Indian Journal of Marine Sciences
Vol. 11, March 1982, pp. 35-42

Morphological Changes of the Beaches of Goa

C S MURTY, M VEERAYYA & V V R VARADACHARI
National Institute of Oceanography, Dona Paula, Goa 403 004

Received 16 *March* 1981; *revised received* 13 *October* 1981

Morphological variations of 2 of the major beaches of Goa have been found to be cyclic over a period of approximately 1 yr. These beaches attain their maximum sediment storage around April/May. They are then subjected to rapid rates of erosion with the onset of the southwest monsoon wind and wave conditions followed by slower rates during the subsequent period of the monsoon. This continues till August when the beaches have minimum sediment storage. The wave climates during the postmonsoon and winter months help the beaches in recovering gradually after passing through a secondary phase of erosion associated closely with the onset of the northeast monsoon, during November/December.

The coast of Goa is oriented in a NNW-SSE direction and consists of sandy beaches separated by rocky promontories and river mouths. The beaches, situated close to each other and exposed to similar wind and deep water wave climates, present conspicuous intra and inter differences in their morphology, and sediments which they are compsed of[1,2]. For example, the beach at Calangute is steep and its sediments are in the range of gravel to fine sand class[3] while the beach at Colva is flat with its sediments in the size range of medium to fine sand class[4]. In order to understand the probable mechanisms responsible for these differences, studies have been carried out at different stations along the Calangute and Colva beaches (Fig. 1) for 4 yr commencing from 1969. The present paper dèals with the salient aspects of the morphology of the beaches in relation to the environmental factors such as winds, waves and fluctuations in ground water table, etc.

Materials and Methods

Beach profiles have been measured at fortnightly intervals from a reference point situated well behind the backshore of the beach during the times of low water following the method of LaFond and Prasada Rao[5] and Emery[6]. The environmental factors like winds, waves, type of breakers, width of the surf zone, littoral currents and fluctuations in ground water table have also been measured during each survey. For convenience, the beach terminology adopted and general beach features observed in the area of study are schematically shown in Fig. 2. The time variation of the changes in the elevation of contours(m) at different points along the transect from the reference point is shown in Figs 3 to 12. The general qualitative picture of erosion and accretion from month to month together with the details regarding upper, middle and lower foreshore at all the stations are presented in Tables 1 and 2.

Results and Discussion

The studies reveal the following salient features.

i) The morphological changes are cyclic over a period of 1 yr.

ii) Erosion of significant magnitude of the beaches commences during April-June (Calangute beach: late April/May; Colva beach: May/June)

iii) Even though erosion continues till July/August, the rate of erosion decreases considerably after the initial rapid rate.

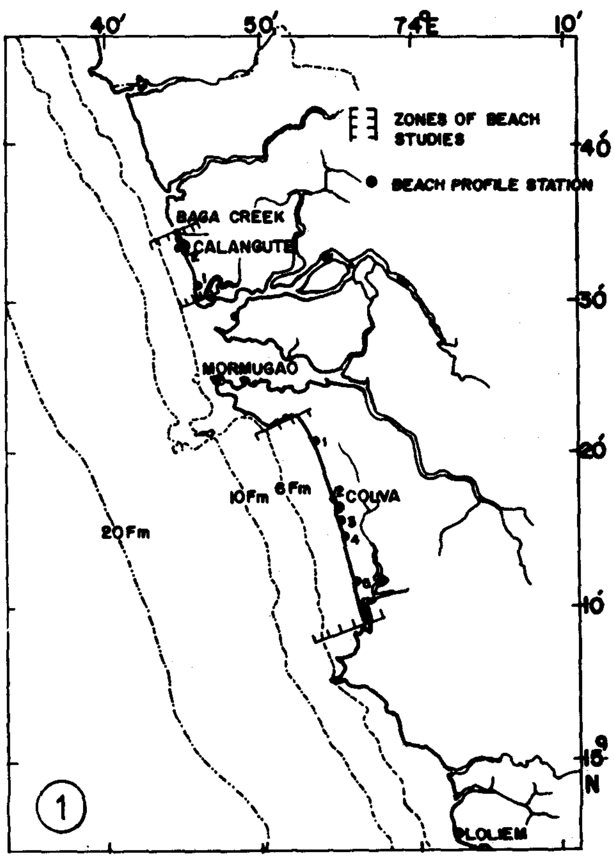


Fig. 1—Location map showing beach profile stations

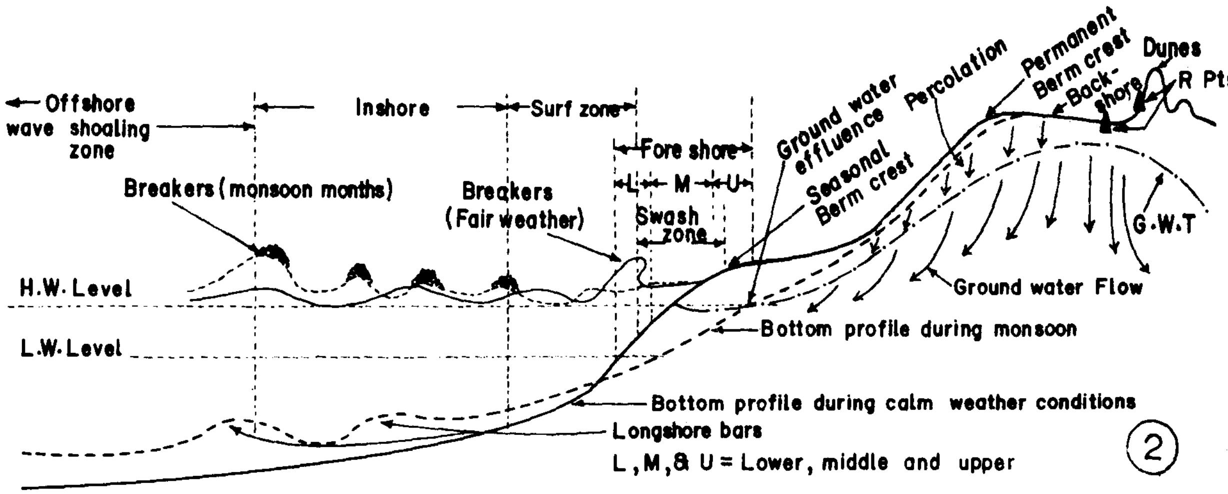


Fig. 2—Schematic picture showing the terminology of the beach adopted

iv) During the above period (ii and iii) the shoreline recedes by about 30 to 40 m.

v) After the beaches show minimum sediment storage during July/August the beaches tend to grow till March/April.

vi) During the accretionary phase(v) a secondary cycle of erosion occurs during November/December.

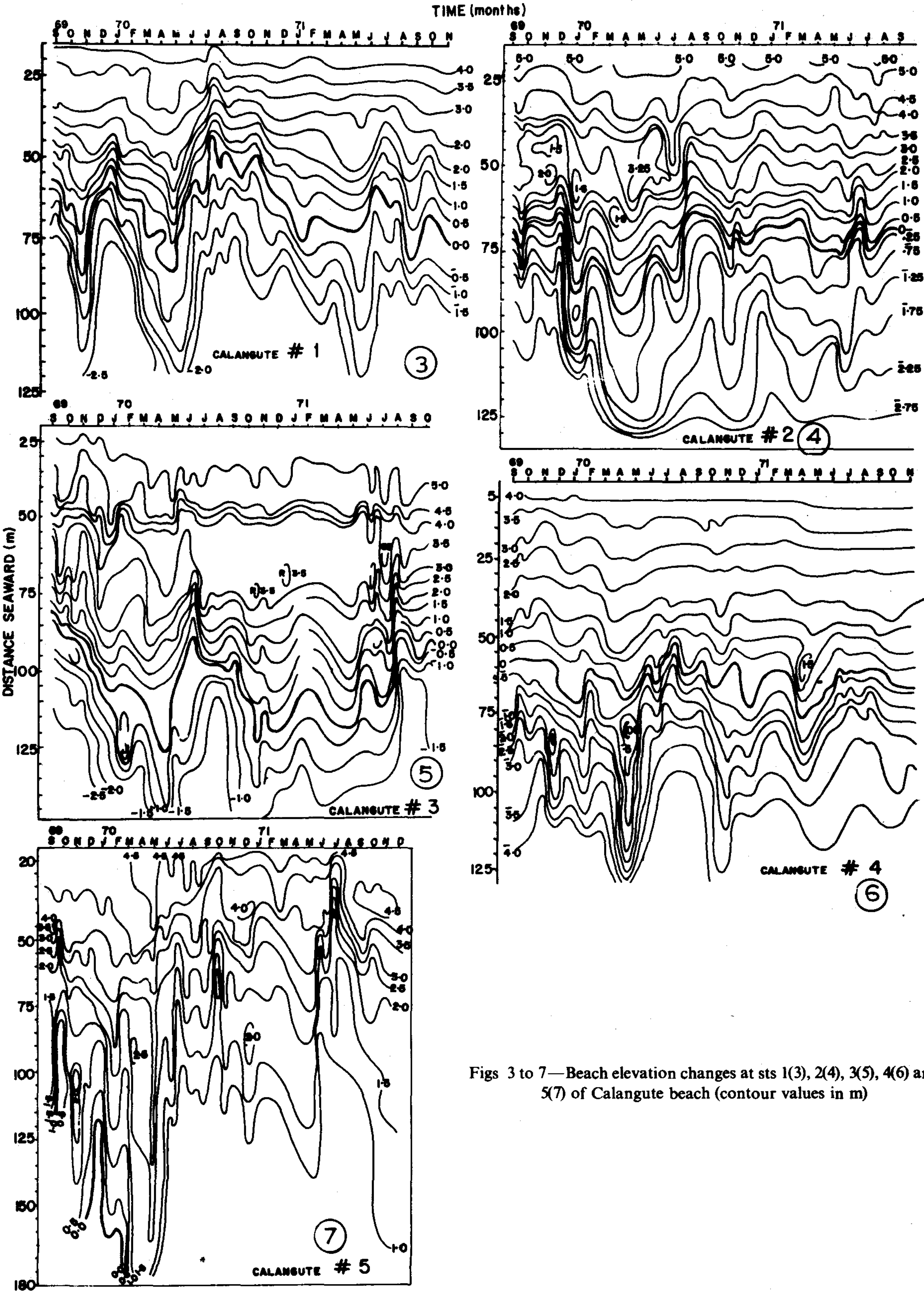
These changes in the morphology of the beaches are brought about by various environmental factors such as winds, waves, currents, ground water table, etc. hence, a detailed examination of these factors would be pertinent to understand the above features.

During March-May the winds over this region alter from a predominantly northerly to northeasterly direction to westerly to southwesterly direction and increase in their speeds from about 3 m/sec to as much as 10 m/sec[7]. This change in the wind field contributes to a rise in the water level in the nearshore regions by about May in the form of wind set-up and influences larger areas of the beach face leading to the saturation of the beach face due to increased volume of water.

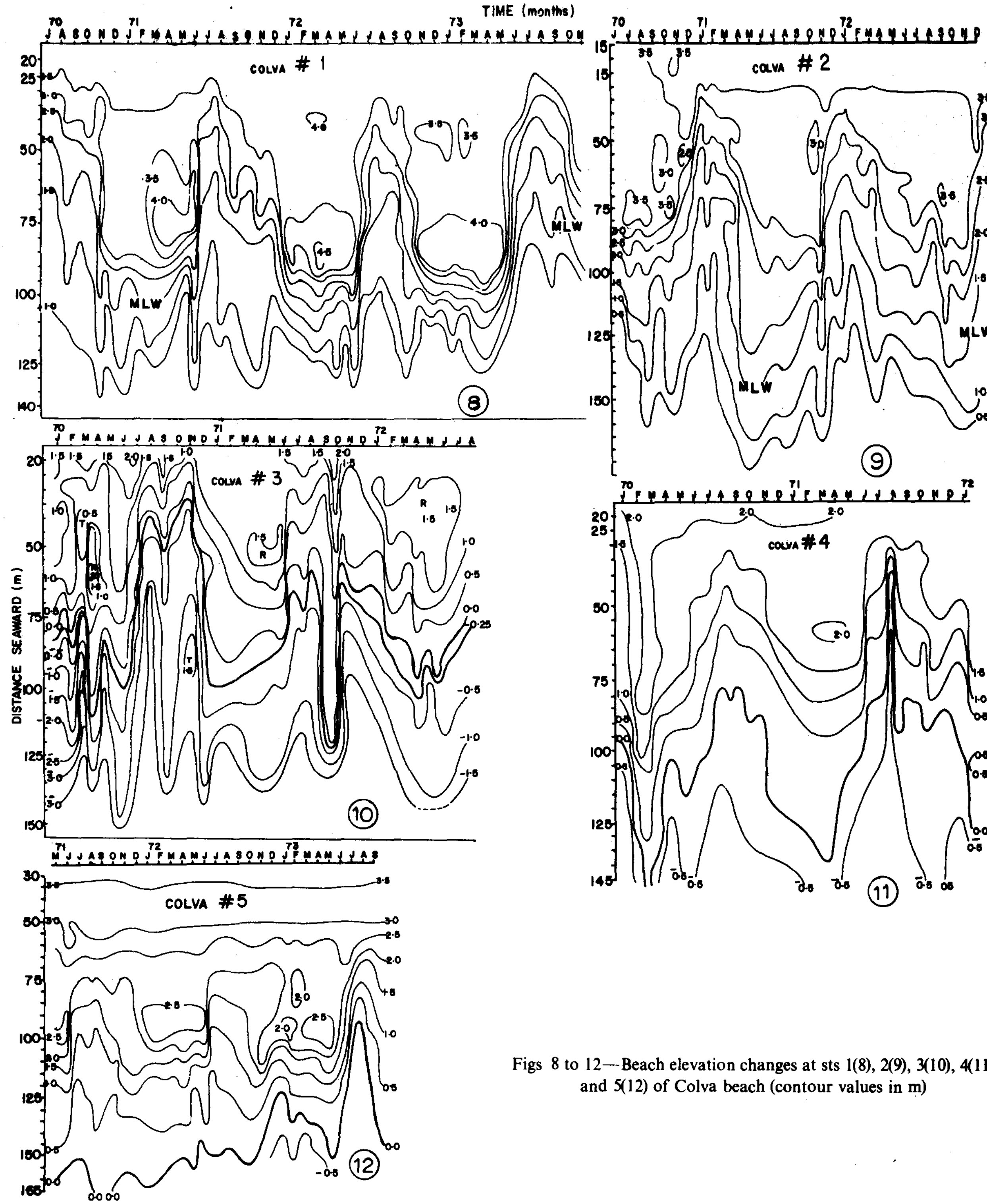
Associated with the changing wind pattern the wave characteristics undergo corresponding changes. During March the swell waves approach from NW and by May they approach from W and SW (Fig.13). The wave heights also show considerable increase. However, for more specific and detailed informations on wave characteristics it is necessary to look into real-time wave records preferably obtained over sufficiently long periods e.g a year or so. No such records obtained from nearshore regions of the Goa coast which would be of any significant use for objectives of the present study are available. Even so this problem could be justifiably circumvented assuming that the overall monsoon (SW and NE) wind and wave climates would not differ markedly within short geographical distances - they being a part of the general circulation patterns - by making use of available recorded wave data from nearby localities. Thus, the wave spectra obtained for a station off Mangalore over 1 yr through the use of wave recorders[8,9] have been made use for this study which, in general, show the predominance of low period waves during March and a slight shift towards higher periods by April. The same feature appears to be more pronounced with waves of 6 and 7 sec periods approaching for more than 40% of the time during May. Wave heights in the range of 1 to 2 m prevail for more than 60% of the time. This increase in deep water wave height results in an increase in the wave steepness.

In addition to these steep swell waves; the locally generated waves of short periods caused by strong and steady on shore winds in May contribute to a confused state of the sea by way of interference. These winds generally give rise to fully arisen and rough seas. Owing to the fully arisen states of the sea shortcrested waves dominate during May as a result of the admixture and interference of the sea waves with the incoming swells. These shortcrested waves which are asymmetric in form with increased steepness lead to complicated water particle motions, vortex formations and macroturbulence[10]. The increased wave activity in addition produces wave set-up which associated with the wind set-up contributes to increased run up on the beach face under the prevailing inshore bottom slopes. This wave set-up is about 5 times more during May as compared to that of March.

Thus, the steady and strong onshore winds coupled with high, steep and asymmetrical waves from different directions contribute to shortcrested waves from May onwards. As a consequence, the increase in the height of the breakers, the wave run up and wave set-up further contribute to an increase in the strength of the backwash over the saturated beach zone. Due to sudden changes in the wave characteristics in May, the beach yields quickly and looses its constituent materials (initially at a rapid rate) from the subaerial



Figs 3 to 7—Beach elevation changes at sts 1(3), 2(4), 3(5), 4(6) and 5(7) of Calangute beach (contour values in m)



Figs 8 to 12—Beach elevation changes at sts 1(8), 2(9), 3(10), 4(11) and 5(12) of Colva beach (contour values in m)

parts of the beach foreshore. The material thus removed is transported by the predominant offshore flows and gets deposited in the nearshore regions. The littoral flows during the field observations carried out with the help of dyes[11,4] indicate weak alongshore flows during these months. The net effect is the development of a flat beach face and a consequent increase in the width of the surf zone. These, in turn, alter the pattern of the breakers from plunging to spilling types and multiple breaking frequently takes place. This multiple breaking dissipates the incoming wave energy over a wider surf zone and not all the energy is propagated to the upper reaches of the beach. At this stage the loss of material due to direct wave action is only of marginal importance. Hence the beach profile gets adjusted to this low wave energy

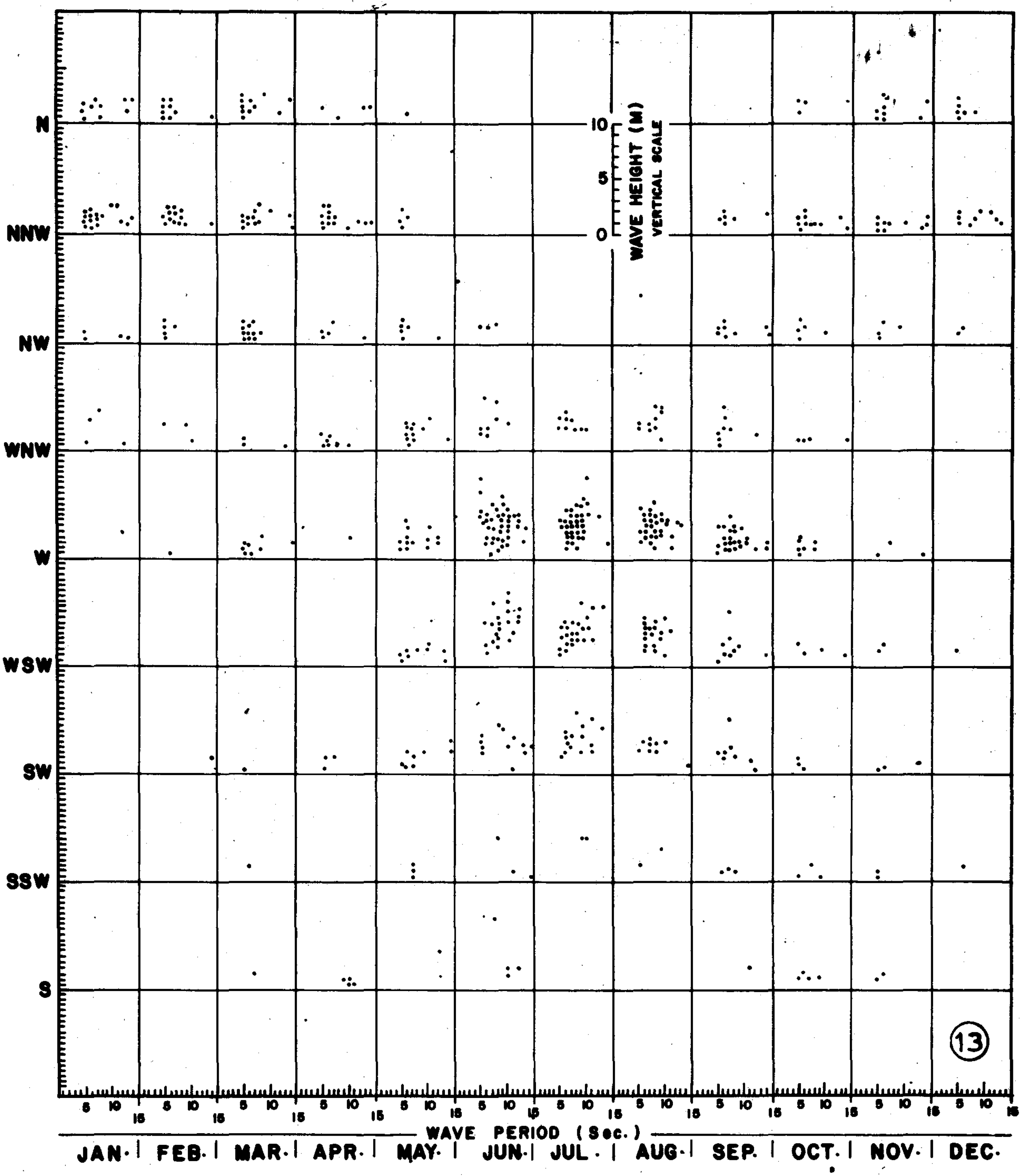


Fig. 13—Swell wave climate in the area 13°-18°N and 70°-74°E during 1970-'74

environment and as a consequence the resistance of the beach increases considerably. Even though waves of longer periods (7 to 12 sec) and heights (~5m) with wave steepness ranging between 0.02 and 0.06, which are conducive to rapid erosion of the beaches, prevail in June, there is an absence of rapid erosion along Calangute beach during this period which could be attributed to the processes mentioned above. This feature continues till July/August when the beach profile is at its nadir. Similar features of erosion have been reported from the beaches of north Carolina[12,13].

The erosion of the beaches during this period is further aided by the presence of ground water table. During the active monsoon months, the rainfall, occurring within a span of about 3 months, contributes to heavy run off. In addition, the ground water table also rises rapidly (Fig.14). This increased elevation of the ground water table affects the beach face and

Table 1—Observed Accretion/Erosion on the Beach Face along the Calangute Beach (1969-70)

Months	Stations 1				2				3				4				5			
	T	L	M	U	T	L	M	U	T	L	M	U	T	L	M	U	T	L	M	U
Sept.-Oct.	+	+	+	—	*				+	+	+	—	—	—	—	—	+	+	—	0
Oct.-Nov.	+	—	+	+	(+	+	—	+)	+	+	+	+	+	+	+	+	0	+	0	—
Nov.-Dec.	—	—	—	—	+	+	+	—	—	+	—	+	+	+	+	+	+	+	+	+
Dec.-Jan.	+	+	+	+	—	—	—	+	—	—	+	—	+	+	+	—	+	+	—	+
Jan.-Feb.	+	+	+	+	+	+	+	+	+	+	+	+	0	—	—	+	—	—	—	+
Feb.-March	+	+	+	+	0	+	—	+	—	—	—	—	0	—	—	+	+	+	+	+
March-April	+	+	+	+	+	—	+	—	—	—	+	+	+	+	+	+	+	+	—	+
April-May	—	—	—	—	—	—	+	—	—	—	—	0	—	—	—	+	—	—	—	—
May-June	—	—	—	—	+	—	+	+	+	+	+	0	—	—	+	—	—	—	—	—
June-July	—	—	—	—	—	—	—	—	+	+	—	+	+	—	—	+	+	+	—	+
July-Aug.	+	+	+	+	+	+	+	+	—	—	—	+	+	+	+	+	0	+	—	+
Aug.-Sept.	+	—	—	+	+	+	+	—	—	+	+	+	+	+	+	+	—	—	+	—

+ = Accretion; — = Erosion; 0 = No change; * = No data for Oct.; ( ) = Between Sept. and Nov.; T = Total; L = Lower foreshore; M = Middle foreshore; and U = Upper foreshore

Table 2—Observed Accretion/Erosion on the Beach Face along the Colva Beach (1972-'73)

Months	Stations 1				2				3				4				5			
	T	L	M	U	T	L	M	U	T	L	M	U	T	L	M	U	T	L	M	U
Jan.-Feb.	0	+	—	—	+	+	+	+	+	+	+	+	+	+	+	—	—	+	0	—
Feb.-March	0	—	0	+	+	+	+	+	+	+	+	+	+	—	—	+	+	—	+	—
March-April	+	—	+	+	+	—	+	+	—	—	+	—	—	—	—	+	—	—	—	—
April-May	0	+	—	—	+	+	+	—	+	0	+	0	+	+	+	+	+	+	+	+
May-June	—	—	—	+	—	+	—	+	—	—	—	+	—	—	—	—	—	—	—	—
June-July	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
July-Aug.	+	+	+	—	—	+	—	+	+	+	+	—	+	—	—	—	+	+	+	+
Aug.-Sept.	+	+	+	+	+	—	+	+	+	+	+	+	+	+	—	+	+	+	—	+
Sept.-Oct.	+	+	+	+	+	+	—	+	+	—	+	+	+	+	+	+	+	—	+	0
Oct.-Nov.	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+	—	—	—	—	+
Nov.-Dec.	—	—	—	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	—	+
Dec.-Jan.	+	+	—	+	—	—	—	+	+	+	+	+	—	—	—	—	+	+	+	—

+ = Accretion; — = Erosion; 0 = No change; T = Total; L = Lower foreshore; M = Middle foreshore; and U = Upper foreshore

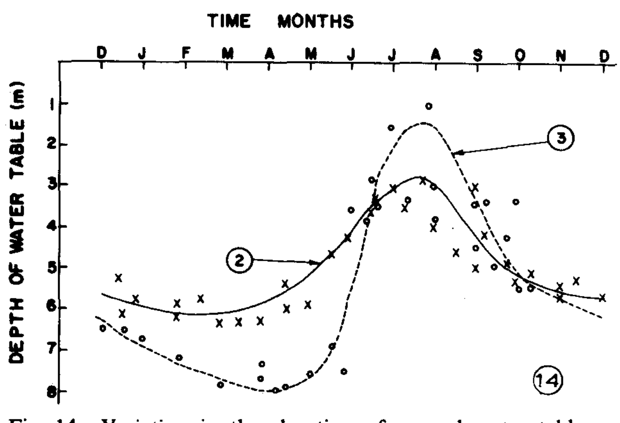
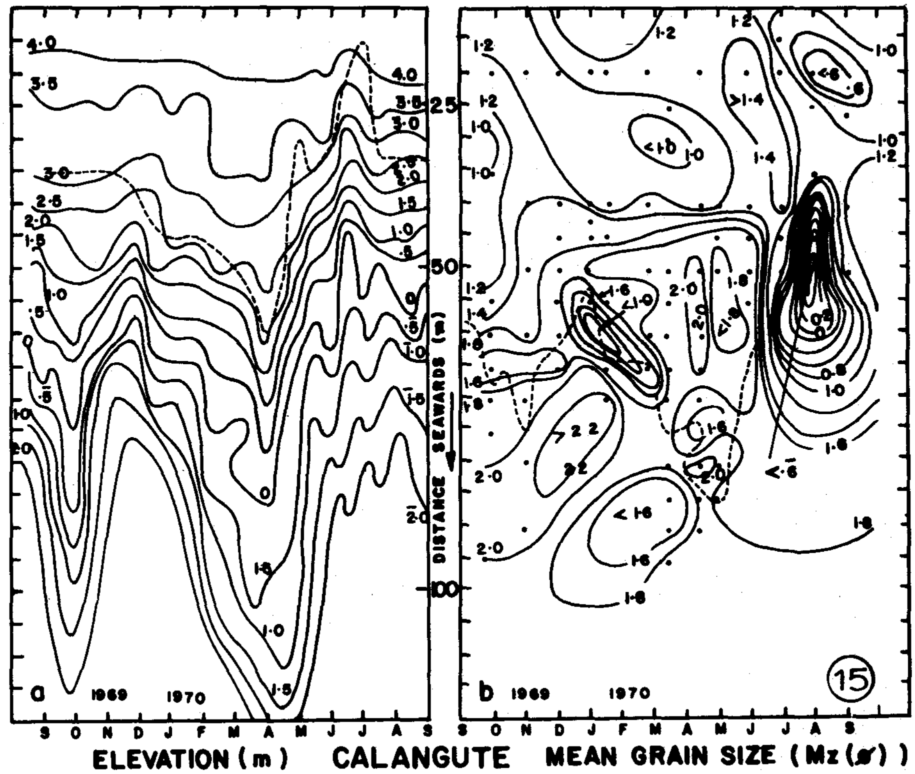


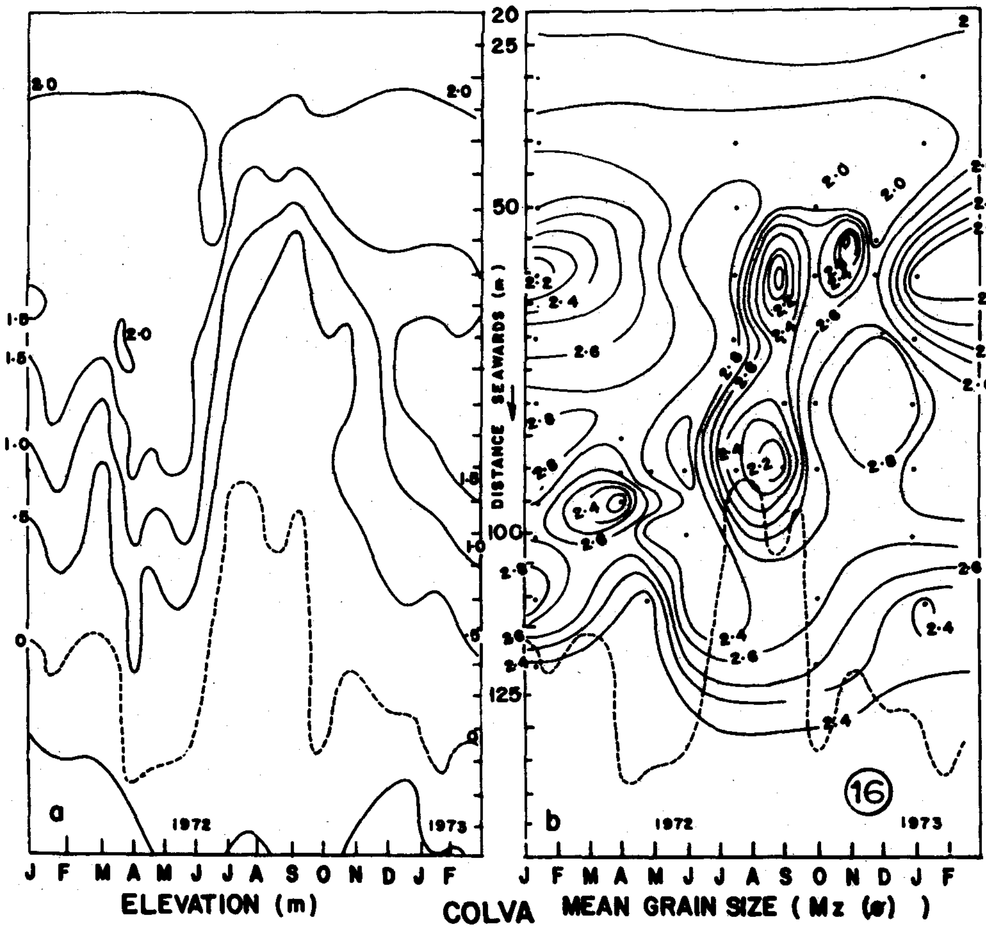
Fig. 14—Variation in the elevation of ground water table as recorded 500 m landwards of profile sts 2 and 3 at Calangute

contributes to the removal of fine-grained particles from the beaches. The run off and rainfall also contribute to losses of sediments from the top layer of the beaches. Consequently, the sediment distribution shows significant changes with coarser material being predominant during the period of erosion (Figs 15 and 16).

During the southwest monsoon season, the time variation graphs occasionally show transient phases of deposition of sediments. This can be attributed to a decrease in the activity of the local seas associated with the lulls in the monsoon winds when the long, low swells affect the shoreline and give rise to accretion.

From September onwards, the beaches experience deposition. During this month the percentage occurrence of low period waves show a decrease compared to that in August and an increase in the occurrence of long period waves. The wave heights also show a decrease till November. In December the winds blow mainly from NE direction and generate waves moving offshore. These winds and waves interact with the onshore moving swells and transform them into shortcrested and steep waves which, in turn,





Figs 15 and 16—Variation in beach elevation(a) and mean grain size(b) of the sediments at st 2 of Calangute (15) and of Colva (16) give rise to erosion of the coastline instead of accretion which would otherwise have been caused by the long low swells. This erosion is of much lower magnitude compared to the erosion caused during the southwest monsoon season.

Tides also contribute to some extent to the depositional pattern on the beach face. Distribution of tidal ranges (Fig.17) for different months during 1969 to 1974 for the Goa region (Mormugao Harbour) shows high tidal ranges during November to January. The tidal range is low during the other months of the year. Further, the tidal range decreases from 2.1 m in 1970 to about 1.9 m in 1973 during September. This difference appears to have influenced to some extent the depositions on the beach face.

The long period low swells prevailing in (late) January contribute to deposition of sediments on the beaches. The characteristics of waves recorded off Goa indicate low significant wave heights (0.33 m) and periods (6.8 sec) with a fairly large spectral width parameter (0.53 to 0.93) for the fair weather months[14].

The general increase in wave period and decrease in wave height during postmonsoon and winter months give rise to low wave steepness (~ 0.001) with resultant general accretion of beaches which continues till April/May.

Although accretion/erosion generally takes place at all the stations some regional variations could be noticed (Tables 1 and 2). For example during April/May along the Calangute beach the foreshore experiences erosion at all transects while deposition prevails in the middle foreshore at sts 2 and 4. Similarly during November/December sts 4 and 5 do not experience erosion while erosion prevails at the other 3 stations at different reaches of the foreshore. These variations indicate the influence of local set-up. The northern sectors of this beach are partly sheltered from the impact of the waves approaching from the northerly quadrants. A similar feature is observed for the stations along the Colva beach.

Major variations also occur along the beaches owing to wave refraction. The beaches along the coast of Goa are no exception to such changes brought about by the phenomenon of wave refraction since the nearshore and offshore bottom topography vary considerably from one place to another[15,16]. Thus, the distribution of wave heights and energy spent through breaking of waves, frictional effects, swash, sediments transport by littoral currents generated by the differential energy distribution due to wave refraction, are never uniform.

The waves in general are higher in the southern and central parts of these 2 beaches during the southwest monsoon. The surf zones are narrow. The variations in the wave energy along the beaches provide the necessary forcing for the advective processes in the surf zone to become operative, carrying sediments either offshore or alongshore, and thus cause morphological changes in the beaches.

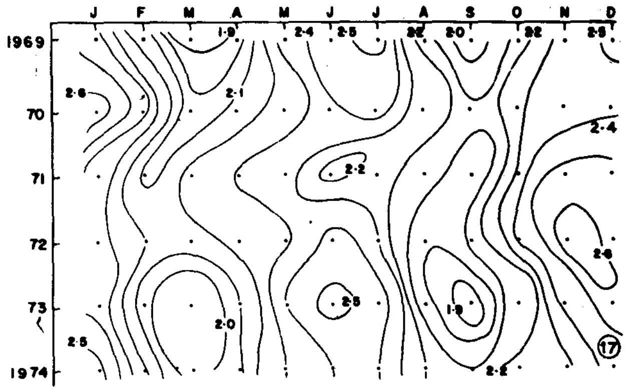


Fig. 17—Variations in tidal ranges as predicted for Mormugao Harbour (contour interval 0.1 m)

Acknowledgement

The authors thank Dr S Z Qasim for providing the necessary facilities and encouragement during the study.

References

1 Murty C S, *Studies on the physical aspects of shoreline dynamics at some selected places along the west coast of India*, Ph.D. thesis, university of Kerala, 1977.
2 Veerayya M, *Studies on the geological aspects of the beaches of Goa, in relation to some meteorological and physical oceanographic factors*, Ph.D. thesis, Andhra University, 1978.
3 Veerayya M, *Indian J mar Sci*, **1** (1972) 28.
4 Veerayya M, Murty C S & Varadachari V V R, *Indian J mar Sci*, **10** (1981) 1.
5 LaFond E C & Prasada Rao R, *Andhra Un Memo in Ocean*, **1** (1954) 63.
6 Emery K O, *Limnol Oceanogr*, **6** (1961) 90.
7 Anonymous, *Indian ocean oceanographic and meteorological charts*, Koninkljk Nederlands Meteorologisch Institute, **135** (1952) 1.
8 Dattatri J, *J Waterways, Harbours Coastal Engg Div, Proc Am Soc Civ Engrs*, **99** (1973) 39.
9 Sundararamam K V, Varkey M J, John V C & Joseph M X, *Indian J Met Geophys*, **25** (1974) 453.
10 Longuet-Higgins M S, *Proc Roy Soc Lond*, **310A** (1969) 151.
11 Murty C S, Veerayya M & Varadachari V V R, *Indian J mar Sci*, **4** (1975) 1.
12 Sonu C J & Van Beek J L, *J Geol*, **79** (1971) 416.
13 Sonu C J, *J Geol*, **81** (1973) 42.
14 Murty C S, Das P K & Varkey M J, unpublished data.
15 Antony M K, *Indian J mar Sci*, **5** (1976) 8.
16 Reddy M P M & Varadachari V V R, *J Indian Geophys Un*, **10** (1972) 161.