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GENUS *CIBICIDES* FROM THE WESTERN BAY OF BENGAL: RELATIONSHIP TO DEEP SEA CHANGES

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ABSTRACT

The genus *Cibicides* and its species were examined from a precisely dated core spanning the last 45 ka from the western Bay of Bengal to understand the impact of oceanographic changes on the microfauna. In all, six species of the genus *Cibicides* were identified. The total abundance variation of the genus *Cibicides* in the studied core revealed an abrupt increase in frequency at ~11 ka, coinciding with the Pleistocene/Holocene boundary. Further, it is interesting to note that *Cibicides robertsonianus* and *Cibicides wuellerstorfi* also show a similar increase in abundance with the beginning of the Holocene. And other species do also show their maximum abundances in the Holocene.

Temporal variation in *Cibicides* species abundances suggest that the sea bottom conditions (oxygen and nutrient level) varied significantly at the end of Marine Isotope Stage 2 (MIS 2). The plausible cause for this abrupt change during the Holocene appears to be due to the reduced export flux of organic carbon to the sea-floor attributed to the surface water stratification associated with increased summer monsoon precipitation and fresh water runoff, and oxygenated sea-bottom condition.

Keywords: Late Quaternary, benthic foraminifera, cibicidids, paleoceanography, Bay of Bengal.

INTRODUCTION

Foraminifera, particularly the benthic foraminifera are mainly depth controlled and some are water-mass related and hence they are sensitive bottom water indicators. They also record history of evolution of bottom water-mass circulations in the world oceans. Benthic foraminiferal tests hold the key to a number of central problems in paleoceanography, such as paleodepth estimation, variations in oxygen level, salinity, nutrients, carbonate saturation and sea level changes, controlled by the water-mass characteristics (Streeter, 1973; Schnitker, 1974; Peterson, 1984; Hermelin and Shimmield, 1990; Jorissen *et al*., 2007). Therefore, benthic foraminifera in deep-sea cores offer the best clues to trace paleobiogeographic patterns, paleocirculation and the resultant climatic changes. According to previous studies made in the Arabian Sea, the regional differences in bathymetry, bottom water oxygenation and organic matter fluxes influence the distribution, biomass and diversity of deep-sea benthic foraminifera (Hermelin and Shimmield, 1990; Gupta, 1994; Gooday *et al*., 1998, 2000; Jannink *et al*., 1998; Kurbjeweit *et al*., 2000; Maas, 2000; Heinz and Hemleben, 2003; Erbacher and Nelskamp, 2006; Schmiedl and Mackensen, 2006; Schumacher *et al*., 2007; Kuhnt *et al*., 2013; Singh *et al*., 2015; Verma *et al*., 2018 add this in reference list). The distribution of $\delta^{13}C$ in the deep ocean is closely related to the circulation pattern of the oxygen and nutrient concentration of water-masses (Kroopnick, 1985). Thus, the carbon isotopic ratios of benthic foraminifera are used to extract information about the changes in the deep oceanic conditions such as nutrient concentration, ventilation and circulation patterns of the deep waters (Scackleton, 1977; Broecker, 1982; Boyle and Keigwin, 1982; Duplessy *et al*., 1988) and it is interesting to note that the dissolved carbon $\delta^{13}C$ has significantly changed since the last glacial maximum (LGM) to the Holocene (Schackleton, 1977; Kallel *et al*., 1988; Curray *et al*., 1988; Ahmad and Labeyrie, 1994). Raza *et al*., (2014) has observed a gradual increase in benthic foraminiferal $\delta^{13}C$, since the last glaciations, is attributed to the introduction of better ventilated deep water with higher $\delta^{13}C$ values in the Bay of Bengal. In this study qualitative and quantitative studies of benthic foraminiferal assemblages of an undisturbed sediment core (SK 218/1) from the western Bay of Bengal, sub-sampled at high resolution interval, were undertaken. The focus of the study is to investigate temporal variation in abundances of *Cibicides,* which are known to be related to the oxic environment and low organic carbon flux to the sea floor (van der Zwaan, 1982; Corliss and Fois, 1990; Kaiho, 1994, 1999). However, some workers considered *Cibicides* as elevated epibenthic taxa characterizing the high energy environments (Schönfeld, 1997, 1998, 2002a, b; Schönfeld and Zahn, 2000; Rogerson *et al*., 2011; Singh *et al*., 2015).

CORE LOCATION AND OCEANOGRAPHIC SETTINGS

A 8.2 m long sediment core (SK 218/1) used in the study was retrieved from the Bay of Bengal [latitude 14^0 02'06" N, longitude 82^0 00'12" E] off Krishna-Godavari basin at 3307 m water depth during ORV Sagar Kanya Cruise, 2005 (Fig. 1).

The site is situated well below the present day Oxygen Minimum Zone (OMZ) in the water column (Wyrtki *et al*., 1971; Olson *et al*., 1993). Previous sedimentological and geochemical studies on this core reveal this to be the undisturbed, turbidites free core suitable for reconstruction of past changes on the shorter time scale (Naidu and Govil, 2010; Govil *et al*., 2011; Pattan *et al*., 2013).

In total, 157 samples were taken for benthic foraminiferal study. For separation of foraminiferal tests, sediment samples were processed following the established micropaleontological techniques. About 5 g of each sediment sample was soaked in 15% Hydrogen Peroxide solution for twenty-four hours and boiled a little before wet screening. Samples were sieved through

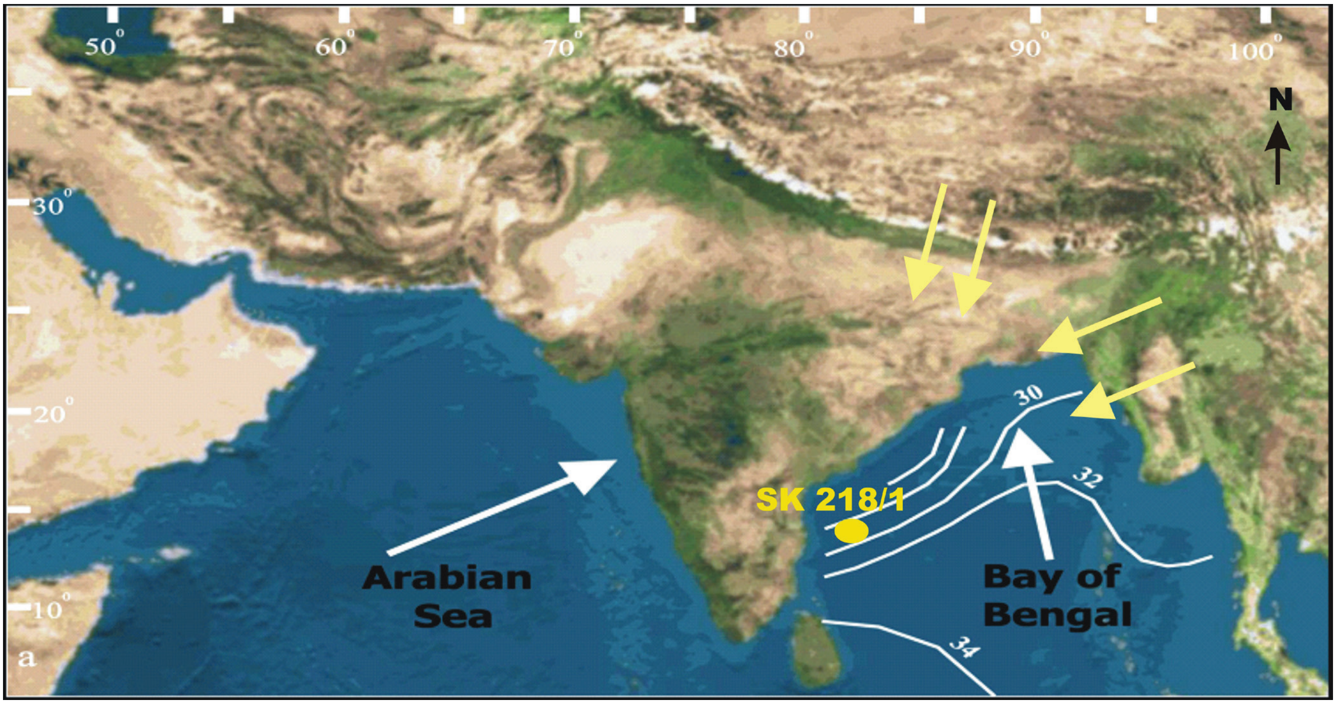


Fig. 1. Location map of the core SK 218/1 in the western Bay of Bengal with the seasonal monsoon wind direction (By arrows: white - summer; yellow - winter) and white lines in the Bay show annual surface salinity condition (after Laviolette, 1967).

a 125-µm screen for census counts. The processed samples were split using the Otto-Splitter to obtain at least 250-300 tests of benthic foraminifera. Total samples were used for counting, where foraminiferal specimens were less in numbers.

For the identification and taxonomic classification of benthic foraminiferal taxa, concepts proposed by Schwager (1866) revised by Srinivasan and Sharma (1980), Brady (1884) revised by Barker (1960) and Loeblich and Tappan (1988, 1992) were mainly followed.

High-resolution chronostratigraphy for the core SK 218/1 developed by Govil *et al*. (2011) was adopted in this study.

RESULTS AND DISCUSSION

The benthic foraminiferal population in the examined core samples comprises of various taxa belonging mainly to the groups uvigerinid, buliminid, cibicidid, miliolid, cassidulinid and bolivinid (in decreasing order of relative abundances). Other quantitatively significant taxa present are *Gyroidinoides* spp., *Oridorsalis* spp., *Chillostomella oolina*, *Eggrella brady, Pullenia* spp. and *Fursenkoinids* spp. The cibicidid group in the core is represented by six species viz. *C. dorsopostulosus* Le Roy*, C. lobatulus* (Walker and Jacob)*, C. kullenbergi* Parker*, C. refulgens* de Montfort*, C. robertsonianus* (Brady) and *C. wuellerstorfi* (Schwager). Systematic descriptions of all the six species with their illustrations by scanning electron micrographs are provided in one plate (Plate 1).

The relative abundance of cibicidids in the examined core varies between a minimum 0.25 % and maximum of 55 % (Fig. 2). The cibicidid group shows relatively high abundance during 0 to 11 ka, Marine Isotope Stage 1 (MIS 1) reaching peaks of abundance 6 to 8 ka, whereas significantly low abundance occurs between 11 ka to 29 ka (MIS 2) and from 29 ka to 45 ka (MIS 3) (Fig. 2). *Cibicides dorsopustulosus* occurs sporadically in the studied core. *C. refulgens* occurs throughout the core with the increased abundances during MIS 1 and MIS 2. *C. wuellerstorfi* occurs commonly throughout the core showing peaks of abundance during latest Holocene, around 41 ka, 20-22 ka and 13-15 ka.

SYSTEMATIC DESCRIPTION

The objective of taxonomy is to evolve a natural system of classification. For taxonomic stability, it is essential to arrange known taxa according to their biological and phyletic relationships.

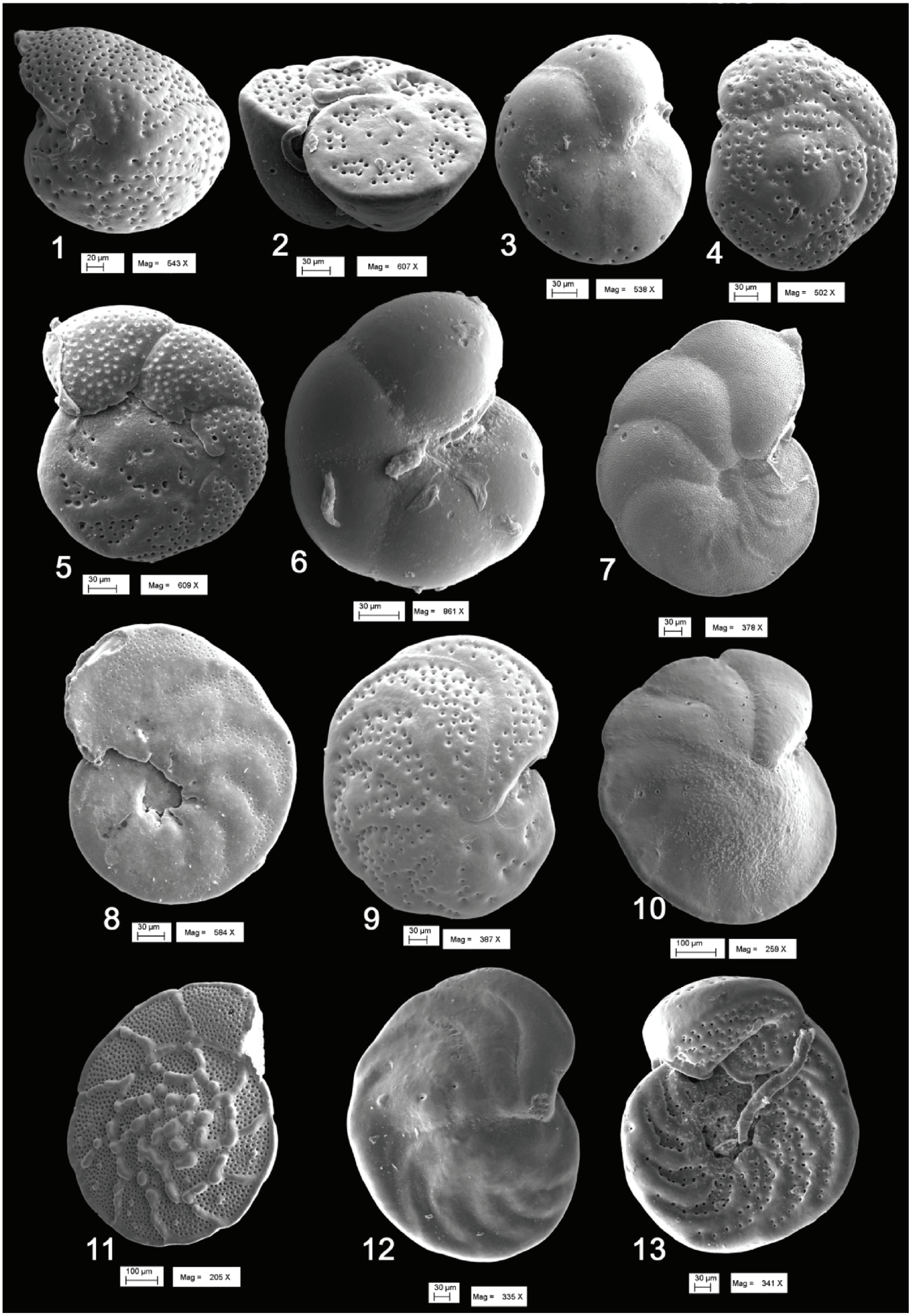
The genera *Cibicides*, *Cibicidoides* and *Planulina* have many features in common suggesting them to be closely allied. All these genera have a coarsely punctate spiral side and an interio-marginal aperture. Unlike *Planulina*, the umbilical side in *Cibicides* and *Cibicidoides* is completely involute, extending on to the spiral side (Gupta, 1994).

EXPLANATION OF PLATE I

The *cibicides* species recorded from the western Bay of Bengal (SK 218/1).

Figs. 1, 2. ***Cibicides lobatulus* (Walker and Jacob)** : (1) Umbilical view: 170-172 cm, 4.63 ka; (2) Spiral view: 170-172 cm, Figs. 4.63 ka; Figs. 3-6. ***Cibicides robertsonianus* (Brady)** : (3, 6) Umbilical view: 214-216 cm, 7.54 ka; (4, 5) Spiral view: 214-216 cm, 7.54 Ka, 238-236 cm, 9.13 ka; Figs. 7, 8. ***Cibicides refulgens* Montfort** : (7) Umbilical view: 118-12 cm, 2.14 ka; (8) Spiral view: 150-152 cm, 3.31 ka; Figs. 9, 10. ***Cibicides kullenbergi* Parker** : Umbilical view: 92-94 cm, 1.18 ka, 290-292 cm, 13.11 ka; Fig. 11. ***Cibicides dorsopostulosus* Le Roy** : Spiral view: 206-208 cm, 7.01 ka; Figs. 12, 13. ***Cibicides wuellerstorfi* (Schwager)** : (12) Umbilical view: 99-100 cm, 1.40 ka; (13) Spiral view: 238-240 cm, 9.13 ka.

Plate I


1
20 µm
Mag = 543 X
2
30 µm
Mag = 607 X
3
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Mag = 538 X
4
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Mag = 502 X
5
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Mag = 609 X
6
30 µm
Mag = 861 X
7
30 µm
Mag = 378 X
8
30 µm
Mag = 584 X
9
30 µm
Mag = 387 X
10
100 µm
Mag = 259 X
11
100 µm
Mag = 205 X
12
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Mag = 335 X
13
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Mag = 341 X

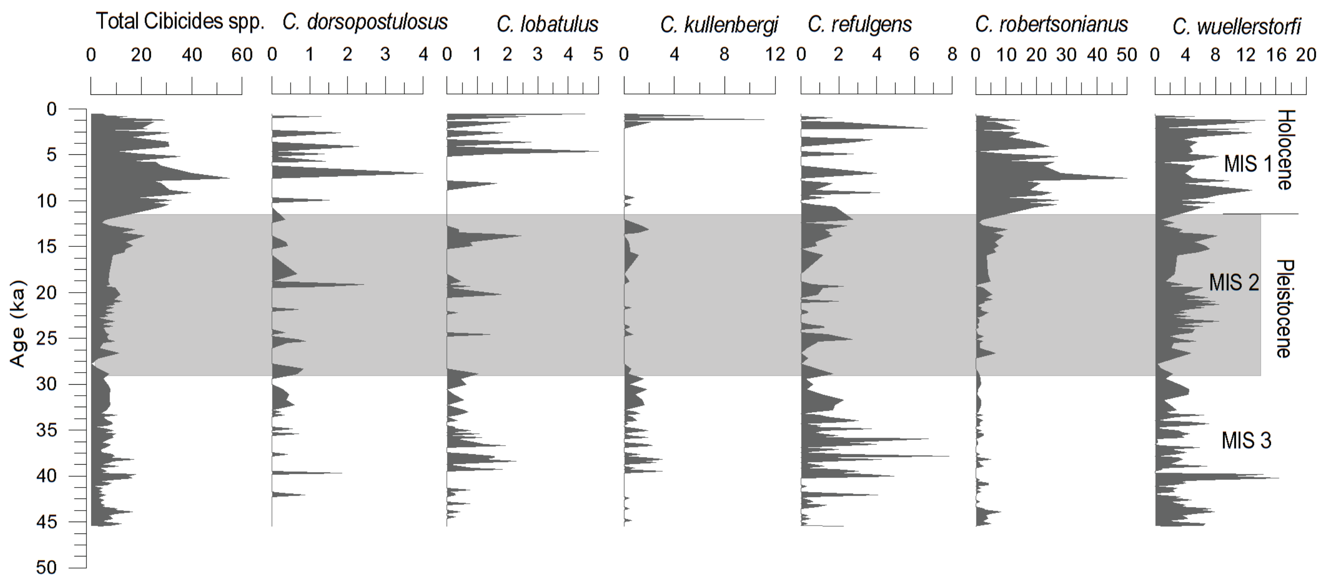

Fig. 2. Plots of relative abundance of total *Cibicides* spp., *C. dorsopostulosus, C. lobatulus, C. kullenbergi, C. refulgence, C. robertsonianus* and *C. wuellerostorfi* foraminifera species (>125 µm) in core SK 218/1. Marine Isotope Stage (MIS 2) shown with dark band and Pleistocene/Holocene epoch boundary marked with line.

From the wall structure studies by Loeblich and Tappan (1964) and Belford (1966), it is apparent that *Cibicides* has radial wall, while *Cibicidoides* has a granular wall structure. Since the author could not carry out comprehensive study of wall structure of *Cibicides* and *Cibicidoides* like specimens encountered, it was not possible to separate them into different genera. Therefore, pending further investigation on wall structure they all are included in the genus *Cibicides*.

Order **Foraminiferida** Eichwald, 1830
Superfamily **Planorbulinacea** Schwager, 1877
Family **Cibicididae** Cushman, 1927
Subfamily **Cibicidininae** Cushman, 1927
Genus ***Cibicides*** Montfort, 1808
Type species ***Cibicides refulgens*** de Montfort, 1808

Cibicides dorsopustulosus Le Roy
(Pl. I, fig. 11)

Cibicides mediocris Le Roy; Le Ray, 1939, p. 268, pl.1, figs. 1-3.

Cibicides dorsopustulosus; (Le Ray); Le Ray, 1944, v. 39, no. 3, pl. 1, p. 42, pl.2, 1-3; pl. 6, figs. 6-9. Srinivasan and Azmi, 1977, p. 346.

Remarks: This species appears to be closely related to *C. ornatus* (Cushman). Because of the presence of large pustules on the dorsal side, the name *C. dorsopustulosus* is very appropriate for the present benthic foraminífer. It has been reported from Late Tertiary sediments of the Indo - Pacific region van Marle (1988) reported this species from the early Pliocene to Quaternary deposits (N19/20-23), and scattered occurence in Recent sediments deeper than 711 m wáter depth from eastern Indonesia.

In the examined core this species is sporadic in its distribution with maximum abundance of 4 % at 7 ka.

Cibicides lobatulus (Walker and Jacob)
(Pl. 1, fig. 1, 2)

Nautilus lobatulus Walker and Jacob, 1798, p. 642, pl. 14 fig. 36.

Truncatulina lobatulus Brady, 1884, v. 9, p. 115, figs. 4, 5.

Cibicides lobatulus (Walker and Jacob); Barker, 1960, no. 9, p. 238, pl. 115, figs. 4, 5.

Remarks: *Cibicides lobatulus* characterized with the thick wall, coarsely and distinctly perforate, interiomarginal aperture, extending onto spiral side, sometimes with small lip. The wide morphological variation of this species is partly due to the fact that specimens live attached, and the test varies in relation to the configuration of the substratum (Todd, 1965; Haller, 1980; van Marle, 1991).

In recent eastern Indonesian sediment *C. lobatulus* occurs at neritic and upper bathyal depths i.e. 150 m to 60 m. Scatter occurrences at deeper level deeper than 150 m. Brady (1884) has reported this species from the Friendly Iceland at 32 m, North of Juan Fernandez at 2502 m and at 3731 m in the Pacific Ocean and in the Atlantic Ocean it is reported from Vigo Harbor, Spain at 20 m, SE of the Azores, at 1820 m. Le Roy (1964) and Pflum and Frerichs (1976) considered *C. labatulus* to be an outer neritic-upper bathyal form. Coustillas (1983) found this species in samples from water depths between 50 and 400 m in the Mahakam Delta and Boichard *et al*. (1985) between 45 and 230 m on the Pater Noster Platform.

Sporadic record of *C. lobatulus* is reported from the studied core samples with the maximum abundance of 5 % at around 5 ka.

Cibicides kullenbergi Parker
(Pl. I, figs. 9, 10)

Cibicides kullenbergi Parker; Phleger, Parker and Peirson, 1953, p. 49, pl. 11, figs. 7-8. Boltovskoy, 1978, v. 26, p. 155, pl. iii, figs. 9-12.

Heterolepa kullenbergi (Parker); Boersma, 1984a, p. 663, pl. 5, fig. 8. Boersma, 1984b, p. 1286, pl. 4, fig. 5; pl. 8, figs. 7, 9.

Cibicidoides kullenbergi (Parker); Thomas, 1985, p. 675, pl. 8, figs. 1-2.

Cibicides kullenbergi Parker; Mead, 1985, v. 31, no. 3, p. 242, pl. 6, figs. 6a-7b.

Remarks: According to Parker (1953; in Phleger *et al.*) *C. kullenbergi* differs from *C. robertsonianus* (Brady) in having a less translucent wall, fewer chambers in the adult form, broader and fewer whorls, more curving sutures, and more, widely spaced, large pores (van Marle, 1991). *Cibicides* *kullenbergi* differs from *C. mundulus* (Brady, Parker and Jones) in its large size, greater convexity of the involute, umbilical side, the strongly curved sutures, and in having an extension of the aperture on to the evolute spiral side. Whereas, van Morkhoven *et al*. (1986) did not find any other morphological differences between these two species except the differences in test size only; therefore considered it to be junior synonym of *C. mundulus*. Because of the apertural characteristics, the peripheral aperture, with lip, extending on to the umbilical side and the spiral side, Boersma (1984a, 1984b, 1986) has put this species in the genus *Heterolepa*. van Marle (1988) found the occurrence of *C. kullenbergi* in Late Miocene - Early Pliocene (N17-18), Late Pliocene – Quaternary deposits (N21-23), and in Recent sediments from ~~the~~ eastern Indonesia. The *Cibicides kullenbergi* a deep water taxon, has worldwide distribution. It has frequent and consistant occurrences in the Northern Indian Ocean (Gupta, 1987).

The scattered occurrence of *C. kullenbergi* has been reported from depths greater than 1288 m in Recent sediments from the eastern Indonesian sediments (van Marle, 1988). Whereas, van Markhoven *et al*., (1986) considered this species to be a common taxon from the Neogene deep sea sediments and according to Pflum and Frerichs (1976), middle bathyal zone in the Gulf of Mexoco. van der Zwaan (1982) observed *C. kullenbergi* prefers deep waters with stable marine conditions.

In the studied samples, *C. kullenbergi* shows sporadic occurrences with its peak of abundance of 11 % in the latest Holocene.

Cibicides refulgens de Montfort
(Pl. I, figs. 7, 8)

Cibicides refulgens de Montfort, 1808, v. 1, Paris, p. 123. Brady, 1884, p. 659, pl. 92, figs. 7-9. Barker, 1960, no. 9, p. 190, pl. 92, figs. 7-9. Srinivasan and Azmi, 1977, Proc. VI Indian Colloq. Micropal. Strat., Varanasi, p. 346, list. Hayward and Buzas, 1979, no. 36, p. 48, pl.10, figs. 130, 131.

Remarks: *C. refulgens* has curved sutures on the flat spiral side and the conical shape of the opposite side. Nylhom (1961) illustrated the wide morphological variability of the test on this species, attributing it to the attached life-style. This species is trochospirally high spired and has a strongly involute umbilical side. Coustillas (1983) recorded a wide morphological variation in this species, which he considered to be related to the nature of substrate; slightly biconvex forms dwell on a soft substrate and planoconvex forms on a harder substrate.

Le Roy (1964) has reported *C. refulgens as* an outer neritic – upper bathyal form. *Cibicides refulgens* shows a scattered depth distribution down from 60 m in Recent eastern Indonesian sediments (van Marle, 1988). According to Coustillas (1983) this species found in sediments between 30 and 400 m, with the highest frequencies between 30 and 90 m, in the Mahakam Delta and Boichard *et al*. (1985) at a depth of 220 m on the Pater Noster Platform. Brady (1884) has reported this species from the SW of Ireland, Atlantic (1319 m) and from the West coast of Patagonia, Pacific (218 m).

In the examined core, this species occurs almost throughout with relative abundance of >5 % between 36 and 40 ka and at around 2 ka.

Cibicides robertsonianus (Brady)
(Pl. I, figs. 3-6)

Truncatulina robertsoniana Brady, 1881, 21, n. s., p. 65. Brady, 1884, p. 664, pl. 95, fig. 4. *Cibicides robertsonianus* (Brady) Hornibrook, 1961, v. 34, no. 1, p. 160. *Cibicides robertsonianus*; Barker, 1960, no. 9, p. 196, pl. 95, figs. 4. Srinivasan and Azmi, 1977, p. 346, list.

Remarks: *Cibicides robertsonianus* differs from *C. bradyi* by its larger test, less rounded periphery with distinct keel and imperforate umbilical side. The specimens of this species encountered in the present work closely resemble with the forms figured as *Truncatulina robertsoniana* by Brady (1884) which was later described as *C. robertsonianus* by Barker (1960). This species has been reported from a depth of 709 m near West Indies.

It has been reported from the abysso-bathyal depths in the world ocean including the Indian Ocean (van Morkhoven et al., 1986; Hermelin and Schimmield, 1990; Nomura, 1991; Gupta, 1994; Murgese and Deckker, 2005, 2007). However, Pflum and Frerichs (1976) observed this species from the upper middle bathyal zone in the Gulf of Mexico.

Cibicides robertsonianus, generally shows less abundance in the lower part of the core with increasing abundance during Holocene, the maximum reaching upto 50 % at 8 ka.

Cibicides wuellerstorfi (Schwager)
(Pl. I, figs. 12, 13)

Anomalina wuellerstorfi Schwager, 1866, v. 2, no. 1, p. 258, pl. 7, figs. 105-107.

Truncatulina wuellerstorfi (Schwager) Brady, 1884, p. 662, pl. 93, figs.8-9.

Cibicides wuellerstorfi (Schwager) Le Roy, 1941, v. 36, no. 1, pt. 1, p. 33, pl.1, figs. 27-29.

Planulina wuellerstorfi (Schwager) Barker, 1960, no. 9, p. 192, pl. 93, figs. 9a-c.

Cibicides wuellerstorfi (Schwager) Srinivasan and Sharma, 1969, v. 15, no. 1, p. 107-110. Srinivasan and Azmi, 1977, p. 346, list. Lohmann 1978, v. 8, p. 25, pl. 2, figs. 16-17. Boltovskoy, 1978, v. 26, p. 157, pl. 3, figs. 19-21. Srinivasan and Sharma, 1980, p. 56, 57, pl. 8, figs. 11-13. Gupta, 1994, v. 40, no. 4, p. 360, pl. 5, figs. 8, 9.

Remarks: *Cibicides wuellerstorfi* is characterized by its flattened to concave spiral side with fine pores, strongly recurved and limbate sutures. This species has been placed in various genera by different workers. Schwager (1866) placed it under *Anomalina*, whereas other workers have placed it under *Cibicides* (e.g. Hofker, 1951; Srinivasan and Sharma, 1980; Boltovskoy, 1985; Sen Gupta, 1988; 1989; Kawagata, 1999), *Planulina* (e.g. Cushman, 1929; Bermudez, 1949; Phleger *et al*., 1953; Barker, 1960; Corliss and Chen, 1988), *Cibicidoides* (e.g. Parker, 1964, Lutze and Coulbourn, 1984; Thomas, 1986; Hermelin and Schimmield, 1990) and *Fontbotia* (Gonzalez-Donso and Linares 1970). Brady (1884) has reported this species from the West coast of New Zealand at 500 m.

Cibicides wuellerstorfi occurs throughout the core with a prominent increase in abundance during the Holocene.

RELATIONSHIP TO THE DEEP SEA CHANGES

It is interesting to note that a major increase in abundance of *Cibicides* at around 11 ka coincides with the Pleistocene/Holocene boundary and high abundance continues to the present. Therefore, based on total abundance record of *Cibicides* can be observed that since the Pleistocene/Holocene boundary there has been a major change in the deep oceanic conditions in the western Bay of Bengal

The *Cibicides* species generally prefer epifaunal or shallow-infaunal habitat and are known to be associated with well-oxygenated environments with stable physico-chemical sea bottom conditions (van der Zwaan, 1982; Corliss and Fois, 1990; Kahio, 1994, 1999; Kouwenhoven, 2000; Schweizer *et al*., 2009).

van der Zwaan (1982) considered, *C. dorsopustulosus* as an open mud-dweller without tolerance to oxygen deficiency or raised salinities. Therefore, an increase in abundance of this species may be related to the presence of low oxic conditions at the core site.

According to van der Zwaan (1982), *C. labatulus* is an epibenthic form showing tolerance to increased salinity (van Marle, 1988). Hageman (1979) suggested that *C. labatulus* has tolerance for restricted marine conditions and according to Sejrup *et al*. (1981) this species is common on coarse sediments, deposited in higher energy environments. Therefore, increased abundance of *C. labatulus* suggests high energy environment at the core site, which predominates during the Holocene.

According to Corliss (1985), *C. kullenbergi* is an infaunal species lives within the top 0-2 cm of the sediment. This species occurs in oligotrophic environments (Woodruff, 1992; Miao and Thunell, 1993; Almogi-Labin *et al*., 2000). Hence, the peaks of abundance of *C. kullenbergi* suggests the nutrient deficient environment during the latest Holocene as compared to the other older periods.

Cibicides refulgence is recorded from high latitudes in both the southern and northern oceans. Thus, the occurrence of this species from the studied core indicates that the deep sea conditions were more similar during the MIS 1 and MIS 3 as compared to the MIS 2. By the previous studies it is observed that *C. refulgence* is a typically neritic species, found chiefly from the beach to about 200 m depth (Sejrup *et al*., 1981; Altenbach et al., 1999; Schönfeld & Zahn, 2000; Holbourn and Henderson, 2002) and common between 345 and 950 m in Antarctica (Murray, 1991). The presence of living specimens of *C. refulgence* at least down to 1000 m depth indicates that it can also live in bathyal environments and well known as inhabiting elevated microhabitats (Schweizer, 2006).

Cibicides robertsonianus occurs throughout the core with a sudden increase in abundance during the Holocene as compared to the MIS 2 and MIS 3. The abundance of this species was more than all of six *Cibicides* species. *Cibicides robertsonianus* is an epifaunal species with has its predominance in the top 1 cm within sediments (Corliss, 1985, 1991; Corliss and Chen, 1988). According to van der Zwaan (1982), it is a mud-dweller with little tolerance to increased salinity and oxygen deficiency. Whereas, Kaiho (1994) observed that *Cibicides robertsonianus* has preference for oxygenated environment. Since, the abundance record of total *Cibicides* species is mainly controlled by *C. robertsonianus* thus, the record of this species appears to be most important for interpreting the deep sea conditions in the western Bay of Bengal. High abundance of *Cibicides robertsonianus* from the core-top suggests that the deep sea environment was more oxygenated during the Holocene (MIS 1) as compared to the Pleistocene (MIS 2 and MIS 3).

Cibicides wuellerstorfi is a cosmopolitan deep sea species, which is known to occur abundantly at bathyal to abyssal depths (Miao and Thunell 1993; Gupta, 1994; Rai and Srinivasan, 1994; Bornmalm, 1997; Murgese and Deckker, 2005, 2007). This species is considered to be associated with deep water masses such as the Pacific Deep Water (Culp, 1977; Douglas and Woodruff, 1981), North Atlantic Deep Water (Uchio, 1960; Streeter, 1973; Lohmann, 1978; Douglas and Woodruff, 1981; Schnitker, 1980; Hermelin, 1989), Indian Ocean Deep Water (Peterson and Lohmann, 1982), the Antarctic circumpolar water (Corliss and Thunell, 1983), and Caribbean Bottom Water (Sen Gupta, 1988). *Cibicides wuellerstorfi* is also reported as the representative species associated with the warm and high salinity NADW in the southeast Indian Ocean (Corliss, 1983). This species is an epibenthic foraminifer living on the structures elevated above the substrate in the regions of strong bottom currents (Weston, 1985; Lutze and Thiel, 1989; Mackensen and Douglas, 1989; Gooday *et al*., 1992; Linke and Lutze, 1993; Altenbach *et al*. 1999) and *C. wuellerstorfi* is known to prefer oxic environment (Kaiho, 1994). The higher abundance of *C. wuellerstorfi* is attributed to lower organic carbon flux and decreased food supply associated with regions of low surface water productivity (Altenbach, 1988; Burke *et al*, 1993; Sarnethin and Altenbach, 1995; Miao and Thunell 1996; Kuhnt *et al*., 1999; Murgese and Deckker, 2007).

CONCLUSIONS

The microhabitat patterns of cibicidid group suggest that dissolved oxygen level of underlying waters in the Bay of Bengal has varied considerably during the last 45 ka.

Marked variation in abundance of cibicidid group suggests pronounced changes in bottom oxygenation history and surface productivity related organic carbon flux.

The abrupt increase in abundance of total cibicidid species in the studied core from 11 ka onwards (Holocene epoch) provides an additional tool to delineate Pleistocene/Holocene epoch boundary in the core.

Predominance of *C. robertsonianus, C. wuellerstorfi, C. labatulus, C. dorsopostulosus* and *C. kullenbergi* since 11 ka (Holocene), as compared to low-oxygen taxa during the late Pleistocene (11 ka to 45 ka) suggests oligotrophic high oxygen bottom environment. .

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Medals and Awards Instituted by the Palaeontological Society of India

NOTICE

The Palaeontological Society of India awards the following Gold Medals/Awards instituted by benevolent grants/funds received through the families and friends of the Fellows of the Society. These Medals and Awards are given away each year except the Prof. S.N. Bhalla Gold Medal which is awarded once in two years. Applications and Nominations for the award and Medals are invited up to 31st January 2020.

1. Sharda Chandra Gold Medal for outstanding research publications on Indian material in the field of palaeontology.
2. Mani Shanker Shukla Gold Medal to a young research worker (below 40 years of age) in recognition of his outstanding contributions on Indian material in the field of micropalaeontology.
3. Prof. M. R. Sahni Gold Medal for a post graduate Student of University of Lucknow securing highest percentage of marks in the examination in Palaeontology Paper.
4. Prof. S. N. Bhalla Gold Medal for outstanding contributions in the field of micropalaeontology.
5. Prof. S. K. Singh Memorial Gold Medal for best research paper published in the immediate past volume of the Journal of the Palaeontological Society of India.
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