Palaeocene Faunal Events and Fossil Records of Andaman Islands, India

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Abstract Two distinct foraminiferal assemblages, viz., (a) larger benthic foraminifera viz; *Ranikothalia* sp., *Miscellanea* sp., *Daviesina* sp. and *Discocyclina* spp. and (b) planktonic foraminifera viz; *Globigerina daubjergensis, Globorotalia fringa* and *Chiloguembelina* sp. cf. C. *wilcoxiensis* represent two prominent Palaeocene faunal events and marks the basal and top part of the Palaeocene sequence in Andaman Islands. Deep water depositional environment beyond the influence of clastic supply prevailed during Lower Palaeocene and shallow marine high energy condition during Upper Palaeocene period. Process of accretion started during later part of Palaeocene as evidenced in the North and Middle Andaman but not witnessed in South Andaman. Non-availability of the Palaeocene sequence in South Andaman maybe due of presence of barrier causing hindrance to sediment supply towards South.

Keywords Andaman islands · Palaeocene · Larger foraminifera · Ranikot sea

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Introduction

Marine Palaeocene sequences are described form numerous localities in India, though some of which are substantiated by undoubted palaeontological evidences (Samanta 1974). Among the Indian occurrences, Palaeocene sequences of Andaman Islands, due to its crucial geographic position and tectonic setup (Fig. 1), deserve special attention for reconstruction of palaeogeography and interpreting the tectonic history of the islands.

Andaman and Nicobar Islands are part of the tectonic belt which is extending from Arakan Yoma to the far East (Karunakaran et al. 1964) and are situated on the outer arc ridge (Fig. 1) of the northern segment of the Sunda Subduction Complex (Weeks et al. 1967; Curray 2005). There was an long standing dispute on the development of Palaeocene sequence in this belt and extension of the Palaeocene Sea beyond Burma toward south. Palaeocene sequence is well developed in Burma, towards north of the Andaman Islands (Nagappa 1959). Towards south, in the islands of the Far East, Middle Eocene sediments unconformably overlie the Cretaceous rocks (Adams 1965, 1970; Nagappa 1959; Glaessner 1959). Hence, there is a gap in sedimentation during Palaeocene—Early Eocene can be inferred.

Prior to 1964, geological investigations by pioneer workers like Oldham (1885), Rink (1870), Tipper (1911) and Gee (1926) considered the thick pile of sedimentary sequence of Andaman Islands as Eocene. Existence of Palaeocene sequence in the Andaman Islands was first mentioned by Chatterjee (1964), though the palaeontological evidences provided by him were not much supportive and firm. The claim of presence of Palaeocene sequence in Andaman Island was based simply on the identification of *Distichoplax biserialis* Dietrich and *Rotalia trochiformis* in stray boulders (Chatterjee 1964). This report of occurrence of Palaeocene rocks was undermined by Samanta (1974) on the ground that *Distichoplax biserialis* is long ranging from Upper Cretaceous to Upper Eocene. Similar conclusion regarding the status of this species of dascycladacean algae was drawn by Mishra and Kumar (1988). However, Samanta (1974) did not make any comment on the report of *Rotalia trochiformis*, a well known Palaeocene foraminifera. It must be mentioned that none of the taxa i.e. *Rotaliatrochi formis* or *Distichoplax biserialis* Dietrich has been illustrated by Chatterjee (1964). In addition to this, records of definite Palaeocene foraminiferal assemblage are available from few localities in Andaman Islands. Limited occurrence of in situ fossiliferous horizon poses hindrance for proper understanding of the Palaeocene events and deciphering the Cretaceous-Palaeocene boundary in the Andaman Islands.

The well illustrated assemblage of Early Palaeocene planktonic foraminifera (Kumar and Soodan 1976) is registered from the area viz. (a) between Mayabunder and Webi and (b) 8 km east of Webi, Middle Andaman. This assemblage is comparable with that of *Globorotalia uncinata* Zone of Bolli (1957) and is equivalent to Zone P-2 of Blow and Berggren (1969). Five species of *Daviesina* (Table 1) along with fossil algae from the limestone of Tugapur, Middle Andaman were reported by Kundal and Wanjarwadkar (2002) indicating Upper Palaeocene age. Later, Koley

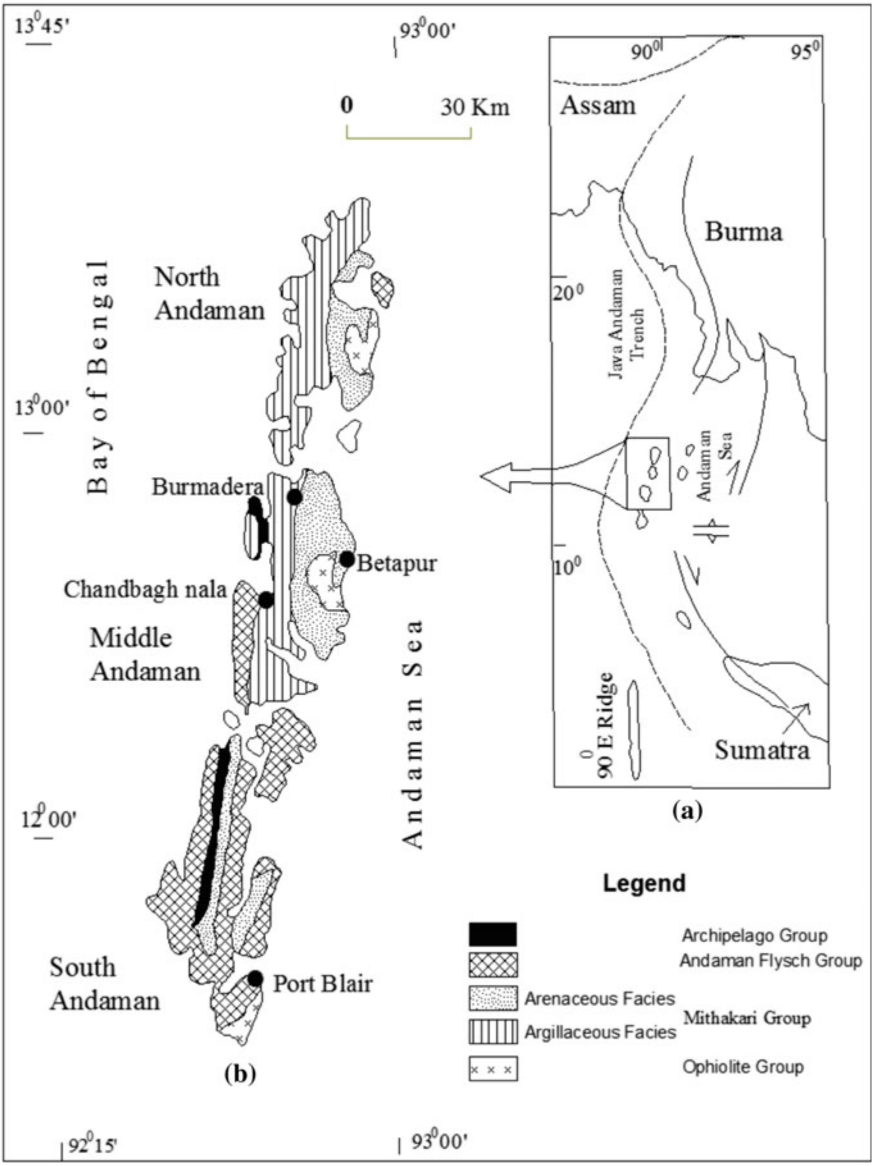

Fig. 1 **a** Location map with tectonic elements of the region. **b** General geological map of South, Middle and North Andaman (modified after Bandopadhyay 2005)

and Wanjarwadkar (2013) indicated the interbedded nature of the Tugapur limestone and reported *Ranikothalia* and *Discocyclina* (Table 1) indicating Upper Palaeocene age of the limestone.

Table 1 Available records of foraminifers of palaeocene affinity from Andaman Islands

Authors	Fossil records	Locality	Remarks
Present work	*Ranikothalia* sp., *Miscellanea* sp., *Daviesina* sp., *Discocyclina ramaroi, Discocyclina haynesi Globigerina daubjergensis, Globorotalia fringa, Globorotalia compressa* and *Chiloguembelina* sp. cf. C. *wilcoxiensis*	Limestone exposed in melange zone at Betapur coast Shale from Chandhbagh nala, Middle Andaman	Taxa identified from random thin section Taxa identified from discrete forms
Koley and Wanjarwadkar (2013)	*Ranikothalia sidensis,Ranikothalia* cf. *tobleri, Ranikothalia* cf. *nuttalli, Discocyclina* sp.	Bedded limestone from Tugapur and limestone boulder in conglomerate	Identified from random thin sections
Bandopadhyay (2011)	*Assilina* sp.	Rampur and Kalipur coast	Three oblique sections are provided
Kundal and Wanjarwadkar (2002)	*Daviesina danieli* Smout, D. *garumensis Tambareau*, D. *langhami* Tambareau, D. *ruida* Tambareau	Burmadera Limestone	–
Roy et al. (1988)	*Globigerina linaperta*, G. *triloculinoides, Globigerina* sp., G. cf. *daubjergensis*, G. cf. *velascoensis, Globigerinelloides* sp., *Globorotalia compressa*	Pelagic sediments from South Andaman	Taxa are identified from random thin section
Kumar and Soodan (1976)	*Globoconusa daubjergensis* Bronninmann, *Sub-botina triloculinoides* Plummer, *Globorotalia angulata* White, *G. compressa*, Plummer, *G. imitata* Subbotina, *G. perclara* Loeblich and Tappan, *G. pseudobuloides* Plummer, *G. uncinata* Bolli, *G. varianta* Subbotina	Shale exposed east of Tugapur and Mayabunder	

(continued)

Table 1 (continued)

Authors	Fossil records	Locality	Remarks
Karunakaran et al. (1964)	*Distichoplax biserialis*	Limestone boulder from Conglomerate	This species of algae is no longer index of Palaeocene
Chatterjee (1964)	*Distichoplax biserialis, Rotalia trochiformis*	Limestone boulder from Chiriyatapu Conglomerate	Taxa are neither described nor illustrated This algal species is no longer index of Palaeocene

Records of Palaeocene fossils are rare from North Andaman except the *Assilina* reported by Bandopadhyay (2011) from Kalipur and Rampur coast. However, the illustrations raise some doubts in identification. Moreover, the present authors studied the section and reported undoubted Middle-Upper Eocene Nummulitids and Discocyclinids (Koley and Anju 2013).

Palaeocene fauna from the Tertiary sequence of South Andaman were reported by Roy et al. (1988) from the pelagic sediments associated with the pillow basalt (Table 1). Their report of Palaeocene planktonic foraminiferal assemblage including *Globigerina eugubina*, *G.linaperta*, *G. velascoensis*, *G. trilocunoides*, *G.* cf. *daubjergensis*, *Globorotalia compressa* are identified in the random thin sections. Moreover, typical Cretaceous planktonic foraminiferal genera like *Globotruncna, Reugobgobligerina, Heterohelix, Pseudotextularia* are associated with the Palaeocene forms in their assemblage. Causes for the anomalous mixing of the distinct assemblages are not explained. As sanctity of the identifications of the planktonic foraminifers from random thin sections is always questionable, records of definite Palaeocene fossils are not available.

General consensus is that the trench outer arc setting with active subduction prevailed during the Cretaceous time onwards (Pal et al. 2003; Bandopadhyay 2005) in Andaman and Nicobar Islands. In a subduction zone setting the sediments deposited on the oceanic crust is finally accreted to the continental mass by the process of underplating and tectonically to the toe of the prism (Wakita and Metcalfe 2005). Fossil records of the marine sequence are a necessity to reconstruct the history of the oceanic crust from its initiation and to subduction in the trench. Scarcity of the Cretaceous–Palaeogene fossil records from Andaman leaves limited scope to reconstruct its tectonic history with high degree of confidence. In this work, attempt has been made to establish the limits the Palaeocene sequence of Andaman Island based on the Palaeocene faunal events and to discuss its implications on the palaeogeographic reconstruction and tectonic events of the area.

Material and Method

Identification of fossils is based on the examination of rock sections and processed samples of shales from the argillaceous sequence and limestone exposure which is observed to occur as huge boulders within the melange zone exposed in Betapur coastal section. Planktonic foraminifera are ill preserved and identification of the planktonic foraminifers is based on the SEM images. The cream colour limestone from the melange zone is very hard and porcellanetic as found in the Tugapur and Burmadera area, Middle Andaman. Larger benthic foraminifers are completely fused with the matrix and impossible to extracts. Therefore, the larger benthic foraminifera were identified from random thin sections.

Geological Set Up

Ophiolite Group comprising ultramafics, dacite, basalt, plagiogranite and pelagic sediments is the oldest unit of the Andaman Islands. Thick Tertiary sediments comprising dark grey shale, sandstone, conglomerate and limestone unconformably overlie the Ophiolite Group (Fig. 1b).

In Middle Andaman ophiolites are exposed as dismembered bodies and are mainly concentrated in the eastern part of the Island (Fig. 1b). However, pillowed basalt with chert and limestone are observed in the western part of the Island. Betapur–Pancahwati coast exposes the melange zone consisting of assorted blocks and boulders of basalt, chert limestone, greywacke, shale in a fine grained shale matrix. Western part of the island exposes dark grey shale with interlayered thin sandstone and occasional limestone. Limestone band with linear isolated out crops is observed toward the top of the argillaceous facies. Ultimately the argillaceous sequence is overlain by anarenaceous sequence of polymictic conglomerate, coarse to fine grained sandstone and shale.

Similar geological setup is continuing from Middle Andaman towards north to North Andaman (Fig. 1b). The limestone facies is not exposed in the North Andaman. The sedimentary sequence displays two distinct facies viz. lower argillaceous facies and upper arenaceous facies. The argillaceous facies comprises of dominantly shale with minor interlayered sandstone and the arenaceous facies comprises polymictic conglomerate, gritty sandstone, coarse to fine sandstone, calcareous sandstone, siltstone and interlayered thin shale. Dismembered ophiolite bodies occur mainly within arenaceous facies. The melange zone is exposed in the Rampur coast.

Ophiolite slices are mainly occurring along the eastern coast of the South Andaman Island (Fig. 1b). Chert beds are associated with the ophiolite and as dismembered bodies within the polymictic conglomerate, gritty sandstone of Namunagarh and Hopetown formations. Interestingly, the argillaceous facies (=Lipa Black Shale Formation) is not developed in South Andaman Islands. Thick sequence of con-

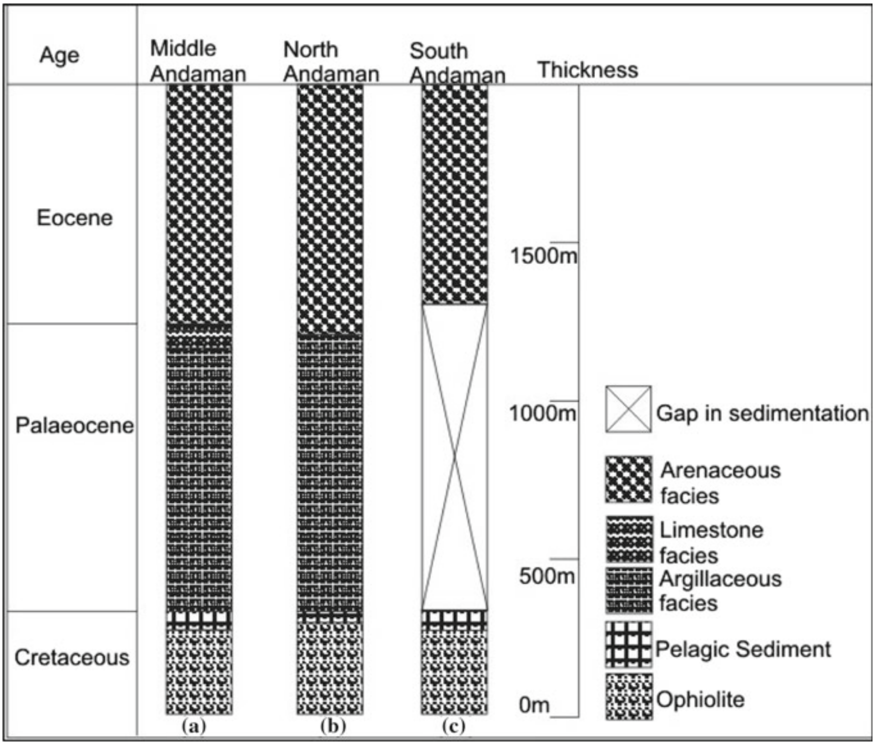

Fig. 2 Temporal distribution of Cretaceous- Eocene litho-facies in Middle, North and south Anaman

glomerate, coarse grained sandstone and shale is overlain by thick turbidite sequence of Andaman Flysch Group of Oligocene age (Fig. 2).

Observations

Two distinct foraminiferal assemblage have been identified from Middle Andaman—(a) planktonic foraminifera assemblage comprising *Globigerina daubjergensis* (Fig. 3a–c), *Globorotalia fringa* (Fig. 3d–e) and *Chiloguembelina* sp. cf. *C. wilcoxiensis* (Fig. 3f–g) assemblage from the argillaceous facies and (b) larger foraminifera assemblage comprising *Ranikothalia* sp. (Fig. 4), *Miscellanea* sp. (Figs. 4 and 5), *Daviesina* sp. (Figs. 4 and 5) and *Discocyclina* sp. (Figs. 4 and 5) from the arenaceous facies.

Limestone containing Upper Palaeocene larger benthic foraminifera are recorded from the sediments of younger stratigraphic level (Koley and Wanjarwadkar 2013). Larger foraminifera indentified are from limestone occurring in the arenaceous

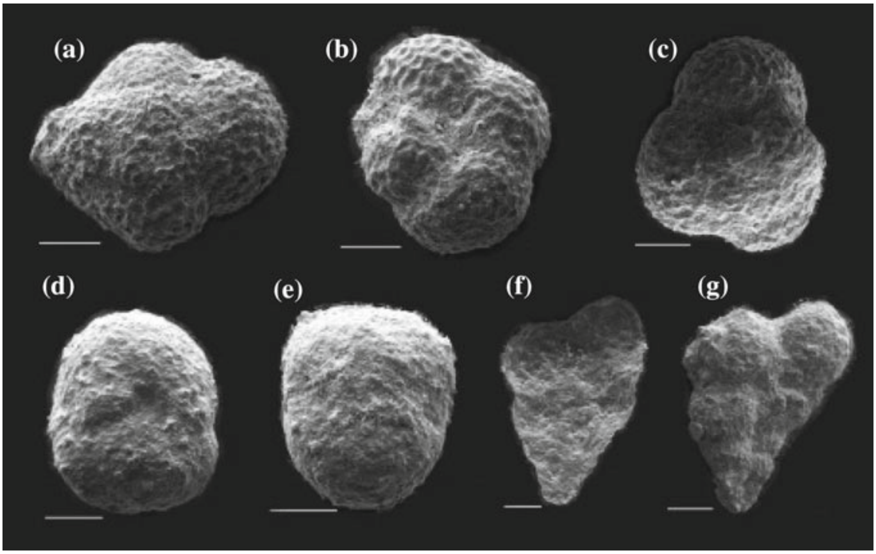

Fig. 3 Planktonic foraminifera from shale exposed in western part of Middle Andaman. Scale bar represent 60µm

facies of Mithakhari Group exposed in the melange zone of Betapur coast, Middle Andaman. Nevertheless, occurrence of the larger foraminifera in this sequence indicates a Palaeocene faunal event.

Discussion

The Palaeogene sequence of this area is classified into two groups viz. Mithakhari Group and Andaman Flysch Group (Table 2). Cretaceous to Upper Eocene age was assigned to the Mithakhari Group (Karunakaran et al. 1968; Ray 1982) though there remained arbitrariness in assigning the upper and lower boundaries due to limited fossil control. While discussing the foraminiferal biostratigraphy of India, Pakistan and Burma, Nagappa (1959) suspected non-development of Palaeocene and Lower Eocene sequence in Andaman and Nicobar Islands. His reasoning was based on the analogy that the oldest Tertiary rocks in Ramree Island towards north of the Andaman and Nicobar Islands is Middle Eocene. Towards South of Andaman and Nicobar Islands, in the Far East region, Middle Eocene sequences directly overly the Cretaceous rocks.

Limestone boulders within the melange zone of Betapur coast, Middle Andaman yielded Palaeocene larger foraminiferal assemblage of *Ranikothalia, Miscellanea, Daviesina* and *Discocyclina*. Fossil algae *Jania, Corallina* and *Distichoplax* are associated with the larger foraminifera indicating shallow marine high energy condition.

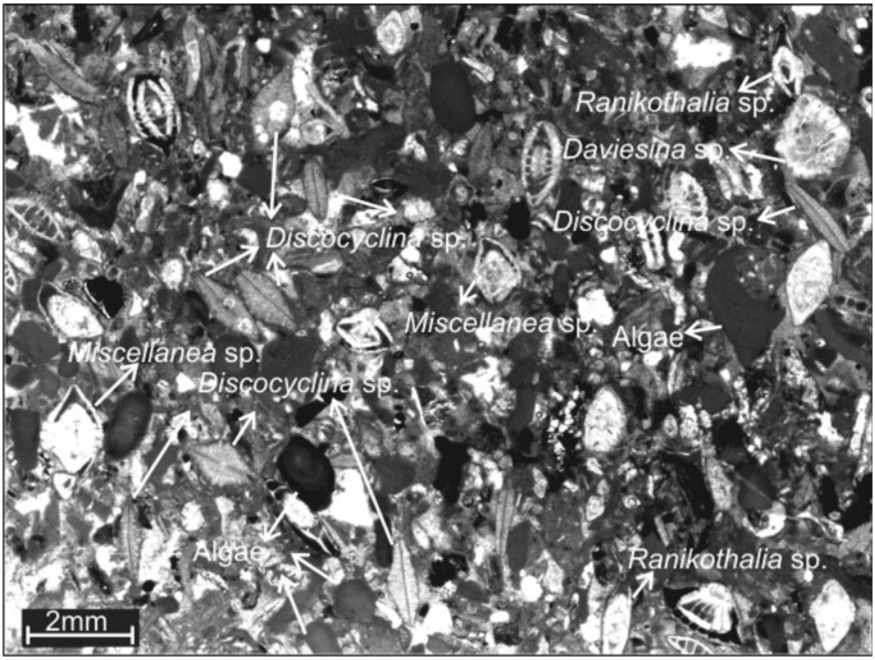

Fig. 4 Photomicrograph of foraminiferal limestone showing assemblage of *Ranikothalia, Miscellanea, Discocyclina, Daviesina* and fossil algae

Mithakhari Group in Middle and North Andaman can be classified broadly into two facies (Fig. 1b) viz. lower argillaceous facies with the limestone towards top and upper arenaceous facies. These two facies together constitute the Tertiary sequence of Middle Andaman; the argillaceous facies and the arenaceous facies broadly correspond to the Lipa Black Shale and Namunagarh Grit formations respectively. Foraminifera of Palaeocene affinity has been identified from basal and upper part of Lipa Black Shale. *Globigerina daubjergensis, Globorotalia compressa, Globigerina* cf. *fringa* and *Chiloguembelina* sp. cf. C. *wilcoxiensis* assemblage from Chandbagh Nala and *Ranikothalia–Miscellanea–Daviesina–Discocyclina* assemblage from the limestone exposed in Burmadera. The Planktonic foraminiferal assemblages of *Globigerina daubjergensis, Globorotalia compressa, Globigerina* cf. *fringa* and *Chiloguembelina* sp.cf. *C. wilcoxiensis* indicates Early Palaeocene age. As towards top of the sequence the limestone exposed near Tugapur has yielded Late Palaeoocene larger foraminifera, Palaeocene age for the argillaceous sequence can be assigned. This corroborates with the view of Allen et al. (2007) that the Mithakhari Group was deposited during Palaeocene–Eocene with a maximum age of ca. 60 Ma (Zr-radiometric dates derived from sandstones).

Slivers of dismembered ophiolite have been recorded at different stratigraphic levels within the argillaceous facies, represented by grey to dark grey shale and thin sandstone alternations. The report of Maastrichtian planktonic foraminiferal

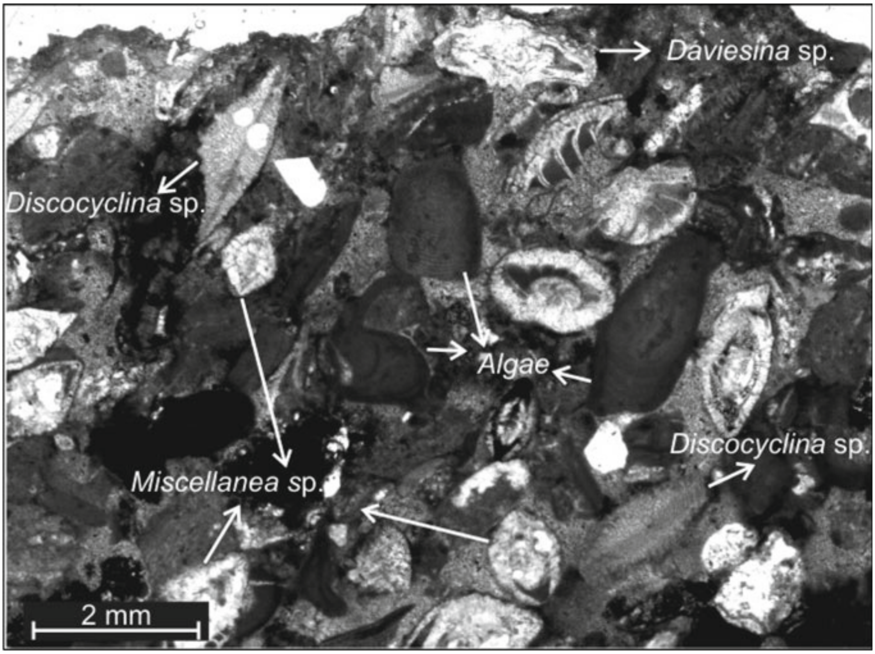

Fig. 5 Photomicrograph of foraminiferal limestone showing assemblage of *Ranikothalia, Miscellanea, Discocyclina, Daviesina* and fossil algae

assemblage by Pandey and Rao (1976) from Neali and Chandbagh Nala is probably from such pelagic sediments as present within the Mithakhari Group. In Middle Andaman, the Tertiary sequence represented by clastic sediments starts from Lower Palaeocene and the age of the pelagic sediments associated with the ophiolite can be extended up to Maastrichtian. It is mention worthy that Gee (1926) considered the cream colour porcellanitic limestone exposed near Tugapur and Burmadera as post-Eocene and correlated the limestone with the Yaw Limestone of Burma. The report of *Miscellanea* from similar type of limestone during the present work confirms the presence of the genus in the islands. *Miscellanea* has restricted stratigraphic range within Upper Palaeocene in the Indian Subcontinent of Indian, Pakistan and Burma (Nagappa 1951).

As already mentioned, limestone containing Upper Palaeocene larger benthic foraminifera are recorded from the arenaceous sediments of younger stratigraphic level and from the melange zone of Betapur coast, Middle Andaman. The larger foraminifers identified are from such limestone occurring with in the melange zone. Melange zones are important in reconstructing the Ocean Plate Stratigraphy (Wakita and Metcalfe 2005). Presence of larger benthic foraminifers indicates a Palaeocene event in Andaman. Hence, two prominent Palaeocene faunal events, viz. proliferation of planktonic foraminifers forming a remarkable foraminiferal assemblage comprising *Globigerina daubjergensis, Globorotalia fringa* and *Chiloguembelina*

Table 2 Generalized stratigraphy of Andaman and Nicobar Island (after Ray 1982)

Group	Formation	Litho units	Age
Archipelago Group		Limestone-Chalk-Claystone-sandstone—Conglomerate	Lower Miocene
Andaman Flysch Group		Sandstone—shale rhythmites with Bouma sequences	Oligocene-Eocene
Mithakhari Group	Namunagarh Grit Formation	Pebbly and gritty greywacke, green sandstone, siltstone	Middle to late Eocene
	Hope Town Conglomerate Formation	Polymictic matrix supported conglomerate alternated with pebbly-gritty sandstone and greenish claystone	
	Lipa Black Shale Formation	Pyritiferous black shale and radiolarite earth	
Ophiolite Group		Basic, ultrabasic and intermediate igneous rocks and pelagic sediments	Cretaceous to Palaeocene

sp. cf. C. *wilcoxiensis* in the basal part and development of *Ranikothalia, Miscellanea, Daviesina* and *Discocyclina* association in the upper part, can be readily be recognized in Middle Andaman. As a matter of support to the explanation of existence of Palaeocene sequence it may be noted that all these genera are reported from the Palaeocene sequence of Khasi and Jaintia hill, Garo hills and Pondicherry in India. In Pondichery Formation *Ranikothalia* is represented by *Ranikothalia nuttalli* Davies where as in Khasi Jaintia Hills this genus is represented by both *R. nuttalli* and *R. sidensis* (Samanta 1980). In Middle Andaman *Ranikothalia* is represented by species (Table 1) similar to those of Eastern India (Koley and Wanjarwadkar 2013). *Daviesina* is always reported to be associated with *Ranikothalia* and *Miscellanea* in these sequences. Hence, as of now, *Ranikothalia* and *Daviesina* assemblage in India is restricted only in Pondichery, Khasi-Jaintia and Middle Andaman; Middle Andaman being its easternmost boundary. Apart from India, the morphologically distinct genus *Ranikothalia* is recorded from Caribbean region, Oman, Venezuela, Salt Range. *Ranikothalia* (*Nummulites thalicus*) was also reported from Sarawak (Adams 1965) and Borneo (Van der Vlerk 1929), but proper taxonomic description and illustrations are lacking. Later workers (Nagappa 1959; Samanta 1980) did not agree with the presence of *Ranikothalia* in Far East region. Therefore, the occurrence of this genus in Middle Andaman indicates a possible limit of Ranikot sequence.

The argillaceous facies (=Lipa Black Shale Formation) is not developed in South Andaman (Fig. 2); only the arenaceous facies of the Mithakhari Group is developed. Adequate palaeontological evidence of the development of Palaeocene sequence in South Andaman is still lacking. Probably the Tertiary sequence in South Andaman starts with Middle Eocene which resembles the set up of far East where the lowermost Tertiary unit too is Middle Eocene. During Palaeocene, towards south of Middle Andaman sedimentation is negligible probably because of lack of sediment supply beyond Middle Andaman.

Pal et al. (2003) considered that accretionary prism formed during Lower to Late Eocene and Bandopadhyay (2005) suggested accretion broadly during Palaeogene. Flysch type trench fill sediments cover the pelagic sediments when it arrives in the trench (Wakita and Metcalfe 2005). During Cretaceous, pelagic sediments represented by chert, limestone and claystone were deposited on the subducting oceanic crust of Indian Plate. Presence of *Globotruncana* and Radiolaria in the Cretaceous sediments of Andaman Islands indicates deposition in deep water and beyond the influence of terrestrial sediment source. On its arrival in the trench during Palaeocene, shale dominated sediments started accumulating as trench fill deposits as evidenced in Middle and North Andaman. Accumulation of the clastic sediments marks the lower boundary of the argillacoues facies which is equivalent to Lipa Black Shale (Fig. 1b) well developed in Middle and North Andaman. The thick Palaeocene sequence developed in Middle Andaman and North Andaman indicates that the rate of sedimentation outweighed the rate of subduction. The change in the environment of deposition from deep water to high energy shallow marine condition during Palaeocene implies shallowing which in turn indicates uplift during the process of accretion. The process of accretion of the trench sediments started during the later part of the Palaeocene. Absence of the Palaeocene sediments suggests the South Andaman and the area further south were either geomorphologically positive or there was geomorphologic barrier which restricted the sediment supply to the locale during Palaeocene and even Lower Eocene.

Conclusions

1. Planktonic and larger foraminiferal assemblage recorded from Middle Andaman indicates that the age of the argillacous facies (=Lipa Black Shale Formation) is Palaeocene.
2. There was no deposition or negligible deposition of the clastic sediments in areas beyond Middle Andaman and further South during Palaeocene.

3. Depositional environment changes from deep marine during Early Palaeocene to shallow marine high energy condition during Late Palaeocene. Accretion of the trench sediments started after the Late Palaeocene.

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