

## Sea Level Fluctuations during last 15000 years and their Impact on Human Settlements\*

**Rajiv Nigam**

*Scientist G,*

*National Institute of Oceanography, Goa*

*Email : nigam@nio.org*

**A**s an oceanographer, I am taking you into the deep of the Indian Ocean. I must admit that my work was not to provide any answer to archaeological problem, rather the intention was to work on past and future climate. But, it is the influence of originally Dr. S.R. Rao that we have started providing certain explanation to unresolved questions of archaeology.

Every year, every day, everybody is talking about the change in climate, and all these things are related to global warming (Fig. 1). The global warming is likely to create problems in the form of the accelerated rise in sea level changes, in monsoon patterns, and in the intensity and frequency of the storms. With reference to the sea level fluctuations we have certain questions to answer; the impact of human behaviour and of anthropogenic changes. The sea level kept fluctuating when man was not on this planet. There are references to such fluctuations available in several ancient books and religious writings. *Gita* contains a reference indicating that Krishna knew pretty well that the city of Dwarka is going to be submerged. If you refer to Quran or see in Bible when Hazarath Nooh was building an ark in the desert area, he was ridiculed by his fellow citizens that he is building a boat but there is no water. Probably he knew pretty well that in future there is going to be water there and he may require that boat.

---

\* Text of invited talk prepared through transcription

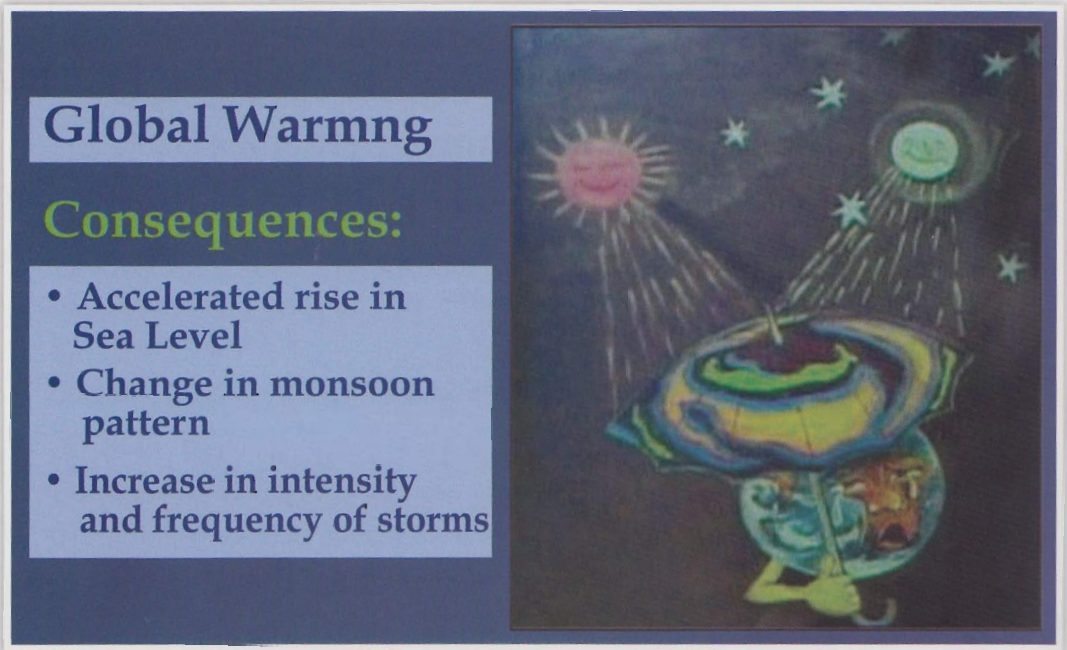


Fig. 1: Showing the Global Warming

As geologists we all know that where the mighty Himalaya stands today there was a sea, the Tethys Sea, once upon a time, but these stories are very old. However, Holocene records of the sea level fluctuations and the sea level curves have also been generated by many scientists for many parts of the world (Fig. 2). In fact the sea level has been going up and down with reference to the mean sea level.

We wanted to have a record of sea level fluctuations in our region. Earlier, it was the climate, which was deciding the destiny of man. Now, probably for the first time it is going to be recorded in the history that man is affecting the climate. Let us see how this relationship goes and how to generate a sea level curve for our region. In order to know how much it will fluctuate there is a growing need to delineate the natural and human induced changes.

Now, here we come in contact with archaeology. The archaeology may be subtly defined as a systemic study of antiques as the means to reconstruct past. The marine sediment can be used to decipher the changes of the Oceanic conditions due to climatic variations in the past. Then the archaeologist and the oceanographer both are reconstructing their past, therefore they have to be

## Past Records [in Oceanography]

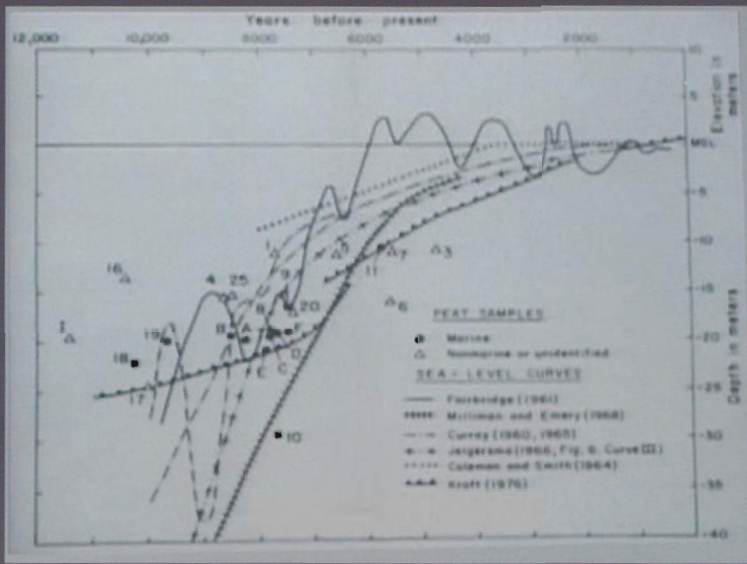


Fig. 2: Sea level curves, generated for many parts of the world

synchronistic in their interpretations. And because of that, we started looking into the results with the reference to the archaeology in the Indian region.

But the big question is how to get the idea of the relative sea level changes during last thousands of years? Therefore our thrust is to enhance the understanding of past sea level changes through the study of micro fossils in marine sediments from the Indian Ocean and adjoining seas. How we get the information? Our tool from which we get the idea about past changes is Foraminifera, a type of micro fossils.

The rivers and the winds bring the sediments into the ocean. The ocean itself is also having a number of small organisms, micro-organisms, which reveal the environment of their lifetime. After their death they all get to the bottom of the sea and form layer after the layer (Fig. 3). If you can collect these layers from sediments at the bottom of the sea and take the core sample, you can separate out these layers and then you can tell about the climate. The sea level at that time and about the types of palaeoclimatic changes which have taken place.



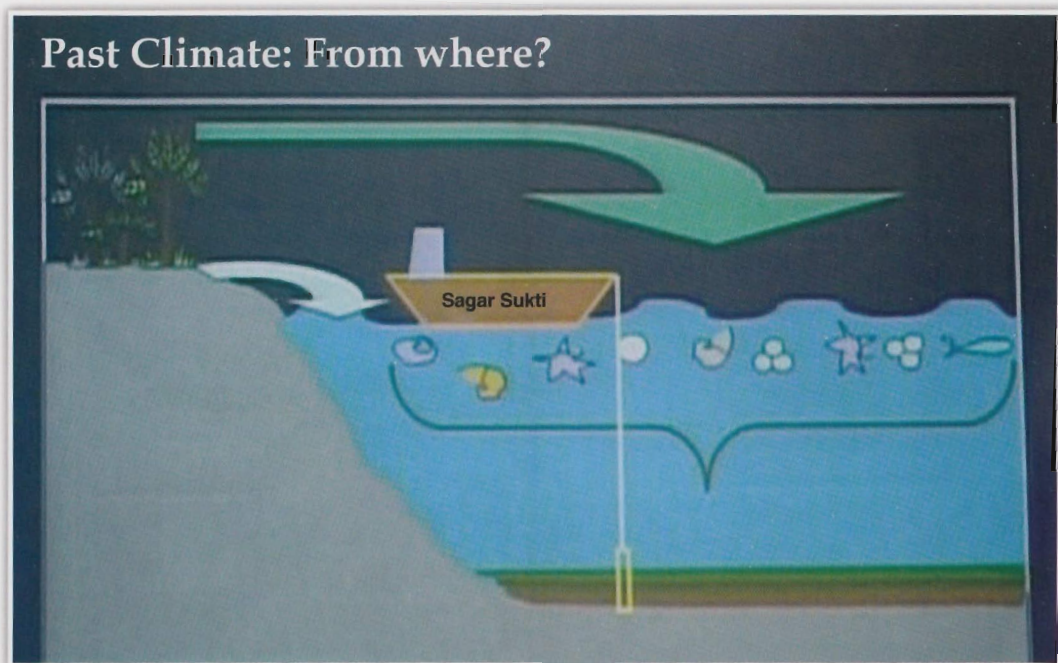


Fig. 3: Showing deposition of microorganisms in bottom of the sea.

This is a basic concept on which out of so many type of microfossils, we take a microorganism called Foraminifera. There are two types of Foraminifera; one is called Planktic Foraminifera and other one is Benthic Foraminifera (Fig. 4).

You can see all of them are something like balloons put together. And some of these live at the bottom of the sea, and after their death get preserved at the bottom of the sea. We have identified about more than 1,000 species from the Indian Ocean. They are less than a millimetre, they are exclusive marine organisms and very sensitive to the environmental changes. Therefore, we use them for deciphering the sea level changes, past monsoon changes and for palaeotsunamis. We also use them for engineering aspects, for pollution monitoring and so on. Today, I will just state a few examples, how did they help for ascertaining the sea level changes? Five slides in Fig. 5 show the Benthic Foraminifera and one shows Planktonic Foraminifera (Fig. 5).

Now, how we can use Foraminifera for determining the palaeo sea levels. Methods of determining palaeo sea level changes based on Foraminifera include: presence or absence of Foraminifera, spacious occurrences, ratios of different groups, oxygen isotopes and morphological variations etc. There are also a number

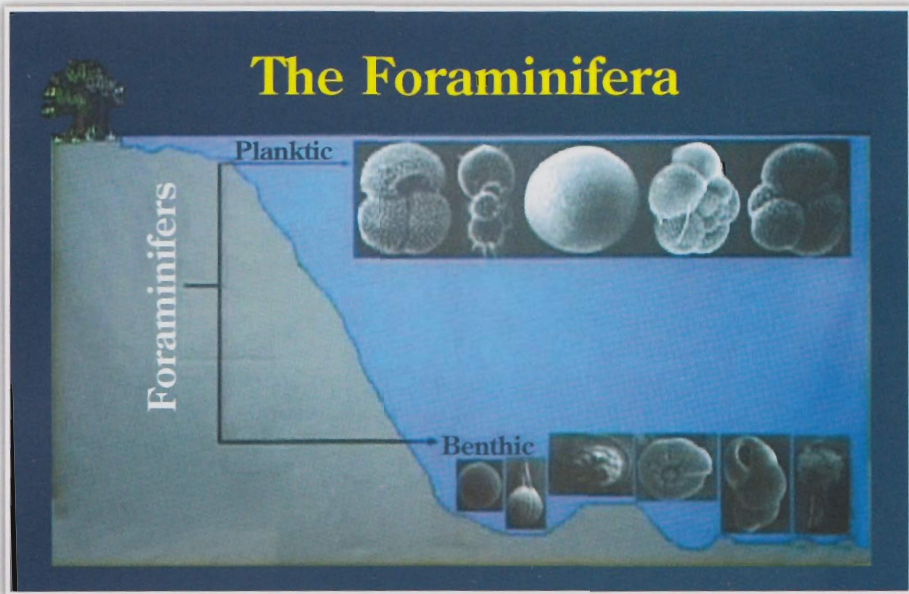


Fig. 4: Various types of Foraminifera

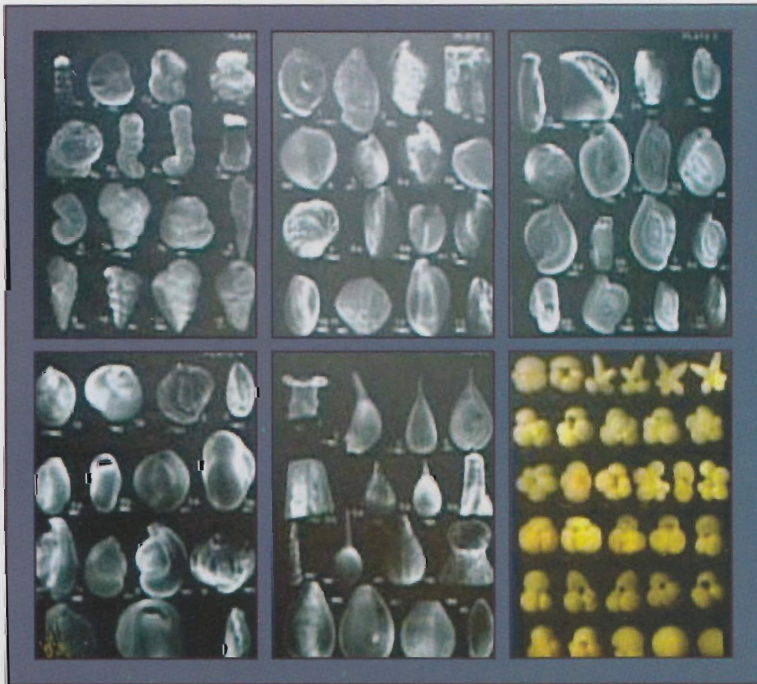


Fig. 5: Showing the Benthic Foraminifera and one is Planktonic Foraminifera (shown in yellow colour)



of other parameters, which we can use to decide further changes in sea levels. I will not go into detail. I will just show some examples. If we want to generate the record of past sea level changes, our strategy has to be two folds. When sea level was higher than today we have to look for those records on land today and when sea level was lower than today we will discuss a little later. First, let us see when sea level was higher than today.

You need not be a palaeontologist or geologists to have this type of application. Since Foraminifera are exclusively marine organisms, we used these for marine archaeology.

Archaeologists use the artefacts like coins or pottery etc, we use these micro fossils. In this context, we may take an example of the site of Lothal which is roughly about 10 to 12 kilometres away from the sea, and few meters above the present sea level (Fig. 6).

In 1954, S. R. Rao had excavated the site which was a very famous discovery! See the picture of the water body called the dockyard (Fig. 7).



Fig. 6: Lothal and other archaeological sites of Gujarat, in red colour

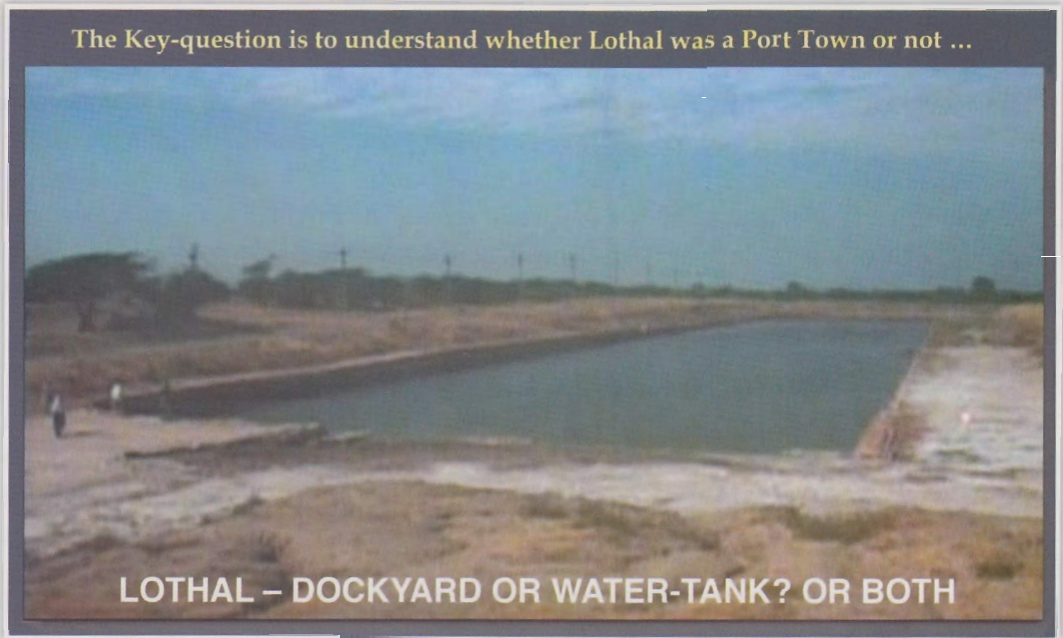


Fig. 7: Dockyard of Lothal

Whether it is science or whether it is archaeology nothing goes without controversy. The moment it was discovered, the controversies also got created. Dr. Assad was of the opinion that it was a dockyard about 4 to 5 thousand years back, and according to him it is a first ever dockyard discovered anywhere in the world, supported by I think Mortimer Wheeler and the other group led by Professor Sankalia of Pune University were of the opinion that this was a fresh water irrigation tank. This controversy went on for about 30 to 40 years. Out of many other arguments I will pick up the argument on how this controversy got created. We found a few stones with the holes like those for an anchor and this indicated that it was a dockyard.

One group said that this stone was used as an anchor stone, and since we found the anchor there must be a boat, therefore, it has to be dockyard. It is not the only argument. There were several other arguments, but others said that the stone was used as a counter weight to lift the water for the irrigation. So, the stone is the same, but interpretations were different.

This controversy went on for a long time because no geologists or palaeontologist were asked to solve this problem. Finally National Institute of Oceanography



(NIO) team was asked to supply the answer after carrying out scientific research. We collected a few samples and analyzed in our lab, and we found existence of well preserved Foraminifera populations (Fig. 8). As we know, Foraminiferas are exclusively marine organisms. So, when these organisms are found in a water body, it cannot be a fresh water body but it has to be a marine water body. And therefore it substantiated the evidence in favour of dockyard theory. Now, still a few things remain to be answered. If this was a dockyard, why is it 12 kilometres away from the sea? What is it doing two meters above the present sea level? Does it indicate that actually this was a dockyard when sea level was higher than today?

This dockyard was connected to the sea through the channel which was also later on discovered by Aniruddha Khadkikar and his team through the remote sensing providing the missing link (Khadkikar *et al.* 2004). When sea level started going down, it went out of use, and the water logged inside slowly evaporated

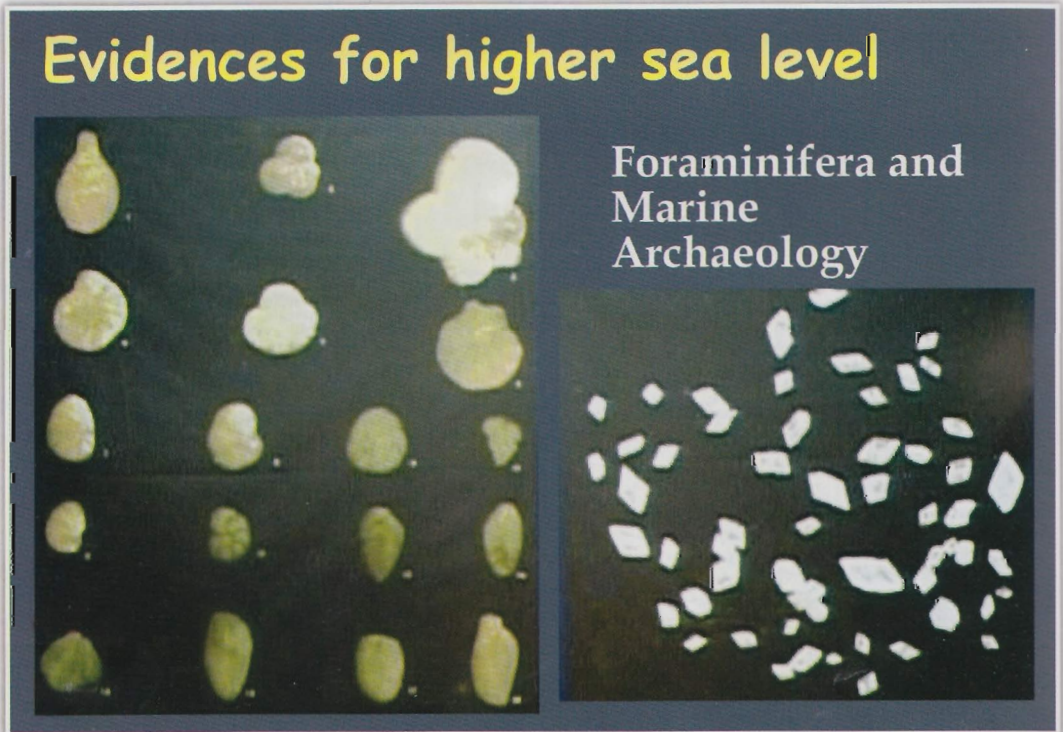


Fig. 8: Samples of Foraminifera (in yellow) and gypsum crystals (in white) collected form Lothal Dockyard



forming some gypsum crystals (Fig. 8). So this is a very classical example emphasizing the need for adoption of an integrated approach. If archaeologists argue among archaeologists or geologists argue among geologists, they cannot solve the problem. If archaeologists, geologists, and space scientists had all come together, they could have provided a credible answer based on pure scientific evidence within two days. In this way it was concluded that this was the first dockyard ever discovered in the world.

It is possible to adopt a two way strategy and you should have knowledge about the shoreline indicator. If today the sea level is increasing the beach and the shoreline move towards the land and if sea level is going down the shoreline moves towards the seaside. Either of these would tell us something about our past. If the sea level is going up, the depth is increasing and if the sea level is going down, the depth is decreasing. Can we get the reports on such kind of fluctuations? Yes, the first report on this region came from Dr. R.R. Nayer (Fig. 9). He proposed a theory that probably sea level was lower than today about 60 to 80 meters around 10,000 years back because fossils in the sediments are found at that depth. Again, controversy never leaves the science. He was criticized that

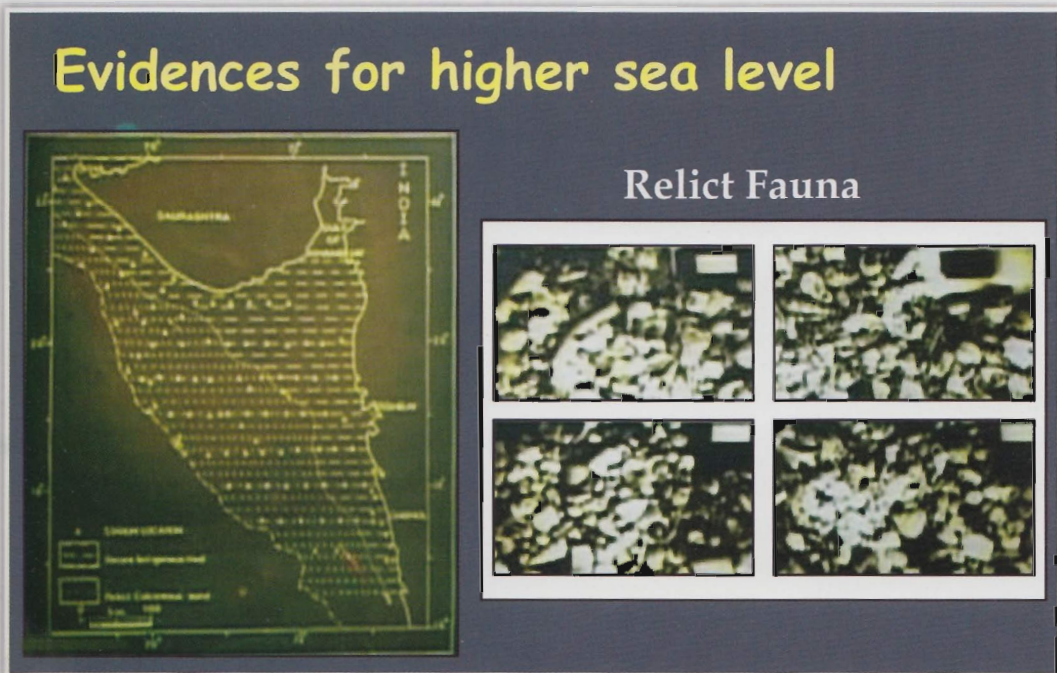


Fig. 9: Showing the evidences for lower sea level, lower than today





and the Red Sea. So, these became the palaeoshoreline indicators which help us to generate the final curve. Therefore, the specimens of relict Foraminifera with barnacle growth could be considered as tools to monitor palaeo sea levels.

Planktonic Foraminifera species are found in abundance in deeper seas above calcium carbonate composition depth. They have been used extensively to record past oxygen and carbon isotopic fluctuations. Attempts were made to use certain morphological properties (e.g. diameter) of Planktonic Foraminifera for the study of sea level fluctuations during last 10,000 years. The Planktonic Foraminifera species *Orbulina universa* d'Orbigni are found in all oceans. Bé *et al.* (1973) and Hecht *et al.* (1976) studied the variation in mean diameter of the spherical test (external shell) of this species and found that a direct correlation between mean test diameter of *O. universa* and surface water temperature. Some time back Haenel (1987) statistically reanalysed the data of Bé *et al.* (1973) and showed that mean diameter of this species is directly proportional to temperature ( $r=0.90$ ) and inversely proportional to salinity ( $r=-0.46$ ) and density ( $r=-0.93$ ).

A study of the area of western shelf in Indian Ocean was done. They estimated the percentage of Planktonic specimens in Foraminifera assemblages in 126 surface sediment samples (depth range from 13 to 1050 m) and the resultant model could be expressed in the following equation:

$$P = 20.18 \text{ Log. } D - 61.27$$

$$P = \% \text{ of Planktonic Foraminifera in fauna and } D = \text{depth in meters}$$

We develop a palaeodepth model based on the percentages. Now, in this if you put the percentage of the Planktonic Foraminifera you can get the depth. It means you take a core sample and then simply see how many of the Planktonic Foraminifera at given different depths are found at different times in the past 10,000 years. Then you get the palaeodepth, put the time versus the depth and you get the sea level curve. Accordingly we find out that around 8800, 5500, and 2200 the sea level was high, punctuated by the lower sea level twice (Fig. 11).

There is another attempt, along the west coast of India, and along the Myanmar coast. If we see the seismic record we see the collection of relict Foraminifera at deferent depths under the sea on the pinnacle points. These indicate the presence of ancient coral reef and we can date them because their potassium carbonate can be dated. When the sea level was going up these became dead reefs, and the reefs moved because these can live only at a particular depth. So as the sea

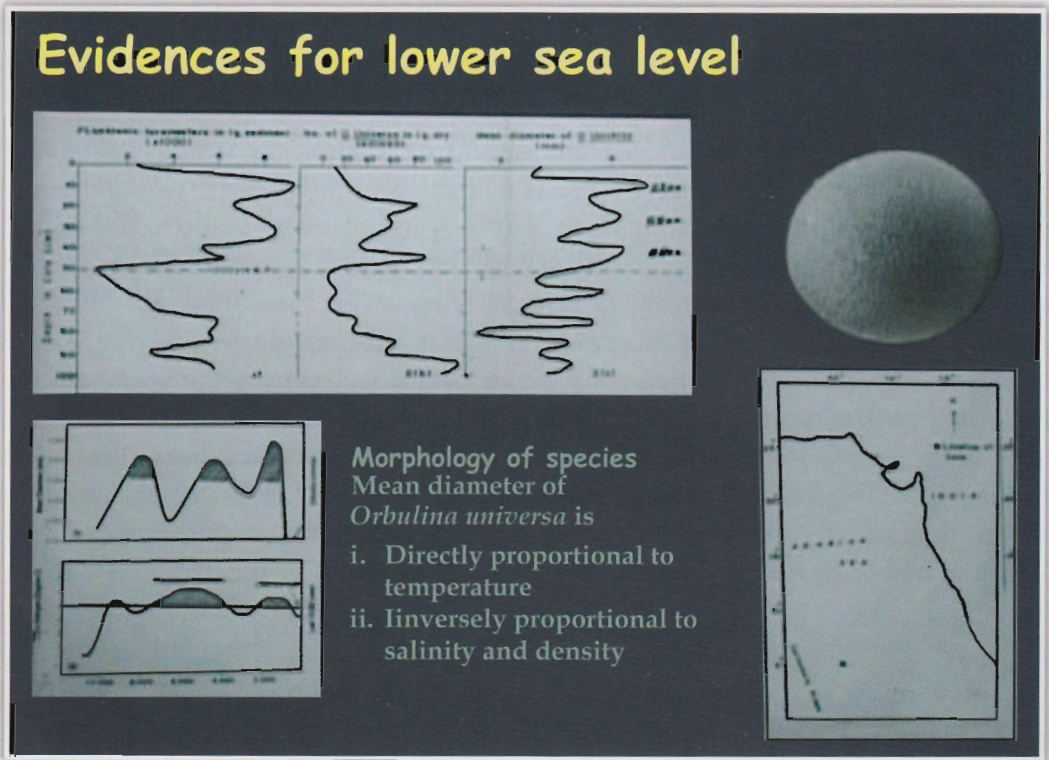


Fig. 11: The palaeodepth model based on the percentages of Planktonic Foraminifera

level started going up they started moving up and finally we got all these dead reefs (Fig. 12), because rise in the sea level was so fast that the reef could not keep the pace and became extinct. If you date these sediments, you can identify the oldest and the youngest.

If you put the depth versus the time you get the sea level curve. Now, by putting all the information together which has been summarized above, the sea level curve for the west coast of India was generated.

Now, let us come back to Lothal, which is around 4500 years BP. The sea level at present is at the dividing line between red and green. The sea level fluctuation curve makes it clear that 4500 years back sea level was at the white dot on the curve on green portion (Fig. 13), which is now land locked. This also explains without a doubt that at Lothal we have a dockyard which is the oldest dockyard in the world.



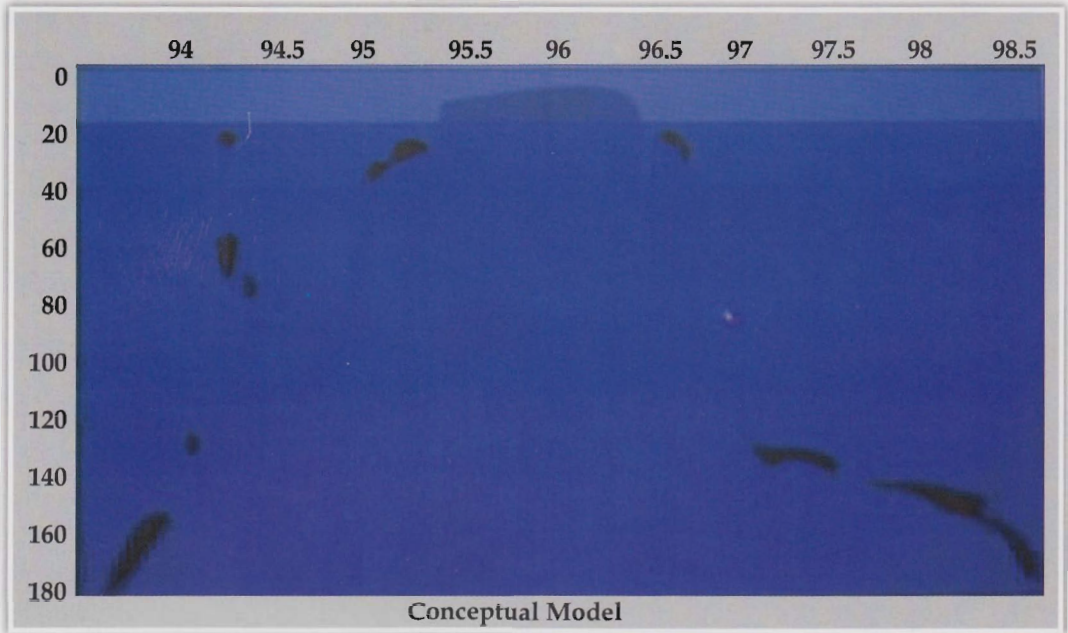


Fig. 12: Showing the deposition of dead reefs in red colour

After that you can see the sea level is going down. This explains another big phenomenon. We are very proud of having excavated the Ancient Dwarka. We got a lot of fame and name for this discovery. This exploration was done by Dr. S. R. Rao and his team (Fig. 14). Dr. Rao was a great pioneer of marine archaeology and he was instrumental in establishing a unit of marine archaeology at the National Institute of Oceanography (NIO) at Goa. There are some very important evidences of the submerged city of Dwarka. We all remember that in Mahabharat it has been stated that Lord Krishna had reclaimed the land from the sea to build the city of Dwarka. When can you reclaim the land? Obviously land can be reclaimed only when the sea level is going down. The curve in the slide clearly reveals that after 4500 BP water level was going down. Consequently Lothal did not remain a port town anymore and slowly became land locked. Since the sea level had come down by more than 4-5 meters in next 1000 years, it became possible to reclaim the land and build the city of Dwarka here around 3500 BP. Various artefacts have been found i.e. lustrous Red ware and other pottery, a copper *lota*, and a bronze bell which have been assigned dates around 3500 BP. Therefore references to building the city of Dwarka by Krishna after reclaiming a part of land get corroborated by this sea level curve. Subsequently

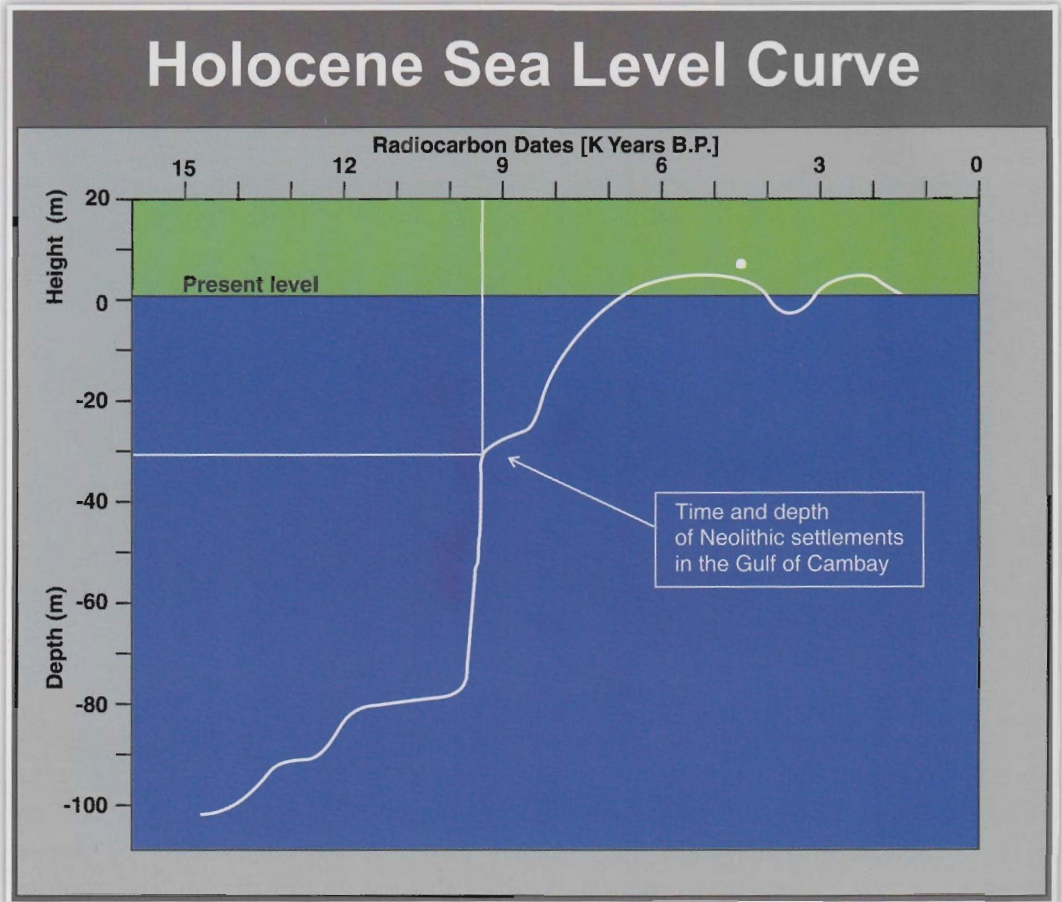


Fig. 13: The Holocene Sea level curve

the sea level started rising and there was some event like Tsunami, under which the city of Dwarka got submerged.

Now, here lies a lesson for all of us. When we talk about reclamation of land from the sea at Bandra, does it not mean the same thing? And when you come very close to the sea and reclaim the land, what can happen? The sea had not pardoned even Lord Krishna and it will not pardon the man also. Therefore never go very close to the sea to construct your properties because due to the global warming sea level might go up and you may lose your property. Therefore laws framed by the government in this regard are people friendly and deserve to be followed.



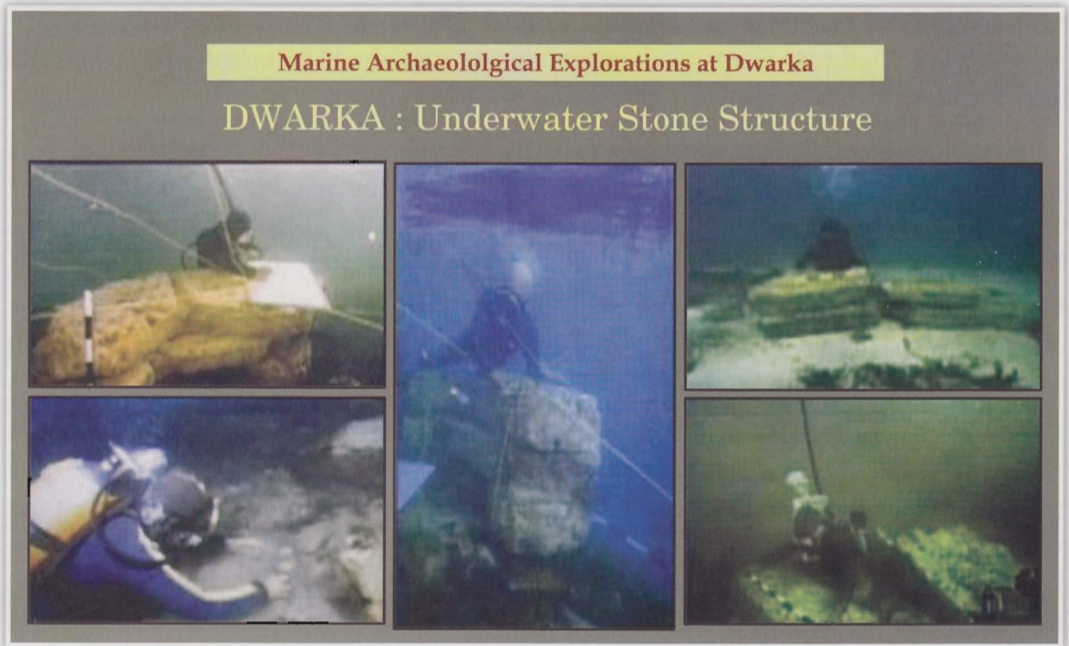


Fig. 14: Showing underwater documentation at Dwarka

But, the story doesn't end here. So far we have explained Lothal and we have explained the submerged city of Dwarka. In the same sequence there was another discovery in Gulf of Khambhat between 20 and 40 km west of Hazira near Surat (Gujarat), which was covered by India Today in a special issue on the archaeology in 2000. National Institute of Ocean Technology by a chance discovery found the remains of an ancient city submerged deep into the ocean. It was really exciting and was a milestone in the field of marine archaeology. The materials collected at the site include artefacts, possible construction elements with holes and studs, pot sherds, beads, fossil bones etc., which provide significant evidence of human activity in the area. A detailed examination in the area has revealed riverine conglomerate at water depth of 30-40 m between 20 and 40 km west of Hazira near Surat (Gujarat). This was dated to be in existence in 7,500 BC. And this was a very sensational study because this was the world's oldest city. Minister gave a press conference and India Today brought out a special magazine. But again nothing goes without controversy. Within a few months the Outlook magazine brought out another issue claiming that it was all hoax and that the story was not true. An important reason due to which such an important discovery got questioned was; how you can have a city at 30-40 meter

water depth? Those who had found it probably were not aware of the history of sea level changes. They tried to answer or explain it in terms of earthquake and tectonic movements etc.

It may be recalled that the news about the 9500 years old submerged city was published in 2000, and the sea level curve explained above was published in 1995. So, nobody can say that we generated a curve to suit a discovery. The sea level curve for the west coast of India shown above may be referred to if this submerged settlement is plotted over this curve, it gives a water depth between 30 to 40 m. This exactly matches with the depth zone in which new findings are reported.

These details thus revealed that a Neolithic settlement in Gulf of Khambhat, setup in 7500 BC, was lost because it submerged under the sea due to the rise in the water level (Fig. 13). Thereafter a civilised port town settlement at Lothal, which was flourishing in 2500 BC, went out of use because of fall in sea level. By 1500 BC the sea level had gone down to such an extent that land could be resumed for setting up the city of Dwarka. However, the rise in sea level and occurrence of Tsunami like phenomenon devoured by the sea again. These discoveries push back the hither to held view of the first human settlement from around 3500 BC to 7500 BC.

A separate sea level curve has not so far been drawn by us for the east coast of India. Since both the west coast as well as the east coast are extended arms of the Indian Ocean, the fluctuations in water level would have been quite similar. Around 7000 years back the sea level was not the same as at present. One look at the sea level curve in the slide makes it clear that between 7000–7200 BP the water level was about three meter below the present level. The astronomical dating of the Rama era has been placed around 7100 BP and Ram Sethu is found submerged at about three meters depth. The above study suggests a need for more concentrated efforts to compile historic and archaeological records through the fluctuations of the sea levels and correlation of fluctuations in sea level curve with the other scientific evidences to arrive at the scientific dating of ancient events and occurrences. The need for collaborative interdisciplinary studies is even more important for Indians because it is likely to make them proud of their most ancient rich cultural heritage. If we shared the pride in this rich heritage, we shall work hard to maintain the high level of civilization and try to enhance the living standard of our fellow citizens:



Who else can be more proud than us as we had the oldest city, dated in 9500 BP within our territory?

Who else can be more proud than us as we had the first ever dockyard, dated in 4500 BP within our territory?

And who else can be more proud than us to have Lord Krishna's Dwarka, dated 2500 BP within our territory, which is the best explored marine archaeological finding in the world?

## Select Bibliography

- Bé, A.W.H., S.M. Harrison and L. Lott.** 1973. *Orbulina universa* d'Orbigny in the Indian Ocean. *Micropalaeontology* 19:150-192.
- Chengappa, R.,** 2002. The lost Civilization. *India Today* 27 (6):38-46.
- Gupta, H.K.,** 2002. Oldest Neolithic settlements discovered in Gulf of Cambay. *Journal of Geological Society of India* 59 (3): 277- 278.
- Haenel, P.** 1987. Palaeoceanographic value of *Orbulina universa* d'Orbigny (Foraminifera). *Oceanologica Acta*, 15:15-25.
- Hashimi, N.H., R. Nigam, R.R. Nair and C. Rajagopalan.** 1995. Holocene sea level curve and related climatic fluctuations for western Indian continental margin: An Update. *Journal of Geological Society of India* 46:157-162. Reprinted in "Vedic Saraswati Evolutionary History of a Lost River of Northwestern India ", B.P.Radhakrishna and S.S Merh (eds.) (1999) Geological Society of India, Memoir 42: 297-302.
- Hecht, A.D., A.W.H. Bé and L. Lott.** 1976. Ecologic and Palaeoclimatic Implications of Morphologic Variation of *Orbulina universa* in the Indian Ocean. *Science* 194:422-424.
- Khadkikar, A.S., C. Rajshekhar, and K.P.N. Kumaran.** 2004. Palaeogeography around the Harappan port of Lothal, Gujarat, western India. *Antiquity* 78 (302): 896-903.
- Nigam, R.,** 1988. Was the large rectangular structure at Lothal (Harappan settlement) a "Dockyard" or an "Irrigation Tank"? In *Proc. of first Indian Conference on Marine Archaeology of Indian Ocean Countries*, S.R. Rao (ed.): 20-22.
- Nigam, R., N.H. Hashimi and M.C. Pathak.** 1990. Sea level fluctuations: Inferences from religious and archaeological records and their oceanographic evidences. *Journal of Marine Archaeology* 1: 16-18.
- Nigam, R., N.H. Hashimi, E.T. Menezes and A.B. Wagh.** 1992. Fluctuating sea level off Bombay (India) between 14,500 to 10,000 years, before present. *Current Science* 62: 309-311.
- Nigam, R. and N. Khare.** 1992. Oceanographic evidences of the great floods at 2000 & 1500 BC documented in Archaeological records. In *New Trends in Indian Arts & Archaeology*, N.C. Ghose and B.U. Nayak (eds.), Vol. 2: 517-522.
- Nigam, R. and N.H. Hashimi.** 1995. Marine sediments and paleoclimatic variations since the

- Late Pleistocene: An overview for the Arabian Sea. *Geological Society of India, Memoir* 32: 380-390.
- Nigam, R. and N.H. Hashimi.** 2002. Has sea level fluctuation modulated human settlements in Gulf of Khambhat (Cambay). *Journal of Geological Society of India* 59 (6): 583-84.
- Nigam, R.** 2006. Foraminifera [Marine Microfossil] as an additional tool for archaeologists - Examples from the Arabian Sea. In *Glimpses of Marine Archaeology in India*, A. S. Gaur and K. H. Vora (ed.): 94-99.
- Nigam, R., R. Saraswat.** 2002. खम्भात की खाड़ी में भारत की प्राचीनतम सभ्यता की खोज: समुद्र तल परिवर्तनों द्वारा आकलन (Oldest civilization in the Gulf of Khambhat, India: Clues from seafloor changes). *Samudrika* 9 (1): 20-22.
- Nigam, R., N. Khare and S. Chaturvedi.** 1999. बदलती जलवायु के साक्षी समुद्री अवसाद एवं पुरातात्विक अभिलेख: एक समालोचन [Marine sediments and archaeological inscriptions as witnesses of changing climate: A review]. In *सागर शुक्ति [Ocean shells]*, E. Desa, U.K. Singh and S.P. Sharma (eds.): 138-144.
- Nigam, R. and N. Khare.** 1997. Evidences of monsoon variability from marine sediments: A comparison with archaeological records. In *An integrated approach to marine archaeology*, S.R. Rao (ed.): 27-31.
- Nigam, R.** 1996. Potentiality of Foraminifera in deciphering paleo-sea levels. In *India's exclusive economic zone*, S.Z. Qasim and G.S. Roonwal (eds.). New Delhi: Omega Scientific Publishers: 225-232.
- Nigam, R., P.J. Henriques, A.B. Wagh.** 1993. Barnacle fouling on relict Foraminiferal specimens from the western continental margin of India: An indicator of paleosealevel. *Continental Shelf Research* Vol.13 (2-3): 279-286.
- Rana, S.S., R. Nigam, R. Panchang.** 2007. Relict benthic Foraminifera in surface sediments off central east coast of India as indicator of sea level changes. *Indian Journal of Marine Sciences* 36 (4): 355-360.
- Rao, S.R.** 1985. Lothal. New Delhi: Archaeological Survey of India.