record of 1999 Chamoli earthquake. The main peak at 1.9 Hz shows up in both sets of data. It may be noted that Singh *et al.*[4] estimated the ratio of amplitude of the horizontal components of site 14 with the same component record at the hard-rock site at the Ridge observatory (Figures 1 and 4). As this is different from the H/V ratio, amplification factors cannot be compared directly.

The data set shows that the resonance frequency varies within a short distance in Delhi (Figure 1, Table 1). This could be because of undulations in the basement, causing variations in soil thickness. The soil type also changes from place to place. Near the bank of Yamuna river and on its eastern side, recent alluvial deposits are present and near the ridge old, hilly soil is present[9–11]. This would also affect the resonance frequency.

The resonance frequency is higher near the ridge and lower near the river (Figure 1, Table 1). The basement depth on the other hand, is lower near the ridge and higher near the river[9–11]. Hence the resonance frequency varies inversely with basement depth, as expected. This shows that even if the basement depths were not known, we could have used the variations in resonance frequency to make some inferences.

Amplification of ground motion is more at sites located on soft-soil sites compared to those located on the ridge. Most sites close to the ridge show site response pattern similar to those in areas with very thin soil cover. Whereas most sites close to Yamuna river show clear-cut resonance frequency.

From this preliminary investigation we conclude that a detailed study using microtremor data as well as the available earthquake data should be carried out for Delhi. The resulting information should be compared with available soil profile and basement depth information for a more accurate seismic hazard microzonation of the city.

A comparison of resonance frequency obtained by microtremor data with that estimated from strong motion records at site 14 showed that this parameter was estimated quite accurately, by the former type of data.

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ACKNOWLEDGEMENTS. We thank the Director, CBRI for permission to carry out this work. S.M. thanks AICTE for funding a part of this research work. Constructive comments by the referees helped to improve the quality of the manuscript.

Received 16 June 2001; revised accepted 9 January 2002

Ecology of beach rock fauna of the south Andaman Island, Bay of Bengal

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The late Holocene microfauna from the beach-rock of the south Andaman Island has been investigated. The beach-rock fauna reflects the reefal environment of deposition. The occurrence of raised beaches and terraces has been attributed to the neotectonic activity in recent times. C-14 dates indicate that the Wandoor beach-rock is younger (1540–1350 years B.P.) than the Chidyatapu beach rock (4410–3900 years B.P.) indicating at least two phases of neotectonic activity.

THE Andaman–Nicobar islands in the Bay of Bengal between 6°45′ and 14°N latitudes belong to the tectonically active Arakan Yoma–Java Sumatra ridge (Figure 1 *a*, *b*). Geologically, this region represents a thick pile of marine sediments ranging from Late Mesozoic to Quaternary age[1] and is divided into five lithological units, viz. Porlob, Serpentine, Baratang, Port Blair and Archipelago groups in ascending stratigraphic order[2]. Among these groups, the Archipelago Group was studied extensively for its rich and diverse planktic and smaller benthic foraminifera, radiolarians and nanofossils to record the Miocene, Pliocene and Pleistocene litho-bio-chrono events[3–9]. However, the Holocene sediments have not received much attention despite their bearing on climatic changes of the immediate past, and significance of the sea-level changes and neotectonic activity on the evolution of the coasts. Accordingly, this communication focuses on the hitherto unreported Holocene beach-rock foraminifera of Andaman Island.

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Beach-rock formations are the most common features of the tropical coasts[10]. In India, they occur as discrete pockets all along the coasts of the mainland and Andaman–Nicobar islands[11]. They are medium to coarse grained, soft to moderately hard, buff to brownish-yellow biocalcarenite to calcarenite rock (Figure 2) containing abundant *Nerita* shells. These shell beds at most of the places are horizontal and can be differentiated into lower thinly laminated and upper massive outcrops. They have unconformable relation with the rock formation on which they rest. The average carbon dates of these rocks fall within the range of Holocene period[12–13]. The overall fauna of the beach-rocks of India shows low diversity, fairly good preservation and reflects the transgressive phase characterized by shallow marine conditions. Their occurrence above the average mean sea-level has been attributed to neotectonic activity[14–16] and glacio-eustatic events[17].

In Andaman, alluvium terraces, raised beaches, wave-cut platforms, coral rags, calcareous tuffa and beach-rock are the main constituents of Holocene sediments[2,18,19]. Though the beach-rocks are common along the coasts of Andaman–Nicobar islands, good and workable outcrops are restricted to only south Andaman region (Figure 3). In the present study the fauna, C-14 dates and petrography of rocks from the two outcrop sections, viz. Wandoor and the Chidyatapu (Figure 1 *c*) have been analysed. The Wandoor section is located along the South Andaman coast between a forest jetty and a primary school. The beach-rocks are buff-coloured, medium to coarse grained, moderately soft to highly calcareous, light-weight biocalcarenite to calcarenite and contained minute shells and abundant coral fragments (Figure 4). The embedded shells are highly bored and bryozoan encrustations are common. The C-14 date of the Wandoor beach-rock ranges from 1540 to 1350 years B.P. The Chidyatapu section is located on the eastern side of the reserve forest block near the guest house. Except its thinly-laminated form and its weight due to highly compact nature, it resembles the Wandoor section in all other characteristics (Figure 4). However, the C-14 date (calibrated 4410–3900 years B.P.) reveals that it is older than the Wandoor beach-rocks. In the absence of a formal lithostratigraphic terminology, the authors formally propose Chidyatapu Formation for the beach-rocks after the Chidyatapu locality.

The microfauna was recovered using common H_2O_2 method. In general, the foraminiferal preservation is moderate to fair. The low diversity benthic forms consist of *Borelis schlumbergeri*, *Peneroplis pertusus*, *Sorites orbiculus*, *Amphistegina lessonii*, *Amphistegina gibbosa*, *Amphistegina radiata*, *Quinqueloculina* sp., *Cymbaloporetta bradyi*, *Elphidium crispum*, *E. craticulatum*, *E. advenum*, *Neocorboides* sp., *Pararotalia* sp. A & sp. B. Besides foraminifera it contained fragments of corals, coralline algae, echinoid spines, ostracod and several types of micro-gastropods.

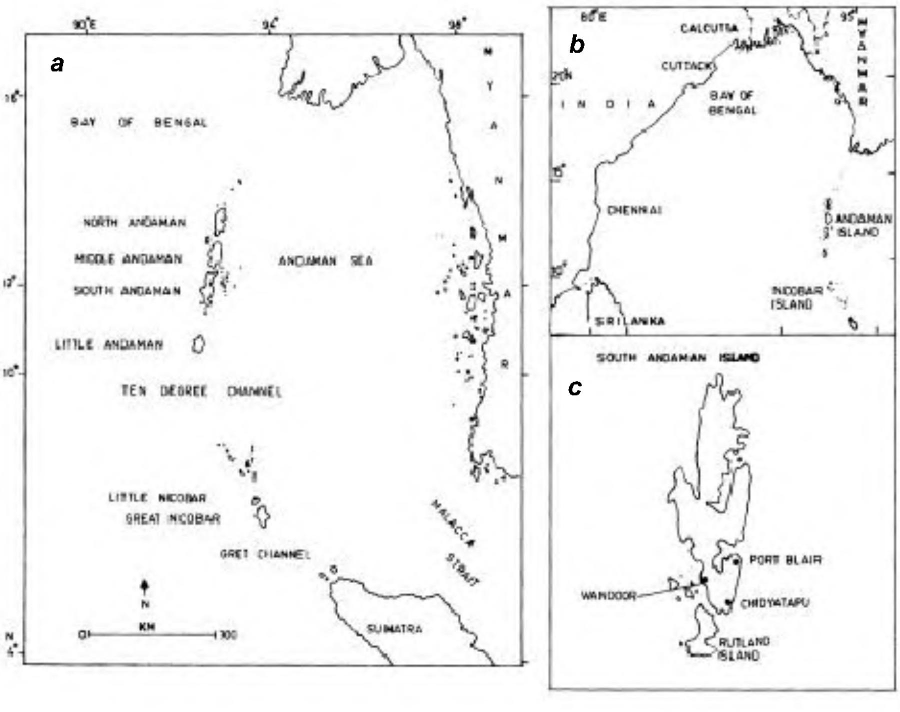

Figure 1. ***a***, Location of Andaman–Nicobar islands with respect to Myanmar and Sumatra; ***b***, location of Andaman–Nicobar islands in the Bay of Bengal with respect to east coast of mainland, India; and ***c***, position of Chidyatapu and Wandoor in south Andaman Island.

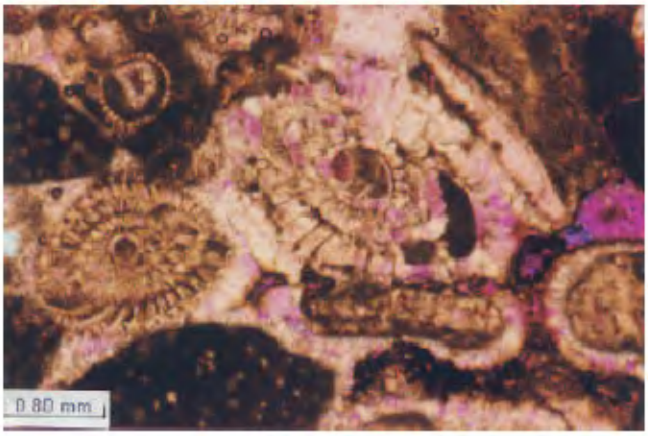

Figure 2. Thin section photomicrograph of beach-rock showing foraminiferal fragments, aragonitic needdles and algal fragments, Chidyatapu section, south Andaman Island.

Figure 3. Beach-rock outcrops at Wandoor during low tide.

The fauna as such is not rich but the occurrence of larger foraminifera is significant because they are the important constituents of the Tethyan Tertiary fauna and their present-day distribution resembles that of the modern corals[20]. Also their symbiotic relationship with the unicellular algae, along with their adaptability to seasonal changes in warm oligotrophic environment[21] made them indispensable in ecological interpretations. The important constituents of the larger foraminifera in the beach-rock are *B. schlumbergeri*, *S. orbiculus*, *A. gibbosa*, *A. lessonii*, *A. radiata* and *P. pertusus* (Figure 5). It may be mentioned here that *S. orbiculus and B. schlumbergeri* are circumtropical cosmopolitan taxa and the latter has not yet been reported from the eutrophic coastal areas around India[21].

As far as larger benthic foraminifera are concerned, the major coral environments, viz. Laccadives, Gulf of Kachchh–Arabian Sea, Krusadi island[22] and Andaman Islands–Bay of Bengal have similar foraminiferal assemblages. These assemblages are also not very different from the other contemporaneous tropical coral environments across the tropics. This corroborates the views expressed by Murray[20] and more recently by Langer and Hottinger[21] and Hoheneggar[23] about the relationship between the larger benthic foraminifera and reefoidal environments.

The occurrence of *A. lessonii*, *A. radiata*, *B. schlumbergeri* and *S. orbiculus* indicates tropical reefoidal environment. Bhattacharjee and Ghosh[24] have reported from an invisible reefoidal ridge off Andaman coast, a rich and varied assemblage consisting of *A. gibbosa*, *A. lessonii*, *Alveolinella quoyi*, *Baculogypsina sperulata*, *Borelis pulchara*, *Calcarina calcar*, *Heterostegina depressa* and *Tinoporus spengleri*.

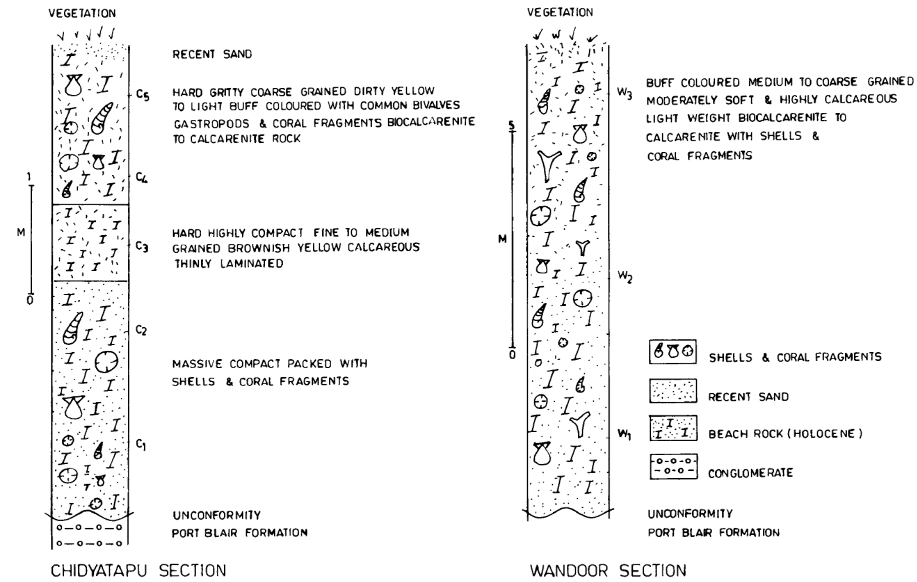

Figure 4. Lithologic column, lithological variation and sample positions of beach-rock at Chidyatapu and Wandoor sections, south Andaman Island.

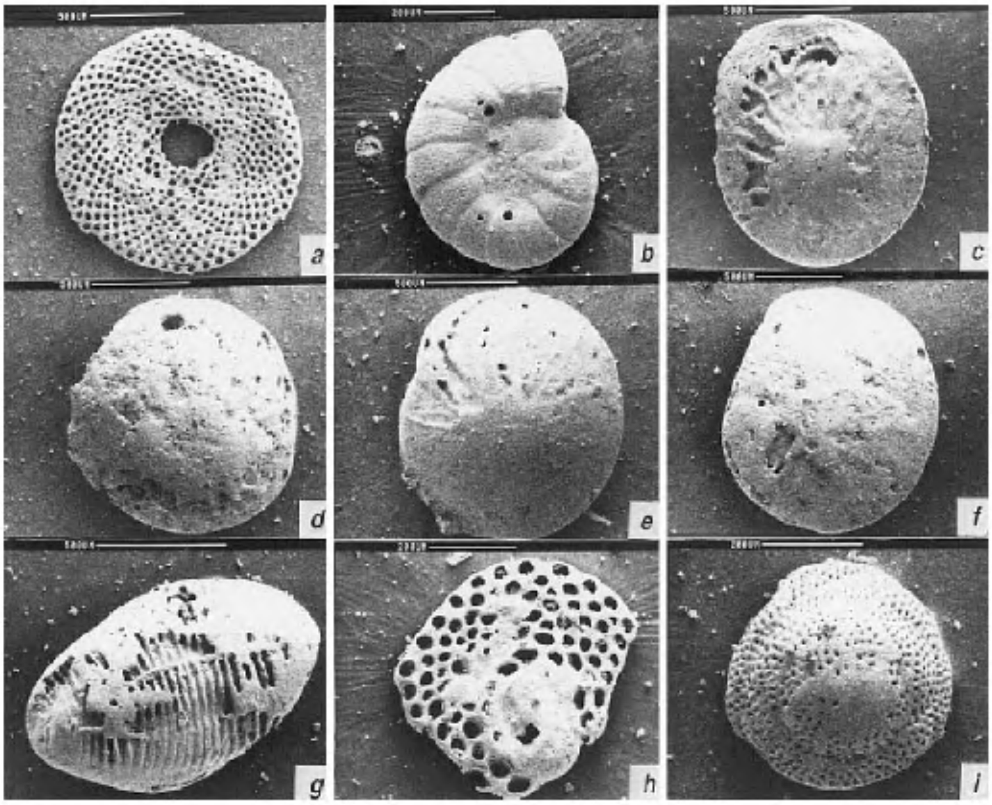

Figure 5. ***a***, ***h***, *Sorites orbiculus*; ***b***, *Peneroplis pertusus*; ***c*** and ***e***, *Amphistegina lessonii*; ***d*** and ***f***, *Amphistegina radiata*; ***g***, *Borelis schlumbergeri*; ***i***, *Cymbaloporetta bradyi*.

Modern biogeographic distribution of larger foraminifera reveals that the aura of core province of tropical Indo-Pacific realm is highly diversified and consists of *Marginulina vertebralis*, *A. radiata*, *A. quoyii*, *Calcarina* sp., *Nummulites venosus* and *Cycloclypeus carpenteri*[21].

Interestingly, two foraminiferal elements of this aura, viz. *A. radiata* and *A. quoyii* are also present in the Andaman assemblage, indicating Indo-Pacific affinity. It may be worth mentioning here that there are some foraminiferal elements which also indicate the tropical Indo-Pacific affinity to east[25] and west coast[26] fauna of the Indian mainland and suggesting free communication of surfacial waters between tropical Indian-Pacific oceans. As mentioned earlier, Srinivasan and coworkers[27–30] have presented a comprehensive foraminiferal study of the Late Cenozoic sequences of Andaman and assigned tropical Indo-Pacific affinity.

Age difference among the beach-rocks of Andaman suggests that the area has been tectonically active during the Late Holocene. At least two phases of neotectonic activity and sea-level change can be inferred. One during 4410–3900 years B.P. and the other during 1540–1350 years B.P. Thus a more systematic study on the age and faunal contents of the beach-rock would enable us to trace the chronology of Holocene neotectonic events and sea-level changes during the Holocene in the Andaman–Nicobar region.

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ACKNOWLEDGEMENTS. We are indebted to Prof. M. S. Srinivasan, Department of Geology, Banaras Hindu University, for critically reviewing the manuscript and also providing valuable suggestions. We are also grateful to Dr V. S. P. Rao, Director, Agharkar Research Institute, for encouragement. C.R. thanks DST (ESS/CA/A3-23/98) for financial assistance and the Conservator of Forests, Andaman, for providing necessary facilities during field work.

Received 20 October 2001; revised accepted 17 January 2002