

# Absence of Terraces on a Submerged Carbonate Bank and its Implication to Holocene Sea Level Transgression on the Western Continental Margin of India

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Estimates of the Holocene sea level transgression have an important bearing on a host of geological and archaeological problems. An universally applicable eustatic curve appears unrealistic in view of the global geoidal variations.

Radiocarbon dated samples of shallow water origin from the western shelf indicate a low stand of sea level between 90 and 100 m about 10000 years ago. From the lack of evidence of still-stands on a submerged shelf edge reef and from coral growth rates, it is inferred that sea level rose at the rate of 10 m/1000 years on the western continental margin of India.

## INTRODUCTION

The determination of the rate of rise of post glacial sea level (the Holocene transgression) finds important applications in geodesy, marine archaeology, particularly in the growth and decline of ancient civilisations that developed at coastal sites, paleoclimatology and marine sedimentation. It is generally accepted that a major regression of the sea accompanied the last glacial stage, about 18000 years ago and that de-glaciation brought the sea level to its present position. Several recent estimates (Milliman and Emery, 1968: 1121-1123) put the maximum lowering to about 130 m below the present at about 15000 years before the present. However, Dillon and Oldale (1978: 56) indicated that the Milliman and Emery curve may be erroneously deep at glacial maximum. Blackwelder, Pilkey and Howard (1979: 618-620) based on in place lagoonal and salt marsh sediments from vibro cores from the Carolina continental shelf, suggested that the regression during the glacial maximum was not as profound as has been indicated in the literature.

Regardless of the precise level of the maximum low stand the level rose in response to the ensuing de-glaciation, the so called Holocene transgression. There are considerable differences of opinion at present regarding the mode of this eustatic rise. Fairbridge (1961: 99-185) proposed a Holocene sea level rise curve with pronounced variations, whereas Shepard and Curry (1967: 283-291) showed it to be smoothly rising, and Emiliani *et al.* (1975: 1083-1090) proposed that the sea level rose rapidly, at decimetres per year, about 11600 years BP. Disagreements between the findings of the various workers have been attributed to changes in the geoid that took place during the glacial and interglacial configuration of the earth. Because of the differing tectonic histories of the various regions and the geoidal shift it is now regarded that no universal eustatic curve appears possible (Morner, 1976: 123-151; Bowen, 1978; Vita-Finzi, 1973).

In view of the reasons advanced above no attempt will be made here to arrive at an absolute chronology of the sea level rise in the conventional manner by plotting the available dates from the west-

ern continental shelf of India in the many sea level variation diagrams from the other parts of the world. The reason in part is also due to the fact that definitive evidence of the dated samples (ooid grains, oolitic limestones, algal limestones, aragonite cemented limestones, and composite shells) being in-place samples is lacking. The available dates however, are shown in *Fig. 1* and it shows that the age of the sediments and rocks on the western shelf are between 9000 to 14000 years. On the basis of a well dated core, from the Arabian Sea the date of the glacial inter glacial boundary has been placed at 10200 years, and the climate during this period has been inferred to be arid (Nair and Hashimi, 1980: 229-315; Hashimi and Nair, 1986: 309-319).

In this report field evidence is adduced to demonstrate that the post-glacial rise of sea level on the western continental margin of India was 'rapid'. The evidence consists of the absence of nicks, ledges and allied features associated with the intermittent rise of sea level on a submerged shelf margin coral reef, the Gaveshani Bank (Nair and Qasim, 1978: 55-58) and the presence of a number of drowned carbonate banks in the Laccadive Sea.

## GEOLOGICAL SETTING OF WESTERN CONTINENTAL MARGIN OF INDIA.

The western continental margin of India is a mid-plate continental margin. The lands bordering this continental margin on the northwest (the Saurashtra Peninsula) are subjected to seismic activity while those on the central and southern parts consist of seismically stable Pre-Cambrian shield rocks. The entire western shelf and slope is devoid of any major earthquake epicentres (Gutenberg and Richter, 1965) and may therefore be considered tectonically stable. Furthermore, there are no deltas on the western shelf, which if present, tend to cause subsidence of the shelf. The sediments on the western shelf consist of two facies, terrigenous and carbonate. The modern terrigenous facies (silts and clays) are present to a depth of 50 to 60 m and seaward of these depths are found the relict carbonate sand facies extending

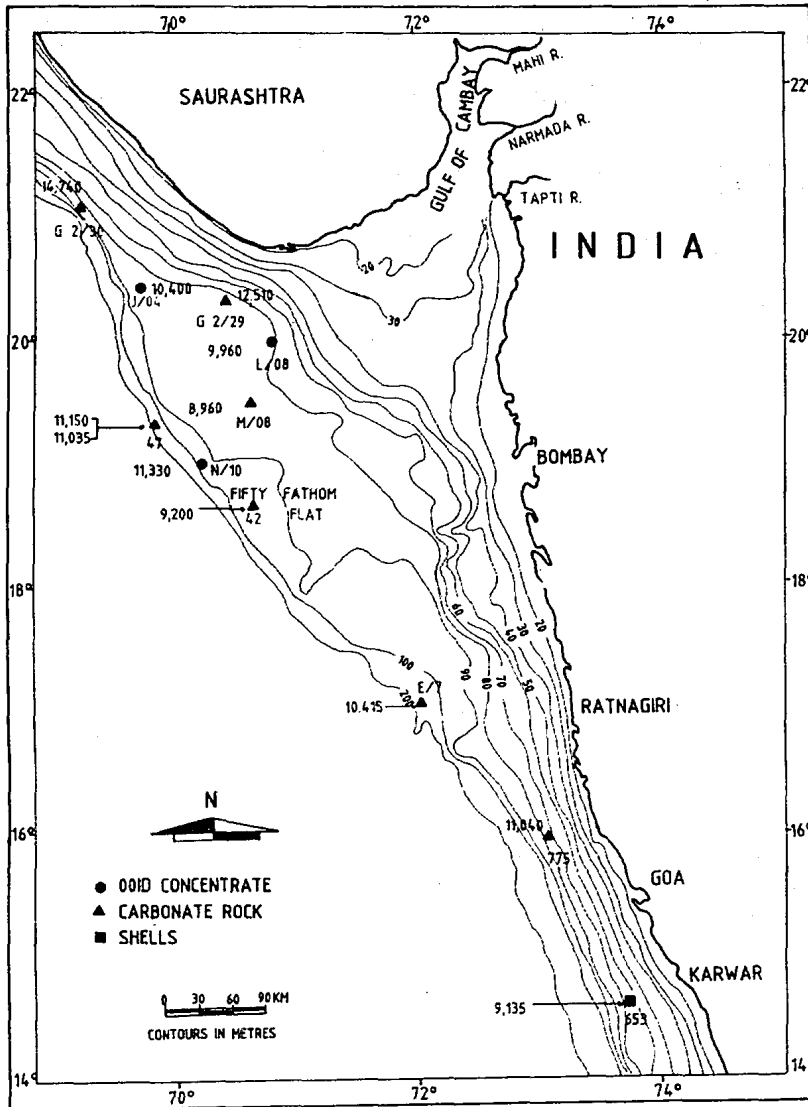


Fig. 1 Radiocarbon dates and bathymetry

to the shelf edge (90 to 100 m). The outer shelf carbonate sands consists of a variety of skeletal and non-skeletal grains like ooids, peloids, grapestones in varying proportions. Linear outcrops of oolitic limestones, algal limestones and aragonite cemented sandstones occur throughout the outer shelf.

**EVIDENCE FROM GAVESHANI BANK**

Bathymetric features such as nicks, ledges, and terraces are usually advanced as evidence of low stands of sea level. Such features result from still stand of transgressive and regressive sea and are considered to be, in the broadest sense, drowned shorelines. Raised beaches are their subaerial counterparts indicating high stands of past sea level. The origin of such notches and terraces on submerged features are attributed to a combination of physical, chemical and biomechanical causes. Their configuration depends on the geometry of the intersection of the sea level with the topog-

raphic profile. Thus on steeply sloping profiles of insular shelves and submerged banks the result is a notch or ledge while on flat continental shelves wide terraces are formed. They develop more frequently in carbonate material and less so in harder rocks. Their presence has been documented so universally on submerged features that their absence as on Gaveshani Bank, warrants an explanation.

Gaveshani Bank is a submerged, live, hermatypic coral reef located (Lat. 12° 24' N, Long. 73° 45' E) in 75 m water depth on the southwestern part of the shelf (Nair and Qasim, 1978:55-58). It may also be termed as shelf margin reef because of its location close to the shelf edge. Gaveshani Bank is one of a general class of drowned coral reef whose origin is shown schematically in Fig. 2. It consists of two 'sea mount' shaped topographic highs. One of them has a relief of 14 m and the larger one 38 m. The latter has a NW-SE orientation and is about 70 m long and 330 m broad

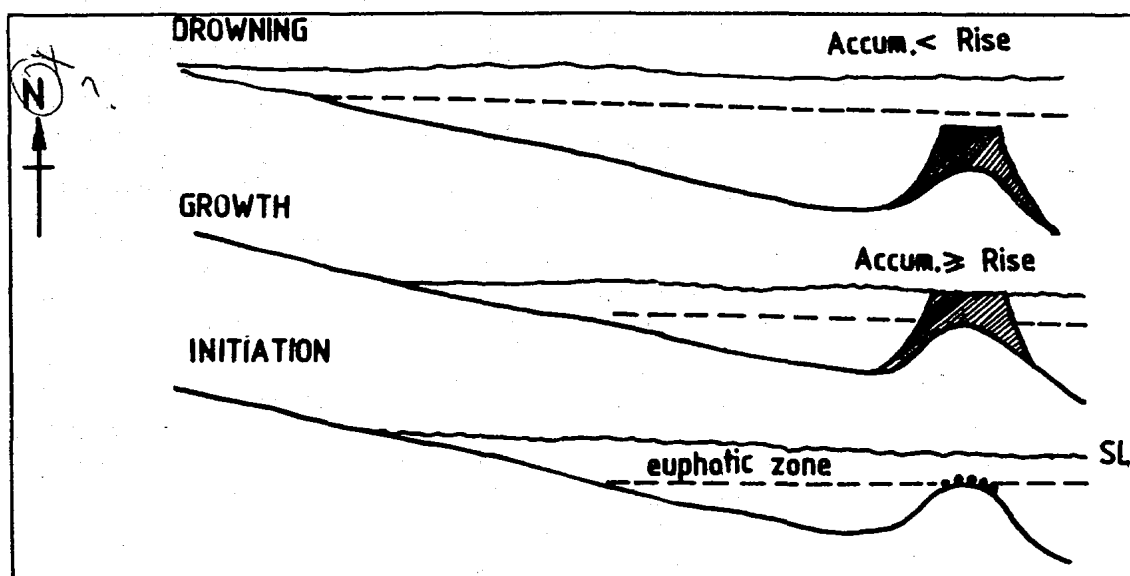


Fig. 2 Schematic diagram of initiation, growth and drowning of carbonate reefs. (Adopted from Schlager (1981 : 197 – 211).

(Qasim, 1979: 261-262). Grab sampling and dredging over this bank yielded mainly live sclerectinian corals and smaller amounts of calcareous algae. A number of transects were made over the bank for echosounding purposes at a ship speed of one to three knots.

Shown in *Plate 38* are two of the clearest echograms that were obtained. *Plate 38a* across the bank (east-west section) and *Plate 38b* is diagonally across in the northwest-southeast direction, approximately along the long axis of the larger feature. These echograms were obtained with a Kelvin Hughes MS-45 operating at a fixed frequency of 30 KHz. The echograms demonstrate clearly, in notable contrast to similar submerged features, the conspicuous absence of any kind of notch or terrace. The sides of the bank, on the other hand, are very smooth and have near perfect bi-lateral symmetry. This carbonate bank is thus an exception to the general rule in so far as the presence of notches and terraces are concerned. Is their absence apparent or real? Four factors are here critically evaluated to resolve this question. They are (a) inability of the echosounder sound beam to 'see' and record small scale features, (b) steepness of the sides of the bank, (c) overgrowth of corals on ledges and notches resulting in masking them, (d) rate of rise of sea level continuous and rapid resulting in insufficient time available for notching and terrace formation.

a) The Kelvin Hughes MS-45 echosounder used in the present study is a shallow water echosounder commonly used for continental shelf survey. It's characteristics, mentioned earlier, render it unlikely that at the shallow depths (75 m) involved in the present instance, small scale features go unrecorded. On steep slopes the possibility of the suppression or masking of features due to side echoes and so forth is greater, for example, in precision depth recorders used in deep sea surveys. Furthermore the vertical exaggeration of the record is much greater in the MS-45 than in deep sea echosounders. These properties coupled with the fact that the profiles were obtained at slow ship's speed makes the possibility of terraces being not re-

corded due to instrument artefact rather remote.

- b) The presence or absence of wave cut terraces has been related to the degree of steepness of the profile by Flemming (1968: 1097-1099). He finds that if the slope of the profile is  $1/4$ , erosion is slow because most of the wave energy is reflected. Maximum erosion takes place when the slopes are between  $1/4$  and  $1/10$  and extremely slow when less than  $1/50$ . An estimate, derived from the horizontal distance between the fix marks (about 1400 m) and the height of the bank (38 m), of the slope of the sides of the bank yields a value of about  $1/15$ . This value is close to the range of slopes which result in maximum erosion. It would appear that the steepness of the sides of the Gaveshani Bank, which in any case appears exaggerated in the echogram, is not the limiting factor.
- c) Masking by overgrowth of corals of erosional features is an admitted possibility but will be restricted to a depth of 48 m, that is 10 m below the bank top. The restriction is due to the fact that the compensation depth (the depth at which one percent of the surface illumination is available for the photosynthesis of the symbiotically associated *zooxanthellae*) is 48 m over the bank waters. Below this depth little or no coral growth is possible. In any event, most overgrowths or secondary growths take place only after the occurrence of abnormal conditions such as storms which tend to destroy the reef colony wholly or partially and not under normal conditions.
- d) The final possibility is that the rate of rise of sea level was rapid. If the rise was intermittent then at still stands during the course of its rise, physical (wave), chemical (solution of the carbonates), biomechanical (borers and so forth) should have caused one or more distinct indentation circumscribing the bank at various heights. Earlier arguments have demonstrated that in fact the absence of terraces is a real and not an apparent phenomena.

It would thus appear that the evidence favours the rapid rise of the Holocene transgression resulting in the drowning of the coral

bank. Some idea, admittedly crude of the rate of rise may be obtained from the growth rate of corals. Published data (Moore and Krishnaswamy, 1974: 269-276; Macintyre and Smith, 1974: 277-287) suggest growth rates of the order of 0.5 cms per year. Assuming this growth rate and assuming further that the sea level rose twice as fast as the growth rate (the height of the bank being one-half the maximum water depth), one obtains the sea level rising at the rate of 10 m/1000 years about 10000 to 11000 years ago on the western continental margin of India. The principal drawback in this estimate, which must be considered as order of magnitude figure only, is that coral growth rates vary with the species and the environment in which they grow. The conclusion from this study and specific to the western continental margin of India is that the Holocene transgression was of the nature of a rapid drowning. Additional evidence of the rapid rise of Holocene sea level is the presence of number of drowned banks of coral or coralline algae in the Laccadive sea. These are the Bassas de Pedro (42 m below surface), Sesotris Bank (32 m), Cora Divh (41 m) and Angria Bank, located some distance north of these and submerged under 24 m of water.

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