

## **Time and Causes of Submergence of ancient temple structures off Mahabalipuram, East Coast of India**

**A.S. Gaur<sup>1\*</sup>, Sundaresh<sup>1</sup>, Rajesh Agnihotri<sup>2</sup>, Pramod Maurya<sup>1</sup>  
S. Jayakumar<sup>1</sup> and B.R. Thorat<sup>1</sup>**

1. CSIR National Institute of Oceanography, Dona Paula, Goa
2. Birbal Sahani Institute of Palaeosciences, Lucknow

\*Email: [asgaur@nio.org](mailto:asgaur@nio.org)

### **Abstract**

As per traditional belief, some part of the ancient town of Mahabalipuram had been submerged just off the Shore Temple and this oral story was recorded by the several British travellers during the 18<sup>th</sup>-19<sup>th</sup> century. During the present underwater exploration of the Mahabalipuram area (lat 12°36'43" N; long 80°12'14"), three sites along with a large number of scattered dressed stones were found in the intertidal zone. Calcareous materials grown over these stone structures after their submergence in seawater were subjected to radiocarbon (<sup>14</sup>C) dating. Using obtained <sup>14</sup>C dates, we infer submergence time-periods of these structures. The submergence date for the site I is the late 14<sup>th</sup> century CE; whereas the submergence date from site II comes ~1<sup>st</sup> century CE. According to the water-depths from where studied structural remains were excavated and obtained <sup>14</sup>C dates of submergence, it could be surmised that these stone-structures off Mahabalipuram town were submerged in two phases and the submergence might have induced by natural events such as coastal cyclone activity or Tsunami, that flushed off sand around these structures and rose sea-levels locally over the coast.

**Keywords:** Submerged structures; Radiocarbon dates; Sea level change; Cyclone/Tsunami; Coastal erosion, Marine Growth

## **Introduction**

The small town of Mahabalipuram 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 (Crole, 1879). However, in the present communication, we adopt the name Mahabalipuram and use it 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, Prinsep (1832) 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 *Perumpanarrupatai*, 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.

William Chambers (1869) 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 incrustated mould and verdigris". Though the initial research on Mahabalipuram initiated about two decades earlier (Sundaresh et. al, 2004), however the present paper deals with the archaeological findings off Mahabalipuram during the underwater survey undertaken in 2017 and samples for radiocarbon dates have been analyzed. The study focuses on the understanding of time and causes of the submergence of archaeological structures in Mahabalipuram waters.

## **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 (Foote, 1869). At some places, the top of the reef gets exposed during the lowest low tide.

What happened to the Mahabalipuram town and its rich culture with time? This important question could be addressed by investigation of the coastal marine realm off present-day Mahabalipuram town (Fig.1). We recently (in 2017) carried out underwater archaeological investigations in this area, found submerged man-made structures in a water depth of 4 to 9 m. Underwater investigations include diving, underwater photography and various measurements of the submerged structures. We collected three marine grown calcareous material from 6 to 9 m water depth for  $^{14}\text{C}$  dating to assess the timing and then to analyse probable causes of submergence of these ancient structures of the Mahabalipuram area.

### **Radiocarbon dating of marine-grown carbonate deposits**

For obtaining chronological control using  $^{14}\text{C}$  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  $\text{H}_2\text{O}_2$  solution and then dried. Thus thoroughly cleaned shell material were then acid-hydrolyzed and subjected to  $^{14}\text{C}$  radiometric dating (using Beta counting in Liquid Scintillation Counter). Measured  $^{14}\text{C}$  contents were corrected for fractionation using stable carbon isotopic fractionation measured as  $\delta^{13}\text{C} = -25.0\%$ . Corrected  $^{14}\text{C}$  activity in samples for the  $^{14}\text{C}$  activity of wood grown in 1950 provides the radiocarbon age (Stuiver and Polach, 1977). These radiocarbon ages were then converted to calendar ages using online software OxCal v 4.1.7 (Bronk, 2010) that utilizes the IntCal13 dataset (Reimer, 2013). 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 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 on the north of the Shore temples. The structural remains include a wall running for about 6 m perpendicular to the shore (Figure 2a) 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  $1.8 \times 0.4$  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 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.

### **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 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, Polychaeten, corals, and algae was 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  $30 \text{ m} \times 50 \text{ m}$  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. 2c). The most important feature of the site was two long walls and smaller walls. A brief description of these walls is as follow.

**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  $4 \text{ m} \times 4 \text{ m}$ , and then in the middle of this structure (Figure 2b), the wall commences which is made of large-sized blocks measuring about  $1 \text{ m} \times 0.5 \text{ m}$ ., and a 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 a ~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 (Figure 2d) 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 evidence 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 site was identified based on the information provided by the Geophysical surveys in 2003 (NIO Technical Report). 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 <sup>14</sup>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 (Reimer, et al., 2013) and marine reservoir age correction factor  $\Delta R = 32 \pm 20$  year for all three samples. Table 1 shows the radiocarbon and calibrated ages of these samples.

**Table 1.** Radiocarbon dates from the samples of Mahabalipuram.

Sl. No.	Lab no.	Water depth	<sup>14</sup> C date (±1σ standard deviation)	Mean calibrated ages (±1σ) [Marine calibration data set: marine13.14c]	Calibrated Age range (with 2σ 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

## Discussions

The underwater exploration off Mahabalipuram opens up 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 (Sundaresh et al., 2004). 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. We attempt 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. The 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 were observed between shore temple and submerged structures.

- 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 the structures observed in the 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 (Gaur and Vora, 2007 and Gaur et al., 2019). 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 hump bull shaped structure supports this possibility. 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 an 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 older citizens of the area that in the 14<sup>th</sup> century CE, Vijayanagara King Parangusa shifted the temple to the current location fearing destruction due to high sea waves.

The groups of the temple remain (both rock-cuts and structures of temples) of Mahabalipuram have been earlier dated to the Pallava period (from 7<sup>th</sup> CE to early 9<sup>th</sup> CE) (Srinivasan, 1985). Based on that, it has been suggested earlier that underwater structures under discussion might have been constructed during the Pallava period (late 7<sup>th</sup> to the early 8<sup>th</sup> century CE) (Sundaresh et al., 2004). Hence a likely time-bracket for submergence of these structures could be between the 9<sup>th</sup> to 17<sup>th</sup> century CE.

In order to get some reliable dates it was consider appropriate to obtain some radiocarbon dateable material from submerged structure. 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  $1398 \pm 78$  CE indicates that the site was already underwater by this time range and closely corresponding to the expected time-bracket. The second  $^{14}\text{C}$  date ( $1825 \pm 103$  CE) indicates a continuation of these structures underwater till 19<sup>th</sup> century. The third  $^{14}\text{C}$  date, however, from the site II located slightly deeper (~9 m) produced a relatively older age ( $35 \pm 52$  BCE). This  $^{14}\text{C}$  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 the architecture of the older period and during that period Mahabalipuram was an early historic port town (Aiyangar, 1928).

### **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 (Srinivasan et al., 2017 and Kankara et al., 2018) and the destruction of coastal monuments and archaeological sites over the period of history (Gaur et al., 2007, Gaur and Sundaresh, 2014). Earlier studies (Sundaresh et al., 2014 and Sundaresh, et al., 2017) along the Tamilnadu 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 (Ramaiyan, 1997). 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 seafront 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 drawn (Figure 3) suggests that the originally temple may have been built over an exposed area which maybe 1-2 m above the sea level (Figure 3a). Due to extreme events shoreline could be eroded exposing the ancient temple complex to withering action sea waves. Semi-exposed structures close to the present waterline are prone to sinking due to liquefaction (Khan-Mozahedy, 2015) of sand below and around the temple complex (Figure 3b), which ultimately destroyed the temple and sank in the sea (Figure 3c).

It has to be noted that, amidst planet-warming led climate change possibility of enhancement (both in strength and number) of extreme events in terms of monsoonal fury 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 a potential threat for coastal life. From the 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 (Goswami et al., 2019). Minor fluctuations (~2-6 m) in sea level have been recorded after mid-Holocene at some places (Merh, 1992), but it is unlikely that sea-level change could be a probable cause of the submergence of ancient temple structures off Mahabalipuram.

## **Conclusive remarks**

The European travellers in the 18<sup>th</sup> and 19<sup>th</sup> 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, 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 suggests that both have close similarity, therefore, we submit similar age-bracket for both belonging to Pallava dynasty period (7<sup>th</sup>-8<sup>th</sup> 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, we surmise this scenario to be less probable. As cyclonic storm-surges and extreme monsoonal events are expected to enhance in the ongoing global warming scenario, a deeper understanding of probable causes of submergence of ancient structures along the shoreline of important Indian business centres 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 evidence 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.

## **Acknowledgements**

The authors are thankful to the Director CSIR-National Institute of Oceanography, Goa for encouragement and permission to publish this paper. Colleagues from the marine archaeology centre acknowledged for their help during the preparation of the manuscript. This is NIO's contribution number.....

### **Conflict of interest and contribution from authors**

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” A.S. Gaur and Sundaresh of CSIR-NIO, Goa were involved in over all research work including fieldwork data collection and paper writing. Rajsh Agnihotri of BSIP, Lucknow did radiocarbon dating and also helped in finalizing the manuscript. Pramod Maurya was associated during the field work and helped in collecting data and provided underwater photographs. S. Jayakumar contributed during the writing of manuscript through discussion on coastal erosion and B.R. Thorat was involved in entire field work.

### **References**

- Aiyangar, M.R., *Mamallapuram at the Sangam Age*. (Journal of Oriental Research, Madras). 1928
- Bronk R.C., *Radiocarbon Accelerator Unit*. (University of Oxford, UK) 2010, Available from <http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html>
- Chambers, W., Some account of the Sculptures and Ruins at Mavalipuram. *Descriptive & Historical Papers related to Seven Pagodas* edited by Carr, M.W. (Government of Madras) (1869) 1-29.
- Crole, C.S., *The Chingleput, Late Madras District: A Manual Compiled under the orders of the Madras Government*. (W.H. Moore, Madras), 1879.
- Foote, B., Notes on the Geology of Mahavalipuram. *Descriptive & Historical Papers related to Seven Pagodas* edited by M.W. Carr, (Government of Madras) 1869, 245.
- Gaur, A.S. and Vora, K.H., Jetties and anchoring points in ancient India: Study based on underwater archaeological explorations along the Indian coast and traditional sources. *Current Science*, 93.7 (2007) 987-91.
- Gaur, A.S., Vora, K.H., Sundaresh, Shoreline changes during the last 2000 years on the Saurashtra coast of India: Study based on archaeological evidences. *Current Science*, 92.1 (2007) 103-110.
- Gaur, A.S. and Sundaresh, Palaeo-coastline of Saurashtra, Gujarat: A Study based on archaeological proxies, *Indian Journal of Geo-Marine Sciences*, 43.7 (2014) 1224-1229.
- Gaur, A.S., Sundaresh, and Mani Murali, R. Looking for the Harappan Ports around Dholavira, Khadir Bet, Kachchh, Gujarat. *Indian Journal of Geo-Marine Sciences*, 48.11 (2019) 1769-1773.
- Goswami, K., Krishnan, S., Kumersan, A., Sadasivam, S.K, Kumar, P. And Jaiswal, M.K., Luminescence chronology of Fluvial and marine records from subsurface core in Kaveri Delta, Tamil Nadu: Implications to sea level fluctuations. *Geochronometria*, 46 (2019) 125-137.

Kankara, R.S., Ramana Murthy, M.V. and Rajeevan, M., *National Assessment of Shoreline changes along Indian coast: Status Report for 26 years 1990-2016*. Ministry of Earth Sciences, National Centre for Coastal Research, Chennai, 2018.

Khan-Mozahedy, A.B.M., Subsidence Events of the Coastal Structures into offshore sandy seabed: A Review. *International Journal of Scientific and Engineering Research*, 6.7 (2015) 1600-1610.

Merh, S.S., Quaternary Sea Level Changes along Indian Coast. *Proc. Ind. Nat. Sci. Academy*, 58 (1992) 461-472.

Princep, J., On the Ancient Roman Coins in the Cabinet of the Asiatic Society. *Journal of Asiatic Society of Bengal*, 1 (1832) 392.

Ramaiyan, M., Krishna Prasad, E. and Suresh, P.K. Shoreline oscillation of Tamil Nadu coast. In Proceedings of Second Indian National Conference of Harbour and Ocean Engineering, (INCHOE-97), held at Thiruvananthapuram in 1997.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., HattĹ, C., Heaton, T.J., Hoffmann, D.L., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Staff, R.A., Turney, C.S.M. and van der Plicht, J., Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*. 55.4 (2013) 1869-1887.

Srinivasan, K.R., *Temples of South India*. (National Book Trust India, New Delhi), 1985

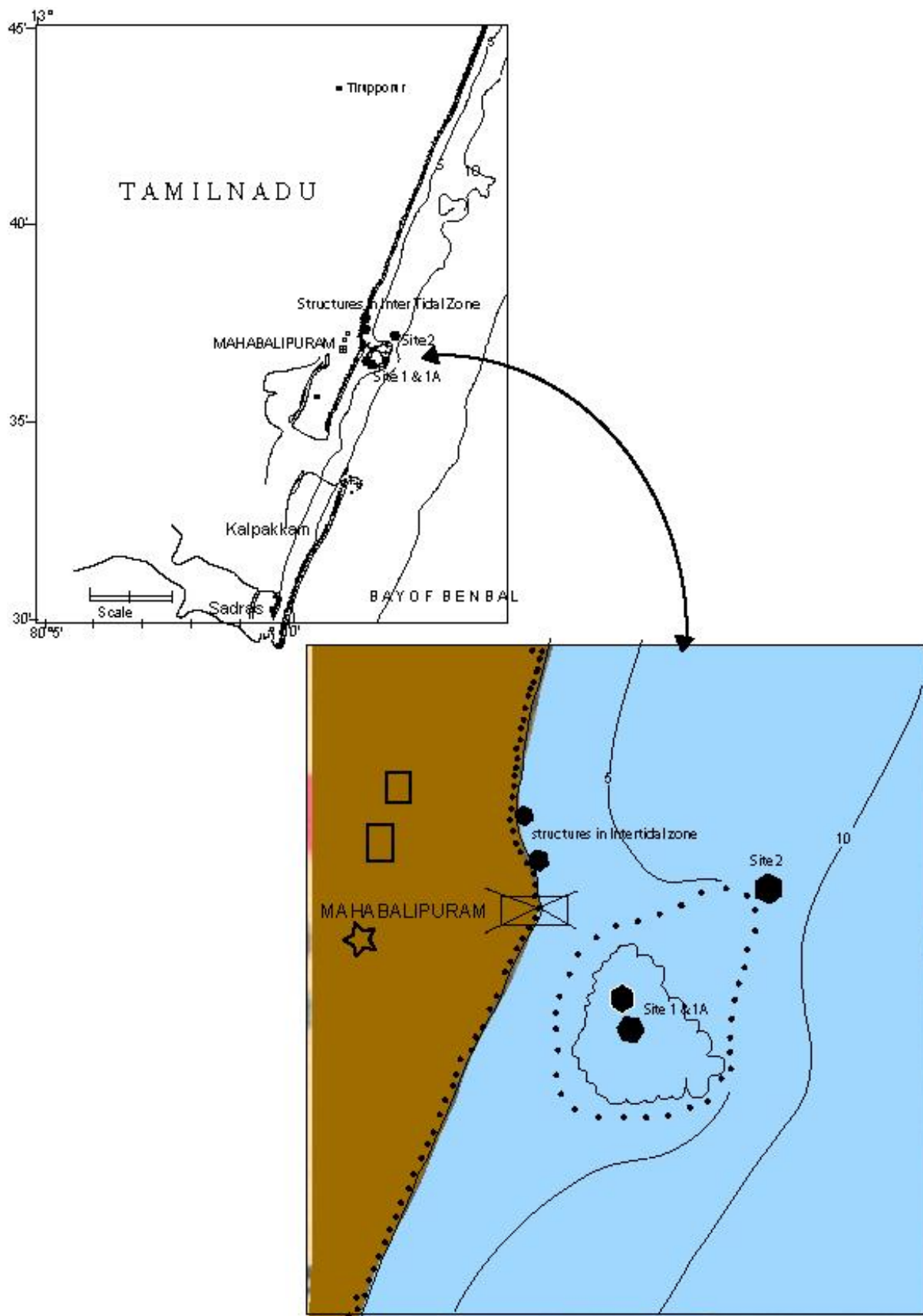
Srinivasan, R., Krishnan, V., Jaya Gopal, R. Natural coastal Processes and its Geo-environmental impact in the Area between Chennai and Nagapattinam coast of Tamil Nadu and Pondicherry. *International Journal of Engineering Science Invention*, 6.8 (2017) 11-25

Stuiver, M. and Polach, H.A., Discussion: reporting of <sup>14</sup>C data. *Radiocarbon*. 19.3 (1977) 355–363.

Sundaresh, Gaur, A.S. Sila Tripathi and Vora, K.H., Underwater Investigations off Mahabalipuram, Tamil Nadu, India. *Current Science*, 86.9 (2004) 1231-37.

Sundaresh, Mani Murali, R., Jaykumar, S. And Gaur, A.S., Shoreline changes along the Tamil Nadu Coast: A Study based on archaeological and coastal dynamics perspective. *Indian Journal of Geo-Marine Sciences*, 43.7 (2014) 1167-1176.

Sundaresh, Mani Murali, R., Gaur, A.S., Dhivya Sree, M., Use of geospatial techniques in maritime archaeology with reference to the Tamil Nadu coast. *Current Science*, 113.10 (2017) 1891-1898.



**Figure 1.** Location of underwater archaeological sites off Mahabalipuram

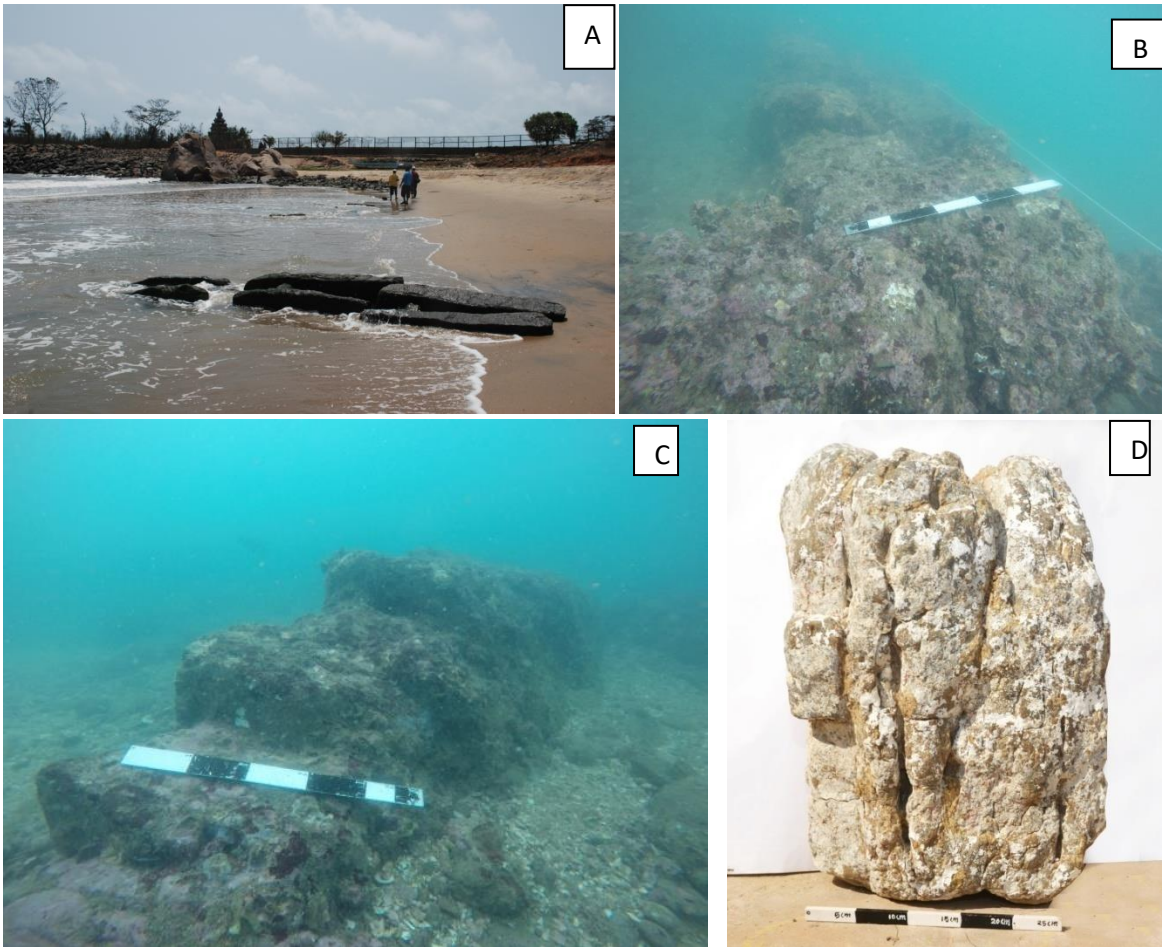


Figure 2. A. Stone structures exposed during low tide. B. Foundation of wall extending a few meters found in 6 m water depth. C. Steeped wall was observed in a water depth of 6 m. D. An eroded sculpture recovered from 6 m water depth.

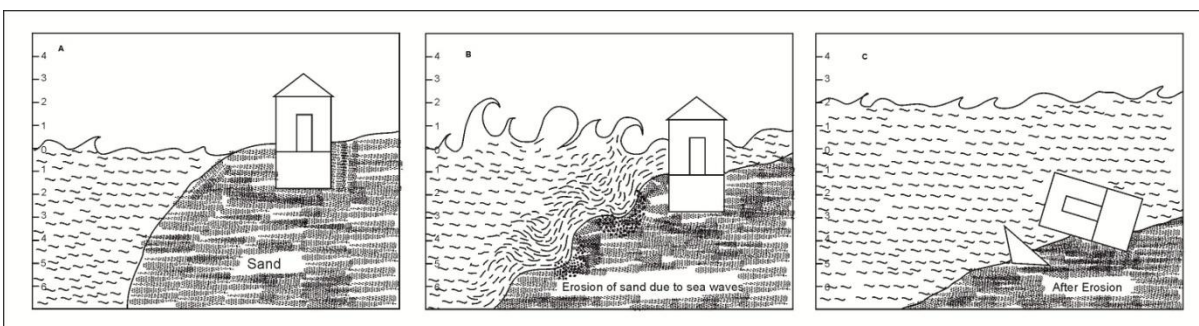


Figure 3. Schematic representation of the process of submergence of the structures.