

Shoreline changes along Tamil Nadu coast: A study based on archaeological and coastal dynamics perspective

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Available geophysical survey data confirm submergence of a large area comprising of building complex, which are possible remains of a submerged township. A global sea level rise estimate of 1-2 mm per year would inundate up to several hundred meters of coast line over a period of 2000 years. Shore line changes have been calculated to about 497 m and 380 m at Poompuhar and Tranquebar during the last 75 years. Apart from prevailing waves and currents, past sea level change estimates, tectonic movement induced subduction, erosion from storms and palaeo-tsunamis events, are plausible reasons for the shoreline retreat. It can be said that the coastal erosion due to invasion of sea has played a major role in submergence of these structures. The present paper deals with the shoreline retreat estimates resulting from underwater explorations, past sea level changes and extreme events along the Tamil Nadu coast.

[Keywords: Ancient ports, Tamil Nadu, Maritime Trade, Shoreline changes, submerged structures.]

Introduction

Shoreline is a place where land and sea meets. The shoreline position changes continuously because of long shore sediment movement due to waves, tides, storm surge, etc. Coastlines have played a major role in human settlement since the beginning and continued till today. Several Mesolithic and Neolithic sites are located along the coastal belt of India and also evidences of exploitation of marine resources. The changes in shoreline directly affect the dawn and devolution of civilization along the coast. Archaeologists have long been aware that in the past the coastline had been a focus for man's activities and thus archaeological sites can be one of the most promising indicators of former shorelines, particularly of the late Quaternary period.

Many port towns that existed along the coast lines have played a major role in maritime activity. Ancient literatures across the country refer to the submergence of prosperous cities. The traditions, like submergence of Golden City of the Dwarka mentioned in the Mahabharata, Sangam literature referring to the submergence of Poompuhar and popular belief of submergence of Temples of Mahabalipuram,

'Kumari Kandam' traditions of Tamil Nadu etc., are well known as they are passed down the generation as a local tradition¹.

Tamil Nadu, having more than 906.9 km long coast line played an important role in the trans-oceanic trade from the beginning of the Christian era. The important ports that existed were Arikamedu, Mahabalipuram, Kaveripattinam, Tranquebar, Nagapattinam, Korkai, Alagankulam, and Periyapattinam. The Periplus² has mentioned the ports on Tamil Nadu coast such as Camara, (Kaveripattinam) and Sopatma, (Mamallapuram), had maritime contacts with Roman countries during early centuries of Christian era³. Many such port towns that existed on the coastal region vanished or were submerged in the sea, maybe due to coastal erosion, sea level changes and or neo-tectonic activity.

A few archaeological sites including Mahabalipuram, Poompuhar and Korkai showing direct or indirect connection with shoreline changes have been selected on Tamil Nadu coast and examined in detail with respect to the present shoreline (Fig. 1). The shoreline mapping to quantify erosion and accretion during a span of 41 years at Mahabalipuram, 36 years at Poompuhar and 25 years at Korkai were carried out.

Materials and Methods

Marine archaeological explorations were carried out to find out the submerged structures at Mahabalipuram and Poompuhar region and at Korkai with relevance to maritime trade. The LANDSAT satellite images were downloaded from Global land- cover facility website and used for assessment of geomorphic features of study area. All imageries were geo-coded with UTM projection WGS 84 datum parameters. Processed satellite imagery is used to digitize shorelines. These digitized shorelines were then overlaid for different years to quantify the erosion and accretion at study site. Later, GIS was used to calculate the erosion and accretion.

Results and discussion

Mahabalipuram:

Mahabalipuram, also known as Mamallapuram, is situated about 55 km south of Chennai. It is said to have been a seaport right from the beginning of the Christian era. An 8th century AD Tamil text written by Tirumangai Alwar who described this place as Kadal Mallai³. A few Roman coins of Theodosius (4th century AD) suggest that Mahabalipuram had trade contact with the Roman world around the Christian era. The epigraphical sources mentioned that the Pallava kings were in active contact with Ceylon, China and the Southeast Asian countries.

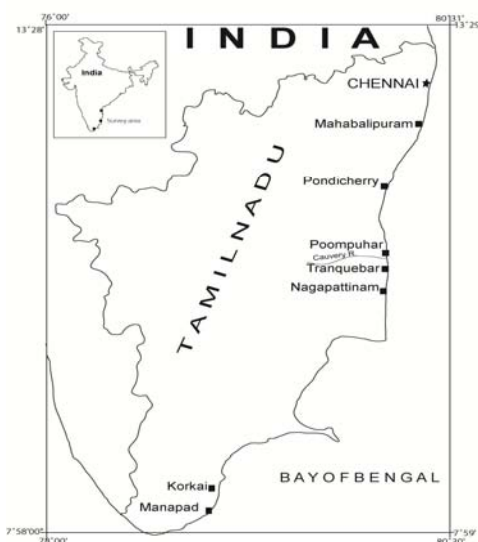


Fig. 1. Map showing the sites selected for underwater explorations on Tamil Nadu coast

Pallava embassy and Vajradanthi, the famous Buddhist monk (who introduced Mahayana Buddhism to Sri Lanka) sailed to China from Mamallapuram port³. Mahabalipuram was well known to earlier mariners as 'Seven Pagodas' since the 17th century. It is generally believed that out of seven temples originally constructed, all have submerged in the sea over a period of time except Shore temple. European travellers in the 18th and 19th century have recorded this folk tradition³. To confirm the popular tradition underwater investigations were carried out at Mahabalipuram.

Table 1: Location details of study area

Sr. No	Name	Location	Length of Coast
1.	Mahabalipuram	80°11'14.86"E 12°35'1.374"N 80°12'57.857"E 12°40'5.814"N 79°51'29.417"E	10 Km
2.	Poompuhar	11°53'31.301"N 79°51'27.332"E 11°9'19.252"N 78°8'17.31"E	10 Km
3.	Korkai	8°35'4.468"N 78°7'39.012"E 8°38'43.408"N	16 Km

Table 2 : Satellite Data information used for Study

Location	Time Span	Satellite ID and Sensor	Duration
Mahabalipuram	1972 - 2013	1972-Landsat 1 – MSS 2013-Landsat 8 – ETM+	41 Years
Poompuhar	1977 - 2013	1977-Landsat 2 – MSS 2013-Landsat 8 – ETM+	36 Years
Korkai	1988 - 2013	1988-Landsat 4 – TM 2013-Landsat 8 – ETM+	25 Years

Geophysical surveys off Mahabalipuram revealed that the seabed is found highly undulating with variations in height from 1 to 6 m between 6 and 15 m water depth. Granitic rocks with patches of coarse-grained sand are found at the sea bottom.

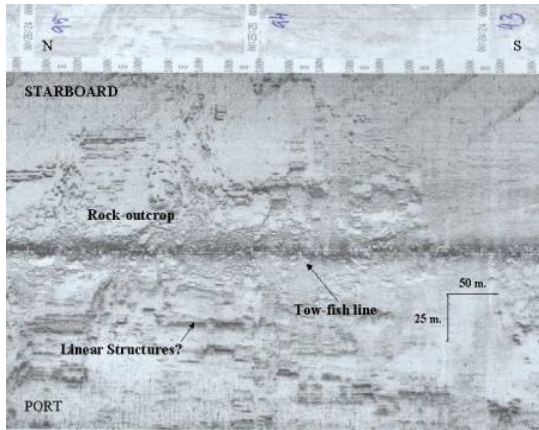


Fig. 2. Side scan sonar image showing the linear structural features in shallow waters off Mahabalipuram.

Several rectangular and square shaped features were observed on the sonographs on the northern part in a systematic pattern. The features are mostly discontinuous, short linearly found parallel to each other. Strong reflections of the images suggest that they are well shaped, massive hard bodies (Fig. 2).



Fig. 3. Dressed granite block having joinery projections were used for the construction of this structure

Among many submerged structures, one big structure was found at about 700 m east of the Shore Temple at 6 m water depth along with several small structures. The upper portion of the structure gets exposed during the low tide. The structure covers an area of approximately 75 x 35 m and has several submerged walls oriented North-south direction. Dressed granite blocks having joinery projections were used for the construction of this structure (Fig. 3).

A wall, measuring ~ 25 m in length and 65 cm in width with two to four courses was noticed. Another wall, measuring ~ 5.40 m in length was seen on the northern side along with two parallel walls on southern side of the main structure with step-like structure leading from down to up. The length of these six walls varies from 7 to 32.5 m. Other walls found in this region were shorter in length. Large-sized square and rectangular blocks were noticed at the middle of the structure, which had a height of 4 m above the seabed. The entire structure has a thick marine growth of sponges, shells, barnacles and mussels.



Fig. 4. Remains of the fallen wall found in Mahabalipuram waters.



Fig. 5. Steps leading to a platform found in Mahabalipuram waters.

Another site was located about 200 m towards NNE of the former structure between 5 and 8 m water depths. The site has remains of wall, dressed stone blocks and the natural boulders.

Some of the stone blocks appear to have figurines carved on them. Identification was however not possible due to thick marine growth. There was a wall of 2 m wide and 5 m in length running E – W direction and many fallen dressed stone blocks found scattered around it. Another wall was found running more than 10 m in length with a width of ~ 2.5 m.

Besides, there were many more structures found in the vicinity which includes fallen walls (Fig. 4), dressed square and rectangular stone blocks, a square platform leading with steps (Fig. 5) and stone figurines etc.

The underwater investigations off Mahabalipuram revealed the presence of submerged fallen and scattered long walls, structures at various locations, large number of dressed stone blocks of rectangular and square type of building materials at several places and perhaps a quarry. Many of them are manmade in nature. Sometimes the extension of these structures can be noticed at least a few hundred meters parallel to the shore at various depths between 5 to 10 m. A few continuous remains of walls have been noticed at all the places. Structures running more than 25 m in length suggest that they are part of some building complex. At several places high platforms and steps leading to platforms are also noticed. It is, however, difficult to determine the layout for all sites as the structures have been badly damaged and are covered with a thick biological growth. *Dating of underwater structures: Ramaswami⁴ refers to several accounts of the Europeans about the submergence of the city and the tradition that 'a large city and 5 magnificent pagodas have been swallowed up at this place by the sea'. Rabe⁵, Chambers⁶, Graham Hancock⁷, Mohan and Rajamanickam⁸ believe that out of seven temples carved out of granite during the 8th century AD only one has survived and the rest have submerged. However, based on the fact that the rock art sculpture was encouraged by the Pallavas at this place, most of the temples were made during that period and therefore dated as 1500 -1200 years BP Subsequent to the 2004 Tsunami, ASI had conducted excavations at two locations at Mahabalipuram. One excavation on the southern side of present shore temple in the beach and the other at Saluvankuppam about 1.5 km north of Mahabalipuram about 150 m from the sea.*

The excavation on the southern side of shore temple revealed the temple remains in the intertidal zone. The excavations at Saluvankuppam revealed three phases of construction belonging to the 8-9th CAD, the 6-8th CAD and the 4th CAD at a depth of 3.2 m below the present ground level. These structures were destroyed by the coastal flooding during 950 AD and between 320 and 560 AD, as evident found from the stratigraphy⁹.



Fig. 6. Terracotta ring well with three rings exposed in the intertidal zone at Poompuhar

Poompuhar:

Poompuhar also known as Kaveripattinam is believed to be the port capital of the Early Cholas, located at the point where the river Kaveri joins the Bay of Bengal. Sangam period texts such as Silappatikaram, Pattinapalai and later ones including Manimekhalai, Ahananaru vividly describes about the port city. Land excavations at Poompuhar brought to light two brick structures, described as Wharves^{10,11} possibly on ancient channel of the river Kaveri. Coastal archaeological explorations revealed a brick structure of eleven courses having 1.2 m width, 1.2 m height and 4 m length parallel to the coast and terracotta ring well with three courses of 25 cm height, 4 cm thickness of rim with a diameter of 75 cm were exposed in the inter tidal zone at Poompuhar (Fig. 6). Four brick structures of 25 m in length, 3.4 m in width aligned in a line were noticed at 1 m water depth off present Cauvery temple. Geophysical surveys revealed several isolated objects as rock boulders at a depth of 7-8 m and 11-13 m between Tranquebar and Nayakankuppam¹²⁻¹⁴. The echograms of the Sub-bottom profiler revealed a submerged palaeo-channel of river Cauvery on the north of Poompuhar at 10 to 15 m water depth, with a

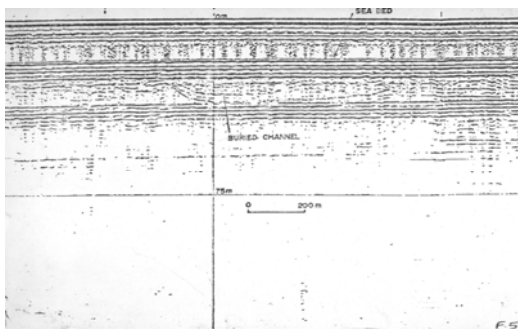


Fig. 7. Echograms of the Sub-bottom profiler reflecting the submerged palaeo-channel of river at 10 to 15 m water depth, at Poompuhar.

width of 300 m to 500 m, buried 20 m below the sea bottom (Fig. 7)¹⁵. The objects identified by

geophysical surveys were later confirmed by diving at different water depths. A few dressed stone blocks, brickbats and early historic pottery of Black and Red ware, Red ware, Buff ware and Grey ware were noticed at 5 to 8 m water depth off the river Cauvery mouth¹⁶.

Three objects found orienting in north-south direction between 22 and 24 m water depth. The first structure was found in a oval shape with a periphery of 140 m located at 23 m water depth with a distance about 5 km from the shore. The height of the object on the outer edge is 3 m while on the inner side maximum height is 1 m. The width of the arm varies from 3 to 6 m. About 40 m north of the oval-shaped object, two small objects of the same material were noticed. These two objects are lying in east-west direction with a distance of 10 m. The circumference of each object is not more than 15 m and their height is about 2 m. They have a maximum height in the centre and edges are sloping. A few blocks are of 2 m in length 1.5 m in breadth and 1 m in height. A few smaller blocks measure 100 X 60 X 20 cm^{15,16}.



Fig. 8. A 11th century AD Yellaiyamman temple has been collapsed and the remains are scattered in the intertidal zone at Vanagiri

Vanagiri

Vanagiri is located on the coast ~ 1 km south of Poompuhar. The 11th century AD Yellaiyamman temple has been collapsed and the remains were scattered in the inter-tidal zone at Vanagiri (Fig. 8). Three terracotta ring wells of 75 cm diameter with 15 cm height and 6 cm thickness of the rim was exposed about 300 m south of Yellaiyamman temple at Vanagiri. A neatly paved floor of a brick structure, probably floor of a house was exposed in the inter-tidal excavation.

Chinnavanagiri:

Chinnavanagiri is located on the coast ~ 3 km south of Poompuhar. A terracotta ring well with a rings of 25 cm height, 5 cm rim thickness and 115 cm diameter surrounded with burnt bricks, associated with megalithic black and red ware and other associated materials like beads of semi-precious stones such as agate, crystal carnelian and varieties of glass and terracotta were noticed in a trench at beach site near Chinnavanagiri. The other important finds from here are inscribed Brahmi 'Ma' on a potsherd an early Chola square coin (completely eroded) and the later Chola coins.

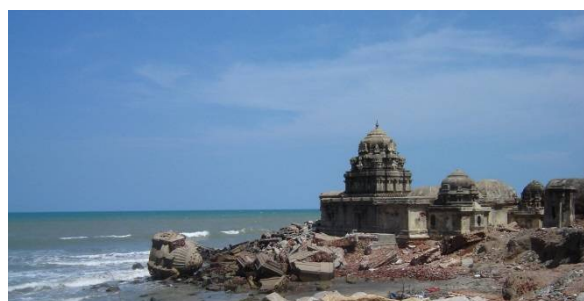
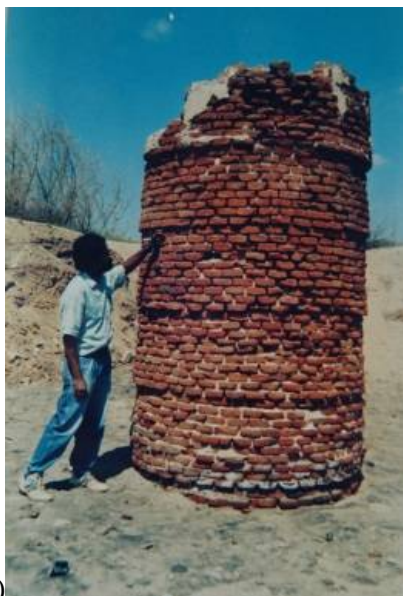


Fig. 9. Partly collapsed Masilamani temple found in the intertidal zone at Tranquebar

Tranquebar

Tranquebar is situated ~15 km south of Poompuhar and has a continuous habitation commencing from the 13 Century AD to till date. It had become a principal port during Dutch and Danish periods. The entire Tranquebar village was well protected by a fort wall including Masilamani temple¹⁷(1305 AD) and Dansberg Castle (16th C AD) with a sufficient distance from the shore line as shown in the map prepared by the Danish rulers in the mid-17th century.

The Masilamani temple is under threat as the sea has destroyed more than 50% of the temple (Fig. 9) and is likely to engulf the entire temple in near future. Two brick wells were completely exposed in the inter-tidal zone and the remains of the fort wall were found in the



(a)



(b)

Fig. 10. Remains of (a) brick well and (b) fort wall exposed in the intertidal zone at Tranquebar (Fig. 10). There are also evidences in Tranquebar about the destruction of modern houses due to the encroachment of sea¹⁸. The coins of Chola, Dutch, and Danish period were collected in inter tidal zone of Tranquebar. Offshore explorations through sonograms and echograms revealed the extension of submerged river valleys of Nandalar and Uppanar¹⁴. Findings of the brick structures, terracotta ringwells, storage jars and the brick paved platforms are the habitation evidences in the intertidal zone. A ring well was excavated near Chinnavanagiri where habitation site was also noticed. The pottery from the site suggests that the ring well can be dated to the 2nd century BC, as one of the potsherds is inscribed in Brahmi 'Ma'.

The other ring wells found at Vanagiri and Poompuhar are of the same period. Similar kind of ring wells found at Arikamedu and Vasavasamudram belong to the 2nd Century BC to the 3rd Century AD¹⁹.

Underwater exploration in shallow water revealed a few well-dressed stone blocks. Airlift operation suggests that habitation site was buried at least 1 m below sediment. The archaeological evidences in inter-tidal zone and offshore at Poompuhar confirmed that they belong to Sangam period (3rd century BC to 3rd century AD) based on the antiquity. Evidences in the inter-tidal zone, hydrographic charts, and the map of the 17th Century at Tranquebar confirm the shoreline recession.

This suggests that about 300 m recession of shoreline occurred in the last 300 years at an average rate of one meter per year. If the same rate was continued for the last 2000 years then definitely ancient Poompuhar must have extended much seaward from the present coast. The relative sea level rise has undoubtedly been taking place on coasts where the land margin is subsiding. It is worth mentioning here that shifting of Kannagi statue for about 150 m land ward from its original place after it was destroyed by the sea during 1994, was said to have been installed during 1973, about 200 m from the high water line which is a clear indication of advancement of sea. Similarly, other monuments also were destroyed in the vicinity by the wave activity.

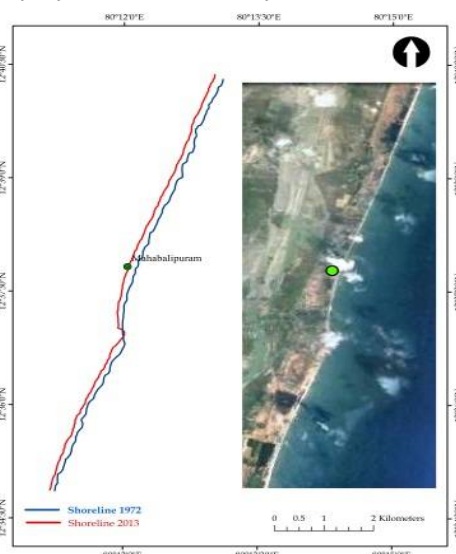


Fig. 11. Fig. showing shoreline changes along Mahabalipuram coast

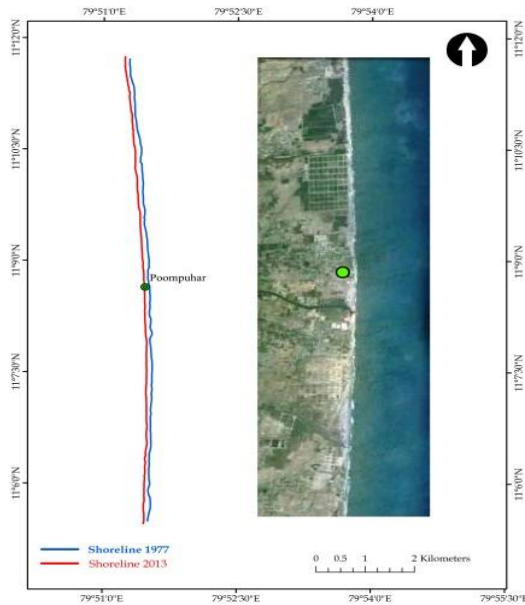


Fig. 12. Fig. showing shoreline changes at Poompuhar coast

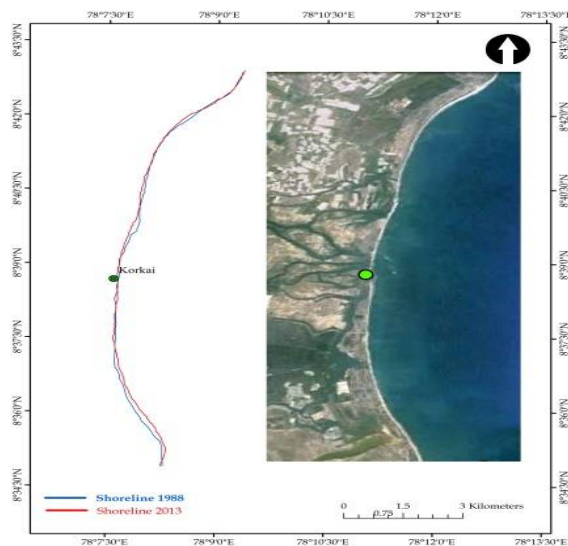


Fig. 13. Fig. showing shoreline changes at Korkai coast

Korkai:

Ancient port of Korkai, was located on the mouth of river Tambraparani, referred in early Sangam literature and mentioned in the notices of the classical geographers²⁰. This was the ancient port capital of Pandya king and had maritime contacts with Mediterranean countries during 3rd Century BC to 3rd Century AD. Korkai was described by Ptolemy²¹, the author of Peryplus of the Erythrean Sea²² about its location on the sea coast. This was an important port for pearl fishery (IAR 1968-69).

McGrindle 1879²² further mentions that “Originally Korkai was situated on the sea coast and later the sea regressed and it was not suitable for carrying out trade”. Presently it is situated about 7 km away from the sea coast. This is the clear indication of shoreline change may be due to accretion. The rate at accretion near Tiruchendur was found at the rate of 0.33 m/y²³.

Accurate demarcation of most erosion susceptible region was done for the study areas. Mahabalipuram had undergone 177 m erosion in the past 41 years (Fig. 11). Poompuhar experienced 129 m erosion in the past 36 years (Fig. 12). Korkai revealed 134 m accretion in the past 25 years (Fig. 13). Detailed description of area under maximum erosion and accretion are mentioned in Table 3:

The erosion on sandy coastlines is due to less sediment supply from the rivers, especially where dams have been built for reservoirs and also due to shifting of river mouths. Subsequently, the sea began to erode the coastline, leading to submergence of several ancient coastal structures of the Poompuhar¹⁸. The response to a possible rise in sea level relative to the land and the possibility of increased storminess in coastal waters, also long duration storms can erode the beach to a considerable extent²⁴. The Bay of Bengal is subjected to a large number of high intensity of cyclones, causing immense amounts of destruction on the coastline. There are more than 30 severe cyclones storms that cross Tamil Nadu coast between 1891 and 2006 (www.imd.gov.in). The narrowness of the eastern continental shelf is also another responsible factor for the coastal erosion. This shelf is about 32 km wide. Wave propagation over a narrow shelf results in low frictional loss of energy and thus expends much energy on the coastline, causing great coastal erosion. The removal of sand from the beaches results in destabilization and destruction of coastal structures. Possible causes of submergence: Geological studies carried out in the water depths between 20 and 30 m in the central eastern continental shelf of India have indicated the evidences of submerged beaches and beach ridges formed during the lowered sea level²⁵⁻²⁷. Srinivasa Rao et al.,²⁸ obtained a radio

carbon date of 8200 yrs for the carbonate sample recovered at 17 m water depth in the Nizamapatnam bay in the east coast of India. Banerjee and Sengupta²⁹ have broadly identified two low sea level stands, one at around 30 m and other at around 100 m depth based on anomalous sediment, geomorphic, Paleontological and geological criteria. However, the shelf of Tamil Nadu coast is believed to have undergone severe tectonic activity and therefore the sea level history in this region is different from the rest of the coast.

Table 3: Geomorphic assessment details of the study area

Study Area	Erosion	Location
Mahabalipuram	177 m	80°12'5.987"E 12°37'49.553"N
Poompuhar	129 m	79°51'28.32"E 11°9'3.005"N
Korkai	-134 m (accretion)	78°89.262"E 8°35'36.992"N

It has been observed that many places, which were along the shore some centuries ago, are now a few miles inland. Coringa, near mouth of Godavari, Kaveripattinam in the Cauvery delta and Korkai on the coast of Tinnevely, were all flourishing seaports about 1000–2000 years ago but are now defunct due to siltation or erosion. Their present position some distance inland may be attributed to the gradual growth of deltas of the rivers. Similarly on the Tinnevely coast, in the Valinokkam bay, a submerged forest has been noticed, with numerous tree trunks of about 0.6 m diameter at the base, getting exposed at low tide over a bed of black clay containing oyster and other marine shells, a clear indication of earlier prevalence of marine environment³⁰.

The study of LANDSAT satellite images of Mahabalipuram for the past 41 years indicates the shoreline changes to about 177 m and 129 m for the last 36 years at Poompuhar. Korkai revealed 134 m accretion during the last 25 years. Comparison with the Indian Naval hydrographic Charts (Nos. 3006 and 3007) surveyed during 1963 and 1993 indicates that 150–200 m erosion noticed during the last 30 years and the erosion is still continuing between

Poompuhar and Nagapattinam³¹. Recent studies on beach measurements also indicate the severe erosion on the northern side of Masilamani temple³².

The manmade structures along Tamil Nadu coast are prone to erosion³³. Ramaiyan et al³⁴ documented coastal erosion at Poompuhar and Tranquebar at the rate of 3.44 m/year and at Mahabalipuram 0.55 m/yr. Recent analysis based on comparative study of the topographic sheets, the erosion at Chavadikuppam near Poompuhar was observed 497 m for the last 75 years is almost at the rate of 6.6 m/y and at Tranquebar 380 m for 75 years is at the rate of 5.0 m/y^{35,36}. Observed the rate of erosion at Poompuhar 0.15 m/y, Tranquebar 0.65 m/y and at Nagapattinam 1.8 m/y, whereas maximum rate of erosion on Tamil Nadu coast was observed to about 6.6 m/y²³.

The universally accepted sea level rise is 1–2 mm per year. A rise in 1 mm per year could cause a shoreline recession of 0.5 m per year³⁷. Heavy storms including severe monsoons and cyclones cause maximum erosion. This is because these produce high and steep waves which up rush and often break the dunes or coastal platforms and erode the coastline. Sea level / shoreline changes and Tectonic history of the region: This aspect is very critical in determining the dates of the structures. The sea level has fluctuated between 2 and 6 m about 2–3 times during mid-Holocene period on both the coasts of India³⁸. The sea level fluctuation of about was documented on the East Coast of India for the last 5000 years³⁹.

In continuation of general background on history of sea level changes Krishnan⁴⁰, Mohapatra and Prasad⁴¹ pointed out that the major and important factor affecting Mahabalipuram coast is erosion. Severe erosion at Kalpakkam, south of Mahabalipuram due to long shore sediment drift has also been reported⁴¹. A recent study suggests the rate of coastal erosion in and around Mahabalipuram is 55 cm/yr³⁴. If the same rate has prevailed since last 1500 years, then shoreline at that time might have been around 800 m eastward and all the structures noticed underwater would have been on the land. If the rate of coastal erosion derived for Poompuhar, located 125 km to south, are applied for Mahabalipuram, then the

structures at -5 to -8 m must have been on the land at ~1500 year BP¹⁸. Interestingly, due to construction of semi-circular breakwater recently, the shoreline over a stretch of 3 km towards north of Shore Temple experiences accelerated erosion⁴².

There is an evidence of the tectonic activity around Mahabalipuram during early Quaternary period⁴³. However, there is no evidence of tectonic activity on the coast during last 1200 years BP as shore temple has not been affected⁴¹.

The references cited clearly indicate the violent fluctuations in the sea levels / shoreline in last few thousand years and clear trend of changing shoreline at many places on the Tamil Nadu coast. From the above discussion, the coastal erosion has played a major role in submergence at Mahabalipuram, Poompuhar, Tranquebar, Nagapattinam and sea level changes might have played a contributory role. The sediment deposit causes accretion at Korkai, which was supposed to be on the sea coast, is found about 7 km inland from the coast.

Conclusions

Poompuhar and Mahabalipuram were flourished port towns and had maritime activities with the outside world including Rome, China, Ceylone and South East Asian countries. The marine archaeological exploration off Poompuhar and Mahabalipuram brought to light remains of ancient settlement submerged underwater and the traditions mentioning the submergence of these towns, have been partially confirmed. The coastal monuments at Mahabalipuram, Poompuhar, Vanagiri, Tranquebar etc along the Tamil Nadu coast are partly submerged due to coastal erosion. The archaeological evidences in the intertidal zone have confirmed that they belong to the medieval period. Evidences in the intertidal zone, topographic charts and the map of the 17th Century at Tranquebar confirm the shoreline advancement. The relative sea level rise has undoubtedly been taking place on coasts where the land margin is subsiding or sediment transport is prevalent. Coastal archaeological monuments/sites on the coastal region are always under threat either due to erosion or accretion, but those are the direct evidences to determine the shore line changes with exact time frame.

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