The Role of Tropics in Climate Change

Global Case Studies

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CHAPTER 15

Geological/paleontological applications in marine archeology: few examples from Indian waters

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The instinct of all human beings is to know his/her roots and get attached to the same. Archeology helps them to connect to their cultural heritage and makes them proud of their roots. The dividing line between history and archeology is a little diffused. History is generally considered as written records of the developments and happenings of the different rulers and dynasties, their rise and fall, and the living conditions of the man during their regime with some information on the climatic fluctuations. Whereas artifact-based reconstructions of similar information, beyond the written records, is archeology.

According to Dr. Graham Clark, Professor of Archeology at the University of Cambridge, "archeology may be subtly defined as the systematic study of antiquities as a means of reconstructing the past." Archeology is not only of academic importance to cultural heritage but also has large financial implications as well due to Archeo-tourism (Table 15.1).

Table 15.1 Earning in Rs. During 2013−14 [Hampi 2016−17] from few popular archeological/historical sites exhibiting scope for archeotourism in India as we have much older spectacular sites but lesser known like Lothal and Dholavira.

Tajmahal	21,84,88,950
Kutubminar	10,16,05,890
Agra fort	10,22,56,790
Humanu tomb	7,12,88,110
Red fort	6,15,89,750
Fatehpur sikri	5,62,14,640
Mahabalipuram	2,72,93,480
Konark	2,43,52,060
Khajuraho	2,24,47,030
Ellora	2,06,72,820
Hampi [2016−17]	3,40,00,000

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Therefore, archeological studies are gaining a lot of attention. To enhance the value and reliability of archeological interpretations, inputs from the different branches of sciences are the need of the hour. Here, we attempted to exhibit the usefulness of the geological/paleontological tools in the field of marine archeological investigations. Marine archeology is the branch of archeology where the sea has played a role in shaping the destiny of the ancient coastal towns and other maritime activities (Nigam, 2005). The study of shipwrecks also comes under marine archeology. But, we decided to concentrate here on the role of geology in explaining or making new findings related to ancient coastal towns with examples from the Indian waters.

Based on the artifacts, a number of climatic changes in the past are documented in archeological investigations, which are reported to have been the cause of the rise and fall of human civilizations. The unique contribution of the marine sediments has been for deciphering the changes in oceanographic conditions due to climatic variations in the past. Since the common aim of oceanography and archeology lies in the illumination of the past, it is apparent to bring coherence between the two.

There are various geological, geophysical, and paleontological tools have applications in the field of marine archeological studies (Nigam, 2005). However, in recent years, studies of microfossils (mainly foraminifera) and ground penetrating radar (GPR) gain special significance and are discussed here in detail with examples.

1. Ground penetrating radar for subsurface information

Much information about the past is hidden under the cover of sediments in the coastal areas like Dholavira, Mahabalipuram, etc. Archaeologists go for excavations in any potential archeological sites based on their experience based on preliminary information available on the surface. Excavation is a very expensive and time-consuming process and sometimes does not ravel the expected structures and cause disappointment and discouragement. The excavation of every nook and corner of the big archeological sites is not possible due to logistic reasons, and thus, sometimes, the important information remained buried forever. This necessitated the need for an instrument, which can give clues about buried structures without excavation.

Ground penetrating radar (GPR) is such an instrument, which can assist the archeologist in very effective ways. GPR is a geophysical tool designed to generate sub-surface details. Initially, this instrument was extensively used by civil engineers for locating buried pipelines, cables, etc. GPR is a tool archeologist which is used more and more for excavations in the 21st century.

GPR essentially consists of a controlling unit, recording, and storage unit and antenna (Fig. 15.1).

The guiding principle, the antenna, transmits pulses of high-frequency (radio waves) energy into materials. The other unit records the strength and the time required for the return of any reflected energy. The reflection phenomenon is mainly governed by the electrical properties of the ground. A GPR profile is generated when the antenna is moved along the surface. This movement can be done by hand, by vehicle, or even by air. The radar unit emits and receives reflected signals up to a 1000 times per second. As a result, not only do the relative depths and “strengths” of the targets appear, but the image or shape of the target is “seen” on the monitor. GPR data are presented as a Radargram (Fig. 15.2).

This instrument is used to study the subsurface sediments in Dholavira and Mahabalipuram areas, and results are discussed later.

FIGURE 15.1

Ground penetrating radar (GPR). (A) different components of the instruments, (B) survey for a small area by dragging the antenna with a walk, and (C) survey for the large area by car by dragging the antenna.

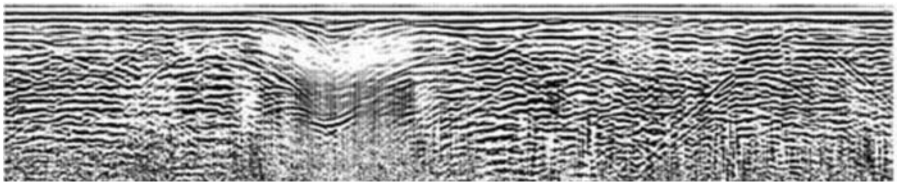

FIGURE 15.2

The output of ground penetrating radar (GPR) as radargram showing subsurface features.

2. Marine sediments as a source of reconstruction of the past

There is a continuous supply of sediments from land to the sea, either by river or wind. These sediments contained a lot of information about the climate and keep getting deposited year by year and layer by layer. These layers also contained the fossils of the organisms that lived in equilibrium with seawater conditions. Therefore, these layers served as pages of climatic changes on Earth at various time scales. With help of research vessels, through coring equipment, these layered sediments can be collected (Fig. 15.3). With the help of microfossils like foraminifera and dating techniques like radiocarbon dates, we can reconstruct the past climate on any time scale from year to thousands of years.

3. Microfossils with special reference to foraminifera

As discussed above, microfossils embedded in layered marine sediments are the prime source for the reconstruction of past climates. The study of microfossils is known as micropaleontology, which is an important subdivision of marine geology and oceanography. Based on composition, morphology, and ecology, microfossils are classified as Calcareous (Foraminifera, Calcareous Nannoplankton, Ostraoda, Pteropods, Calcareous Algae, Bryozoa), Silicieous (Radiolaria, Marine diatoms,

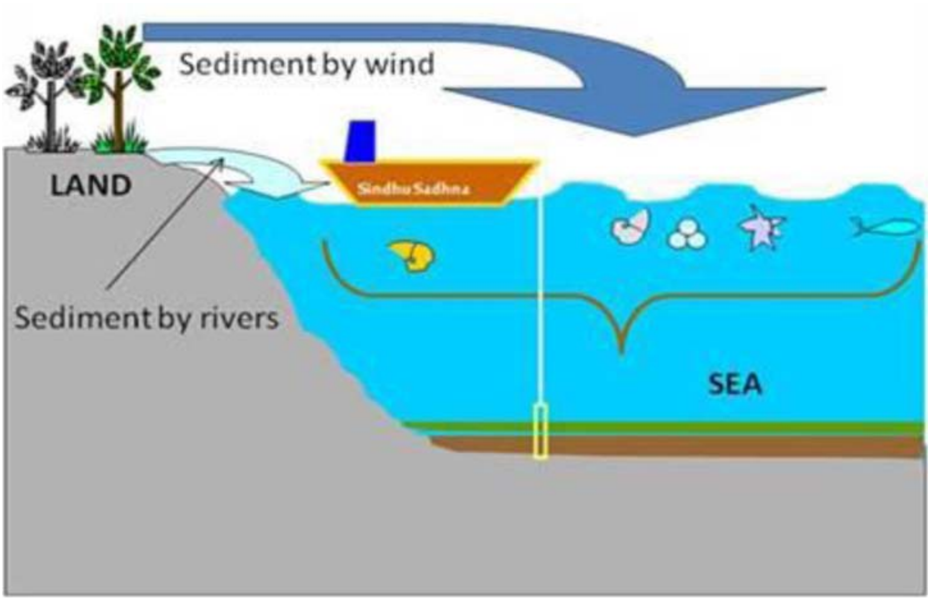

FIGURE 15.3

Coring through layered sediments (embedded with fossils of microorganisms) deposited at the bottom of the sea.

Silicoflagellates), Phosphatic (Conodonts), and organic-walled (Dinoflagellates, Acritarchs and tismanida; spores and pollen) microfossils (Haq and Borsema, 1998). Among these, foraminifera has been used traditionally for biostratigraphy with applications in oil industries. Besides this, foraminifera is useful (Fig. 15.4) for studying sea-level changes, paleomonsoons, sediment transport, paleotsunamis, fisheries, pollution monitoring, etc (Nigam, 2005). The usefulness of foraminifera in reconstructing paleomonsoon reconstructions and application of the same to support the two great floods in 2000 and 1500BCE reported in archeological literature (Rao et al., 1963) has already been published (Nigam and Khare, 1992). The main objective of this article is to create more awareness about their use as a tool to address the marine archeological applications where sea level fluctuations played a great role by providing examples from the Indian waters. In this communication, examples are given where either the presence/absence of foraminifera as an indicator of marine and nonmarine past environments (Lothal and Dholavira) or the sea-level curves (largely using foraminifera-based information) are used to explain marine archeological findings like Lothal, Neolithic settlements off Surat, Dholavira, Submerged Dwarka and Ramsetu, etc. Therefore, it is essential to know some basic aspects of foraminifera before discussing their applications.

4. Foraminifera

Foraminifera (except for a few species without good fossilization potentials) are exclusively marine organisms (Boltovskoy and Wright, 1976). They have widespread geographical (horizontal) and bathymetric (vertical) distribution in ocean including marginal marine bodies like estuaries, lagoons,

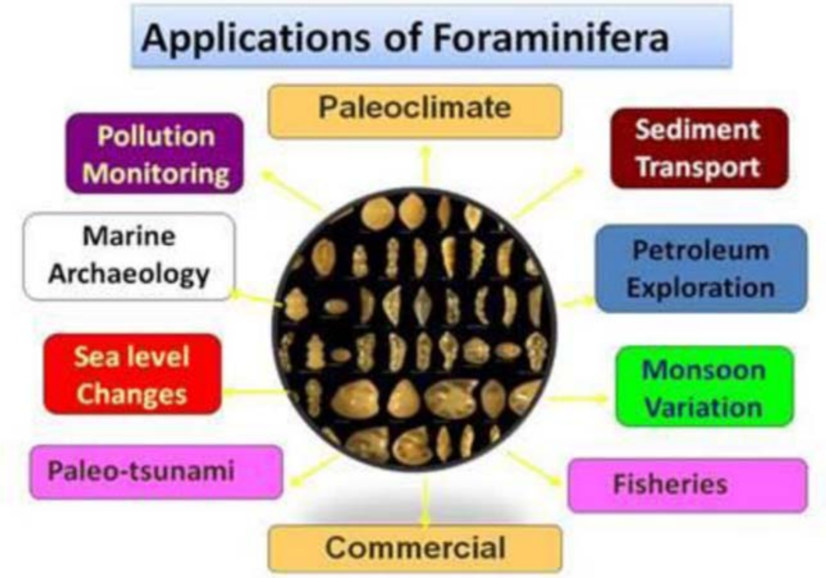

FIGURE 15.4

Applications of foraminifera (microfossil) in different fields including marine archeology.

bays, etc. With reference to habitat, they are classified as benthic (or benthonic) and planktic (or planktonic) (Fig. 15.5).

They are very sensitive to all the physico-chemical environmental parameters. During their lifetime, their hard covering shell (known as a test), which is made up of calcium carbonate, incorporates the effect of prevailing parameters. After their death, this test gets buried in sediments as fossils and served as the key to reconstructing past climatic conditions.

5. Reconstruction of past sea-level changes

It is important to understand sea level fluctuations in the recent past to assess accurately the magnitude of the suspected future rise in sea level due to global warming. At the same time, knowledge of sea-level fluctuations helps to understand the rise and fall of several important cities in coastal areas.

Sea-level fluctuations studied all over the world by many workers (Nigam and Henriques, 1992) cannot be applied as such to our region. Due to the possible role of neotectonics and other factors, curves exhibiting relative sea-level changes are expected to be region specific. In numerous international and national conferences, it has been emphasized that specific areas should have their Holocene sea-level curves rather than following or adopting the generalized curves generated for other regions. The final report of the International Geological Correlation Program (sea-level changes during the last hemicycle) also contains recommendations for these effects (Pirazzoli, 1991).

In India, some of the earliest attempts to study variations within the Holocene sea level on the western Indian shelf were made by Nair (1974), kale and Rajaguru (1985), Merh (1987, 1992). Later,

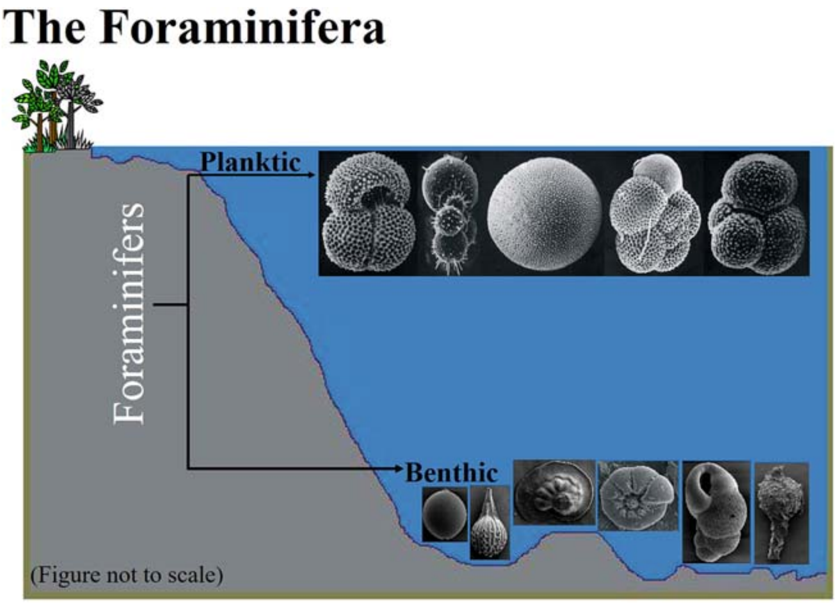

FIGURE 15.5

The types of foraminifera as per habitat, benthic and planktic.

based on the foraminifera, many publications appeared which had enhanced our understanding of sea-level fluctuations. Nigam et al. (1990) collected evidence of paleo-sea level fluctuations in religious and archeological records and supplemented them with inferences from oceanographic studies. Based on the planktic percentage of foraminifera in the surface sediment of the Arabian Sea, a regional model was developed for paleodepth determination. One of the main advantages of the proposed model is that it requires no detailed taxonomic study of the fauna. It is sufficient to separate the fauna into two groups, that is, planktic and benthic. Preliminary sea-level fluctuation curves can be prepared by using paleobathymetric information through the proposed model. Such information is of immense use to develop predictive models (Nigam et al., 1992). During investigations, it was discovered that barnacle fouling on relict foraminiferal tests could be used as an additional tool for identifying paleoshore line changes (Nigam et al., 1993). During the last 10,000 years, three major episodes of sea-level fluctuations were also reported (Nigam, 1990). To produce an updated sea-level curve for the Arabian Sea, Hashimi et al. (1995) summarized a large number of published records. The studies successfully demonstrated that, as compared to the present, sea level was lower by 100 m about 14,500 years BP and 60 m by about 10,000 years BP. Later publications (Nigam and Hashimi, 2002) used this information to further enhance our understanding of the sea level curve (Nigam, 2012) and its use in marine archeology. Fig. 15.6 exhibits a comprehensive account of the fluctuations in sea levels in the Arabian Sea.

By adopting a similar approach, another comprehensive sea-level curve was published for the Bay of Bengal (Loveson and Nigam, 2016). Many workers, explain a number of paleoclimatic events like the destruction of ancient coral reefs, intensification of monsoons, etc. Here, some examples are given below to show how this curve helps explain some of the important archeological discoveries like Lothal, Dholavira, submerged Dwarka, Neolithic settlement off Surat, Ramsetu, etc.

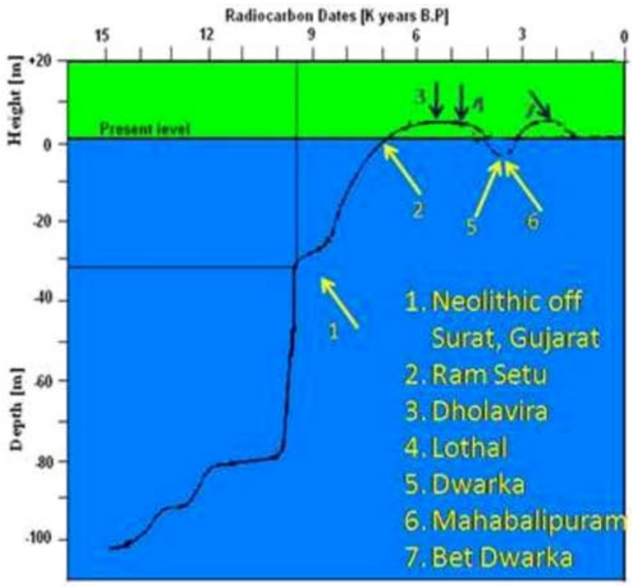

FIGURE 15.6

Holocene sea-level curve showing sea level fluctuations off the West Coast of India (Arabian Sea) and the position of various ancient Coastal towns.

6. Sea-level fluctuations and marine archeology

The archeological monuments which were shaped by fluctuating sea are studied under the heading Marine Archeology. The necessity to study Marine Archeology was felt about 4 decades ago, and Marine Archeology emerged as a new arena of scientific pursuit in India. Dr. S.R.Rao, a retired archeologist from the Archeological Survey of India (ASI), came to NIO in 1981 and started this new branch of Marine Archeology as a project. Later, encouraged by the initial findings, officially in 1990, a unit of Marine Archeology was established at NIO, Goa. Subsequently, both geological evidence and archeological explorations underneath sea waters have worked in tandem but with a synergy between them. Such integrated scientific investigations have yielded good results, and some very interesting long pending unanswered archeological riddles could be solved with the aid of geological interpretations. Some of the examples are discussed below.

6.1 Lothal

Lothal is an important and famous name in Indian cultural heritage, presented as the oldest dockyard (ever discovered in the world as claimed by archaeologists) and evidence of advanced maritime activities around 4500 Years B.P. (before present). Lothal was discovered as a result of a systematic survey undertaken by S.R. Rao in the year 1954 as a part of the program locating Harappan settlements within the present-day boarders of India (Fig. 15.7). Out of several important structures excavated, a large basin-like structure (Fig. 15.8A) became the most important and disputed one. Several arguments were given for its possible use. Using almost similar artifacts like triangular and/or rectangular stones (Fig. 15.8B) to interpret the purpose of the structures to different opinions was advanced by galaxies of Indian and foreign archaeologists. One school (Rao, 1979–1985; Wheeler, 1973) proposed the

FIGURE 15.7

Location of Lothal (Gujarat), India where the oldest dockyard was discovered. The location of Dholavira is also shown.

possible use as a "Dockyard" for maritime activities (Fig. 15.8C) whereas, other schools (Shah. 1960; Sankalia, 1974; Lesnik, 1968; Fairservice, 1971) opined in favor of "freshwater storage tank" mostly for irrigation purpose (Fig. 15.8D) and bathing. This controversy was continuing for almost 4 decades and was finally solved with the help of foraminiferal studies (Nigam, 1988).

Since fossils of foraminifera are exclusively marine, their presence and absence could be a decisive factor in interpreting whether any ancient water body was filled with fresh or marine (brackish) waters. Therefore, with this intention, samples were collected from the sediments deposited at the bottom of the rectangular body. The study ravels the presence of well-preserved in situ foraminiferal assemblages (Fig. 15.8E) comparable with marginal marine environments (Nigam, 1988). This helped to summarize that the rectangular structure was a dockyard, connected to the sea through the estuarine channel and high tidal range and thus settled the old archeological controversy.

However, one question remained to be answered. If this was a dockyard, how it is on land? This question is reasonably answered through the sea-level curve for this region (Fig. 15.6). Around 4500 years B.P. (time of Lothal), the sea level was higher than today. When the sea level has gone down, this connection was lost and the dock became out of use. These results were further supported by Khadkaikar et al. (2004), who by using remote sensing techniques, reported ancient estuarine channels through which this dockyard was connected to the sea (Fig. 15.8F). However, some limited roles played by neotectonic cannot be ruled out.

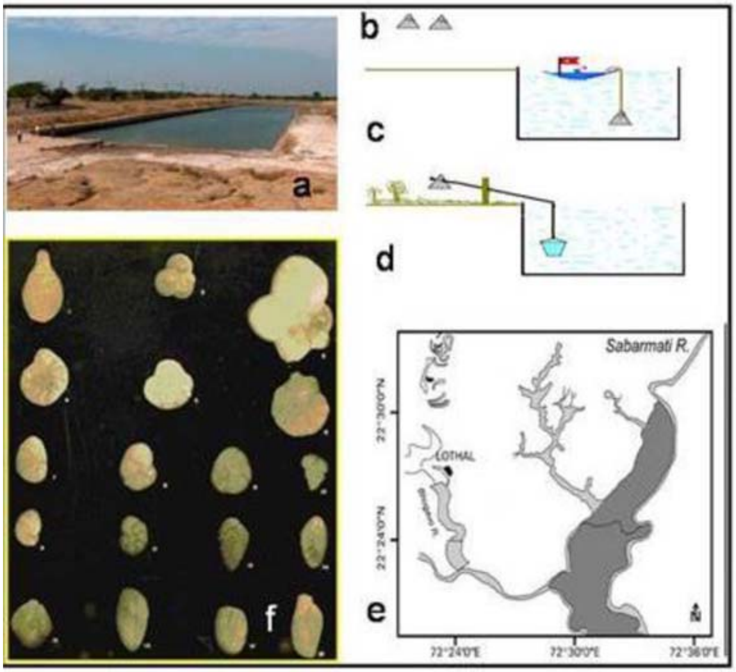

FIGURE 15.8

(A) Tank-like body deciphered as dockyard, (B) triangular stones, (C) showing stones as anchor thus a dockyard, (D) stone as a counter weight to lift the water thus an irrigation tank, (E) remote sensing data showing the connection with the sea, and (F) foraminifera in sediments from the bottom of the rectangular body confirming the dockyard.

Considering the good conditions in which various ancient structures, especially the world's oldest dockyard at Lothal, are there and also the tremendous scope for archaeo-tourisms, under consideration for the tag of the world''s cultural heritage by UNESCO and the Government of India decided to have a National Maritime Museum at Lothal.

6.2 Unknown city off Surat, Gujarat

During 2000–02, the discovery of remnants of an ancient city in an offshore area off Surat in the Gulf of Khambhat (Gupta, 2002) was real excitement when the famous magazine India Today brought out a cover story (Chengappa, 2002) as this was a milestone in marine archeological studies (Fig. 15.9).

As described by Gupta (2002) "The material collected at the site include artifacts, possible construction elements with holes and studs, pot shreds, beads, fossil bones etc. which provide significant evidence of human activity in the area. A detailed examination of the area has revealed riverine conglomerate at a water depth of 30–40 m between 20 and 40 km west of Hazira near Surat (Gujarat)." Based on the radiocarbon dating of wooden pieces recovered from the site, age of 7500 BCE (~9500

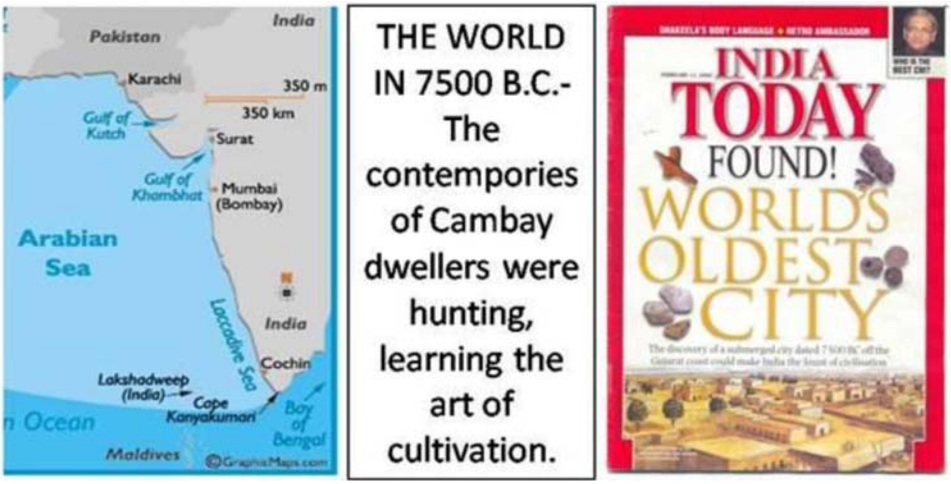

FIGURE 15.9

Location of Gulf of Khambhat (Combay), timing and special issues of India today on the discovery of ancient submerged city off Surat (Gujarat).

BP) is assigned to the human settlement on the bank of the river that was present at that time. The remnant of this time, "push back the hitherto held view of first human civilization from around 3500BCE (C.3500BC-valley of Sumer; c.3000 BCE, - Egypt and c. 2500 BC-Harappa) to 7500 BCE, thus making the present find the oldest known to man" (Gupta, 2002). Because of its linkage to cultural heritage, this discovery was hotly debated and contested for archeological significance (Bavadam, 2002; kathiroli, 2004 etc.). Here, discussion on artifacts is beyond the scope and may be left to archaeologists. But, the role of sea-level fluctuations regarding this settlement was largely ignored (Nigam and Hashimi, 2002).

If the age of discovered settlement (Gupta, 2002) is ~7500 B.C. (i.e., ~9500 years old) as plotted in Fig. 15.6, it gives a depth of 30–40 m water depth. This matches with the depth zone in which this settlement is reported. If the isobaths of 40 m are considered as paleo shoreline, the view of Prof. Rajguru (in Gupta, 2002) comes true that "Bhavnagar and Hazira were probably connected at 7000B.C." This also implies that the river (as suggested) must have been passing through the area (now under the sea) before joining the sea of that time and thus, supporting the postulation of Gupta (2002) "Further, acoustic images present channel-like features indicating the presence of the river in the region." Further observation of the curve (Fig. 15.6) indicates that the sea came to stand still (or rise very slowly) at the said level for some time, thus providing time for civilization to flourish before being engulfed by the sea. This is similar to the happening at submerged Dwarka, which is discussed below.

6.3 Submerged Dwarka

Explorations off Dwarka (Fig. 15.10) by the Marine Archeology Center of the National Institute of Oceanography were initiated by Dr. S.R. Rao in 1983 with small funding from Indian National Science Academy (INSA) and have been continued with other agencies like the Archeological Survey

FIGURE 15.10

Location of Dwarka and Bet Dwarka (Gujarat).

of India (ASI), Department of Science and Technology (DST), Council and Scientific and Industrial Research (CSIR), Department of Ocean Development (DOS, now Ministry of Earth Sciences) etc (NIO, Report, 2001).

Exploration of Dwarka has created great interest among historians, archaeologists, and oceanographers. Rao (1997) stated, “the existence of a port town more than 3500 years ago and its submergence by the sea are now proved beyond doubt as results of scientific excavation in the Arabian Sea off Dwarka and in the Gulf of Kutch off Bet Dvaraka island both of which are considered holy because they are associated with Sri Krishna’s activities” (Rao, 1997). He (Rao, 2006) further stated “… Dwarka on the mainland was built by Krishna, which was contemporary to Bet Dwaraka (Kussthali). It can be dated to the 17th century BC. This date is also confirmed by Gaur and Sundaresh (2004) for the Belapur Fishhook.” Alok Tripathi (2015) presents an account of excavations and explorations done on land and in areas of Dwarka led by Prof. H.D. Sankalia of Deccan College and Research Institute, Pune; Dr. S.R Rao and Prof. A. Tripathi of the Archeological Survey of India (ASI) and 2 decades of Marine surveys off Dwarka by the National Institute of Oceanography, Goa. He postulated that “ …the structural remains found scattered on the bed of the sea are not in situ but transported by waves and currents.”

However, the underwater photographs of the area presented in Fig. 15.11 show stones one above another one exhibiting it as part of an ancient wall and origin as autochthonous. Thus remnants exhibit the existence of an ancient city at that time which was later engulfed by sea. However, the submergence of the Ancient city off Dwarka remained debatable. There are three possibilities suggested for the destruction/submergence of Dwarka. First, the cause could be erosion by the sea. Of course, out of several geological works of the sea, one is to erode the coastal rocks and deposit the eroded material in form of beaches. If beach sediments are eroded and deposited somewhere else, overlaying structures may collapse but that will not cause submergence. Second, the cause could be a tsunami. Yes, a tsunami can submerge a large area on land and destroy many structures due to very high waves. But submergence by the tsunami is a temporary phenomenon. Once the tsunami is over, the water returned

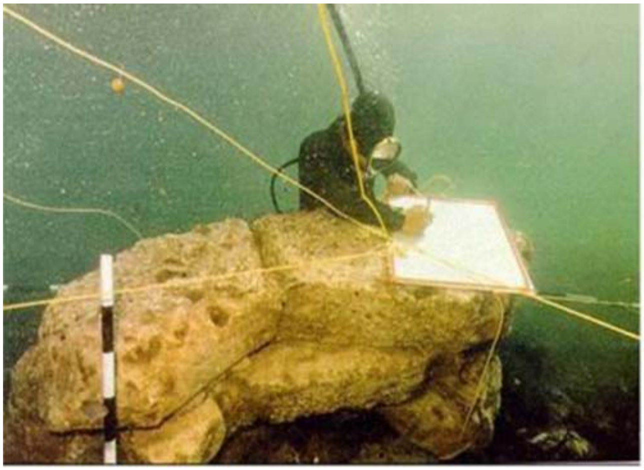

FIGURE 15.11

Photographer showing submerged remnant of ancient wall exhibiting stones one above another indicating in-situ structure.

to its original level and thus cannot be permanently submerged (more than 6 m water depth where structures are found at Dwarka) in any area. Therefore, the last and most pliable explanation is the sea-level fluctuations as the cause of submergence. The relative sea-level curve presented in Fig. 15.6 shows that after the mid-Holocene higher than today's sea levels, a gradual regression of level started and leaving behind the large land area, which could be used to build the city of Dwarka (as the port town). At the time of Dwarka (1500–1700 BCE), the sea level reached to lowest and further transgressions lead to the submergence of Dwarka.

6.4 Dholavira

The recent announcement of declaring Dholavira as India's 40th World Heritage Site by UNESCO created tremendous interest in the common man in knowing more about Archeology in India and abroad. This site was first noticed by Dr. J. P. Joshi of ASI (Fig. 15.7). Later, the archeological excavations in Gujarat from 1989–90 to 2004-05 led to the discovery of Dholavira (Fig. 15.12), which is located on Khadir island between the two minor rivers Mahar and Mansa and comes under district Kutch, Gujarat. It covers an area of about 50 ha (Bisht, 2015). Dholavira is a fortified city and world-famous for its excellent water conservation system. Dholavira is the second-largest Harappan settlement known in India. To quote the Chief excavator, Dr. R.S. Bisht, "it was, perhaps, the best planned Harappan city with several divisions and many new features hitherto unknown."

This well-planned urban settlement flourished for about 1500 years from about 5000 to 3450 years before the present. Archeological excavations show that the township comprised three parts—the castle, middle town and the lower town. Thick walls (12–18 m) around the city and castle was built as a protective measure. The real purpose of the Dholavira thick wall has been a topic of considerable debate. Intriguingly, walls of such thickness are not found even in historic times when conflicts have been more common, and weapons have become increasingly destructive. Even the third century BC China wall is 4.6–9.1 m thick at the base and tapers to 3.7 m at the top. Similarly, protection against floods is not tenable as this is a water-starved area, which is evident from the extensive water conservation system developed at Dholavira. Dholavira being a port town could have been vulnerable to

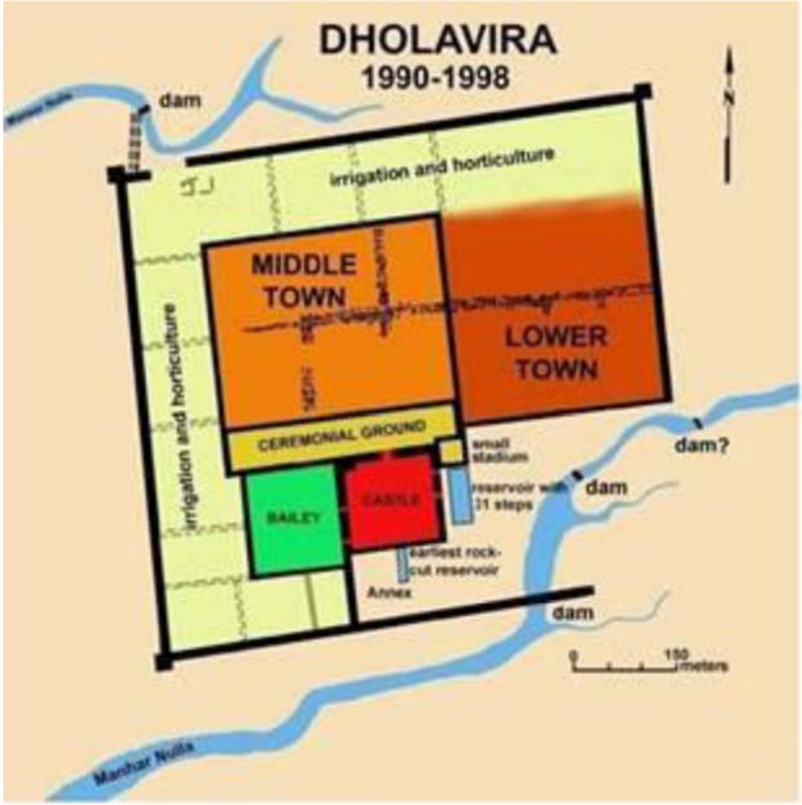

FIGURE 15.12

Site plan of Dhoavira (Gujarat).

oceanic calamities. Are the unusually thick walls an answer to this? Being part of the Makran coast, the area is prone to tsunami-like events Mahmood et al. (2012). Evidence of paleotsunami at 8000-7000 years BP is known from the region (Nigam and Chaturvedi, 2006). Therefore, it can be postulated that ancient Settlers at Dholavira were aware of the vulnerability of the area due to tsunamis but due to trade-related strategic location to build this city around 5 to 6 1000 years back. However, the thick wall was built to protect the town from extreme oceanic events such as tsunamis. Similar protective walls come under coastal hazard management as adopted in Japan and New Orleans in recent times. Therefore, it can be concluded that ancient Dholavirians were aware of tsunami protective measures and that is probably the oldest evidence in the world (Nigam et al., 2016).

To study the possibility of the area impacted by tsunami post-construction, CSIR-NIO has carried out additional work at this site. A team of paleoclimatologists, archaeologists, and geophysicists from the institute surveyed a hitherto unexcavated area using GPR and systematically collected soil samples in the middle town area (Fig. 15.13). The GPR records show a 2.5−3.5 m thick homogenous soil layer (without any layering) below the surface, which suggests its episodic deposition, possible due to an extreme event.

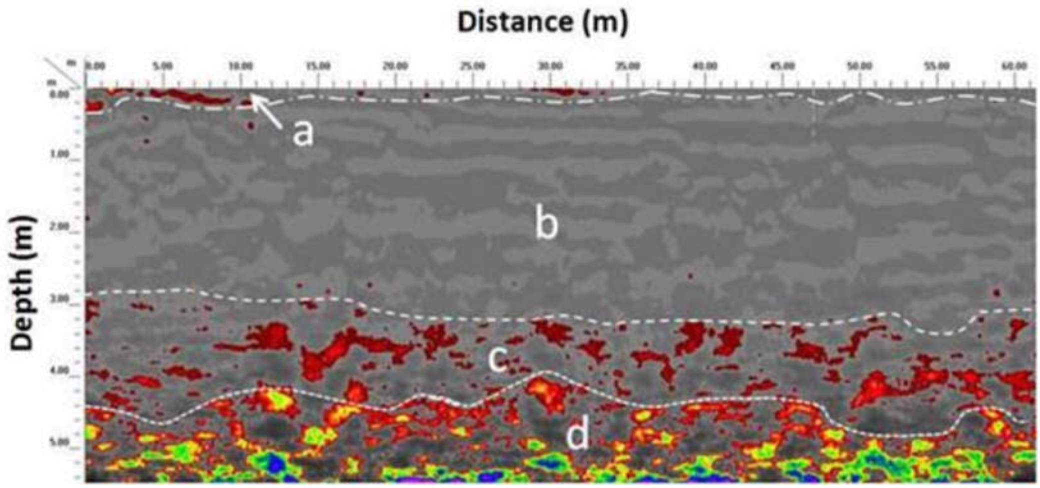

FIGURE 15.13

Ground penetrating radar (GPR) record at middle town of Fig. 15.12 showing thick subsurface sediments without any layering (~3m).

A 2.5 × 2.5 m trench was dug in the north-western corner of the Middle Town to a depth of 3.65 m (Fig. 15.14A). The soil samples have been found to contain fossils of "*foraminifera*," microscopic organisms that build calcareous shells and live only in seawater. The presence of shells of marine

FIGURE 15.14

(A) Trench at the location of ground penetrating radar (GPR) record showing sediments without layering in middle town and (B) foraminifera encountered in sediments.

organisms foraminifera (Fig. 15.14B) in the soil strongly suggests an episodic deposition of marine sediments in the area. This deposition could have occurred as a result of a massive tsunami. The exact timing of the sediments deposited in Dholavira is yet to be established. The presence of exclusively marine organisms (foraminifera) in subsurface sediments outside the citadel (Middle town) indicated the possibility that Dholavira, at least in part, could have been destroyed by the tsunami. In addition to this, the thick wall in Dholavira shows that the Harappans were not only aware of the potential threats from tsunamis, but they were also pioneers in coastal disaster management.

Studies indicate a need for a long-term detailed survey of the entire area by GPR to decipher the buried structures, geological analysis of the subsurface sediments, dating of the datable material like radiocarbon dating, and/or TL/OSL dating to ascertain the time of the event/s. The deciphered structures in unexcavated area/s may be excavated by the Archeological Survey of India to expose the full grandiose of this most important archeological site. These will enlighten the golden pages of the rich cultural heritage of Gujarat, India. A fully exposed site will also enhance tourism potential.

6.5 Ramsetu

Ramsetu (or Adam's bridge) at the southern tip of India also became a very lively controversy in India due to its religious connection with lord Ram and thus a very emotional issue. It is believed that the army of lord Ram constructed the bridge over the sea between India and Sri Lanka. The supposed to be pictured by NASA (Fig. 15.15) also generated a big interest in this area. However, the controversy became very intense when Setu Samdurum Project was conceived by the government to dredge the area so that the ships can pass through this region while going from the Arabian Sea to the Bay of Bengal. Otherwise, the water depth in this area is approximately only 3 m, and therefore, ships have to take more time to encircle Sri Lanka. But the belief of its association with Lord Ram created a big debate due to the response of the government challenging any such structure ever existed/constructed.

However, most of the arguments given in support of the possible existence of Ramsetu came from the religious literature and for a more conclusive settlement, a scientific understanding of the area is the need of the hour. This required the answer to the 3 questions.

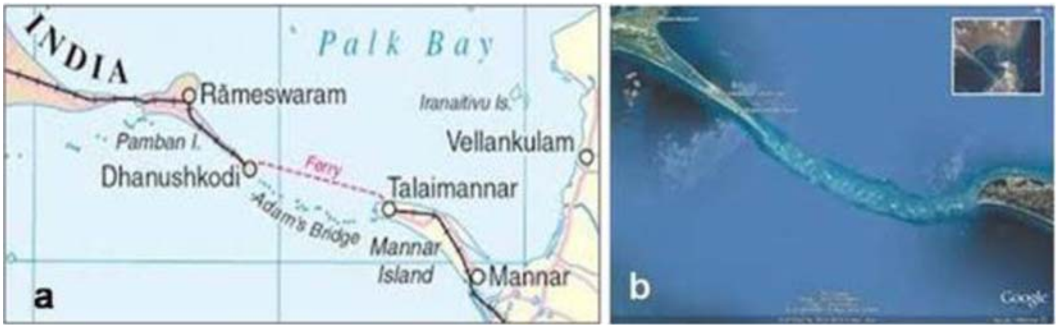

FIGURE 15.15

(A) Location of ramsetu (Adam's bridge) at rameswaram and (B) NASA picture showing the possibility of ramsetu.

i. what was the timing of Ram and thus the construction of Ramsetu?
ii. What is the water depth between India and Sri Lanka now?
iii. Is it possible to know the fluctuations of the sea levels at that time and is it possible to cross over to Sri Lanka at that time?

The answer to the first question came from following a very novel approach considering the positions of stars at the time of Rama as mentioned in ancient literature (mostly in Sanskrit) and planetarium software (Pushkar Bhatnagar *In* Bala, 2019 and Bala and Mishra, 2012). The timing concluded was 5100 BCE (i.e., ~7100 years old). The second question is easy to answer through the hydrographic (bathymetric) charts of this region. The sea between India and Sri Lanka is very shallow, and the average depth is about 3 m. The answer to the third question and the most relevant information was provided by the understanding of the Holocene sea-level fluctuations (Fig. 15.6) in published literature. By adopting various scientific equipment and methods (Hashimi et al., 1995; Nigam, 2012; Loveson and Nigam, 2016) relative sea-level fluctuations were inferred from the sea-level curves published for the Arabian Sea and the Bay of Bengal. Both the curves show that at the time of Rama ~7100 BP, the sea level was 2–3 m lower than today. This employs that during this time sea between India and Si Lanka was very shallow (almost connected) and it was possible to connect the two regions with some efforts to fill the depressions in between. The correct word used in ancient literature is "Setubandh Rameshwaram" bandh means the causeway and not the bridge (which give the impression of a flyover) and thus supports our conclusion. This was the only time when construction of a causeway (Bandh) was possible. Because, if the timing is older, there was no need to construct Ramsetu as the water depth level was much older (30–40 m at ~9.5 K and ~100 m at 14.5 k) which automatically connect India and Sri Lanka without any sea in between. Whereas if the timing is Younger than 7.5 k, the sea level was higher than today (when Dholavira and Lothal were port towns due to higher than today sea level) and thus it was not possible to make a bandh or causeway.

In view of the foregoing, it is summarized that the scientific evidence indicates that it was possible ~7100 BP to construct Ramsetu as a causeway between India and Sri Lanka.

6.6 Other areas

Some of the other important sites of marine Archeological interests where sea level must have played a leading role to shape the destiny of these cities are Pumphar, Mahabalipuram on the east coast and Somnath, Gopikapatnam (Goa) and a few areas of Kerala on the west coast of India. Investigations are going on in these areas by various agencies like the National Institute of Oceanography, Archeological Survey of India, Bhartidasan University, various IITs etc. are in progress and results are expected to be published in due course.

7. Conclusions

Marine Archeology is an upcoming branch of Science which needs a multidisciplinary approach for more acceptable conclusions. In this, the tools used by Geologists and Paleontologists can play significant roles as exhibited by the few examples from The Indian waters. India has more than a 7000 km long cost line and a large number of researchers are required with inclinations to apply their expertise in the field of marine archeology. This need requires more training programs and starting of specialized courses in universities and research organizations. Marine archeological sites especially places like Lothal (oldest dockyard) and Dholavira (oldest evidence of tsunami protection measures and water conservation knowledge) also provide an excellent opportunity to enhance international tourism and thus increase national earning and job opportunities.

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