GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL CHANGES DURING AND AFTER THE DECEMBER-2004 INDIAN OCEAN TSUNAMI NEAR THE VELLAR RIVER AND THE M.G.R. ISLAND AREA OF THE CENTRAL TAMIL NADU COAST, INDIA

S.R. Singarasubramanian[1], M.V. Mukesh[1], K. Manoharan[1], P. Seralathan[2], K.Sujatha[1], and D. Bakkiaraj[1]

1. Department of Earth Sciences, Annamalai University, Annamalainagar, Tamilnadu, India. 608002. laksrs@yahoo.com

2. Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Cochin, Kerala, India 682016

ABSTRACT

The present study reviews geomorphic changes and sediment characteristics in the Vellar river and the M.G.R. island in the Cuddalore District, of Tamilnadu, India, caused by the 26th December, 2004 Indian Ocean Tsunami. The island has an area of about 12,000 m^2 and it is separated from the mainland by a channel. It is bounded to the east by the Vellar River and to the north and south by the Muzhukkuthurai lagoon. A vegetated coastal dune with a length of about 1.5 km protected the island. Tsunami waves ranging in height from 4 to 6 meters breached the dunes, caused erosion and carried debris of destroyed coastal buildings westward to more than 50 m inland. The tsunami run up was up to 1.3 m. Very fine sand with a thickness of one meter filled the Muzhukkuthurai lagoon in the west. Heavy erosion resulted in a steep beach gradient. Sediments transported from the SE and the SSE direction resulted in greater accretion along the intertidal region. The sediment layer exhibited trampled and load structures, indicating deposition by the flooding and receding motion of the water, moving at high velocity. The sediments ranged from fine to medium in size and were well sorted.

Key Words: *2004 Indian Ocean Tsunami, breaching, sedimentation, trampled and load structures.*

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1. INTRODUCTION

Tamilnadu has a coastline of about 1026 kms in length. The coastal zone is one of the most fragile, complex and productive ecosystems. The various geomorphic landforms developed during the Quaternary period register the imprints of past geological processes. A widely varying nature of landforms and their disposition along the beaches and inland represents the successive phases of transgression and regression of sea level. In India, coastal geomorphologic studies have been given new impetus only in the early 1980s, since the advent of aerial photos and remote sensing. In the study area, Loveson and Rajamanickam (1998) have observed an emergence along the Southern Tamilnadu coast. Anbarasu (1994) has given a broad spectrum of evolution of coastal landforms of Northern Tamilnadu. Karikalan (1996) and Karikalan, et. al. (2001a) have studied the heavy mineral assemblages of different quaternary landforms. Coastal geomorphic features of Porto Novo region, Tamilnadu was studied by Karikalan et. al (2001b).

On 26th December 2004, a massive, shallow-focus (10 km) earthquake (epicenter 3° 7'N, 95° 7'E, origin time 6.29 IST) occurred in the seismically active zone along the Sunda Trench, near NW of Sumatra at a depth of about 1300 meters. The earthquake-triggered tsunami waves that begun striking the Tamilnadu coast of India at about 8.45 IST. The waves ranged from 3 to 10m in height.

Most of the geomorphic or sedimentologic studies that have been carried out in the past were on the tsunami sediment deposition along coasts. The majority of the research has been conducted along the coasts of the Pacific Ocean, particularly along the North American coast (e.g. Clague, 1997; Atwater and Moore, 1992; Nichol et. al. 2002). The 26th December 2004, Indian Ocean tsunami inundation and its sediment deposits were studied by Chandrasekaran (2005); Narayan, et. al., (2005); Narayana et. al (2005); Raval (2005); Singarasubramnaian, et. al (2005 & 2006), and others.

The present study describes some of the changes to coastal geomorphic features, such as sand dunes and channels, caused by the destructive tsunami waves. The observed impact included erosion but also inland deposition of new sediments and re-deposition of eroded sediments.

2. STUDY AREA

The study area forms part of Vellar river basin in central Tamilnadu, on the east coast of India. The major land area is called “M.G.R. Tittu” and is bounded by the Bay of Bengal to the east, Vellar to the north and the Muzhukkuthurai lagoon in the south and west. The aerial extent of the island is about 12,000 m^2. The study area is depicted in the Survey of India topo-sheet 58 M/10, which covers the area extending from 79º 45’ to 79º 50’ E, and from 11º 30’ to 11º 27’30” N. (g.1).

3. GEOMORPHOLOGY

The landforms in the study area are primarily of depositional nature, such as deltaic alluvial plains, chenniers, palaeo-lagoonal plains, beach ridges, sand dunes, beaches, palaeo-barriers, palaeo-tidal flats, river mouth bars and natural levees. The Vellar River is ephemeral in nature and flows south easterly at the lower reaches.

4. METHODOLOGY

The coastal geomorphic features were studied by a field survey and use of the topographic maps. The extent of tsunami inundation was determined from high water marks and debris deposits. Trenching, at intervals of 5cm from the top collected sediment samples. Standard sediment size analysis was carried out and statistical parameters were calculated (Folk and Ward, 1957) to deduce the depositional environment.

5. RESULTS AND DISCUSSION

The coastal area between the Vellar estuary and Muzhukkuthurai has prominent, stable sand dunes and ridges 4 to 6 m in height and with a lot of vegetation. The M.G.R. Island, between Vellar and Muzhukkuthurai, is relatively small in size and sustained greater destruction by the tsunami. About 175 people, mostly fishermen, lived in about 80 houses constructed over the crest of the stable palaeo dunes. A long sand dune of about 3m in height protected the island community. There were several more major and stable dunes with vegetation on the island as well as a major coconut tree plantation.

5.1 Post Tsunami changes

A series of three waves from a SE direction begun to strike the coast at about 8.50 IST. The waves devastated the entire island and the adjoining regions. The maximum tsunami run-up height at M.G.R. Island was more than 3m. The waves completely inundated the island, destroyed all homes and killed about 80 people. The Muzhukkuthurai lagoon and Vellar River apparently reduced the extent of tsunami inundation and the intensity of the waves in other banks further inland. At Muzhukkuthurai the extent of flooding ranged from 1,000 to 1,200 meters inland and the maximum tsunami run-up was 1.2 m. Most of the breached or eroded sediments were deposited along the shores of the Muzhukkuthurai lagoon and the Vellar River.

The fore dunes offered coastal protection by reducing tsunami wave velocities and by refracting wave paths. However, they were completely eroded. The waves not only altered the geomorphic features of the island and of the adjoining areas but also brought voluminous sediments from the shelf and the coast. Also the stable palaeo dunes were breached by the waves. Three months after the tsunami sand bars developed in the south with orientation perpendicularly to the coast. This is evidence of changes in local coastal morphology and wave direction caused by the tsunami. Small-elevated land surfaces could also be seen near the mouth of the Vellar River immediately after tsunami (Plate-I), but slowly these became flatter and merged. Complete closure of both the Vellar estuary and the Muzhukkuthurai lagoon inlet were evidence of post tsunami sedimentation. Also, reworked dune sediments were deposited in the Muzhukkuthrai lagoon west of the M.G.R. Island. In the canal, the thickness of the tsunami deposit was about one meter. These changes were evidence of the ferocity of tsunami waves. Near the coast, the thickness of the tsunami deposits varied from 5 to 15 cm. The erosional features were more prominent in the small island. Tsunami waves had eroded the profile of the beaches to a depth of about 120 cm. Tsunami deposits had a buff coloration and could be easily differentiated from normal tidal dune sediments. Trampled structures were prominent over the planar beds (Plate-I). This was indicative that the

sediments were deposited under conditions of high water velocity and turbulence. Their size varied from fine to medium with the phi mean size ranging from 1.567 to 2.3 and the standard deviation from 0.277 to 0.422. This indicates that the sediments were composed mainly of medium, well-sorted sand. Nearly positively skewed sediments were dominant with platykurtic to leptokurtic nature.

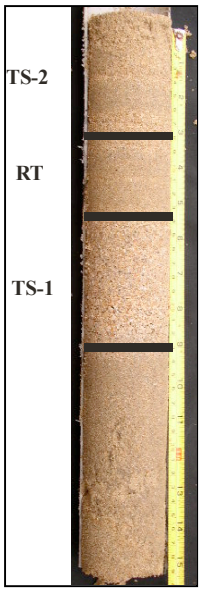
As shown in the core (Fig.1), medium sands were dominant over the fine sands at certain depths. The presence of the fine sands indicates deposition from suspension. Tsunami deposits were well to very well sorted in character. Sands which are normally deposited on portions of beaches within the breaking wave zone, wash continuously thin sheets of sediments which invariably lack admixtures of fine-grained sediments (Friedman and Sanders, 1978). The shelf region normally contains well-sorted river sediments deposited by rivers during the ice age, when the coastal areas emerged. Though the wave action is considered to be responsible for sorting the sediments on the beaches, the dominance of well-sorted sediments is attributed to improvement of uniformity in grain size by the removal of both coarser and finer fractions by strong wave energy. Well to very well sorted sediments in the study region indicated sudden winnowing or back and forth motion by the depositing agent.

Friedman (1961) has attributed that such winnowing action is the reason for positive skewness of beach sands and that such action removes the fine grained particles leading to a back of tail of fine-grained material. Also, predominant positive skewness in size of sediments indicates unidirectional transport (channel flow) or deposition in sheltered, low energy environment (Brambati, 1969). The sediment characteristics in the study area indicated scouring which changed the local bathymetry from 20 to 30 m, i.e. the low energy marine environment where waves cannot interact with seabed sediments. The leptokurtic nature of sediments indicated fluctuation in energy conditions of the depositing medium.

6. CONCLUSIONS

The 26th December, 2004 tsunami event along the Tamilnadu coast brought lot of geomorphic and sedimentological changes. In the study area the tsunami resulted in the breaching of sand dunes, the filling of lagoon, erosion and the loss of numerous lives. It can be concluded from the study that stabilized dunes with vegetation offer some protection to the coast from natural marine disasters like cyclone surges, tsunamis or extreme storm waves. Also that the Vellar river and the Muzhukkuthurai lagoon reduced tsunami inundation and extent of destruction in the inland region. Thus, the coastal morphologies played an important role in protecting the coast and the coastal communities. The particle size analysis in the study area indicates that the sediments that were deposited by the waves of the tsunami inland ranged from fine to medium, well-sorted sands. These deposits showed typical color and textural variations from the normal tidal sediments. Near the estuary they were superimposed over the pre-existing dark carbonaceous estuarine clays. Overall, the deposits exhibited trampled structures over the planar beds which indicates that the tsunami deposition of sediments occurred under high wave velocity conditions.

PLATE- I DESTRUCTIONS BY TSUNAMI WAVES: A- SAND BAR DEPOSITION IN VELLAR ESTUARY; B- SAND BAR DEVELOPMENT IN M.G.R. ISLAND; C- AERIAL VIEW AND ERODED SAND DUNE IN M.G.R.ISLAND; D- WATER RUN-UP HEIGHT (1.2m) IN MUZHUKKUTHURAI; E- STABLE DUNE WITH VEGETATION, PARTIALLY BREACHED; F- ERODED DUNE AND UPROOTED TREES; G- 4' EROSION IN THE SETTLEMENT AREA IN M.G.R.ISLAND; H-HANGING HOUSE AFTER EROSION; I- STABLE CONTINUOUS DUNE WITH VEGETATION, BUT PARTIALLY BREACHED; J- LAYERED SEDIMENTS OVER ESTUARINE CLAY BY TSUNAMI; K- LAYERED SEDIEMENTATION OVER CARBONISED CLAY; L- TRAMPLED STRUCTURE OF TSUNAMI SEDIMENTS OVER MASSIVE DEPOSITS.



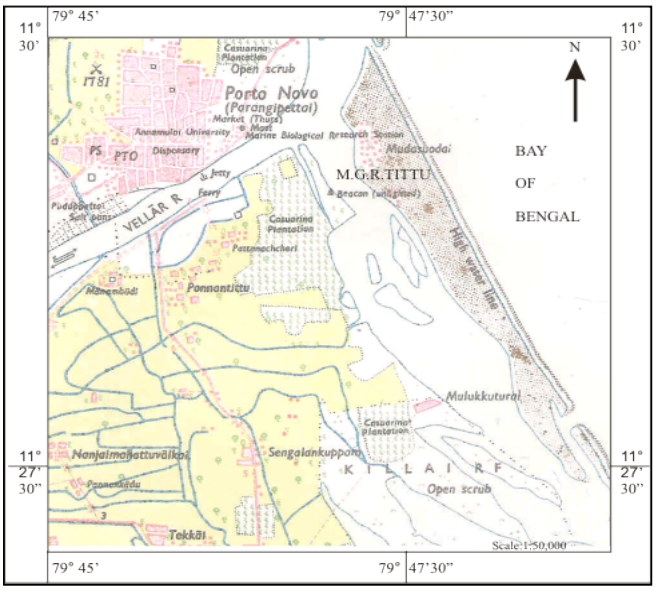


Fig. 1. Core sampled near Vellar

Map 1 Showing study area

TS-1 &2 Tsunamigenic Sediment

RT- Retreating wave deposit.

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