

HOLOCENE SEA-LEVELS ON THE WESTERN CONTINENTAL SHELF OF INDIA

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ABSTRACT

Submerged terraces on the Western Continental Shelf between Bombay and Karwar at depths of -92 , -85 , -75 and -55 meters are inferred, on the basis of radiocarbon dates, to be of Holocene age (about 10,000 years before present) and thus suggest apparent similarities to Global Holocene sea-level fluctuations. An unequivocal chronology of the sea-level fluctuations is however not possible at present due to the limited data points, the possible tectonic instability of the shelf and the unknown extent of the influence of the downwarping by the Indus cone on the shelves bordering the Arabian Sea.

INTRODUCTION

The majority of the continental shelves have been affected to a greater or lesser degree by the Pleistocene glacial conditions (Emery, 1968). The effect of the glacial and interglacial periods naturally has been more intense in the northern latitudes where glacial activity during Pleistocene would have extended to the continental shelf itself. For shelves of low latitudes the influence of the cold and warm conditions would be at best indirect. Four major periods of cold climates have been postulated to have occurred during the Pleistocene. Recent studies by Emilliani (1972), however, indicate that many more than four glacial periods, each with a shorter duration than hitherto believed, have taken place.

A common global feature met with on the continental shelf is the result of the lowering of sea-level due to the removal of water from the oceans and its storing up in the form of ice on the continents or, in other words, glacio-eustatic sea-level fluctuations. The imprint of such lowered sea-levels and associated shore lines varies with the morphology, structure and sedimentation characteristics of the shelf in question. Optimum conditions for the study of Pleistocene and later low stands of the sea-level would be those

shelves which are tectonically stable (at least over the period of time in consideration, *i.e.*, 1.5 to 2 million years before present), absence of deltas causing downwarping of the shelf, and presence of suitable materials for radiocarbon and other radiometric methods of dating (Fairbridge, 1961). The western continental shelf may for the purpose of this study be considered as tectonically stable over the Holocene period—this assumption, though it may not be wholly correct because of the possible effects on the continental shelf of the occurrence of recent earthquakes and the manifestation of volcanic phenomenon such as hot springs on the adjacent peninsula and along the Konkan coast respectively (Guha, Murti, Gosavi and Padale, 1970). Additional characteristics of the shelf such as absence of deltas and the presence of carbonate sediments and rocks of datable nature renders the shelf suitable for the study of sea-level variation through Pleistocene and later times.

The necessity for undertaking such studies partly stems from the fact that the old shorelines on the continental shelves may be the repository of economic heavy minerals analogues to those found on the recent beaches along the coast (Emery and Noakes, 1968).

RESULTS AND DISCUSSION

Echosounding on the continental shelf with a view to locate submerged terraces are sparse and have limited coverage. These preliminary studies (Nair, 1971 *b*) have provided indication of the presence of terraces of Bombay, Ratnagiri and Goa. By far the most extensive and prominently developed is the one called the Fifty Fathom Flat which as the name suggests is found at a depth of approximately 90 meters. This terrace consists over its width, of minor prominences (1–8 meters in height) of algal and oolitic limestone. The debris resulting from the erosion of these prominences, remnants of organisms (molluscs, bryozoa, foraminifera) and oolites constitute the dominant sediments on the terrace (Nair, 1971 *a*; Stackelberg, 1972). As mentioned earlier, this terrace is developed prominently off Bombay where the shelf is widest (about 280 km) and is seen to be much less prominent as one proceeds southwards with progressively narrowing shelf widths.

Other terraces which have been observed on the continental shelf are those at –92, –85, –75 and –55 meters (Nair, 1971 *b*). The former three (–92, –85 and –75 meters) along with the Fifty Fathom Flat from their similarities in depth and the nature of the sediments found thereon, probably correspond to the global Holocene still stand of sea-level between 75–90 meters reported by MacIntyre (1972). Terraces at shallower depth probably exist on the western

shelf, for example, the 17 fathom (31 meters) terrace off the Gulf of Cambay reported by Shepard (1963), but have not been investigated in detail. The ideal procedure for obtaining a chronology of various low stands of sea-level would be to obtain radiometrically datable samples from the above-mentioned terraces to yield a reliable depth *versus* date correlation. From Table I, it is obvious that only two samples (*a* and *c*) satisfy the above criteria. They tend to confirm that the 75–90 meter terrace is of Holocene age. Sample *b* (Table I), with the extremely recent age indicates living deep water coral. Moreover, the associated biota in the area such as sponges, gorgonaceans (Neyman, 1969) are suggestive of a reefal environment which is probably dead or inactive at the present day as a result of the oxygen deficient waters present on this part of the shelf (Carruthers, Gogate, Naidu and Leevatsu, 1959; Neyman, 1969).

TABLE I

Radiocarbon dated samples

No.	Station No.	Location	Depth(m)	Nature of Sample.	Radiocarbon Age
(a)	42	18° 36.0' N 70° 39.4' E	96	Oolite limestone	9200 ± 135
(b)	"	"	"	Coral	145 ± 95
(c)	653	10° 33.0' N 73° 43.8' E	58	Shells	9135 ± 130
(d)	47	19° 15.0' N 69° 45.0' E	150	Coralline algae.	11150 ± 130
(e)	"	"	"	"	11035 ± 400
(f)	E/7	17° 00' N 71° 59.0' E	161–181	"	10415 ± 260

The remaining samples (Table I, *d, e, f*) are from seaward off the shelf edge and are concretions of coralline algae yielding comparable ages. It is, however, not possible to attribute a low sea-level stand at 150 meters depth during the period 11,000–10,000 years ago because of inherent drawbacks in the nature of the samples. Milliman and Emery (1968) have pointed

out that algal limestones have limited use as sea-level indicators because of the variable depth range over which the algae have been found to live and that sea-levels based on the ages of such rocks generally indicate a lower stand as compared to oolitic limestones.

From world-wide radiocarbon dates on the continental shelves, Milliman and Emery (1968, Fig. 1) have constructed a sea-level depth *versus* age curve, the important features of which, as cited by Emery, Niino, Sullivan (1971) are, (a) During 13,000 years in the past and particularly the last 3,000 years, the rate of rise of sea-level was faster than at present, (b) the curve shows a sea-level minimum at some intermediate age, generally between 19,000 and 15,000 years ago but nearer to 15,000 years and, (c) the sea-level was higher

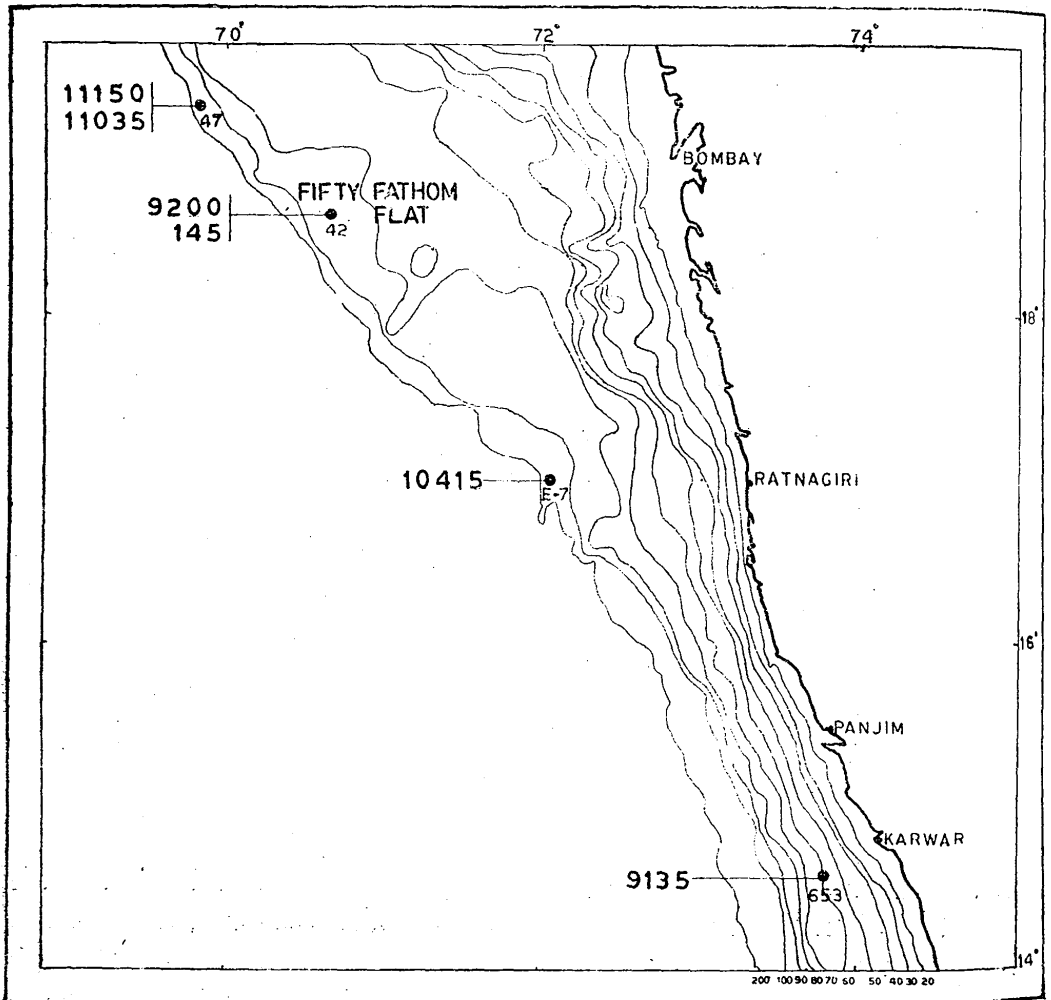


FIG. 1. Radiocarbon dates from the northern half of the Western Continental Shelf of India. Contours in meters.

30,000 to 25,000 years ago than 15,000 years ago and possibly higher than at present—the latter is still a matter of dispute. Additional support for the validity of the Milliman-Emery curve, at least for the period 16,000-8,000 B.P., comes from the work of Bloom (1971, Fig. 4) who compared continental ice sheet area and volume with the above curve of sea-level lowering and found an excellent fit between the two.

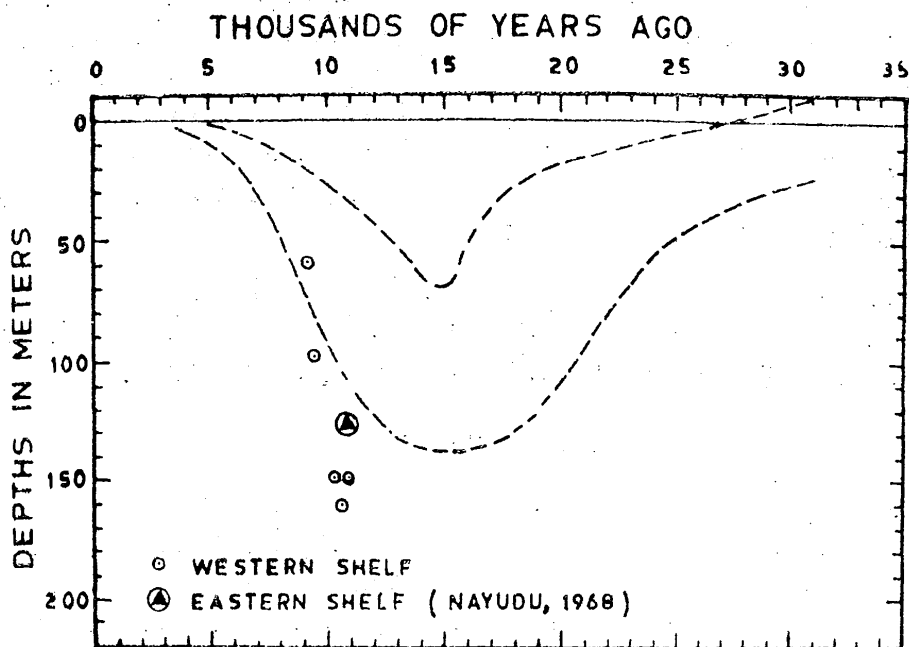


FIG. 2. Radiocarbon ages from the western continental shelf (and one from the eastern shelf) plotted on the Milliman-Emery diagram (see text for explanation of diagram). Note that the coralline algae ages fall outside the envelope represented by the two dashed curves.

The available radiocarbon dates from the western Continental shelf are shown on the map (Fig. 1) and plotted on the Milliman-Emery diagram (Fig. 2). The figures indicate that only two of the available dates fall within the envelope confirming the general trend of sea-level variation. The three remaining dates based on algal samples fall outside the envelope because of reasons cited earlier. A single available data on a composite oolite sample from the eastern continental shelf (Nayudu, 1968) is also plotted for comparison.

The limited data points available for western continental shelf, therefore, permit only of the general inference that parts of the continental shelf show a tendency to follow the general pattern of sea-level fluctuations.

Not taken into account in the above discussion of eustatic changes of sea-level is the result of the change in volume of the ocean basins as a result of sea floor spreading. The increase in volume over the Holocene period is expected to be marginal but when considered over a period of 100,000 years the effect becomes substantial (Bloom, 1971).

An additional factor which probably complicates the study of sea-levels in the Arabian Sea and the Bay of Bengal is the Indus cone and the Bengal fan respectively which because of their large thickness of sediments (Laughton *et al.*, 1971; Curray and Moore, 1971) may cause isostatic downwarping of the crust with attendant change in the volume of the basin. The magnitude of such factors is not known at present but would have to be taken account of in future studies of sea-level variations on the continental shelves bordering the Arabian Sea and the Bay of Bengal.

Additional radiocarbon dates would doubtless be useful in yielding a better chronology of sea-level variation and in contributing to the understanding of the problem of tectonic stability of the western shelf.

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