

## SEDIMENTS OF THE WESTERN CONTINENTAL SHELF OF INDIA— ENVIRONMENTAL SIGNIFICANCE

M. V. SHANKARANARAYANA GUPTHA

### Abstract

The degree of fragmentation and colour of the skeletal fragments, colouration in benthic foraminifers have been studied in surficial sediment samples collected from forty stations from the continental shelf region between Ratnagiri in the south and Indus canyon in the north. The abundance peaks of fragmented shells correspond to the terrace depths of -65, -75, -85 and -92 m in the outer shelf region off Ratnagiri which indicate the different phases of eustatic sea levels. It is inferred from the occurrence of abundance peaks at similar depths in the other regions of the continental shelf that they must correspond to the presence of lowered strands. The disposition of the black shells in a linear fashion parallel to the coast line at the depths mentioned above also supports the proposition.

### INTRODUCTION

In order to understand and establish the eustatic sea level changes and associated shore lines on the continental shelf, many attempts have been made all over the world. There are many indirect means of studying this phenomenon. Milliman and Emery (1968) used the presence of the oyster *Crassostrea virginica* (Gmelin) a shallow water mollusk in the deeper parts of the shelf to locate ancient shorelines. Pilkey *et al.*, (1969) plotted percentage of broken shells versus distance to locate the possible former strand lines. Davies (1970) studied colouration of benthic foraminifers to interpret the depositional environments. Others have used peat on the continental shelf as an indicator of lowered sea-levels. In the present study, the imprint of eustatic sea-levels on the continental shelf has been evaluated by studying the colouration of benthic foraminifera and by the state of preservation of skeletal fragments.

### MATERIAL AND METHODS

Forty surficial samples of sediment were chosen for the present investigation (Fig. 1). The sediment was wet sieved through 230 mesh sieve to separate +62 micron fraction which was dried and dry sieved through half phi interval. Since the present study is mainly concerned with paleoenvironmental/paleodepositional environment, only the coarse fraction of 18 mesh size fraction was chosen for skeletal fragment analyses and the 35 and 60 mesh sizes were taken for the study of colouration in benthic foraminifers. The material was examined under a stereo-binocular microscope and 300 grains were counted to compute the frequency percentage of all the parameters.

The parameters of skeletal fragments studied are indicated in Table I.

### REGIONAL PHYSIOGRAPHY AND SEDIMENTARY FRAMEWORK

The study area lies under the influence of southwest monsoon. The largest river in the area is Indus, which drains the western portion of the Indo-Gangetic plain. The others are the Mahi, Narmada and Tapti emptying into the Gulf of Cambay. The width of the continental shelf varies from about 100 km south of the mouth of Indus to 160 km southwest of the Gulf of Kutch. Off Gulf of Cambay the coast runs almost straight with a shelf width of about 220 km. The continental shelf in the study area can be divided into inner shelf and outer shelf marked by the difference

in topography and sediment type (Stewart *et al.*, 1965). Studies by Nair (1971) and Siddique and Rajamanickam (1974) have shown that the inner shelf has smooth featureless topography, whereas the outer shelf is formed by rugged topography. Further, Nair (1974, 1975) suggests that the outer shelf topography off the Gulf of Cambay and southwards consists of algal and oolitic ridges formed during the Holocene transgression. Sedimentary facies also show marked difference in the inner and outer shelf. The inner shelf consists of modern terrigenous muds and the outer shelf is covered by relict carbonate sands.

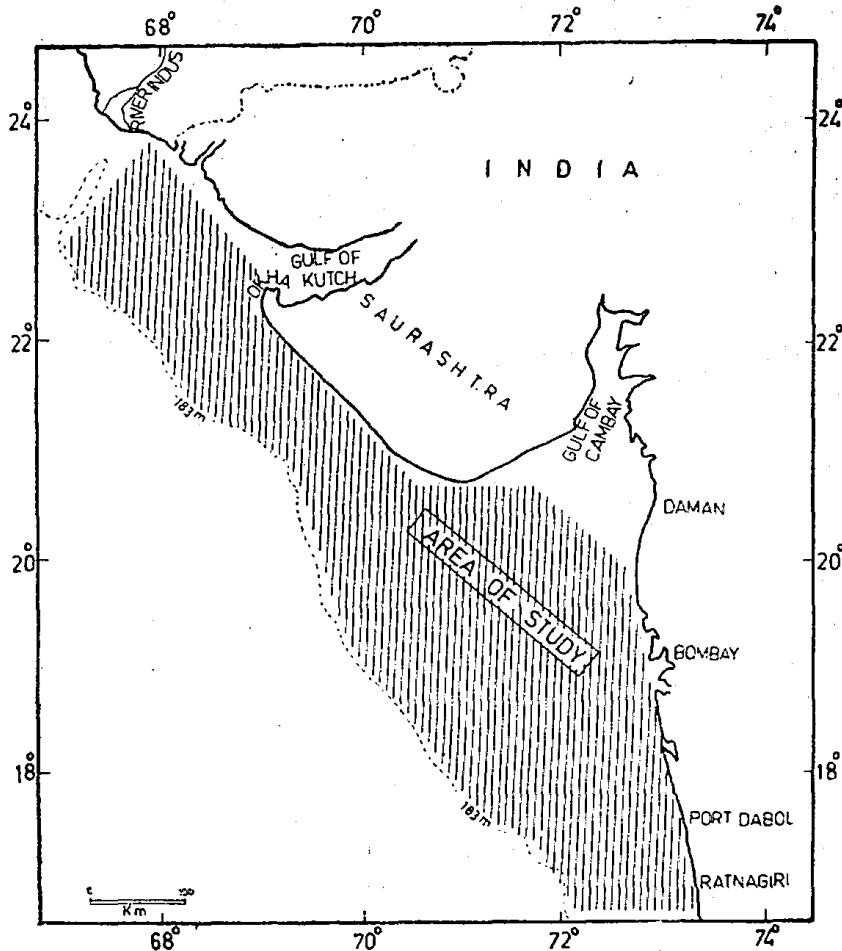


Figure 1. The area of study.

Hashimi and Nair (1976) have shown that the 80% insoluble residue contour is found close to the coast along Ratnagiri and Saurashtra coast, which suggests greater sediment influx in the nearshore region. In the Gulf of Cambay, due to sediment discharge by the Narmada and Tapi, the 80% contour protrudes into the Gulf. On the outer continental shelf off Bombay, the percentage of insoluble residue decreases abruptly which has been attributed to the fact that the bulk of the terrigenous material is confined to the inner shelf leaving the outer shelf area free from sediment accumulation.

#### RESULTS AND DISCUSSION

In the 18 mesh size fraction, molluscan shells are the most important component in the sediment. The fraction also contains a few tests of foraminifera, echinoids,

corals, bryozoa, serpulites etc. It has also been noticed that the bivalves outnumber the gastropods (Hashimi and Nair, 1976).

It is seen that the concentration of fresh shells decreases seaward and worn shells are predominantly distributed on the outer shelf. The number of worn shells is proportional to the distance from the coast and the depth of water. The percentage of worn shells range from 8% on the inner shelf to 100% on the outer continental shelf.

The fragmentation of tests ranges from 65-100% with a progressive increase seaward. The areal distribution of unfragmented shells as defined in Table I; shows linearity in their distribution.

TABLE I. Parameters of skeletal fragments

Parameter	Characteristic features
<b>I. STATE OF PRESERVATION</b>	
Fresh . . . . .	Tests are bright in colour showing characteristic lustre and morphological features such as ornamentation
Worn . . . . .	Shells abraded due to wear and tear caused by physical and biological agencies resulting in the loss of distinct morphological features of the tests; often it is practically impossible to identify the shells as a consequence of high degree of abrasion
<b>II. COLOUR OF THE SHELLS</b>	
Dirty white (various shades of brown) . . . . .	This is prominent in the case of worn shells wherein the outside of the test is subjected to high degree of abrasion, hence looks dirty
Greyish black . . . . .	Here the shells are greyish black and sometimes filled with black/greyish black material
<b>III. DEGREE OF FRAGMENTATION</b>	
Unfragmented . . . . .	The shells are devoid of any damage. A slight damage on the edges has been considered unbroken
Fragmented . . . . .	The shells are considered as fragmented when the breakage of the test is found approximately more than one fourth of the whole test
<b>IV. In the present analyses, broadly three different colours of benthic foraminifera have been considered, viz. Bluish green, greyish brown and black/greyish black.</b>	

White shells are concentrated on the inner and middle shelf, and diminish on the outer continental shelf. Unlike white shells, the dirty white shells (various shades of brown) show larger concentration on the outer continental shelf with a range of 75-100%.

Besides, there are greyish black and black coloured shells, which are considered as one unit. These shells are found confined to the 60-80 m line in the outer continental shelf showing somewhat linear distribution almost parallel to the coast and may perhaps suggest an ancient shoreline between 60-80 m.

Worn shells, result when the sediment is exposed for long periods due to wear and tear caused by various physical and biological agencies and this results in the loss of morphological features of the shells. Maximum concentration of these skeletal

fragments was noted on the middle and outer shelf. When the fresh versus worn shells are plotted, it shows negative correlation (Fig. 2). Hashimi and Nair (1976) on the basis of roundness of skeletal components reported that the percentage of shells in class 1-4 in +35 mesh-fraction shows a decrease to 50 m, and increases to 70 m, remains constant at 90 m depth and thereafter decreases to 120 m depth.

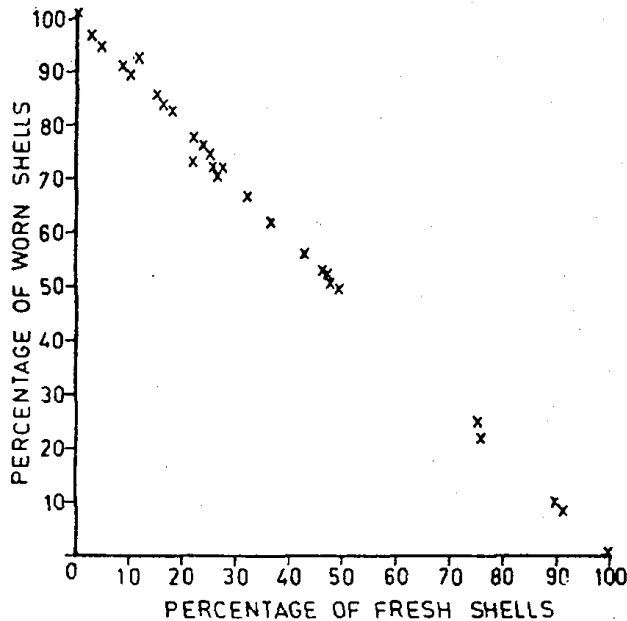


Figure 2. Showing the negative correlation in the distribution of fresh and worn shells.

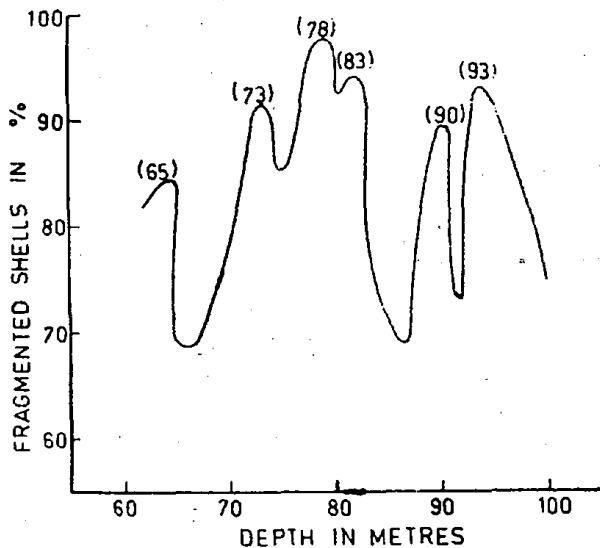


Figure 3. Showing the abundance peaks of fragmented shells corresponding to the terrace depths.

Breakage of shell material may be due to physical and biological agencies. The surf zone along the shore line is very effective in shell fragmentation. Therefore, the presence of worn, dull-lustered fragmented shells, (Plate I, Fig. 1) in large quantities on the outer shelf indicate that this must have occurred in the shallow/near shore regions at the time of a lowered sea level in the past when these were sub-areally exposed. Biological factors also were responsible to some extent for the fragmentation of tests and many borings on the shells may facilitate breakage.

When the water depth versus percentage of fragmented shells are plotted (Fig. 3) it shows peaks corresponding to the terraces showing strand lines at depths of -65, -75, -85 and -92 m indicated by the echograms (Plate I, Fig. 2) off Ratnagiri on the outer continental shelf.

Based on the distribution and proportion of fresh and worn shells in the sediment, the continental shelf region can be classified into three zones as follows:

1. The inner continental shelf (approximately 0-35 m) dominated by the skeletal fragments of fresh appearance.
2. The middle shelf (approximately 30-60 m) having an admixture of both fresh and worn shells in varying proportions.
3. The outer shelf (beyond 60 m depth seaward) largely constituted by the worn, highly abraded and bored shells.



Figure 1. Showing unfragmented and worn skeletal components.

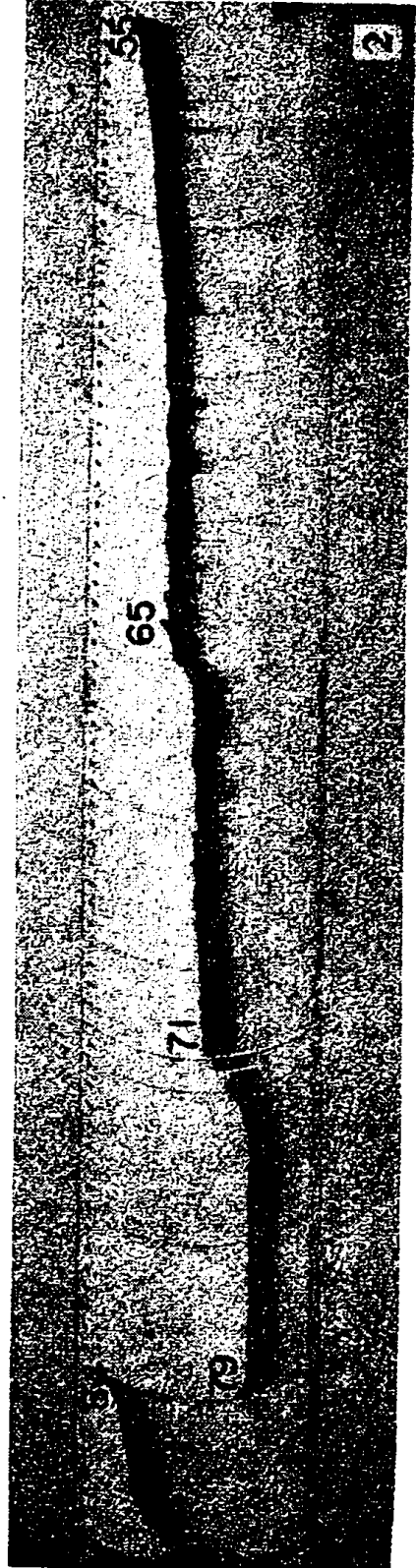


Figure 2. Echogram showing the submerged terraces on the outer shelf off Rainagiri (terrace depths in metres).

## AREAL DISTRIBUTION OF BENTHIC FORAMINIFERAL SHELLS

Greyish brown shells in the 35 and 60 mesh are largely concentrated on the middle shelf and the percentage frequency decreases with increasing depth. There are two small patches of considerably high concentration (40-55% range); one is off Okha and the other one is just south of Bombay, both in the nearshore regions. This may be due to the oxidising environments existing at the time of deposition. According to Maiklem (1967) brown colouration of calcareous skeletal components is probably due to the oxidised iron stain. Pilkey *et al.*, (1969) have also noticed that the brown shells are restricted to nearshore region.

A unique distribution of bluish green foraminiferal tests in 35 mesh fraction (0-15%) is present on the middle shelf. The maximum concentration of about 60-85% was found off the southern Saurashtra Coast. This bluish green colouration may be attributed to the presence of glauconitic sand which might have induced the colour.

Similarly, in 60 mesh fraction, these shells are sparsely distributed in the middle and outer shelf, whereas off south of Saurashtra coast these suddenly increase to 60-65%.

Black shells are distributed sparsely with a range of 5-10% on the continental shelf. These are defined as those shells which range from dark bluish grey to true black. There are diverse opinions regarding the origin of the black colouration of the skeletal material. The blackening of tests is believed to be due to prevailing reducing conditions at the time of deposition. Black pigmented carbonate grains are found in varied amounts in the Shark bay sediments, of which the most commonly pigmented skeletal grains are porcellaneous foraminifers (Davies, 1970). Similarly, in the western continental shelf sediments also, it was found that miliolids are frequently stained with black pigmentation either wholly or partially with a gradation of pigmentation. This may be due to the infilling of chambers by pyrite in an anaerobic environment on a microscale, as also reported by Davies (1970) from the Shark bay. Further, in support of the above, it was found that the sediment in the shelf region shows the presence of pyrite (Hashimi *et al.*, 1977). Doyle (1967) opines that the blackening may be the result of burial in reducing condition. Milliman and Emery (1968) stress that such reducing conditions are found only in muddy nearshore environment.

In order to understand the phenomenon responsible for the blackening of foraminiferal tests, the black foraminiferal tests were separated from a sediment sample in the east coast of India from a depth of 165 m, and were analysed for the following elements by Atomic Absorption Spectrophotometer.

Element	in ppm
Cu	25
Pb	177
Ni	128
Co	96
Mn	306
Fe	3472
Zn	861

The high concentration of Ni, Zn, Co and Pb coupled with the black colouration of the shells are indicative of an oxygen poor benthic environment usually associated with regions of upwelling. Since all the elements analysed for may have a biogenic origin also it is not possible to indicate what proportion of these elements are associated with the coating of the shells and what proportion are

associated with the hard parts.

The state of preservation of shells show linear distribution parallel to the coast-line and close correspondence of abundance peaks to submerged terrace depths at -65, -75, -85 and -92 m suggesting the presence of different strand lines. Additional

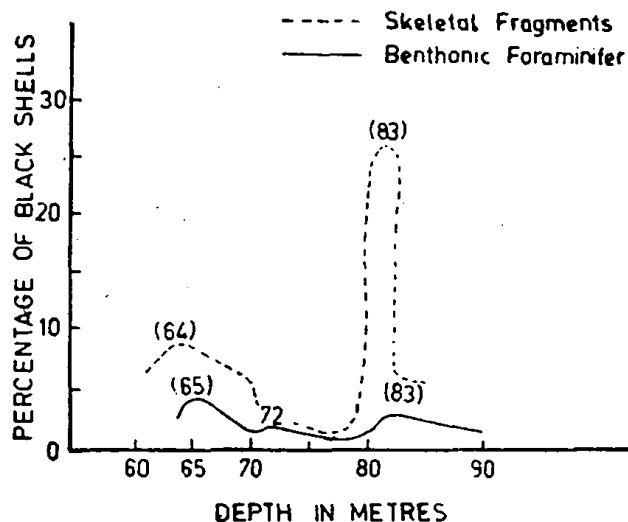


Figure 4. Showing the correspondence of terrace depths with the peaks of black skeletal fragments and foraminifer shells.

evidence in the form of black shells on the outer shelf which also show linear distribution produces supporting evidence for the presence of old shorelines. When the distribution of black shells of both skeletal fragments and foraminifers (Fig. 4) versus depth are plotted, close correspondence of terrace depths with the peaks of abundance of the black shells is observed.

#### ACKNOWLEDGEMENTS

The author wishes to thank Captain K. L. Chopra, Officers and crew of *I.N.S.*

*Darshak* for their cooperation in collecting the samples. Grateful thanks are due to Dr. S. Z. Qasim and Shri H. N. Siddiquie for their encouragement and guidance, and to Messrs. R. R. Nair and P. S. N. Murthy for their critical review of the manuscript and valuable suggestions. Thanks are also due to Messrs. M. Wahidulla and V. M. Date for drawings and photographs respectively, and to R. S. Topgi for atomic absorption spectrophotometric analysis of black shells.

#### References

- DAVIES, G. R., (1970) Carbonate Bank Sedimentation, Eastern Shark Bay, Western Australia, pp. 85-169. *In* Carbonate Sedimentation and Environments, Shark Bay, Western Australia. *Memoir Amer. Assoc. Petrol. Geol.*, v. 13.
- HASHIMI, N. H. and NAIR, R. R., (1976) Carbonate components in the coarse fraction of Western continental shelf of India (Northern Part). *Indian Jour. Mar. Sci.*, v. 5, pp. 51-57.
- MAIKLEM, W. R., (1967) Black and brown speckled foraminifer sand from southern part of the Great Barrier Reef. *Jour. Sed. Petrology*, v. 37, no. 4, pp. 1023-1030.
- MILLIMAN, J. D. and EMERY, K. O., (1968) Sea Levels during the last 35,000 years. *Science*, v. 162, no. 3858, pp. 1121-1123.
- NAIR, R. R., (1971) Beach rock and associated carbonate sediments of the fifty fathom flat, a submarine terrace on the outer continental shelf off Bombay. *Proc. Indian Acad. Sci.*, v. 72, no. 3, pp. 148-154.
- (1974) Holocene sea levels on the Western Continental shelf of India. *Proc. Indian Acad. Sci.*, v. 79, no. 5(B), pp. 197-203.
- (1975) On the nature and origin of small scale topographic prominence on the western continental shelf of India. *Indian Jour. Mar. Sci.*, v. 4, pp. 25-29.
- PILKEY, O. H., BLACKWELDER, B. W., DOYLE, L. J., ESTES, E. and TERLECKY, P. M., (1969) Aspects of carbonate sedimentation on the Atlantic continental shelf off the Southern United States. *Jour. Sed. Petrology*, v. 39, no. 2, pp. 744-768.
- SIDDIQUIE, H. N. and RAJAMANICKAM, V., (1974) The Geomorphology of the western continental margin of India. Initial Report and Data File of INS *Darshak* Oceanographic Expedition 1973-74. *Unpublished Report of Nat. Inst. of Oceanography*, ref. no. 74-1, pp. 228-233.
- STEWERT, R. H. and PILKEY, O. H., (1965) Sediments of the Northern Arabian Sea. *Mar. Geol.*, v. 3, pp. 411-427.

#### Address of the Author

M. V. SHANKARANARAYANA GUPTHA, National Institute of Oceanography, Dona Paula, Goa-403 004.

(Received: Sept. 12, 1977)