Trans.Inst.Indian Geographers
ISSN 0970-9851

Significance of Holocene littoral terraces in the reconstruction of palaeogeography of Konkan and Goa Coast

Shrikant Karlekar, Pune, Maharashtra

Abstract

The distribution and sediment sequence of Holocene littoral terraces is a fundamental tool for the reconstruction of palaeogeography and neo-tectonic evolution of any backshore area. The distribution of terraces is indicative of raised shorelines and is usually linked to Holocene sea levels in the area. Their evolution from early to late Holocene can be inferred from their relative locations and elevations on the coast and one can identify the palaeo-shorelines planimetrically. Marine and transitional sedimentary deposits can be identified and used to reconstruct the sequence of sedimentation.

The littoral terraces at 12 locations on Konkan and 6 on Goa coast were investigated as representative terrace units. A field geomorphic study of these terraces was undertaken and integrated with interpretation of Google earth images and survey of India topographical maps. The mapping of a sequence of terraces at the respective elevations was attempted using SRTM data. The sedimentary deposits and stratigraphic continuity of the type of sediment and possible fossiliferous content was verified by observing unlined well sections wherever available.

It was seen that the terrace succession suggests different strandlines and contains mainly fluvial sediments of recent origin at the top and palaeo marine sand silt fossil deposits of beach dune origin in the middle and lower parts of the section.

Key Words: *Raised shorelines, Embayments and foothill concavities, Stratigraphy, Elevation levels, Strandlines.*

Introduction:

There are many conflicting field evidences of Holocene sea level changes along entire Konkan coast of Maharashtra and detailed topographic and stratigraphic studies of the coastal area is required to elucidate its Holocene coastal evolution. (Karlekar and Rajguru 2012). On the basis of geomorphic features and available ^{14}C dates it is now fairly clear that in the late Holocene extensive coastal plain development occurred along the coast possibly in response to slight lowering of sea level.

The study of coastal features along the coast reveals that during the late Holocene this coast was characterized by littoral terraces at different levels. Their distribution is indicative of raised shorelines and could be linked to Holocene sea levels in the area. Their evolution mainly in late Holocene can be inferred from the relative locations and elevations on the coast and one can identify the palaeo-shorelines planimetrically.

A littoral terrace is a relatively flat, gently inclined surface of marine origin mostly an old abrasion platform which is away

from the wave activity. It lies above the current sea level and occupies back beach area bordering beaches or banks of the shoreline sectors of tidal inlets. A littoral terrace is an emergent coastal landform. They are raised above the shoreline by a relative fall in the sea level.

Around the world, a combination of tectonic coastal uplift and sea-level fluctuations has resulted in the formation of such marine terraces. A marine terrace commonly retains a shoreline angle between the marine abrasion platform and the associated palaeo sea-cliff. The shoreline angle represents the maximum shoreline of a transgression and therefore a palaeo-sea level (Wikipedia).

The littoral terrace usually has a gradient between 1°–5° depending on the former tidal range with, commonly, a linear to concave profile. The width is quite variable and is controlled by palaeo coastal configuration. Older terraces are covered by marine and/or alluvial or colluvial materials while the uppermost terrace levels usually are less well preserved. The terraces can be covered by a wide variety of sediments with complex histories and different ages.

It is believed that the terrace gradient increases with tidal range and decreases with rock resistance. In addition, the relationship between terrace width and the strength of the rock is inverse and higher rates of uplift and subsidence as well as a higher slope of the hinterland increases the number of terraces formed during a certain time (Trenhaile 1987, Woodroffe 2002). Erosion caused by incisive streams play an important role in the degradation of these terraces.

The morphostratigraphic approach is generally used to study the chronological sequence of terraces found in the region. It is used in the regions of marine regression where altitude is the most important criterion to distinguish coast lines of different ages. Moreover, individual marine terraces can be correlated based on their size and continuity. The lithostratigraphic approach uses typical sequences of sediment and rock strata to prove sea level fluctuations on the basis of an alternation of terrestrial and marine sediments or littoral and shallow marine sediments (Reading 1996).

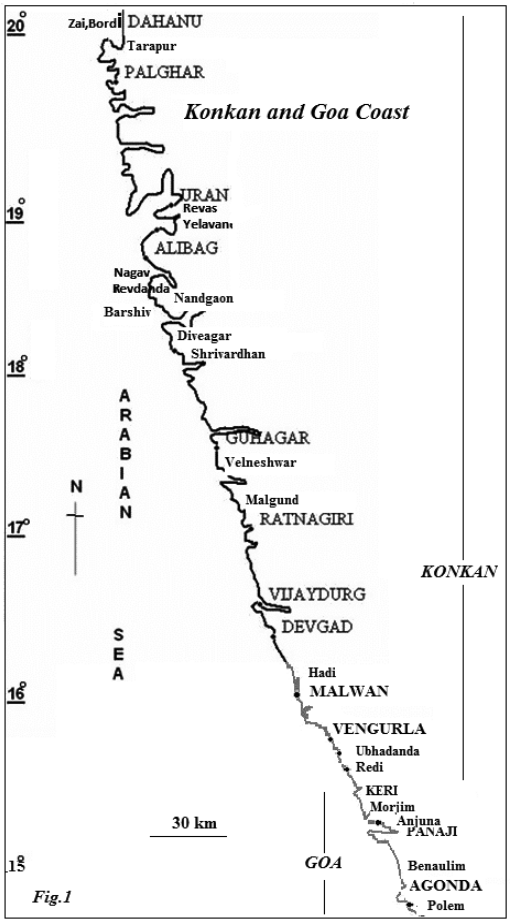

Fig.1 Konkan and Goa Coast

Study area:

The Goa and Konkan coast (Fig. 1) (14° 56'N to 20° N latitudes and 72° 44'E to 74° 5'E longitudes) has experienced a relative sea level fall during the last 4000 years . It is known that the sea reached its present level around 6 to 7 ka BP. Prior to that it was low (-100 to -150 m) around 11 ka to 12 ka. Then it rose rapidly up to 8 ka BP and reached present level around 6 to 7 ka BP. It then fluctuated within the amplitude of couple of meters in mid to late Holocene. There was a major transgressive phase 6 to 4 ka BP. Transgression continued till 2300 BP after which there was a regression causing slight lowering of sea level (Bruckner H.,1987, Guzder S.1980, Hashmi N.H.et al, 1995, Karlekar S. N. 1986, 2000, Karlekar, Shrikant, 2003, 2007 Rajaguru S.N., Deo S.G. 2005, Nigam R., Hashmi N.H.2000, Karlekar and Rajguru 2012).

As sea level fell, numerous sand silt rich embayments on this rocky coast enclosed by headlands and foothill areas bordering headlands and ridges were exposed (Photo plate See page 10)**.** Sediment supply to these exposed concavities and foothills was by wave induced long shore drift (Reading 1996) and sub aerial fluvial input. The filled embayments and foothill concavities were slowly converted to relief less flat terraces having gentle seaward slope.

Such terraces developed well only where sediment supply exceeded the removal by wave erosion and where adequate accommodation space was available. When relative sea level was static or falling these areas were filled by sediments. Beach fronted strandplains of this type may have also prograded for short distances in few areas.

The key factor that controls the nature of sedimentation in these palaeo embayments were probably topography, orientation with respect to approaching waves and tidal range (Tucker 1985). On Konkan coast their width varies from 0.4 to 10 km. (Table). Many of these are cut by shallow channels and are the most favoured areas for agriculture.

Sediment on these areas is deposited horizontally, eventually building up to form a terrace capped by fluvial deposits and deposits of aeolian origin. The sections exposed in unlined wells in the area show sedimentary sequence related to various episodes of deposition. It was seen that the terrace sediment succession contains mainly fluvial sediments of recent origin at the top and palaeo marine sand silt fossil deposits in the middle to lower parts of the section. Marine and transitional deposits were identified as gravel, sand and silt deposits. Sandy gravel beach deposits rich in modern marine fauna at the top could also be seen in some sections.

Methodology:

The littoral terraces at 12 different sites on Konkan coast of Maharashtra 6 sites on Goa coast were investigated as representative terrace units. A field geomorphic study of these terraces was undertaken and integrated with interpretation of Google earth images and survey of India topographical maps. The mapping of a sequence of terraces at the respective elevations was attempted. The sedimentary deposits and stratigraphic continuity of the type of sediment and possible fossiliferous content was verified by observing unlined well sections wherever available.

Maps of type terraces showing elevation levels were generated from SRTM data and were used to identify the probable strandlines in the area.

This paper is primarily based on field observations supported by topographic interpretations and the use of Google earth images. Due to lack of high resolution stratigraphic data, interpretations are subjective and in some cases may not be very precise.

Discussion:

Littoral terraces on Konkan and Goa coast are flat, reliefless wide to narrow sectors bordering the creeks and estuaries or occurring directly back of the beaches and dunes. In majority of the cases they are related to the recent higher sea level in the area. Their gentle seaward gradient and the sandy silty sediment cover suggest their marine origin. The landward margins of these terraces are irregular and also suggest the configuration of ancient coastline when the sea was slightly higher. They help in the identification of limit of the ancient bays or other tidal inlets in the area

The terraces assume importance mainly in the hilly coastal sectors where they are well preserved. The landward portion of these terraces show a surface cover of hill slope wash and weathered material brought from nearby hills. This is the most important land facet on Konkan and Goa coast as regards its flatness and supportive capacity of the land.

Many villages have preferentially developed on these terraces since long, especially on the seaward part comprising of fossil beach dune ridges. The terraces normally occur at an elevation of 3 to 13 m above present sea level (Fig. 2 See page 11). They are being breached and cut by the streams in monsoon. These terraces are the cultivated areas of the coastal villages in the region. Crops grown include salt tolerant varieties of rice.

The littoral terraces on Konkan and Goa coast can be classified in following major types.

1. Type 1: Extensive terraces dotted with numerous local silt sand mounds, fronted by beaches and backed by tidal mud flats and creeks (e.g. Dahanu,Tarapur, Navapur, Satpati, Mahim, Siridao)
2. Type 2: Linear / Semicircular terraces bordered by main tidal sectors of creeks or estuaries that have sand spits on seaward side (e.g. Diveagar, Valavati, Ubhadanda, Keri)
3. Type 3: Narrow, elongated, linear terraces backed by foot hills and fronted by beaches (e.g. Borlai, Barshiv, Anjarle,Guhagar, Malvan, Anjuna)
4. Type 4: Semicircular terraces developed within the embayments and concavities enclosed by headlands / promontories (e.g. Nandgaon, Murud, Bogmalo, Agonda)
5. Type 5: Creek bank terraces (e.g. Vaitarana, Vasai, Uran, Karanja, Dharamatar, Achara, Hadi, Chorao)
6. Type 6: Very narrow terraces bordering the banks of small creeklets (e.g. Zai, Narpad, Malgund, Candolium)
7. Type 7: Bordering tidal embayments (e.g. Shrivardhan).
8. Type 8: Fronted by long stretch of beaches, rock platforms and tidal river mouths (e.g. Avas, Kihim, Thal,

Alibag,Nagaon, Revdanda, Kajarwadi, Arewadi, Velsao, Cansaulim, Benaulim)

The terraces in the north Konkan where tidal range is more than 4 m and backshore is flat are usually extensive and wide. They are narrow linear or semicircular where backshore is rocky characterised by headland and promontories and tidal range is less than 4 m. Such terraces are frequently seen on South Konkan and Goa coast.

The littoral terraces in the area show an elevation range that varies from 3 to 13 m above present sea level. One can identify the palaeo-shorelines planimetrically at 7 m and 11 m levels from the maps of representative terraces (Fig 2, A to D See page 11). The slope of the terraces varies from .05 to 1.5 degrees (Table).

Table: Terraces on Konkan and Goa cost

Sr.No.	Terrace Location	Lat /Long	Type	Tidal Range (m)	Elevation Range (m)	Max. Width (m)	Slope (Degrees)
KONKAN							
1	Zai	20.12/72.74	6	5.4	4 -12	2712	0.17
2	Tarapur	19.83/72.69	1	4.3	3-13	10748	0.05
3	Barshiv	18.48/72.9	3	3.6	3-16	500	1.50
4	Diveagar	18.08/73.0	2	3.5	3-13	1522	0.38
5	Shrivardhan	18.05/73.06	7	3.6	2-12	1908	0.30
6	Guhagar	17.5/73.18	3	2.7	9-14	574	0.50
7	Velneshwar	17.38/73.20	3	2.6	6-15	396	1.30
8	Malgund	17.16/73.26	6	2.2	6-11	440	0.65
9	Hadi	16.14/73.46	5	1.5	5-11	505	0.69
10	Malvan	16.04/73.48	3	1.5	7-13	881	0.39
11	Ubhadanda	15.84/73.64	2	1.6	5-16	1661	0.38
12	Redi	15.74/73.66	5	1.5	4-13	1403	0.37
GOA							
13	Keri	15.71/73.70	5	2.1	3-12	935	0.55
14	Morjim	15.63/73.73	5	2.2	4-11	600	0.67
15	Anjuna	15.61/73.74	3	2.2	4-9	618	0.46
16	Pale	15.36/73.89	8	2.1	4-11	640	0.63
17	Benaulim	15.24/73.90	8	2.1	4-12	1080	0.42
18	Polem	14.97/74.04	3	2.0	8-13	712	0.40

Stratigraphy :

It was seen that these terraces contain mainly fluvial sediments of recent origin at the top and palaeo marine sand silt fossil deposits of beach dune origin in the middle and lower parts of the section. Naturally exposed sections of the terraces could be seen only on their seaward margins and in the unlined dug wells. When relative sea level was static or falling the terraces got filled by sediments brought from the surrounding hills and hill slopes.

Many carbonate sediments were deposited in tidally influenced regions of North Konkan. Silt clay deposits predominate in meso and micro tidal range environments of South Konkan and Goa.

In few sections the sediment strata are overlain by marine deposits which show basal conglomerate that can be interpreted as beach sand and gravel. The organic burrows and bioturbation suggest that they are palaeodune deposits (Fig. 3 and 4 See page 12).

Shoreline gravels in the section are distinguished from fluvial gravel by their higher degree of sorting and the segregation of gravel from sand, rounding of clasts, presence of gently dipping or horizontal lamination and seaward dipping imbrications (Reading 1996). These indicators can also be used effectively in knowing the stratigraphic sequence of Konkan and Goa shoreline terraces, especially the beach ridge component of terraces.

Conclusion:

The most notable feature suggesting earlier higher sea level on Konkan and Goa coast is preserved in the form of littoral terraces. One can find a perfect association between the configuration of the present coast and the occurrence of these palaeo terraces. They occupy various topographic positions along the coast and 8 major types could be clearly identified. The modern sediments, beaches and dunes on this coast are invariably backed by old beach dune sector of the seaward side of littoral terraces. The deposits covering terraces are calcareous and sandy in nature. Many coastal villages are situated on fossil ridges of beach and dune origin. They are concealed under modern sand and alluvium. On an average they can be observed upto a distance of 500 m from HWL and behind the modern dunes.

The terraces have a low gradient that hardly exceeds 1.5 degrees. It appears that the terrace elevation, gradient and the width are not controlled by the tidal range.

The vertical sedimentary sequence always consists of fluvial sediments of recent origin at the top and palaeo marine sand silt fossil deposits of beach dune origin in the middle and lower parts of the section Formation of these terraces could be related to a slow fall in sea level during last 4000 years in Late Holocene.

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Shrikant Karlekar
Former Dean, Faculty of Earth Sciences,
Tilak Maharashtra Vidyapeeth,
Pune, (Maharashtra)
Shrikantkarlekar18@gmail.com