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Time and causes of submergence of ancient temple structures off Mahabalipuram, East Coast of India

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As per traditional belief, some part of the ancient town of Mahabalipuram had been submerged just off the shore temple and this story has been recorded by the several British travelers during the 18th – 19th century. During the underwater exploration of Mahabalipuram area in 2017, three sites along with a large number of scattered dressed stones were found in the intertidal zone. Calcareous material grown over these stone structures after their submergence in seawater was subjected to radiocarbon (^{14}C) dating to infer submergence time-periods of these structures. Submergence date for the site I is the late 14th century CE; whereas the submergence date from the site II comes ~ 1st century CE. According to the water-depths from where the studied structural remains were excavated, and obtained ^{14}C dates of submergence, it could be surmised that these stone-structures off Mahabalipuram town were submerged in two phases. The submergence might have been induced by natural events such as coastal cyclone activity or Tsunami that flushed off sand around these structures and raised the sea-levels locally over the coast.

[**Keywords**: Coastal erosion, Cyclone/Tsunami, Marine growth, Radiocarbon dates, Sea level change, Submerged structures]

Introduction

The small town of Mahabalipuram (lat. 12°36'43" N; long 80°12'14" E) is situated about 55 km south of Chennai between the Buckingham canal and the Bay of Bengal. The name of the city is spelt in various forms such as Mahabalipuram, Mahavellipur, Mavallipuram, Mamalaipuram, Mamallapuram, and Mallapuram[1]. However, in the present communication, the name Mahabalipuram was adopted and is used throughout. Though, the Mahabalipuram town belongs to the Pallava dynasty of Indian history from ~ 275 to ~ 900 CE and is famous for the art and architecture created during the Pallava period. But archaeological investigations and literary evidence push back the history of Mahabalipuram to the early centuries of the Christian era, for instance, Princep[2], described two Roman coins found from Mahabalipuram dating to 379 – 395 CE as this coin belongs to Emperor Theodosius. Mahabalipuram as an early historic port town has been referred in ancient texts such as *Perumpanarruppatai*[3] where the coast has been described as, "one can see within the limits of Nirppeyarru, a harbour full of ships carrying horses from western countries and merchandise from northern countries, a street full of store-houses of rich mariners and a lighthouse in a highly elevated place as if it was a prop to Heaven etc. Mahabalipuram was a famous sea-port with a number of ships busy in foreign trade on an extensive scale.

Chambers[4] establishes the veracity of the Mahabalipuram town and quotes "Some account of the sculptures and ruins at Mavalipuram (Mahabalipuram), a place few miles north of Sadras, and known to seamen by the name of seven Pagodas". He wrote on the traditional folk as "The natives of the place declared to the writer of this account, that the more aged people among them remembered to have seen the tops of several Pagodas for out in the sea, which being covered with copper (probably gilt) were particularly visible at sunrise, as their shining surface used then to reflect the sun's rays, but that now that effect was no longer produced, as the copper had since become incrusted mould and verdigris". The present paper deals with the archaeological findings off Mahabalipuram. The study focuses on the understanding of time and causes of the submergence of archaeological structures in Mahabalipuram waters.

Materials and Methods

Coastal outline of Mahabalipuram

The shoreline at Mahabalipuram is characteristically oriented NE-SW. River Palar joins the sea on the southern side of Mahabalipuram. The

geomorphic feature, the backwaters, the Buckingham canal-about 5 km west of the Mahabalipuram, with outlets at Covelong on the north and Kalpakkam in the south are significant. In the near-shore zone off Mahabalipuram, the seabed is uneven with rocky outcrops of granitic boulders with occasional sand patches, and it gradually slopes down towards the east. There is a shoal called Tripalur reef, which is in the form of submerged rocks[5]. At some places, the top of the reef gets exposed during the lowest low tide.

An important question could be addressed by investigation of coastal marine realm off present-day Mahabalipuram town as to what happened to the Mahabalipuram town and its rich culture in the course of time (Fig. 1). Recent (2017) underwater archaeological investigations in this area, found submerged man-made structures in a water depth of 4 to 9 m. The marine grown calcareous material was used for ^{14}C dating to assess timing and possible causes of submergence of these ancient structures of Mahabalipuram area.

Radiocarbon dating of marine-grown carbonate deposits

For obtaining chronological control using ^{14}C dating, calcareous materials deposited on stone blocks (during their emersion in seawater) were scratched out from the respective sites. These scratched carbonate material were quite dirty and hence cleaned with deionized water, sonicated and treated with mild (1 %) HCL and then thoroughly washed with deionized water again. Acid cleaned shells were then treated with mild H_2O_2 solution and then dried (Fig. 2). Thus thoroughly cleaned shell material was then acid-hydrolyzed and subjected to ^{14}C radiometric dating (using Beta counting in Liquid Scintillation Counter). Measured ^{14}C contents were corrected for fractionation using stable carbon isotopic fractionation measured as $\delta^{13}C = -25.0$ ‰. Corrected ^{14}C activity in samples for the ^{14}C activity of wood grown in 1950 provides the radiocarbon age[6]. These radiocarbon ages were then converted to calendar ages using online software OxCal v 4.1.7[(ref. 7)] that utilizes the IntCal13 dataset[8]. Obtained radiocarbon ages and corresponding calendar ages are presented in Table 1.

Results

The coastal and underwater explorations off Mahabalipuram have been undertaken from the north and the south and about 800 m east of the shore

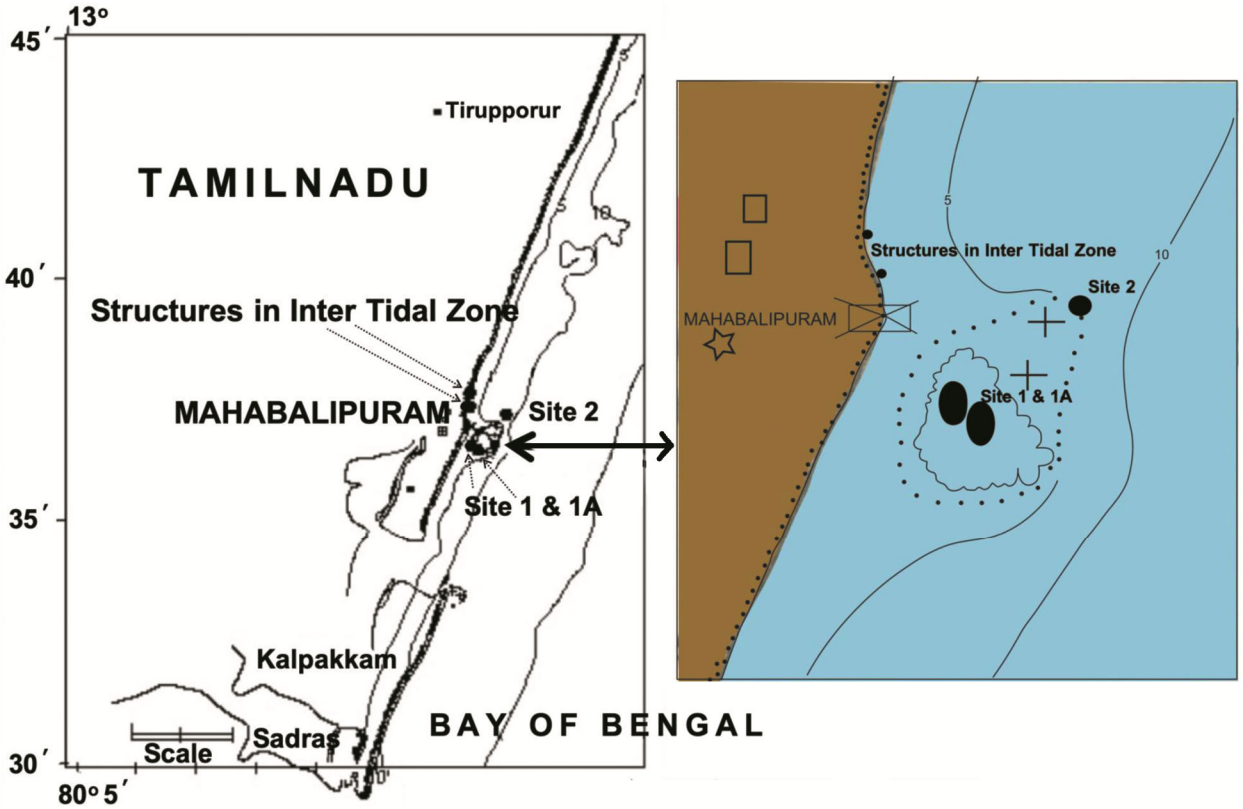

Fig. 1 — Location of underwater archaeological sites off Mahabalipuram

temple. The archaeological findings have been recorded between the intertidal zone and 9 m water with a major concentration at 3 – 6 m water depth. Based on exploration, the entire area is sub-divided into four zones. A detailed description of archaeological findings from each zone is provided herewith.

1. Intertidal zone

The archaeological explorations along the Mahabalipuram coast have yielded a few stone structures to the north of the shore temples. The structural remains include a wall running for about 6 m perpendicular to the shore (Fig. 3a), a few more walls with a shorter length. The average width of these walls is approximately 0.5 m. These structures are partially buried in sediments. The construction pattern of the structure is fascinating as two rectangular blocks (measures 1.8×0.4 m) are parallel erected vertically (lesser height side) and packed with a perpendicular smaller block which is supposed to help in maintaining the width of the wall and then filled with smaller stones. The stones have been fixed in such a way with grooves that they hold the entire structure without any binding material, and it is interesting to note that in the construction of temples at Mahabalipuram, no binding material had been used. Further south, a few scattered blocks were exposed during low tide which appeared to had been fallen from some another structure.

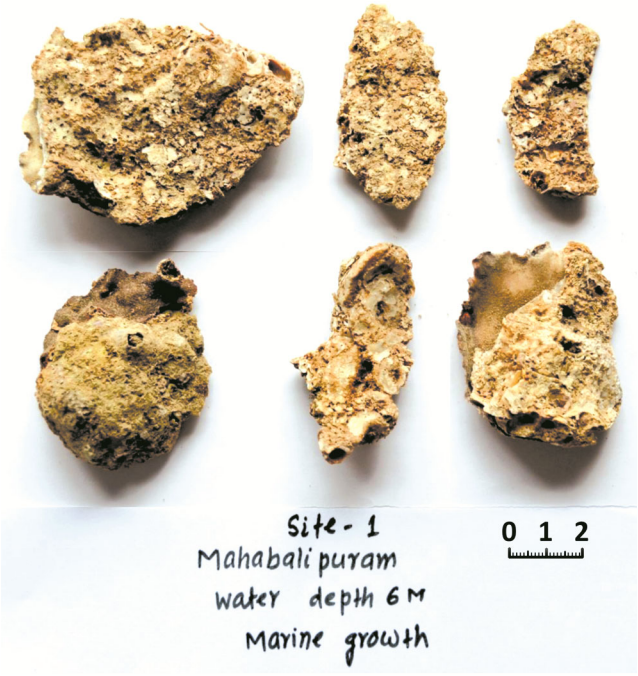

Fig. 2 — Shell samples collected from the structures for Radiocarbon dating

Underwater zone 1

The area of investigation is lying about ~ 500 m east of shore temple. Further east, very close to this location, there were four large reefs where waves are breaking and partially exposing these reefs during low tide. The underwater topography of the area is comprised of undulating seabed with several stone blocks scattered over a large area. These stone blocks are probably part of a larger structure. Besides manmade (submerged) structures there are numerous loose stones which might have fallen from the surrounding reefs are also observed. Due to the presence of the reef in this vicinity, the growth of barnacle shells is noticed in the entire area. Besides barnacles, the growth of other prominent marine species including bryozoans, polychaeates, corals, and algae were also observed.

Underwater zone 1a

The site is situated about ~ 50 m north of site 1 and the same distance from the southeastern reef. The water depth ranges from ~ 3 to 7 m. The entire site is spread over about 30×50 m and the south of the site is fenced with natural rock, which appeared to anthropogenically modified as steps like features could be noticed on it (Fig. 3c). The most important feature of the site was two long walls and smaller walls. A brief description of these walls is given below.

Wall 1: This wall was ~ 20 m long and the width of the wall is ~ 1 m. At the beginning of the wall platform like structure was observed which measures 4×4 m, and then in the middle of this structure

Table 1 — Radiocarbon dates from the samples of Mahabalipuram

Sl. No.	Lab no.	Water depth	^{14}C date (±1σ standard deviation)	Mean calibrated ages (±1σ [Marine calibration data set: marine13.14c]	Calibrated age range (with 2δ uncertainty; 95% confidence level)
1	BS 4005	6 m	980±70 yrs BP	1398±78 CE	1291 – 1502 CE
2	BS 4006	6 m	510±90 yrs BP	1825±103 CE	1679 – 1950 CE
3	BS 4007	9 m	2330±80 yrs BP	35±52 AD	170 BCE – 244 CE

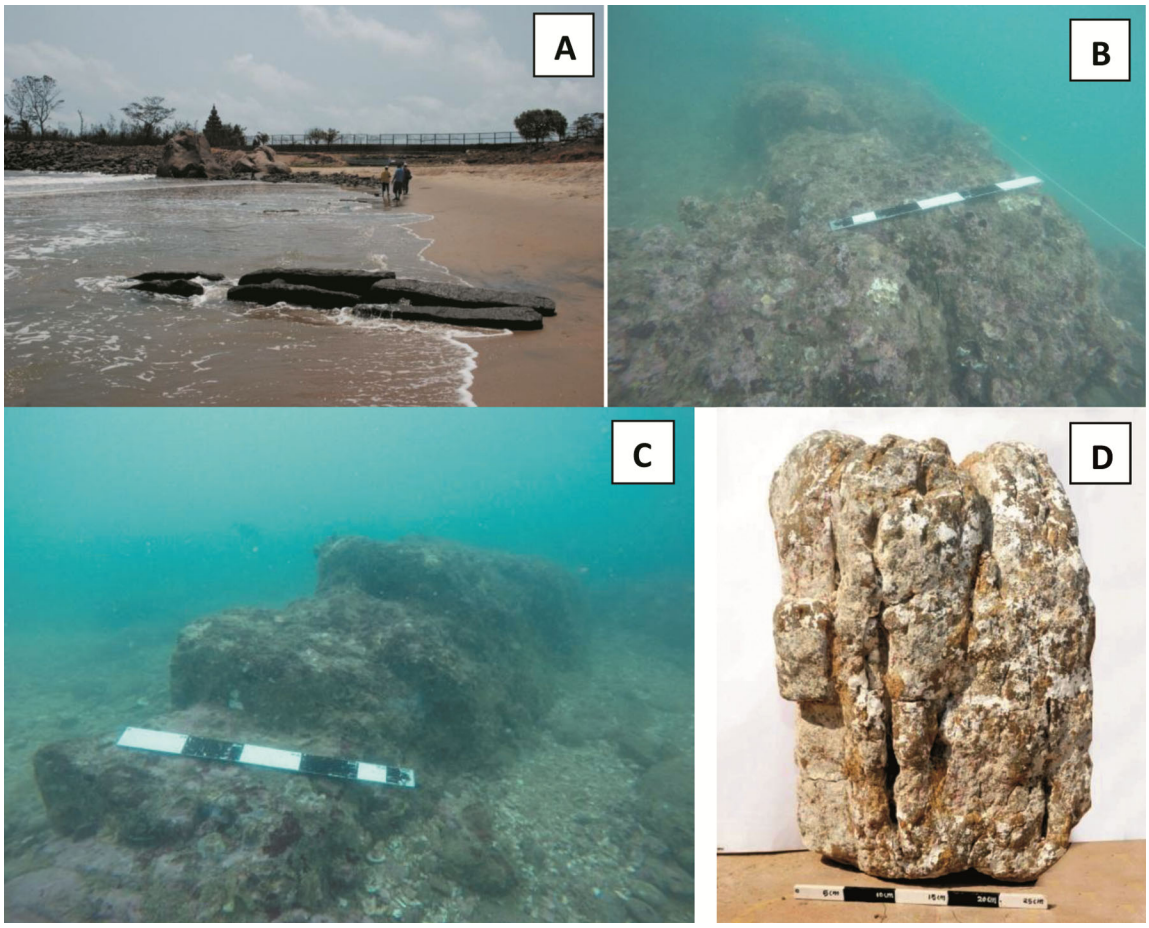

Fig. 3 — A) Stone structures exposed during low tide, B) Foundation of wall extending a few meters found in 6 m water depth, C) Steeped wall was observed in a water depth of 6 m, and D) An eroded sculpture recovered from 6 m water depth

(Fig. 3b), the wall commences which is made of large-sized blocks measuring about 1×0.5 m, and at few places the wall has been collapsed and blocks are scattered. As has been described earlier, these blocks were also covered with thick marine growth.

Wall 2: This wall was ~ 40 m long and the width was between 0.5 to 0.7 m and it was constructed with smaller blocks. The height of the wall was not uniform. Maximum height could be said to be ~ 0.70 m. A few stone blocks were observed with cut-marks.

Other structures

As earlier mentioned, a platform type of structure was noticed along with a few large sized blocks. At ~ 10 m distance, a cluster of the large-sized blocks (around twenty in number) were found to be lying, sizes of which were over 1×1 m. These blocks could be the part of a bigger structure. One of the structures appeared to be humpy bull (*Nandi)*, due to thick marine growth its recognition was difficult though.

Sculptural remains

In the course of the underwater investigation between zones 1 and 2, a large number of the small stone blocks were also seen, they were just scattered around and many of them appeared halfway-finished (Fig. 3d) sculptures. The small corridor of this area was filled with sand and large numbers of stone blocks were found to be covered under the sediments. Observational evidences indicate that this archaeological site could be the remains of some ancient temple complex.

2. Underwater zone 2

The area of investigation is lying about 500 m north of the reef area. The water depth varies between 6 and 9 m. At a few places, the natural rocks are as high as 3 m. This area too has undulating seabed with some big natural stones, archaeological remains are however clearly distinguishable. The site is spread over approximately 70×20 m, there are square and rectangular blocks and few

measuring 1×0.5 m, and few of them are bigger in size and also smaller.

Radiocarbon dates

A total of three samples of marine growth (barnacles) were retrieved from architectural stones recovered from different sites and analyzed for radiometric ^{14}C dating at BSIP Lucknow. Obtained radiocarbon ages were corrected for a marine reservoir age correction and calibrated using Calib7.1 program which used marine calibration data set: marine13.14c[8] and marine reservoir age correction factor $\Delta R = 32+20$ year for all three samples. Table 1 shows the radiocarbon and calibrated ages of these samples.

Discussion

The underwater exploration off Mahabalipuram opens the need for understanding the causes of submergence of coastal monuments. Submerged structures of Mahabalipuram may be contemporary to the monuments surviving on the land of Mahabalipuram, *i.e*., the Pallava period[9]. Archaeological remains off Mahabalipuram were found to be scattered in a relatively vast area (~ 500 m off Shore temple) where four reefs were visible during the low tide. Also a smaller site was found ~ 500 m north of the former site. An attempt is made to understand past conditions that led submergence of stone structures off Mahabalipuram under the following heads.

i. Construction pattern

A careful observation of the underwater archaeological remains off Mahabalipuram particularly from site 1 and 1a suggests that they have been made of well-dressed stone blocks. As expected, the bigger main structures are made of large-sized blocks whereas smaller walls were made of small blocks with loose stone used for filling the middle portion of the walls. A close observation of the construction pattern of the shore temple and the remains of the excavated temple on the shore revealed that they are very similar to those found underwater.

Following similarities between shore temple and submerged structures were observed.

a. Large sized granite blocks used for the construction of main structures.

b. Plain and rectangular stone blocks were used for the construction of mid-structure (above the platform and below the *Sikhara*).

c. The construction pattern and use of raw material in the form of locally available granite stone has been remarkably similar in all coastal structures in Mahabalipuram.

Interestingly, no binding material (mortar) in structural temples of Mahabalipuram appears to have been used and submerged structures were also devoid of any binding material. The construction was based on the interlocking of the stones with each other, and the same can be noticed in structures observed at intertidal zone as no marine growth was observed on them.

ii. Identification of the structures

Archaeologically, the most common antiquity found in any ancient habitation site right from the Neolithic age is pottery, which is absent in the case of findings from Mahabalipuram. Hence, the possibility of residential usage of these structures should be ruled out. Being located in the sub-tidal region, the second possibility could be that these structures represent remains of an ancient port or harbour. This is also unlikely as no anchors or other related antiquities were found to corroborate that these structures were part of ancient jetty or harbour[10,11]. Taken together, the likely interpretation about the usage of these structures is these could be remains of a religious complex (temple). The presence of a humped bull shaped structure supports this possibility. A few sculptural remains near these structures which might have fallen from the main structure also tend to support aforesaid contention. The similarity in construction-pattern between underwater and shore temple also lends support to the possibility that these structures could be remains of the ancient temple(s).

Radiocarbon dates of the submergence of structures

A popular story was noted during the present underwater investigation by interaction with local guides and elder citizens of the area that in the 14th century CE, Vijayanagara King Parangusa shifted the temple to the current location fearing destruction due to high sea waves.

The groups of the temple remains (both rock-cuts and structures of temples) of Mahabalipuram have been earlier dated to the Pallava period (from 7th CE to early 9th CE)[12]. It has been suggested earlier that underwater structures under discussion might have been constructed during the Pallava period (late 7th to the early 8th century CE)[9]. Hence a likely time-bracket

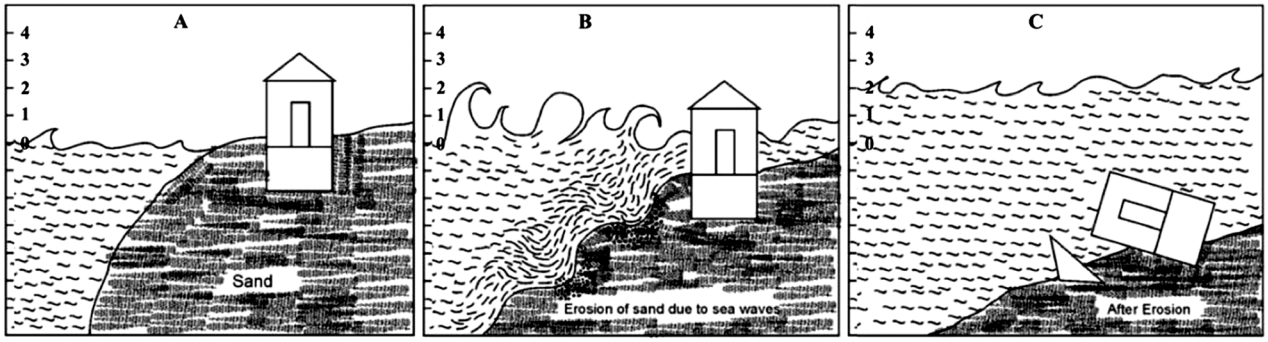

Fig. 4 — Schematic representation of the process of submergence of the structures. A) Temple structure constructed on shore, B) Removal of sand around temple during storm/Cyclone, and C) Structure collapsed and submerged in the sea

for submergence of these structures could be between the 9th to 17th century CE.

Three samples of marine growth were extracted from the structures and were dated by the radiocarbon method (see Table 1). The sample obtained from site I in a water depth of 4 – 6 m yielded the date 1398±78 CE which indicates that the site was already underwater by this time range and closely corresponding to the expected time-bracket. The second ^{14}C date (1825±103 CE) indicates continuation of these structures underwater till 19th century. The third ^{14}C date, however, from the site II located slightly deeper (~ 9 m) produced a relatively older age (35±52 BCE). This ^{14}C date suggests there may have been an older site also that might have submerged off Mahabalipuram. Morphological features of this site (site 2) were distinctly different from site 1 and 1a. Hence, it is likely that the remains of site 2 represent architecture of older period and during that period Mahabalipuram was an early historic port town[3].

Probable causes of the submergence

a. Coastal erosion

Coastal erosion owing to its multi-faceted impacts has been one of the major factors for people living in the coastal areas[13,14] and the destruction of coastal monuments and archaeological sites over the period of history[15,16]. Earlier studies[17,18] along the Tamil Nadu coast, particularly at Poompuhar and Tranquebar indicated the destruction of archaeological sites during the past 2000 years or so. As per one estimate, an average erosion of 0.55 m/yr, the shoreline ~ 1500 years ago must have been about 800 m seaward of the present coastline[19]. It is, therefore, likely to speculate that structures now offshore must have been onshore ~ 1000 years ago.

The present shore temple was considered as under-threat from coastal erosion and to protect it an enclosure of granite boulder on the sea front was placed. This protection saved the monument from further damage mainly from the recent Tsunami in the year 2004. The land excavation within and outside the forecourt of the shore temple indicated that the lowermost foundation of the temple is ~ 2.5 to 3 m below the base of *Garbhagriha* (Sanctum area). Thus, the lowermost foundation is below the high-end of the present waterline. If shore-protection is taken off, the lower part of the temple would be underwater. Therefore, coastal erosion led by extreme events will pose a finite possibility of submergence of these ancient remains. The schematic picture drawn (Fig. 4) suggests that originally temple may have been built over an exposed area which may be 1 – 2 m above the sea level (Fig. 4a). Due to extreme events shoreline could be eroded exposing the ancient temple complex to withering action of sea waves. Semi-exposed structures close to the present waterline are prone to sinking due to liquefaction[20] of sand below and around the temple complex (Fig. 4b), which ultimately destroyed the temple and sank in the sea (Fig. 4c).

It has to be noted that, amidst climate change possibility of enhanced (both in strength and number) extreme events in terms of monsoonal furry as well as cyclonic storm-surges along the east coast of India have been projected. Our underwater archaeological excavations off Mahabalipuram town strongly caution strength and type of damages plausible.

b. Sea level fluctuation

Sea level changes along the coastline also present potential threat for coastal life. From an archaeological point of view, however, we do not anticipate sea level change was a probable cause as

glacio-eustatic sea levels are known to have reached its present level around ~ 6000 Cal yrs BP[21]. Minor fluctuations (~ 2 – 6 m) in sea level have been recorded after mid-Holocene at some places[22], but it is unlikely that sea level change could be possible cause of the submergence of ancient temple structures off Mahabalipuram.

Conclusion

The European travelers in the 18th and 19th centuries provided descriptive information of Mahabalipuram. The underwater archaeological explorations revealed the presence of a large number of stone structures in the vast area just off shore temple in a water depth of ~ 4 – 7 m. These structural remains include running walls and scattered stone blocks. These structures appear to be the remains of the ancient temple structure. Macro-morphological observations of the structures from underwater and shore temple suggest that both have close similarity, therefore, the similar age-bracket was submitted for both, belonging to Pallava dynasty period (7th – 8th century CE).

Heavy coastal invasion of seawaters induced by natural extreme events *e.g.* storm surges and cyclone led high waves might have been responsible for the submergence of these structures. Though, the role of moderate sea level rise also could have played a role in the submergence of these structures, however this scenario is considered to be less probable. As cyclonic storm-surges and extreme monsoonal events are expected to enhance in the ongoing global warming scenario, deeper understanding of probable causes of submergence of ancient structures along the shoreline can provide a magnitude of damage done by these natural hazards. Tropical storms are seasonal (hinged to monsoonal variability), yet highly unpredictable. It is a distinct possibility that the severity of cyclone storms would enhance with continued atmospheric warming (due to energized atmospheric circulations). Recognizing and documenting historical and pre-historical pieces of evidences of coastal damage patterns (such as in this study) can help to identify vulnerable zones and better preparedness in case of such upcoming natural disasters.

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Conflict of Interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Author Contributions

ASG & Sundaresh were involved in over all research work including fieldwork, data collection and paper writing. RA did radiocarbon dating and also helped in finalizing the manuscript. PM was associated during the field work and helped in collecting data and provided underwater photographs. SJ contributed during the writing of manuscript through discussion on coastal erosion and BRT was involved in entire field work.

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