Tuticorin, Thiruchendur, Marina of Chennai and Kanyakumari during the period of high wave activity in other areas

8 The high wave activity were also reported from the west coast of India and also from Sri Lanka, Andaman and Sumatra regions for the above periods

9 Aftershocks followed by the generation of coastal sea high waves (Seiches) are demonstrably correlatable

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NEED TO INVESTIGATE COASTAL MARINE SEDIMENTS TO STUDY THE IMPACT OF TSUNAMI

This note intends to draw the attention of marine geoscientists towards the potential of coastal marine sediments in understanding the impact of tsunami associated with Sumatra earthquake A series of travelling ocean waves generated by the geological changes near or below the ocean floor create a tsunami The ground surface gets displaced due to tremors underneath The slosh on the ocean floor sets off the tsunami Such displacement sends the water radially outward in circles from the epicenter which gets translated into a deep wave, that travels horizontally at extremely high speeds and attains great heights As the waves approach the shore, they rise further and engulf the coastlines with enormous power (energy) Such high energy waves also recede as quickly as they had surfaced The catastrophic Sumatra earthquake created destructive tsunami waves on the Sunday (December 26, 2004), that devastated coastal areas far and wide

South and Southeast Asia including the southern and eastern coasts of India were hit by massive sea waves reaching up to 30 ft in height The Andaman and Nicobar area (Car Nicobar, Katchel and Campbell island) were severely affected by the tsunami surge This massive surge and the gigantic walls of water smashed into the coast line, washing away every thing in their path This resulted in the inundation of the coastal settlements and a reduction in the beach stretch of the island The back wash must have dragged and eroded sediments from beach/coastal regions

Such a higher energetic event might have caused significant changes in the marine environment in general and of coastal regions in particular Such physico-chemical changes must have been preserved in the coastal marine sediments as well Some reports speculate that bigger and deadlier tsunamis often known as mega-tsunamis occur every 1,00,000 years and the last one occurred around 1,10,000 years ago thereby hinting that another mega tsunami might take place any time in the coming 10,000 years Similarly in a recently published report (*Nature*, 20th January, 2005), it has been warned that there is a possibility of further powerful earthquakes both to the north and south of the event that occurred on 26th December, 2004, perhaps within a decade which may cause another tsunami These speculations do not allow us to feel relaxed

Following Hutton's principle "Present is key to past and past is key to future" the study of the impressions left over by the killing waves (tsunami) on the coastal marine sediments looks significant first to understand In the quest for such signals and information, geological investigations of coastal sediments appear an obvious candidates to be exploited. These sediments may indicate the events of prehistoric tsunamis and may alter our knowledge of the past frequency and magnitude of tsunamis for different areas of the world (Dawson and Shi, 2000). The utility of coastal marine sediments and their microlife as an indicator of complex tsunami flooding has already been established. Dawson et al. (1996) reported that grain size analysis from sediment cores showed pronounced vertical variations in grain size as well as changes in standard deviation, skewness and kurtosis that appear to be indicative of complex tsunami flooding associated with the June 2-3, 1994 tsunami in Rajegwesi regions of Java. These costal sediments which were deposited by Java tsunami showed evidence for sediment transport and deposition and was characterized by dominantly unimodal sediments with fine-tailed distributions.

Similarly, the erosion and sedimentation associated with 17th July, 1998 tsunami in Papua New Guinea, were studied by Gelfenbaum and Jaffe (2003). Within two months of the tsunami, they observed distinct deposits of a layer averaging 8 cm thick of grey sand resting on a brown muddy soil. The tsunami eroded approximately 10-25 cm of sand from the beach and berm. The sandy layer deposited by the tsunami began 50-150 m inland from the shoreline and extended across the coastal plain to within about 40 m of the limit of inundation; a total distance of up to 750 m from the beach. As much as 2/3 of the sand in the deposit originated from offshore.

Having gleaned up the clues from the shell and corals deposits atop 30 meters high headland, sand deposits containing large boulders, shells and corals several kilometers inland, and fields of large imbricated boulders across shore platforms, Nott and Bryant (2001) reported extreme marine inundations (tsunamis?) of coastal western Australia. The size of transported boulders and the altitude of these deposits suggest that tsunamis were responsible for their disposition. On the basis of ^{14}C dates it was suggested that three very large tsunamis must have taken place along this coast during the past millennium. On the other hand, the high energy marine sediments from Livadia and Stavrus, Astypalaea Island, Greece are reported to have possible association with the Southern Aegean tsunami of 9th July 1956 (Dominey-Howes et al. 2000).

Previous studies have also established that the marine microfaunal record in the inland, brackish or estuarine assemblages may indicate a short lived coastal flooding over inland areas near coasts. One classic example of such coastal flooding is reported to have been associated with tsunami linked to the Lisbon earthquake of 1755 (Hindson et al. 1999). Nevertheless, there have been relatively few geological studies of modern tsunamis with virtually no direct observations of the processes associated with tsunami sediment transport and deposition (Dawson and Shi, 2000).

In view of the foregoing account of various signatures preserved and reported from the coastal regions immediately after the tsunami event of 26th December 2004, Department of Ocean Development through the National Centre for Antarctic and Ocean Research, Goa launched the first multidisciplinary oceanographic cruise onboard *ORV Sagar Kanya* dedicated to studies of impact of tsunamis in marine environment from the port of Marmugao (Goa) via Chennai to Andaman and Nicobar Island during cruises SK 216 and SK 217 onboard *ORV Sagar Kanya*. Figure 1 shows the

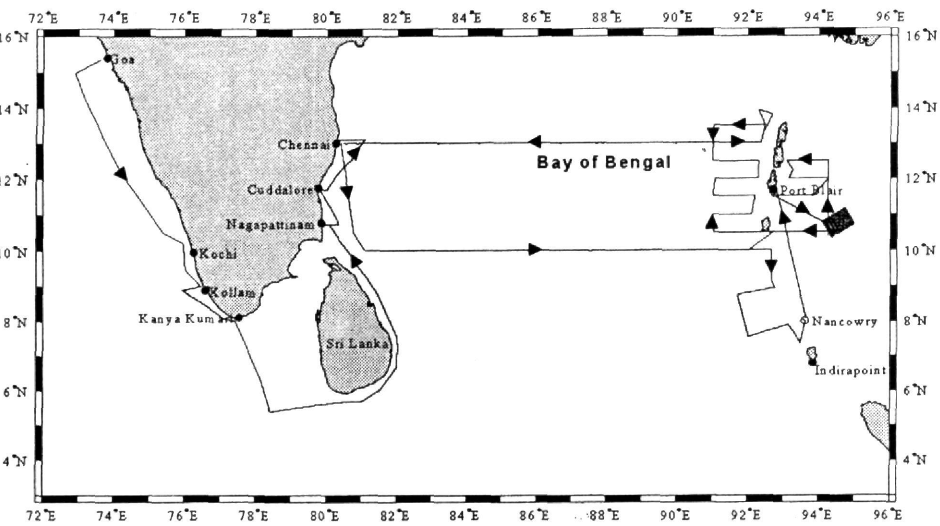

Fig.1. Cruise track.

cruise track. A variety of oceanographic data were collected onboard and a brief report of which has already been published by Murthy (2005).

In the present note, emphasis has been laid on the significance of marine sediments collected in different transects perpendicular to the shore off various coastal states (Fig.2) in assessing the impact of tsunami.

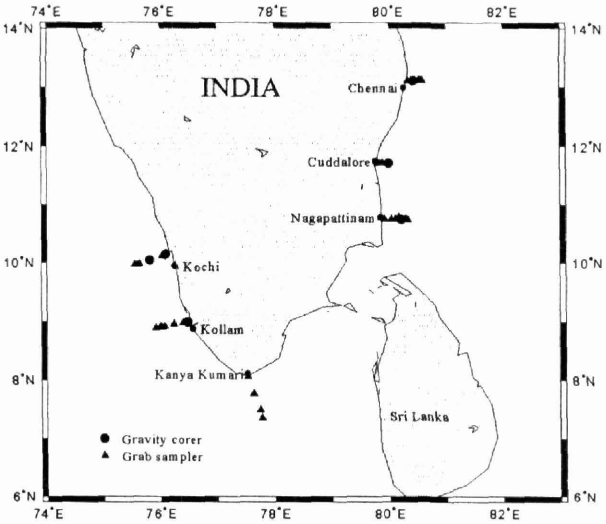

Fig.2. Sediment sample locations collected in different transect perpendicular to the shore off east and west coast of India.

Strategy to study post tsunami impact in marine sediments: In addition to the chemical, physical, biological and hydrological parameters, sedimentological and microfaunal studies of both surface and subsurface sediments need to be analysed along the selected transects shown in Fig.2.

The surficial distribution of sediment texture and the biota therein may reflect either the erosion, or the deposition of back washed eroded beach sediments over much deeper marine sediments. The beach sediments can be easily identified by its own distinct beach fauna (distinct species of foraminifera like Miliolids etc. are found in abundance in beach environment). A reverse situation may also be witnessed where the relatively deeper sediments and associated biota along the transect might have been deposited over shallower costal/near beach sediments after erosion. The marine sediments at different depths have been distinguished by their own distinct characteristics and biota population.

Therefore a detailed sedimentological and foraminiferal/ostracodal studies be undertaken all along these selected transects which would serve our purpose. The coverage of coastal areas right from Cochin to Andaman will also help us to evaluate the relative lessening of the impact which must have been recorded in these marine sediments.

Similarly, subsurface sediments collected all along the transect may reveal the vertical variations in grain size as well as changes in standard deviation, skewness and kurtosis. The sudden/abrupt break in the sediment texture or its faunal assemblages down in the coastal sediment core may imply redeposition of elsewhere eroded sediments. It may perhaps be indicative of complex tsunami flooding. Radiocarbon dating of these sediment cores may also suggest tsunami induced impact. Because, if the core top sediments yield higher ^{14}C ages it would simply imply that the core top is eroded. On the contrary, if ^{14}C dates reveal an inverted sequence it could be assumed that older sediments from other regions have been deposited over younger sediments. Either situation could be linked with the tsunami impact associated with Sumatra earthquake of December 26, 2004. It is significant to highlight that some efforts have already been

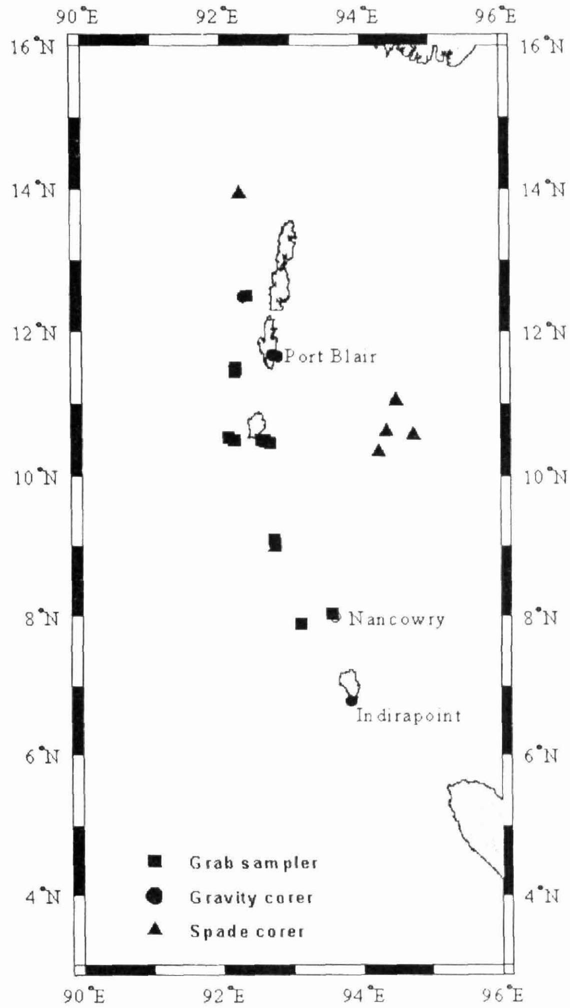

Fig.3. Sediment sample locations collected off Andaman coast and in Andaman Basin.

made to study the signature of paleo storms in sediment cores collected off Gulf of Kachchh (Gujarat) utilizing chronology, sedimentology and micropaleontology of the cores (Chaturvedi, 2000, Nigam and Chaturvedi, *Communicated*)

It is worth mentioning here that soil (sediments) samples collected from the inland (fields) areas lying near the coast line could be another source of vital indication of the impact of tsunami It is expected that strong but short lived coastal flooding due to recent tsunami must have carried marine sediments inland and while receding these marine sediments must have been deposited over the inland fields The examination of these inland soil samples for foraminiferal content (foraminifera are exclusively marine organisms and their presence itself indicate influence/presence of marine sediments) will confirm the impact of such costal flooding and its areal extent The retrieval of vertical sediments peelings from the beach regions may be used as additional tool to decipher and evaluate the tsunami impact by studying its sedimentation sequence and associated characters

Similarly, corals which can only live under water and perish, if the low tide mark recedes or grows, if the low tide mark rises thereby retain a record of the low tide mark Therefore, detailed investigations of the corals all along the west coast of India, witnessing number of active faults may throw light on the changes in average elevation over the past many years Any larger rise could perhaps be associated with past earthquakes

Furthermore, subsurface sediments sequence from the inland regions in the proximity of coast will yield valuable information on the occurrence of similar events in the geological past As a matter of fact, the foraminifera and ostracods available in a late Holocene sedimentary sequence within a fluvial plain in the coastal zone affected by tsunami may reveal a general, though not smooth transition from marine to fluvial conditions or vice versa The relative influence of these two environments is supposed to be dependent on the degree of permeability of the barrier system at the coast Such deposits, containing foraminifera and ostracods will definitely indicate marine conditions, and which contrast markedly with the brackish-water, estuarine assemblages found in the mud deposits The rapid transition in the foraminifera and ostracod assemblages (if any) will indicates a short-lived coastal flooding, which may represent the tsunami's effect of the past

To conclude, it may be reiterated that the detailed scientific (multidisciplinary) investigations of coastal sediments (both offshore and inland) is the need of hour, if we intend to understand post tsunami impacts

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