

Foraminifera [Marine Microfossil] as an additional tool for archaeologists – Examples from the Arabian Sea

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Abstract

During the past few decades, microfossils, especially foraminifers have become the prime source to address paleo-environmental issues. These microfossils also find application in marine archaeological studies. Foraminifers present in the shelly sediment layers in Goa and Lothal Dockyard (Cambay) are discussed as case studies of high sea stand. The results indicate the possibility of higher sea level around 6,000 years BP. Similarly sediments collected from the seafloor show a sea level ~100m lower than the present at around 15,000yr BP. and explained the possibility of having the Neolithic settlements off Surat at depth of 30 to 40 m water depth having an age of 9,500 years before present. In tropical countries like India, changes in monsoon pattern are the most important aspect of climatic variation. Studies show the clear signals of marked high rainfall around 4000, 3500 and 1000 years BP and a prominent low at 2000 years BP, supported by findings from shallow seismic records and palynological investigations.

Introduction

One, who is proud of his /her rich cultural heritage, always works hard to maintain the high level of civilization and tries to enhance further the living standard of fellow citizens. Beyond the written history, it is archaeology, which reconstructs the past and highlights the cultural heritage. According to Graham Clark, Professor of Archaeology at the University of Cambridge "Archaeology may be subtly defined as the systematic study of antiquities as a means of reconstructing past". Therefore, based on the artifacts, a number of climatic changes in the past are documented in archaeological investigations, which are reported to have been the cause of the rise and fall of human civilizations.

At the same time, oceans, a source not only of admiration and awe, but also of confirming speculations of paleoenvironmental conditions mentioned in literature. 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 archaeology lies in the illumination of the past, it is apparent to bring coherence between the two.

Study of microfossils is known as micropaleontology, which is an important sub-discipline of oceanography. Marine microfossils, particularly foraminifera have been used traditionally for biostratigraphy with applications in oil industries. Besides this, foraminifera are useful for studying sea level changes, paleomonsoons, sediment transport, paleostorms/tsunamis, pollution monitoring etc. (Nigam, 2005). The main objective of this article is to create more awareness about their use as a tool to address the archaeological applications by providing examples from the Arabian Sea. The applications of foraminifera in the field of Marine Archaeology can be classified into two categories (i) event related to sea level fluctuations and (ii) changes in palaeo-precipitational history. However, first a brief introduction is given about foraminifera, followed by their applications in reconstructing past sea level and monsoon changes with their archaeological significances.

Foraminifera

Foraminifera are almost exclusively marine organism (Boltovskoy and Wright, 1976) having widespread geographical (horizontal) and bathymetric (vertical) distribution in oceans including marginal marine bodies like estuaries, lagoons, bays etc. As per habitat

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they are classified into benthic or benthonic and planktic or planktonic (Figure 1). They are very sensitive to all the physico-chemical parameters and during their life time incorporate effect of prevailing parameters in their hard covering (test), which is made-up of calcium carbonate and has excellent fossilization potential. Because of these two properties, i.e. sensitivity to climatic changes and fossilization potential, they are used extensively as proxies for long term reconstruction of paleoclimatic condition. In following discussions, besides describing the traditional techniques, an insight is provided about the development of new techniques and significant results with special reference to marine archaeology in India.

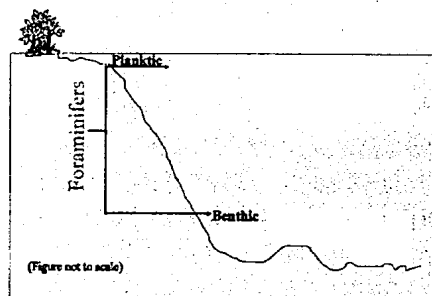


Figure 1: Habitat of benthic [at bottom] and planktic foraminifera [in upper water column]

Sea level Fluctuations, Foraminifera and Archaeology

Earlier Nigam et al. (1990) collected the evidences of paleo-sea level fluctuations in religious and archaeological records and supplemented them with inferences from the oceanographic studies. The relative rise and fall of sea level over the time has been studied with the help of foraminiferal evidences, both from the land (high sea level) as well as from the sea (low sea level). Foraminifera present in the shelly sediment layers in Goa (Nigam et al. 2005) is an indicator of high sea stand. The results indicate the possibility of high sea around 6,000 years BP. Nigam et al. (1992) has succeeded in demonstrating that as compared to present, sea level was lower by ~100 m about 14,500 years BP. and ~60 m about 10,000 years BP. During the last 10,000 years, three major episodes of sea level fluctuations were also reported (Nigam 1990, 1996; Nigam and Hashimi, 1995). The updating of the Holocene sea level curve (Figure 2) for the central west coast of India by Hashimi et al (1995)

will serve a long standing need of a standard sea level curve for the future workers. The understanding developed for sea level fluctuations helped to explain two important archaeological findings i.e. Lothal dockyard and discovery of a Neolithic settlement at 30-40m water depth off Surat.

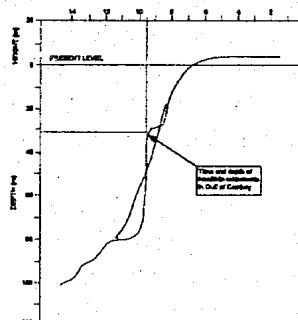


Figure 2: Sea level curve for the west coast of India [After Nigam and Hashimi, 2002].

Discovery of Lothal dockyard (first dockyard of the world as claimed by archaeologists) in Gujarat and drowning of Dwarka (on the west coast) and Poompuhar (on the east coast) of India are the glaring examples of the role of the sea level fluctuations in shaping the history of mankind over this region of the world. Out of these, "Lothal" is an important and famous name in Indian cultural heritage, presented as an evidence of an advanced maritime activities around 4,500 years B.P. Lothal was discovered as a result of systematic survey undertaken by Rao in the year 1954 as part of a program for locating Harappan settlements within the present day borders of India. Out of several important structures excavated, a large rectangular basin like structure [Figure 3 A] became the most important and disputed one. Using almost similar artifacts like triangular stone (Figure 3 B-1) to interpret the purpose of this structure, two different opinions were advanced by galaxies of Indian and foreign archaeologists. One school proposed the possible use as 'dockyard' for maritime activities (Figure 3 B-2) whereas, other school opined in favour of 'fresh water storage tank' for agriculture (Figure 3 B-3) and bathing. This controversy was finally solved with the help of foraminiferal studies (Nigam 1988).

Since foraminifera are almost exclusively marine organisms, their presence and absence could be a deci-

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sive factor in interpreting whether any ancient water body was filled with fresh or marine (brackish) water. With this intention, the author has undertaken a study of sediments deposited in the rectangular body and encountered well-preserved in situ foraminiferal assemblages (Figure 3 C) comparable with marginal marine environment (Nigam, 1988). It was finally summarized that the rectangular structure was a dockyard, connected through open marine environment with high tidal range and thus settled an old archaeological controversy. However, one question remained to be answered. If this was a dockyard, how it is on the land? This question can be answered by sea level curve for this region (Hashimi et al. 1995). Around 4500 years B.P. (time of Lothal) sea level was higher than the present. When sea level started going down, this connection was cut off and what locked inside got evaporated and giving rise to salt and gypsum crystals (Figure 3 D). Recently, Khadkaikar et al. (2004) also reported ancient estuarine channel through which this dockyard was connected to the sea. However some limited role played by neotectonic cannot be completely ruled out.

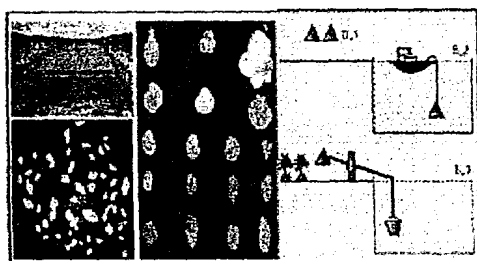


Figure 3: Application of foraminifera in Lothal controversy, [A] tank like rectangular body excavated at Lothal; [B] 1-Stones encountered in the area, 2-possible use of stones as anchor and thus possible use as dockyard, 3- possible use of stones as weight to lift water for irrigation and thus irrigation tank; [C] Foraminifera encountered in the sediments indicating the presence of marine water in rectangular body thus supporting dockyard; [D] salt crystals.

The recent discovery of Neolithic settlements in the Gulf of Khambhat (Chengappa, 2002; Gupta, 2002) is a real excitement and milestone in the field of Marine Archaeology. As described by Gupta (2002) "The materials 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 water depth of 30-40 m between 20 and 40 km west of Hazira near Surat (Gujarat)." Based on the radiocarbon dates of wooden piece recovered from the site an age of 7500 B.C. is assigned to the human settlement on the bank of the river that was present at that time. The sea level curve later helped Nigam and Hashimi (2002) in interpretation of the finding of the Neolithic settlements at 30-40m water depth at ~9500 years BP off Surat. Because of its linkage to cultural heritage, this discovery has been hotly debated for archaeology significance (Bavadam, 2002). Discussion on artifacts is beyond the scope of this paper. But, role of sea level fluctuations as cause for extinction of human settlements (if any) in this area was largely ignored.

The above new findings get an additional support when viewed with reference to the inferred sea level fluctuations over this region. Hashimi et al. (1995, reprinted in 1999) published an updated sea level curve for the west coast of India. If the age of discovered settlement (Gupta, 2002) ~ 7500 B.C. [i.e. ~9500 Before Present (B.P.)] is plotted over this curve, it gives a water depth between 30-40 m (Figure 2). This matches with the depth zone in which new findings are reported. Obviously, if the isobath of 40 m is considered as paleoshoreline, the views of Rajaguru (in Gupta, 2002) comes true that "Bhavnagar and Hazira were probably connected at 7000 BC." This also implies that rivers (if any) must have been passing through the area (now under sea) before joining the sea of that time and thus supporting the postulation of Gupta (2002) "Further, the acoustic images present channel like features indicating the presence of a river in the region."

Further observation of the curve (Figure 2) indicates that sea came to stand still at that level for some time, thus providing time for civilization to flourish before being engulfed by the sea again. The remnants of this time, now discovered (Gupta, 2002) "push back the hitherto held view of first human civilization from around 3500 BC (c.3500 BC- Valley of Sumer; c.3000 BC-Egypt and c.2500 BC- Harappa) to 7500 BC, thus making the present find the oldest known to man."

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The coherence between these two separately carried out studies once again points to the need of collaboration to address the influence of sea levels fluctuation on the rise and fall of ancient civilizations. Continuing to highlight the role of sea level fluctuations in shaping the history of coastal regions, Nigam et al. (1991) pleaded with archaeologists to catalogue the monuments of archaeological importance falling in 'vulnerable zone' of inundation due to likelihood of suspected sea level rise because of global warming associated with greenhouse effect and plan strategy to safeguard them. Otherwise these monuments will become artifacts for future archaeologists.

Rainfall Fluctuations, Foraminifera and Archaeology

In tropical countries like India, monsoonal rain is by far the most important element of climate, which appears often in the form of devastating floods and droughts. Such climatic events (floods, droughts etc.) and their effects on society were recorded right from the early historic period. Such historical climatic records are mostly available in form of inscriptions. Such brief accounts of the rise in the food prices, economic conditions of the society, construction of dams/lakes could be suggestive of severeness of natural disasters, which can cause irreparable destructions to the human society. An abiding regard for the integrity of the archaeological records further increases if compatibility exists between the archaeological and other independent scientific findings.

The high resolution proxy records for paleomonsoonal precipitation are the need of the hour over which man's impact could be more easily evaluated. This object can be achieved by exploring coastal areas of high rate of sedimentation. First, a conceptual model (Figure 4) was provided and techniques were developed for use of foraminifera as a proxy to determine the paleomonsoons. Studies on core samples off Karwar (Figure 5), west coast of India showed the clear signals of marked high rainfall around 4000 and 3500 years BP (Nigam and Khare, 1992, 1999; Nigam, 1993) and reversal of rainfall condition since 3500 B.P. with a marked low at 2000 years BP (Nigam and Khare, 1994). These findings gathered support from

palynological investigations of the same core (Caratini et al., 1994) and foraminiferal studies off Oman, western Arabian Sea by Naidu (1998). Nigam (1993) has inferred that monsoonal precipitations were rather high at 280, 840, 1610 & 2030 years before present. Nigam and Nair (1989) and Nigam et al (1995) also deciphered a cyclicity of approximately 77 years in concentrations of drought years (Figure 6) and also pointed out the possibilities of correlation between inferred cycle and Gleissberg cycle in variation of radius of the sun (Figure 7).

A parallel can be exhibited between foraminifera-based climatic inferences about higher precipitations around 4,000 and 3,000 years before present and archaeological reporting of floods at the same time. It is interesting to note that one of the floods in 2,000 BC (i.e.~4,000 years B.P) seems to have forced some of the residents of Lothal to move further interior into Rangpur, Koth etc. Harappan devised several measures to save their township from floods (Rao et al. 1963). They could not withstand the onslaught of the second great flood in circa 1,500 B.C. (i.e. about 3,500 years B.P.)

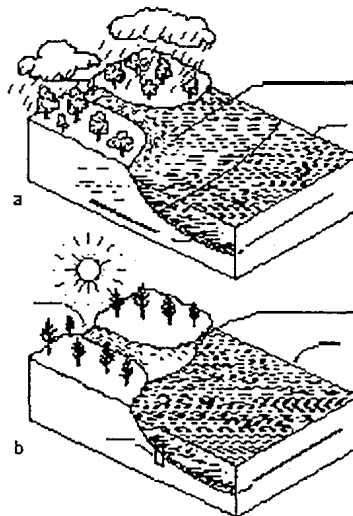


Figure 4: Conceptual model showing use of foraminifera in paleomonsoonal studies. [A] Better rain fall conditions and sediment deposited must have brackish water fauna in sediment and [B] Poor rain fall conditions and sediment deposited must have marine water fauna. A core samples can yield paleomonsoonal history.

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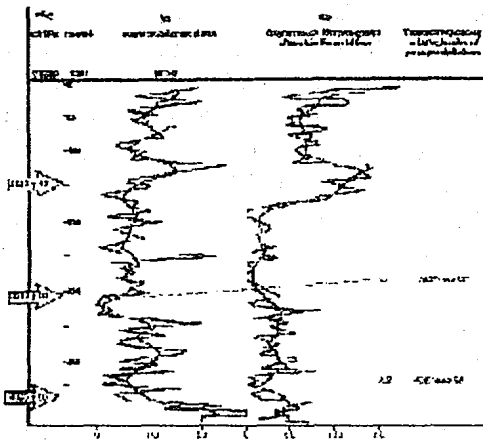


Figure 5: Results of reconstruction of rainfalls during last-4,500 years. High rain falls [floods] conditions ~3500 and 4000 years before present show correspondence with archaeological records of great floods around 1500 and 2000 B.C. [After Nigam and Khare, 1992]

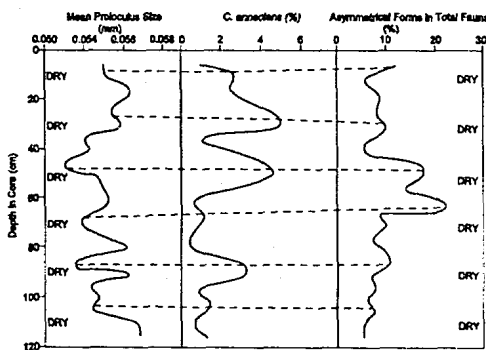


Figure 6: A core off Kali river mouth show records of rainfall for ~500 years. Dry conditions inferred from framiferal proxies show cyclicity of 77 years in concentration of drought years. [After Nigam et al.,1995].

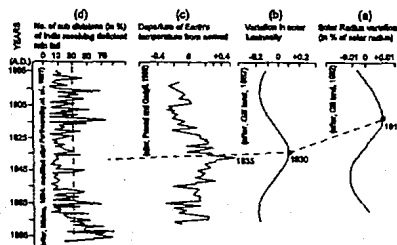


Figure 7: Effect of Gleissberg Solar cycle on rainfall records [After Nigam et al.,1995].

If events like construction of dam on “Sudarsana Lake” during the time of the King Chandragupta Maurya around 300 B.C. and the memorable flood in Tapti in 1727 when boats sailed over the city walls, damaging the property worth 25,00,000 pounds could be taken as indications of higher precipitations, they are well supported by inferences drawn from foraminiferal variations in marine sediments. Same is the case with droughts around the middle of the 13th and 15th centuries.

The above studies suggest a need for more concentrated efforts to compile historical / archaeological records of climatic changes on the one hand and reconstruction of climatic changes through foraminifera from marine sediments on the other hand. The coherent understanding of climatic variability will help to develop futuristic climatic models.

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