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Implication of Foraminifera in Tracing the Suitable Site for Palaeo-Tsunami Impressions: A Case Study from Central Tamil Nadu Coast

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Abstract: A total of 44 (forty-four) pre- and post-tsunami surface sediment samples collected from various coastal geomorphic units at the same locations along 35 km long coastal stretch of Central Tamil Nadu coast between Poompuhar and Nagoor were utilized for foraminiferal studies to trace the tsunami signature. A total of twenty-five foraminifera species belonging to eleven genera and eight families have been identified from the study area. While comparing the foraminifera of the pre-tsunami sediments with the post tsunami sediments, it has been observed that in the post tsunami sediments, the total foraminiferal numbers (TFN) have been increased quite significantly along with the occurrences of several new genera and species of foraminifera in the area where the beach width are wide. The present study indicates that the chances of the preservation of tsunami sediments are more in those tsunami affected coastal area where the beach width are wide.

Keywords:*Indian Ocean Tsunami, foraminifera, sediment, coast*

1. Introduction

The 26th December, 2004 mega tsunami in Indian Ocean has caused variable impacts in the different area of the tsunami affected coasts. Such impact of tsunami in the tsunami affected coast is the manifestation of the topography of the seafloor, distance from the tsunami/earthquake regions, magnitude of the earthquake, type of plate displacement, etc[1,2]. The undersea configurations play an important role in enhancing the wave height. Further, reefs, bays and the nature of entrance to rivers help to modify the tsunami waves as it approaches the shore. Such a huge energetic event causes significant changes in the marine environment in general and in coastal region, in particular. However, in order to minimize the loss of life and property caused due to such natural events it is important to increase our understanding of such events to forecast the future trend of the tsunami occurrences. 26th December, 2004 Indian Ocean tsunami has provided a natural laboratory to study such events in the tsunami affected coastal regions utilizing the sediments and associate fauna that was transported and deposited to shore and inland coastal regions. The understandings of such signatures are helpful to infer the past occurrences of tsunami events. Such data may prove invaluable to model the future trends of tsunami occurrences.

The study of these sediments may alter our knowledge on tsunami, its past frequency and magnitude in the different areas of the world. Though, number of researchers has carried out studies on tsunami sediments and the fauna contained within[3,4,5,6,7,8,9,10,11], locating the suitable sites based on our current understanding for Palaeotsunami signature is a challenging task.

The tracing of the tsunami related signature could be possible if we have samples immediately before and after such a catastrophic tsunami event. The comparison of such samples collected from the same location can provide a wealth of information that will go a long way in assessing the Palaeo-tsunami events. In this endeavor, from the large number of sediment samples systematically collected under CSIR- CMRI network project, right from December 2003 to January 2006 along the 35 km long coastal stretch between Poompuhar and Nagoor, a total of forty four surface sediment samples of pre- and post-tsunami events were utilized for present study. The pre-tsunami sediment samples were collected during 16th to 18th December 2004 while post tsunami sediment samples on January 7th, 8th and February 2nd and 19th, 2005, were utilized for foraminiferal studies to infer the tsunami signatures.

2. Study Area

The study area between Poompuhar in the north and Nagoor in the south is a part of the central Tamil Nadu coast (Figure 1a & b). This 35 km long stretch of coastline from Poompuhar to Nagoor is located between 11º08.470’ to 10º48.807’N and 79º51.426’ to 79º51.058’E.

The coastline of the study area is trending in north-south direction and characterized as an emerging coastline[12]. River Cauvery, Nandalar, Thirumalairajanar and Vettar are the major rivers in the region discharging its water in the Bay of Bengal.

The continental shelf in the study area is very narrow and gradually increases from Poompuhar to Nagoor.

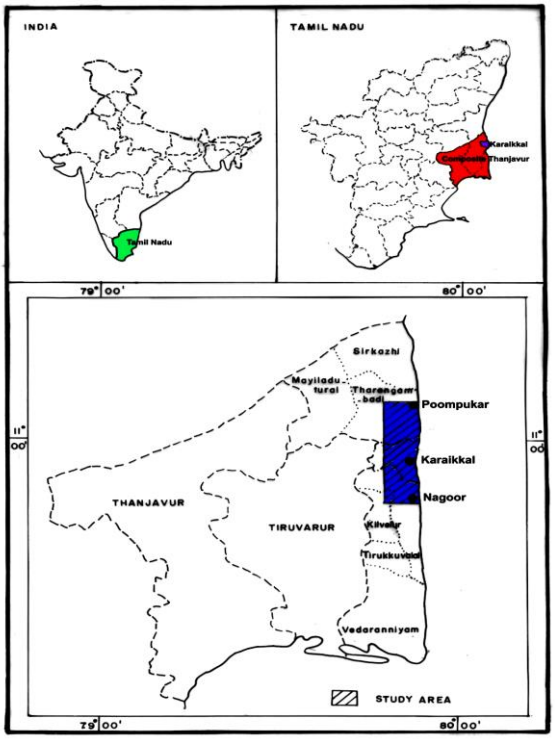

Figure1a. *Location map of the study area*

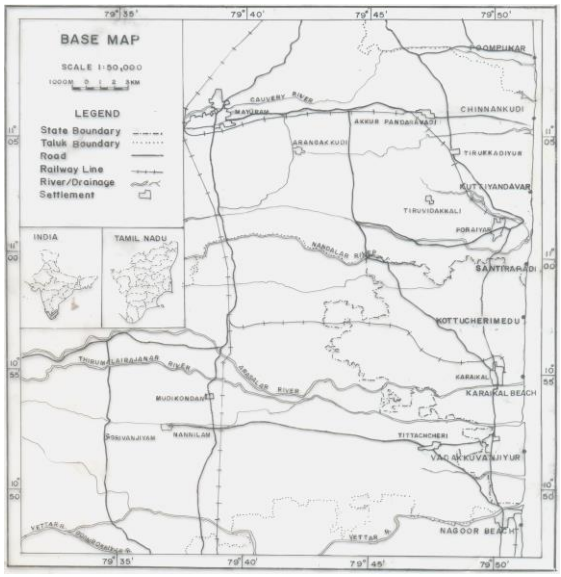

Figure1b. *Base map of the study area*

The current velocity in the month of October to December is 1-2 knots southerly whereas, in February the current direction reverses to northerly and velocity is reduced to 0.5 km.

3. Methodology

From Pre- and Post- tsunami surface sediment samples about 300-400 gram sediments samples at each location were dried in an oven at 60 °C. The dried samples were soaked in water for overnight and then, washed using 63µ sieve under slow water shower in order to avoid foraminiferal breakage. The residue left on the sieve were transferred in the beaker and kept in an oven at 60 °C for drying. From the washed and dried samples, 200 gram sediment samples were weighed and floated in Carbon tetrachloride (CCl_4). In the CCl_4 solution, the lighter foraminifera got floated and the same was decanted using funnel and filter paper. The floating matter in the filter paper was further washed with distilled water using wash bottle and the residue in filter paper were oven dried. The oven dried sample was spread on the picking tray and foraminifera specimens were picked using moist brush under stereo zoom binocular microscope and mounted in 48 chambered foraminiferal slides for detailed studies. The total foraminiferal numbers from each sediment samples were counted and standardized to per 100 grams. All the foraminiferal specimens were identified upto species level. The percentage abundance of all the genera and dominant species for each sample was made. A number of parameters of foraminifera including morphological and compositional parameters were studied and discussed in this paper.

4. Results and Discussion

The foraminiferal content in the coastal regions of the study area is very sparse. A total of twenty five foraminifera species belonging to eleven genera and eight families have been identified from the study area. The presence of foraminiferal species in the sediments of the study area are *Ammonia beccarii, A. infleta, A. sobrina, A. tepida, Amphistegina radiata, Asterorotalia trispinosa, Elphidium crispium, E. discoidale, E. macellum, Elphidium norvangi, Eponides sp., Globigernia bulloides, Nonion scaphum, Nonionoides boueanum, Nonioides elongatum, Quinqueloculina bicarinata, Q. seminulum, Q. venusta, Quinqueloculina sp., Spiroulina antillarium, S. costifera, S. depressa, Spiroloculina sp., Triloculina insignis, T. laevigata.*

A comparative foraminiferal study of the low tide regions of pre- and post-tsunami events points out a drastic reduction in total foraminiferal number (TFN) in the post-tsunami sediments at three stations viz. Kuttiyandiyur, Chandrapadi and Kottucherimedu, while the other three stations viz., Poompuhar, Karaikkal and Vadakkuvanjiyur have recorded an increase of TFN after post tsunami events. However, in the case of Nagoor sediments no much change in TFN were recorded while Chinnankudi sediments were devoid of foraminifera during both pre- and post-tsunami events in low tide regions (Figure 2a). Similarly, in high tide regions, post tsunami sediments have registered a trend of increase in TFN at five stations viz. Poompuhar, Kuttiyandiyur, Chandrapadi, Karaikkal and Vadakkuvanjiyur while a decrease in TFN at Nagoor beach (Figure 3a). Like low tide regions, high tide sediments of Chinnankudi and Kottucherimedu were devoid of forams before and after tsunami events. Out of six stations studied in

berm regions, the sediments in two stations viz. Kottucherimedu and Karaikkal have shown a rise in the foraminifera distribution, while no changes were seen at Vadakkuvanjiyur in foraminiferal numbers. Further, three stations viz. Poompuhar, Kuttiyandiyur and Nagoor were devoid of forams in pre- and post-tsunami events (Figure 4a).

In low tide region the foraminiferal contents were evenly distributed in almost all the locations except at Chinnankudi and Vadakkuvanjiyur regions in pre-tsunami sediments. The maximunm presence of foraminiferal content was observed at Poompuhar with 17 specimens/100 grams followed by Chandrapadi (10 specimens/100 grams), Kottucherimedu and Karaikkal (with 8 specimens/100 grams each) whereas Chinnankudi and Vadakkuvanjiyur showed absence of forams in pre-tsunami samples. In post-tsunami low tide region the maximunm presence of foraminiferal content was observed at Karaikkal with 57 specimens/100 grams followed by Poompuhar (56 specimens/100 grams) and Vadakkavanjiyur where as Chinnankudi sediments was devoid of forams (Figure 2a).

Similarly, the foraminiferal contents in pre-tsunami sediments samples of high tide regions varied from 5 specimens/100 grams at Nagoor to 0 specimens/100 grams at rest of the other places whereas in post-tsunami sediments samples it differ from 1 specimen/100 grams at Nagoor to 5 specimens/ 100 grams in Kuttiuandiyur and Vadakkuvanjiyur, 7 specimen/100 grams at Chandrapadi and 95 specimen/100 grams at Karaikkal whereas 0 specimen/100 gram was observed at Chinnankudi and Kottucherimedu (Figure 3a).

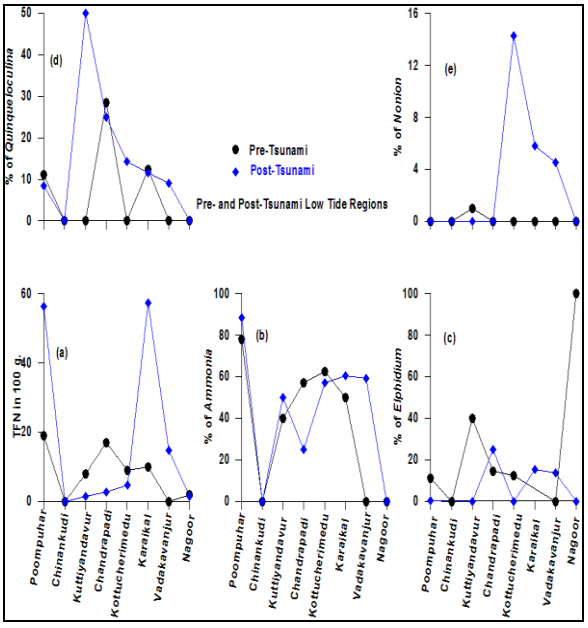

Figure2. *Distribution of (a) total foraminiferal content, (b-e) major genera in the pre- and post-tsunami surface sediments of low tide region between Poompuhar and Nagoor*

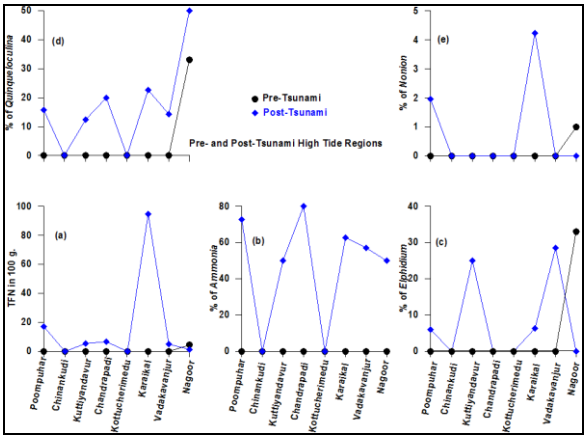

Figure3. *Distribution of (a) total foraminiferal content, (b-e) major genera in the pre- and post-tsunami surface sediments of high tide region between Poompuhar and Nagoor*

In berm regions, foraminiferal content moved from 19 specimens/100 grams at Karaikkal to 0 specimens/100 grams at Poompuhar, Kutiyandiyur and Nagoor in pre-tsunami sediment samples whereas in post tsunami sediment samples it changed from 72 specimens/100 grams at Karaikkal to 0 specimen/100 grams at Poompuhar, Kutiyandiyur and Nagoor (Figure 4a).

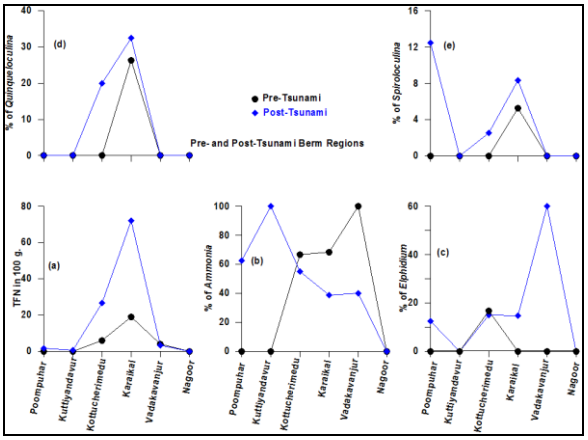

Figure4. *Distribution of (a) total foraminiferal content, (b-e) major genera in the pre- and post-tsunami surface sediments of berm regions between Poompuhar and Nagoor*

The generic and species level investigation of foraminifera in the study area reveals that *Ammonia* is the dominant genera in pre- and post-tsunami sediments followed by *Elphidium, Quinqueloculina, Spiroloculina, Nonion, Asterrotalia,* and *Globigernia* (Figure 2b-e Figure 3b-e Figure 4b-e). While comparing the foraminiferal specimens of pre-tsunami samples with that of post-tsunami samples of exactly the same place, several new genera and species were observed. For example in Poompuhar, the *Ammonia beccarri, Elphidium* and *Quinqueloculina* are the common specimen in both pre- and post-tsunami sediments whereas *Ammonia tepida* and *Spiroloculina* are exclusively noted in the post-tsunami samples of

the low tide regions of Poompuhar. On the other hand Ammonia (*Ammonia beccarri*) is the only common genera noted in pre- and post-tsunami samples of Kottucherimedu. The genera like *Elphidium, Amphistegina, Globegernia* were found to occur in the pre-tsunami samples of Kottucherimedu whereas *Quinqueloculina, Nonion and Asterrotalia* were observed in the post-tsunami low tide sediments at the same place.

At Karaikkal genera like *Ammonia* and *Quinqueloculina* were found to be common in pre- and post-tsunami low tide sediments. However, *Ammonia sobrina* and *Amphistegina* were exclusively present in pre-tsunami sediments whereas *Spiroloculina, Nonion* and *Asterrotalia* are observed in post-tsunami low tide sediments at Karaikkal.

In Vadakkuvanjiyur *Ammonia beccarii, Ammonia tepida, Elphidium, Quinqueloculina and Globegernia* were observed in pre-tsunami low tide sediments whereas *Ammonia beccarii, Ammonia tepida, Elphidium, Quinqueloculina, Spiroloculina and Nonion* were noted in the post tsunami sediments (Figure 2b-e).

Foraminiferal content in low tide regions of Nagoor were observed to be very low with 1 specimen/100 gram in pre-tsunami and post-tsunami sediments. *Elphidium* was the only genera noted in the pre-tsunami samples whereas *Elphidium* and *Quinqueloculina* were noted in the post-tsunami samples of low tide in the Nagoor regions.

The foraminiferal content in the pre-tsunami sediments of high tide regions of the study area were found to be absent except in Nagoor where the foraminiferal content was noticed to be of 5 specimens/100 grams. Further, except in the Chinnankudi the foraminiferal content in the post-tsunami sediments of high tide region were observed at all locations with the maximum presence of total foraminiferal number of 95 specimens/100 grams at Karaikkal. *Ammonia* is the dominant genera in the high tide regions of the post-tsunami samples at Karaikkal. The other genera in the region are *Quinqueloculina, Spiroloculina, Elphidium, Nonion, Asterotalia* and *Globigernia*. The smaller foraminifera such as *Nonion, Ammonia tepida, Ammonia sobrina* were observed in the post tsunami sediment of Karaikkal region. Foraminifers such as *Nonion, Ammonia tepida, Ammonia sobrina, Asterorotalia tepida* are known to live in calm and quiescent environment of deeper regions on muddy substratum. The presence of these specimens in the post-tsunami sediments of high tide regions at Karaikkal clearly revealed the transport of offshore sediments to the high tide regions.

In Poompuhar, the post-tsunami high tide sediments contain moderate foraminifera specimens with the presence of *Ammonia, Quinqueloculina, Elphidium* and *Spiroloculina*.

The post-tsunami sediments from high tide regions of Kuttiyandiyur, Chandiapadi, Vadakkuvanjiyur and Nagoor possess low foraminiferal specimens. The foram content in the post tsunami high tide sediments is marked by the presence of *Ammonia becarri, ammonia sobrina, Ammonia tepida, Elphidium* and *Quinqueloculina*. Chandrapadi sediments contain the presence of *Ammonia beccarii,* whereas at Kuttiyandiyur the presence of *Ammonia beccarii* and *Quinqueloculina* were observed. In Nagoor the foraminifera specimens like *Ammonia tepida* and *Quinqueloculina species were* observed whereas in Kuttiyandiyur *Ammonia beccarii, Elphidium, Quinqueloculina and Spiroloculina* were encountered in the post-tsunami sediments.

In the high tide regions of Nagoor, the presence of *Elphidium, Quinqueloculina and Nonion* of pre-tsunami sediments were replaced by the *Ammonia tepida and Quinqueloculina* in the post tsunami sediments (Figure 3b-e). The absence of foraminifera specimens in the pre-tsunami sediments in the high tide regions may be explained due to selective transport, harsh conditions and low food availability.

The presence of foraminiferal content in pre- and post-tsunami sediment samples of berm regions were noted at Kottucherimedu, Karaikkal and Vadakkuvanjiyur with maximum of 72 specimens/100 grams in the post-tsunami samples of Karaikkal whereas Kuttiyandiyur and Nagoor recorded the absence of foraminifera in the pre- and post-tsunami samples. In Poompuhar the presence of forams like *Ammonia beccarii, Ammonia tepida, Elphidium, Spiroloculina* and *Nonion* are noted only in the post-tsunami samples whereas pre-tsunami samples were marked with the absence of foraminifera (Figure 4b-e).

The presence of forams in appreciable number along with the addition of several new species in post-tsunami sediments in the study area is a definite indicator that forams have been brought from the offshore regions and deposited in the study area. The occurrences of inner shelf species of foraminifera such as *Asterorotalia trispinosa, Ammonia dentate, Ammonia tepida, Amphistegina rediata, Quinqueloculina seminulum, Spiroloculina sp., Nonion sp.,* etc., in the post tsunami sediments of the study area indicate that the sediments have been transported from inner shelf regions. Srinivasalu, et al.[10], while studying the tsunami deposits of northern Tamil Nadu coast observed that nearly 50% of the total foraminifera specimen constitute reworked specimen and they have been transported from 45m water depth. The transportation of foraminiferal assemblages from inner shelf region during tsunami have also been reported by other researchers[7,9,11].

A close look in the beach profiles of the study area[13] indicate that Poompuhar, Karaikkal and Vadakkuvanjiyur have the widest beaches with the

beach width ranging between 75 and 85 meters followed by Chinnankudi with 65 m wide whereas the rest of the beaches are narrow within the range of 50 m. Beaches are the manifestations of the various natural processes of offshore and onshore activities. While examining the foraminiferal contents in light of the beach width along 35 km long coastline of tsunami hit central Tamil Nadu coast, it has been clearly observed high foraminiferal abundance along with several new species in the post tsunami sediments wherever the beach widths are wide such as Poompuhar, Karaikkal and Vadakkuvanjiyur. However, among all the wider beaches Karaikkal beach appears to be suitable for Palaeo-tsunami investigations in the study area.

5. Conclusion

The present distribution of foraminifera along a 35 km coastal stretch between Poompuhar and Nagoor reveals the presence of a total of twenty five foraminifera species belonging to eleven genera and eight families. The presence of forams in appreciable number in post-tsunami sediments in the study area displays a role of offshore regions in transporting the sediments in the study area. Our observations of high foraminiferal abundance along with several new species in the post tsunami sediments at the wider beaches such as Poompuhar, Karaikkal and Vadakkuvanjiyur with the highest abundance of forams at Karaikkal beach clearly demonstrate that the wider beaches are the most suitable site for preservation of the tsunami deposits. The present study reveals that the likelihood chances of preservation of Palaeotsunami deposits in wider beaches are much more compared to the narrower beach sites. Therefore, the wider beaches may be considered to be the suitable site for Palaeotsunami investigations.

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