, 1984
4. *Biscutum novum* (Goy in Goy et al., 1979) Bown, 1987
5. *Biscutum* sp.
6. *Bussonius prinsii* (Noël, 1973) Goy, 1979
7. *Crepidolithus crassus* (Deflandre in Deflandre & Fert, 1954) Noël, 1965
8. *Crepidolithus granulatus* Bown, 1987
9. *Crepidolithus pliensbachensis* Crux, 1985
10. *Crucirhabdus primulus* Rood et al., 1973
11. *Diazmatolithus lehmanii* Noël, 1965
12. *Discorhabdus* cf. *D. criotus* Bown, 1987
13. *Discorhabdus striatus* Moshkovitz & Ehrlich, 1976
14. *Ethmorhabdus gallicus* Noël, 1965
15. *Lotharingius contractus* Bown & Cooper, 1989
16. *Micula staurophora* (Gardet, 1955) Stradner, 1963
17. *Mitrolithus elegans* Deflandre in Deflandre & Fert, 1954
18. *Octopodorhabdus* sp.
19. *Parhabdolithus liassicus* Deflandre in Grassé, 1952
20. *Schizosphaerella* sp.
21. *Triscutum sullivanii* de Kaenel & Bergen, 1993
22. *Tubirhabdus patulus* Rood et al., 1973
23. *Watznaueria barnesae* (Black in Black & Barnes, 1959) Perch-Nielsen, 1968
24. *Watznaueria fossacincta* (Black, 1971) Bown in Bown & Cooper, 1998