

Fossil Sedimentary Deposits on Shrivardhan Coast of Maharashtra, India

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Abstract : *Holocene sediments of Konkan coast of Maharashtra display a transgressive, regressive record. Transgression of sea in early Holocene was followed by a regression, which was possibly interrupted by minor advances of sea level. The fossil sand deposits at various distances inland is an indicator of such fluctuations along this coast.*

Old, fossilized dunes or beaches back the modern sediments, beaches and dunes on this coast. These fossil sedimentary deposits locally known as KARAL are more or less parallel to the present day shoreline. The fossil sediments are calcareous, sandy, shelly deposits dating back to 2200 to 2400 YBP. Many coastal villages in the area are situated on these fossil ridges. The fossil sedimentary deposits occupy varying topographic positions in the area.

This paper deals with the general distribution of regressive, fossil sand deposits and their relationship with sediments in the surrounding area, their topographic position, morphology and stratigraphy with special reference to fossil deposits at Shekhadi on Shrivardhan coast. It also tries to ascertain the relative level of sea indicated by these fossil deposits in the area.

The coastline has preserved fossil sedimentary formations mainly on Shrivardhan coast between 18° 5' N and 18° 15' N latitudes and the beach rock formations can be located all along this stretch. Here the formations are thick and intact.

Introduction

The fossil sandy deposits, variously termed as beach rocks, aeolianites, and Karal found along the Konkan coast are not still properly and extensively studied. Some descriptions although available (Dikshit 1976, Karlekar 1981, Karlekar et al 1998, Guzder 1975) are based on limited field studies and therefore are not useful in bringing out the significance of fossil deposits in the Holocene history of the Konkan coast as a whole.

Fossil deposits do not occur widely along the coast under investigation. At most places they are concealed under the coastal alluvium. More often they are found 20 to 40 meters from the shore. At this distance, they are discontinuous, broken and like narrow ridges running almost parallel to the coastline, with a height rarely exceeding 3 m ASL.

The fossil sediments in Konkan are normally of beach and dune origin and occupy varying topographic positions such as intertidal zone area, leeward side of modern dunes, creeks and streams. Their occurrence in variable settings creates complications in using them as an evidence of sea level fluctuations. Moreover there is a total absence of east west succession of fossil ridges. All along the coast under investigation, only one ridge can be traced. Second ridge, westward of the first could also be traced, but is either concealed under coastal alluvium or broken. The fossil beach ridges in Konkan are heavily eroded and since they are rather thin, it is difficult to estimate their extent at the time of formation.

Field Site

The western littoral of Maharashtra, popularly known as Konkan stretches between 15° 45' N & 20° N latitudes and 72° 44' E & 73° 41' E longitudes (Fig.1). It is 60 km to 90 km wide coastal strip especially to the north of Bombay. To the south of Bombay, Konkan strip is a narrow coastal region of forest-covered hills, coastal plains and tidal creeks,

fringed with swamps and river plains. The south Konkan has a thick and extensive cover of laterites. It is a shoreline broken by drowned river valleys, (Dikshit 1976) and small river mouth creeks and beaches. This study is based on the field observations, measurements and sediment sample collection at Shrivardhan Coast (18° 3' to 18° 15'N) (Fig 1) The Shrivardhan coast (18° 3' N to 18° 15'N) has preserved the fossil sedimentary ridges where they are conspicuous and more or less intact (Fig.2). This area exhibits at least two shore parallel fossil ridges at varying distances and a complete sequence or depositional facies. The occurrence at Shekhadi is especially significant as regards its preservation quality.

Method of Investigation

The fossil sedimentary deposits were identified by a detailed survey in the area. Such deposits were initially identified visually. Their texture, tone, colour and hardness were according to their location (creek, beach or dune), distance from high water mark, composition (shelly or sandy) and height ASL. Vertical sequence of sedimentary facies was studied in detail from naturally exposed litho sections. The sediment samples were collected and analyzed for physical and chemical composition. Birbal Sahani Institute of Paleobotany made radiocarbon dates of a few samples available.

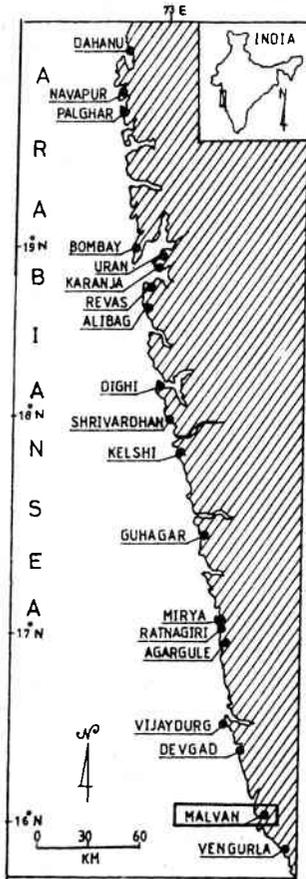


Fig. 1 : Location Map

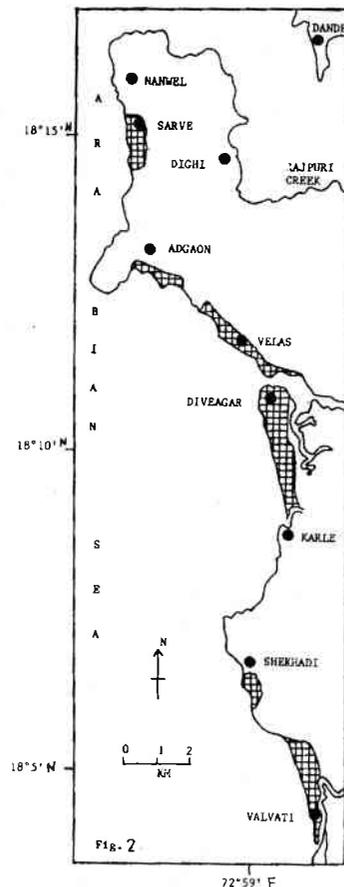


Fig. 2 : Locations of Fossil Beach Ridges

Discussion

The fossil sedimentary deposits observed are like cemented calcareous sandstones. At some places they are so brittle that they can even be crushed with fingers. Even at places where they are lithified, the lithification is not perfect. The intertidal, dunal, creek and beach rocks show significant variations in the degree of cementation and frequency of occurrence.

The intertidal deposits are exposed at low tide. They show relatively better cementing of shells and fine sands. The cemented material is angular or sub angular. The creek beach rocks resemble the intertidal deposits in many ways except the fact that they cover a very narrow zone.

It appears that the fossil sediments of beach and dune origin, locally called "Kara" are geomorphically significant along the Konkan coast. The thickness of these deposits varies from 2 m to 10 m, the thicker formations appearing on leeward sides of sand dunes.

According to Dikshit (1976), the lower part of beach rocks consist of rounded gravels and percentage of marine shells increase towards the top. Fossil beach ridges of this category, as a rule, consist of fine grained loosely cemented sand.

The gradual recession of sea and changes in the relative position of different shore zones is reflected in the different facies of fossil sandy ridges. Lower beach is gradually converted to upper beach and then the dunes are developed over it. The sequence of deposits with variable facies is not always clear. Shrivardhan coast between 18° 3' N and 18° 15' N latitudes is a very rewarding area in this context. Here the variations in deposits of beach and dune origin can be clearly seen.

Fossil Deposits on Shrivardhan Coast

On Shrivardhan coast 300 to 500 m wide ridge runs parallel to the shore and is located

approximately 1 km. Inland. It can be traced from Sarve to Valvati for the entire length of 14km (Fig 2). It is better developed and almost intact near Velas, Diveagar, Shekhadi, Aravi and Valvati. Elsewhere it has a dissected appearance and has been modified and partly destroyed due to human interference. The upper surface of the fossil beach ridge is flat with continuous sand cover that overlies the old deposits.

Another sand ridge more or less parallel to the above, was also found very near to present day high water mark 20 m inland. This ridge is relatively less lithified and could not be traced all along the shore from Sarve to Valvati. The existence of this ridge could be confirmed by occurrence of small discontinuous patches of lithified sand columns at places like Sarve, Adgaon, Velas and Shekhadi.

Beach ridges were probably formed separately as a shoreline deposit. The oldest was located farthest from the sea shore and the youngest closer to it. The present shoreline was in many respects analogous to each of the ridge at the time of its formation.

The older ridge is a metachronous Holocene formation of calcium and beach clasts. It forms a distinct elongated ridge of old sediments parallel to the shore and discontinuous in appearance. It is seen clearly at Velas, Diveagar, Shekhadi, Aravi and Valvati (Fig.2). At Sarve, Adgaon and Shekhadi the ridge consists of the beach rock which is blocky in nature. At Velas, Diveagar, Aravi and Valvati, however, the upper sections of the ridge have block like and lower sections have flaky appearance. These beach rocks although parallel to the shore occupy various topographic positions in the area. At Sarve, Adgaon and Velas, they occur on beaches as well as dunes. At Valvati, beach ridge occurs at the back of present day dune and along tidal channel. At Diveagar, Shekhadi and Aravi, it also occurs at the mouths of tidal channels and creeks. The appearance of beach

rock in this area is distinctive. The lower sections consist of horizontal beds of sediments which could be traced back under the overlying sands. The lower section of the horizontal strata consists of distinct sediment layers and has on an average a thickness of 3 m. The overlying section of compact sandy silty material is relatively massive and has thickness of 4 m. It consists of sand particles, pebbles and in some cases large fragments of basalts in an impure calcareous matter.

The upper sections with their grey black tone look like a lithified dune. Lower sections suggest compact swash and backwash deposits on the beach, whereas the compact blocky deposits suggest lithified blown sand. In other words, the blocky deposits suggest an old dune environment and the flaky sections below, indicate the lithified beach. This sequence also explains that the overlying dune deposits are younger and finer than the low lying, coarser, beach deposits. It was also observed in the field that backshore relief governs the width and length of these fossil ridges. Extensive fossil ridges necessarily occur in the front of the tidal basins. The narrow, insignificant, discontinuous fossil ridges occur in front of shallow and narrow bays at the foot of the old cliffs. The fossil ridge at Diveagar and Valvati are the examples of the former and the ridges at Sarve, Adgaon, Shekhadi are the examples of the later. Most of the wells on the beach ridges show a thin oily layer which is very distinct in appearance.

Once formed, beach rock is extremely resistant to erosion and can remain in the landscape for thousands of years. A shore parallel accumulation of these beach rocks is usually identified as fossil beach ridge. According to Davies (1977), beach rocks are found on the coast where sea is retreating due to regression. The beach rocks and fossil beach ridges occupying various topographic positions are therefore used as the useful indicators of shoreline changes. (Roberts 1989, Tooley & Shennan 1987, Russel & McLintire

1965, Curray & Moore 1968, Guzder 1976, Dikshit 1976, Karlekar 1981, Kale & Rajguru 1985, Reading 1986, Boyd & Penland 1984).

Fossil Beach Ridge at Shekhadi

The occurrence of fossil beach ridge at Shekhadi, which is 2.2 km north of Kondvil is an important fossil beach ridge in the study area. The ridge does not occupy a position in front of tidal basin like that at Aravi. Topographically it borders a small littoral terrace and occurs at the back of present day beach. Here it occurs as a narrow elongated lithified sand ridge with a north south extent of about 500 m. It has an average height of about 3.6 m above present day high water mark. It has an average width of about 86 m. (Fig 3). The lithostratigraphy of this deposit is only visible in a cut exposed along its eastern border which forms the left bank of a small gravel bed channel. The ridge has a seaward dip of 7° that can be easily seen in the cut described above. The ridge was found about 52 m inland from present day high water mark. The stratigraphy studied in the field is shown in Fig 3. The sedimentary deposit 1.9 m below the surface of the ridge dates back to 3800 + 90 YBP. Eight distinct sedimentary layers could be clearly seen in the cut, indicating various episodes of deposition and erosion. They also give an idea of the mode of deposition. The texture, structure, bioturbation, lamination, gradation and inclination of the sedimentary beds are very distinct and hence this sequence can be used as a standard sequence of karal formation in the area. Moreover the interference and disturbance is minimum, which has helped in retaining the original structure intact. It can be seen from the diagram that the total height of the column from channel bed to the top of the ridge is 2.1 m. It is quite likely that the original deposition was slightly thicker and the upper portion has been removed in course of time. The nature of the upper section can be

however inferred from the beach rock exposed at the top of the ridge.

The rock exposed consists of fine sand and has a thickness of about 1.5 m. It is very compact, hard and massive. It is being destroyed marginally on the seaward side. It disintegrates in the form of big blocks. It contains compact brown and black friable sand, and abundant shells, bioturbates and occasional pebbles. This is underlain by a 20 cm column of shells and pebbles with a seaward dip of about 19°. Below this lies a 50 cm thick layer of horizontally bedded swash/backwash deposits. Here sediments appear to be loose and friable. Below this depth there are 3 more layers consisting of shells, sand and silt, pebbles and riverine gravels.

Lower three layers belong to ancient fluvial regime. It seems quite certain that the beds with seaward dip were produced by ancient beach processes and the upper deposits are the result of compaction of aeoline sand. The sediments collected from each layer were sieved mechanically and proportion of material in various size groups was determined. In addition to it, the organic matter and the lime content was also determined for every single layer.

Structural and Textural Variation in the Vertical Section of the Fossil Ridge at Shekhadi

The sedimentary structure of the sand ridge at Shekhadi mainly comprises of low angle subparallel beds, dipping seaward at an angle of 7° (Fig 3). The shell layers alternate with sand layers at most of the places in the section.

The typical swash floated shell deposits could be observed in abundance. Due to the specific shape and low density of shell deposits, shells were easily floated and deposited by ancient swash.

Some layers show large number of burrow-structures that are filled by sand and shell debris. These are analogues to crustacean burrows of modern intertidal beaches in the study area. The bioturbates and burrows in the section indicate old environments of tidal deposition. The textural parameters calculated for the full section are given in table below.

The upper layer of the section is 0.8 m thick and consists of moderate size sand ($M_z = 1.05$ to 1.27) and the lower section 0.5 m thick, consists of coarse to very coarse sand, ($M_z = 0.98$ to 0.68 phi). Except at the bottom of the section where sediments are moderately well sorted ($M_s = 0.67$ phi), the sediments in the section at Shekhadi are poorly sorted ($M_s = 1.25$ to 1.55 phi). The sandy deposits show a positive skewness and leptokurtic distribution ($SK = 0.77$ to 1.49, $K = 1.4$ to 1.97). The mean sediment size therefore seems to be the sensitive parameter by which the environment of deposition can be separated. Coarse to very coarse sediments are considered diagnostic of

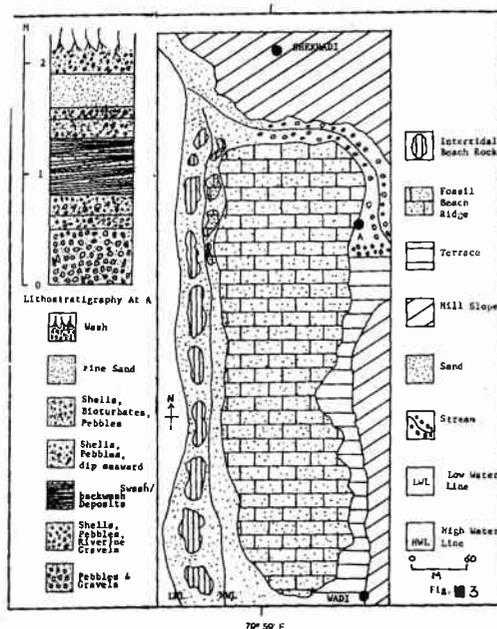


Fig. 3 : Fossil Beach Ridge at Shekhadi

swash environment of beaches and moderate to fine sediment of aeoline dune environment. It seems therefore logical that the sand ridge is created by the fossilification of old beach and dune in the period of slowly regressing sea level in the area. The ancient beach after its creation was left high and dry due to fall of sea level that was initiated 2400 YBP. The sand from the new beach produced with reference to regressed sea level, was blown to the top of the already raised beach. The dunes were formed which were fossilized in turn, as sea regressed to its present position.

To confirm the type of sedimentary environments identified as above, the organic matter and lime content of the various sedimentary facies of the sequences were determined (Table 1). Organic matter of beaches is usually less than that of dunes (Ranwell 1972). This was also ascertained by finding out the organic matter and lime content of present beaches. Organic matter in the present day intertidal beaches varies between 4% to 7% and in dune between 4% to 10%. The organic matter content shows a distinct decrease from the top to the bottom of the vertical column (12% to 0.95%). This sequence clearly distinguishes upper aeoline dune environment from the lower beach environment. The lime content also shows a

progressive decrease from upper dune zones, in a vertical sequence.

Conclusion

Fossil beach ridges in the area occupy various topographic positions. Extensive fossil ridges of beach sand essentially occur in front of tidal basins. Backshore relief governs the width and the length of fossil ridges. The lower sections of beach ridges comprise of swash backwash deposits and have a thickness of 3 m whereas upper sections consists of 4 m thick deposits of dune origin. The fossil beach ridges in the area dipping seaward are the products of ancient beach sedimentation and the upper blocky sections are produced due to compaction of aeoline sand. Swash floated ancient shell deposits are observed in abundance in lower sections. The burrow structures in the fossil ridges filled by sand and shell debris resemble the present day burrows of modern intertidal beaches.

Fossil sandy ridges 200 m to 1000 m inland are created by fossilification of old beach and dune deposits in this slowly prograding area. Ancient beach after its creation was left high and dry due to fall of sea level that was initiated probably 2400 YBP. Sand from the new beach was then blown to the top of already raised beach. Dunes were thus formed

Table 1 : Results of Mechanical and Chemical Analysis of Fossil Deposit at Shekhadi

Site Top of the section	Mean (Phi)	Sorting (Phi)	Skewness	Kurtosis	Organic Matter %	CaCo ₃ %
	1.27	1.45	0.77	1.70	12	79
	1.05	1.55	0.95	1.83	8	40
	1.05	1.55	0.95	1.83	6	38.8
	-0.27	1.36	1.49	1.97	5	38.8
	0.68	1.52	1.25	1.89	6	27.5
	-0.46	1.25	1.46	1.94	4	13.5
	0.19	1.31	1.43	2.04	2	1.5
Base	0.98	0.67	1.01	1.40	1	1.8

which were subsequently fossilized as sea regressed to its present position.

The deposits of dune origin on the fossil ridges are significantly thicker where the present day beaches are backed by wide and complex dunes. Similarly the lower deposits of beach origin contain coarser shells and sand whereas present day beaches also have coarser deposits. This clearly indicates that the ancient depositional environment was very similar to that which exists today. Average thickness of fossil beach deposits in the area varies between 7 to 9 m. The fossil beach ridges 200 to 1000 m inland date back to 2200 to 2400 YBP.

Recent Karal formations 20 m inland are abnormally rich in shells, which are mostly unbroken. Their height is not more than 2 m. They do not form a continuous ridge in the area and occur in separate patches. Similarly they do not show separation of deposits comprising of sediments of beach and dune origin.

It could be convincingly demonstrated that the vertical sedimentary sequences of fossil deposits in the area point to slightly higher sea level where the swash backwash and beach material of the lower column of the section was deposited. A slow regression of this sea level in last 2500 years was responsible for a wide exposure of new beaches from where sand was lifted, drifted and settled on the top of the already deposited beach material.

Recent fall in sea level is evident in the shore parallel terraces at a height of 5 to 7 m from PSL, abandoned, defunct tidal basins and especially the existence of 2 m high loose, friable, partially fossilized shell deposits only 20 m inland from PSL. Thus a general rise of land during Holocene could be considered. The magnitude of such a rise cannot be given precisely. Thus, the Holocene transgression seems to have reached well above the present sea level during 2500 YBP when extensive formation of beach ridge systems took place. The present shoreline and nearshore terrain

features are all indicative of consequent fall of sea level in the study area since then. The burying of intertidal beach rocks in the last few years, under the beach sand is a distinct evidence of falling local sea level in the study area.

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