CHAPTER-5
GEOMORPHIC AND GEOCHRONOLOGICAL ASSESSMENT
OF LATERITES AND LATERITIC LANDSCAPE

Many workers are of the opinion that the Deccan trap formation in Maharashtra cannot be older than the uppermost cretaceous. From the internal evidence such as fossil woods, palms, foraminifera, etc. it can be said that the traps cannot be younger than Eocene. The traps in Maharashtra are a result of volcanic event around late Cretaceous to early Paleocene. The trap formations were succeeded by either the rifting and slow retreat of Western Ghats forming a continental edge or a faulting, resulting into Konkan as a downthrown component. A slow meteoric alteration of the basalts in Paleocene was responsible for the development of thick laterites in the high level areas. There seems to be general agreement on the opinion that the low level laterites were produced between Paleocene and Miocene or even up to Pliocene. These low level laterites cover most of the downthrown or receded component of the Cretaceous formations.

The age of high-level laterites however cannot be determined with certainty. Although, many have identified high level laterites as belonging to Paleocene or an even older period, a possibility has also been suggested that they may be even post-tertiary, belonging to
Pleistocene (Wadia 1978). Consequently, the age of low-level laterites could be very recent. Many Paleolithic tools are found embedded in the low level laterites. It therefore seems certain that the low level laterites in Konkan are not older than 2MYBP. Wadia (1978) is of the opinion that the development of low-level laterites is probably still going on in the area.

Long period with relatively stable sea level, produce wide coastal plains till the end of early Pleistocene. The period was probably characterized by minor regressions of the sea and the incision of major river valleys. This was succeeded by a low level lateritization of coastal plains that continued till early Holocene. This lateritization was responsible for the burial of earlier Pleistocene landforms and land facets developed on the coastal plains. The early Holocene probably witnessed a long period of stable sea level and the development of new drainage on relateritized secondary formations. The probability of few minor movements of upheaval in this period have been suggested, but with very few evidences. The later part of Holocene was affected by the denudational isostacy as a result of weight related subsidence and a slight uplifting of the lateritic plateaus. The consequences of such an uplifting and the weight related subsidence were the occurrence of shore platforms, terraces, and the beach rocks related to the minor regressions in last 3000 years.
The age of the lignite beds (Ratnagiri beds) occurring at a depth of about 15m in the area, according to pollen analysis and carbon 14 dating respectively varies from 30,000 to 10,000 Y.B.P. (Phadtare 1982, Kulkarni 1984, Sakurkar 1999). These beds therefore can be comfortably placed in mid Holocene and not in Miocene or Eocene as reported elsewhere (Wadia 1978).

Early to mid Holocene scenario (30,000 YBP or even earlier)

The degree of preservation of biogenic material in the lignite beds also suggests that these deposits cannot be older than 30,000 Y.B.P. The lignite beds in the study area are almost always covered by laterites and constitute a very striking stratum in the lithostratigraphic sequence exposed in well sections (Photoplate 5.1). Therefore, they are used here as a bio-indicator of the environment in the earlier part of Holocene in the study area.

It seems likely that these deposits are of marine or estuarine origin filling up the broad arms of the sea or the tidal channels along the earlier coast.

The samples collected from lignite deposits show that the material is like loose textured, carbonaceous clays that is argillaceous and gritty in nature (Photoplate 5.2). Its composition varies with respect to the
5.1 LITHOSECTION EXPOSED IN WELL AT SITE K 9
5.2 LOOSE TEXTURED, CARBONACEOUS CLAY IN LIGNITE MATERIAL FROM WELL SITE K 9
topographic location in terms of sulphur content, occurrence of resins, percentage of sand, occurrence of pneumatophores, etc.

The lignite deposits in the study area are especially useful as they exhibit a distinct unconformity with the underlying gravel bed. They yield abundant fossils woods, pneumatophores and fruits. A definite pattern in these constituents and a sharp boundary of the lignite bed therefore could be easily used to reconstruct the environment in which these clays were deposited.

The position of carbonaceous (lignite) clays in the total sedimentary column is of great significance. It lies under the secondary laterites or the detrital laterites. The type of the material found within these clays suggests it to be of tidal origin. The pollen analysis of the leaves and fruit bodies found in this region proves that the fossils belong to mangroves. The presence of mangroves is itself an indication of estuarine environment in the area. The variation in the depth of lignite along with the distribution and occurrence of pneumatophores, sulphur, and amber resin lenses indicate the degree of abundance of vegetation.

Below the laterites on both the plateaus the distribution of carbonaceous clay is not even. The clay is observed in well sections in a restricted area. The wells that are inland from the present day coastline or estuaries contain lignite. The occurrence of the lignite with such a distribution suggests that there was a specific region, which was
favorable for the growth of mangroves. With the help of the 23 well sections, from the northern Kolambe plateau and 14 from the southern Purnagad plateau it was possible to infer the probable limit of carbonaceous clay bed (Fig. 5.1). This line suggests the limits of clay formation. These limits on both the plateaus follow the trends of plateau margins. This typical distribution yields more information regarding the paleo-environment. The existence of clay indicates that the area was covered with mangrove type of vegetation. This type of vegetation grows exclusively in tidal environment. Mangroves thrive in intertidal environments in general and slightly above the lowest low tide level and slightly below the highest high tide level within the sheltered areas like estuaries, tidal inlets, arms of the sea, etc. The distribution confirms that the area of clay was intertidal at the time of formation of the clays, that is 10,000 to 30,000 Y.B.P. The area beyond the limits of clay formation was definitely not intertidal. The depth values of lignite from the well sections when plotted show that the bed is shallow at the centre, and deepens towards the margins (Fig. 5.1). It clearly indicates that the region experienced sub-tidal condition. All these aspects of the clays and the variation within, help in the identification of various facets of paleo-environment like limit of mangroves, the areas of dense growth of mangroves, the tidal range, the sequence of formation etc. These aspects are discussed in the following paragraphs in detail.
As a rule the lignitic clay is found in well sections and never in the natural cuts or sections. Within the well sections clay is always below a column of secondary laterites. The crust, mottled and pallid zone in relateritised section is underlain by the clay (Fig. 5.2). The contact between the clay and upper lateritic profile is sharp and abrupt. There is no gradual merging of lithofacies from laterite to lignite clay. In all the well sections studied on both plateaus there is a thin band of hematite separating laterite from clay. This band is also reported by Bruckner (1987), Karlekar (1981), Sakurkar (1999). This layer made up of iron rich rock has width that varies from 3 to 5.5 cm. The formation of this thin layer is explained by Karlekar (1981). This rock is a product of leaching of the upper laterite. The iron from the upper layers moves down the lateritic column and gets settled at the junctions of clay contact, because of differential percolation co-efficient and pH. This iron rich band is hard and pan like, and is locally known as “Tawa”. This hematite band represents the lower limit of the secondary laterite. The laterite being secondary was formed from sediments having terrestrial origin. The sediments derived from primary high-level laterites were deposited and were relateritised to form the low level laterites, (Karlekar, 1981). The presence of the secondary laterites over clays suggests a sequence where the clays derived from tidal substratum originally occupied the area. The sediments of this period were of marine origin with ample mangrove
LITHOSTRATIGRAPHY OF DUG WELLS

INDEX

C CRUST
M MOTTLED ZONE
P PALLID ZONE
L LIGNITE
W WEATHERED

FIG No. 5-2
detritus. These were subsequently covered by the sediments transported from high-level primary laterites which spread in troughs, bays, and embayment and on hills well beyond the present day coastline as laterite is reported in boreholes offshore of Ratnagiri (Sharma et al., 1989; Karlekar, 1981) and other places. The amount of deposition can be judged from the present day thickness of the low level lateritic column. The relateritisation of the deposited sediment and its hardening along with leaching produced the present day low level laterite especially near the coast (Karlekar, 1981). The leaching produced hematite. Thus it is the boundary between the upper terrestrial sediments and lower marine sediments.

Where the lignite bed is absent the hematite rests on coarse marine sediment. The absence of clay suggests that the estuarine bed was not covered by silt, clay and hence was not conducive for mangrove growth.

The areas of clay formation on northern Kolambe and southern Purnagad plateau could be related to two modern day estuaries namely the Kajali in the north and Muchkundi in south. The northern clay region was a part of the then Kajavi estuary. The clay region on Purnagad plateau was a part of adjacent Muchkundi estuary. Estuaries with wide mouth can be visualized both to south as well as north.
On both the plateaus there is a variation in the depth of the lignite (Table 5.1). The general trend is that the deposits are nearer to surface in the central part and deeper towards the plateau margins (Fig. 5.3). On the northern Kolambe plateau the lignite bed at site K9 occurs at a depth of 11.6m from the surface. The maximum depth at which the lignite bed was found exposed is 15.9m K2 on the northern boundary of Kolambe plateau. In south the lignite bed occurs at the depth of 16.3, 16.4, and 16.0 at sites K17, K19, K20 respectively. Towards the coastline on west the depth is 14.6m. (K8). In the east towards the land the deposits have depth of 13.4 (K10), 12.3 (K13) and 12.6 (K16). Thus the drop in the level is steeper towards south and north while it is gentle towards east and west. Few well (K1, K12, K14, K21, & K22) do not show any trace of lignite deposits. Thus the depth ranges from 11.6m to 16.9m i.e. by 5.3m. This is the elevation difference in which the tidal zone probably extended. Sites where the hematite occurs below 16.9m. in all probability is a limit of lignite occurrence.

On the southern Purnagad plateau the site P6 has shallowest clay bed at a depth of 13.1m. In the north at site P3 it increases to 14.1, in the southwest at P12 it is deepest at 15.4m. A detached plateau segment appears in the north near Ganeshgule. Sections at two sites P1 and P2 on this plateau do not have lignite. Similarly, the sections of sites near the coast P5, P10, and P19 and in the south near the estuary P14 do not show
DEPTH OF LIGNITE OCCURRENCE

LIMIT OF LIGNITE OCCURRENCE

PLATEAU MARGIN

FIG. No. 5.3
Table 5.1: Depth of lignitic bed at various well sites.

<table>
<thead>
<tr>
<th>Depth of Lignite</th>
<th>Kolambe Plateau</th>
<th>Purnagad Plateau</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent</td>
<td>K1, 12, 14, 21, 22</td>
<td>P1, 2, 5, 10, 13, 14</td>
</tr>
<tr>
<td>14</td>
<td>K2, 3, 4, 5, 6, 7, 8, 17, 18, 19, 20</td>
<td>P3, 4, 8, 11, 12</td>
</tr>
<tr>
<td>14</td>
<td>K9, 10, 11, 13, 15, 16</td>
<td>P6, 7, 9</td>
</tr>
</tbody>
</table>

(Ref. Fig. 5.3 for the location)

lignite. The plateau in south is not as extensive as the northern Kolambe plateau. The constituents of lignite clay also do not show much variation. Region at 17m depth is probably a limit of the occurrence of lignite. On both the plateaus the probable limit encircles the areas away from coastline or estuaries, but it continues till margin in the east. Part of Kolambe plateau near Taklewadi, Kurli, Kasop, Ranpar, or Golap lie outside the limit of lignite formation (Fig. 5.3). On the southern Purnagad plateau it borders the central part of main plateau. The Ganeshgule, Mervi, and Purnagad are beyond this limit. The areal coverage of lignite below northern Kolambe plateau is relatively larger. The plateau itself is extensive and comparatively less dissected. It is interesting to note that the area occupied by lignite deposits lie away from the central Pawas bay. On may infer that only small estuary or tidal inlet was connected to
Pawas bay. Otherwise, northern as well as southern tidal systems were separately joined to Kajavi and Muchkundi respectively. Thus, it is more proper to visualize their connection to the respective estuaries rather than with each other (Fig. 5.4 a, b).

Samples from the lignite bed, when analyzed show that there is a definite spatial variation among the various constituents. A count of fossilized remnants of mangroves was taken for the lignite sample from wells. A sample having a volume of 1 cu. Ft. was taken and the actual number of fossilized members was counted (Table 5.2). The fossilized material contained pneumatophores, leaf fossils, fruit bodies, pieces of trunks and branches. (Fig. 5.5) This count served two purposes; one it could be confirmed that the vegetation was definitely related to mangroves and two it yielded information about the abundance or otherwise of the growth.

On the northern Kolambe plateau the highest count is 23 at location K15 and it is 21 in well at K9. These two are in the central part of the plateaus. The count decreases away from here in all directions. It is minimum in the north, in the well at K2, which is not normal considering the trend. It is 10 in wells at K3 and K4 in the north while it is 16 in the wells at K8 and 14 in K19 in the west, 16 at K20 in the south. Along the eastern margin in the well K10, K13, K16 it is 11, 13 and 13 respectively. On the southern Purnagad plateau the highest count is at location P6 and
DIGITAL PALEO TERRAIN MODEL INFERRED FROM LIGNITE DEPOSITS
PURNAGAD PLATEAU

Fig. 5.4, B
FOSSIL COUNT IN THE
LIGNITE DEPOSITS

ARABIAN

PAWAS CREEK

GANESHGULE

PURNAGAD

KASOP

KOLAMBE

BHATYE

RANPAB

GOLAP

Plateau margin

1000 M 0 1000 M

FIG.No.5-5
P7, 23 and 25 respectively. Lowest count is of 3 in the well at P12 to the southwest. Northern locations P3, P4 and western P8 have a count of 6. Thus, on both the plateaus the highest occurrence of fossilized material is in the centre while it decreases towards the margins. This is indicative of the fact that growth of mangroves was luxuriant enough in the central part, which is indicated by such a high number of fossilized woods, and fruits. The growth was relatively scanty towards the margins and it is reflected in the low amount of fossilized material and low count.

Table 5.2: Fossil count in lignite samples

<table>
<thead>
<tr>
<th>No.</th>
<th>Kolambe</th>
<th>Purnagad</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>K1, 2, 3, 4, 12, 14, 21, 22</td>
<td>P1, 2, 3, 4, 5, 8, 9,10,11,12, 13,14.</td>
</tr>
<tr>
<td>10-20</td>
<td>K5, 6, 7, 8, 10, 11, 13,16,17,18,19, 20.</td>
<td>-</td>
</tr>
<tr>
<td>&gt;20</td>
<td>K9, 15</td>
<td>P6, 7</td>
</tr>
</tbody>
</table>

(Per sample of 1 cubic foot)

The mangroves have tendency to accumulate few elements. Sulphur is one of them. Geological survey of India (1964) has reported the amount of sulphur present in clays from two bore wells to be 9%. Sulphur percentage was calculated from the samples of all the well sites (Table 5.2). It indicates that like the fossil count, amount of sulphur is more in the central part. On the northern plateau maximum amount of
sulphur is 9% (K4, K5, K6, K9, K15, K18). (Fig. 5.6) The southern Purnagad plateau is slightly richer in sulphur content. Material from well at P6, and P7 has 10% of sulphur, which is highest, whereas those at P4 and P9 have 9% of sulphur. Only 6% sulphur was obtained from the material in well at P3, P8, P11, and P12. Like pneumatophore count, amount of sulphur also decreases towards the margins of the plateaus. This sulphur imparts typical pungent odor to the well water especially in summer and gives a slightly yellowish tinge. The well water in the central part of the plateau is highly contaminated with sulphur and makes its impotable.

Table 5.3 : Percentage of sulphur

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Kolambe</th>
<th>Purnagad</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>K1, 2, 12, 14, 21, 22</td>
<td>P1, 2, 5, 10, 13, 14</td>
</tr>
<tr>
<td>6-8</td>
<td>K3, 7, 8, 10, 11, 13, 16, 17, 19, 20</td>
<td>P3, 8, 11, 12</td>
</tr>
<tr>
<td>&gt; 8</td>
<td>K4, 5, 6, 9, 15, 18</td>
<td>P4, 6, 7, 9</td>
</tr>
</tbody>
</table>

Similar to sulphur, mangroves also have tendency to store resins in the form of lenses. Amber is the dominant form of resins stored. It is yellow in colour and is amorphous. It is found in the clay in the form of oval shaped lenses. The amount of deposition of amber was determined
by counting the number of lenses in 1 cu ft volume of clay (Table 5.4, Fig. 5.7).

On the northern Kolambe plateau the highest count of lenses was obtained from the material in wells at K15 (33) in K6 (32) and K9, K13, K16 (more than 30) from the northern plateau. These well sites are spread over a large part of the northern plateau. The count decreases towards the margins. In the north at K3 material has amber count of 14 while in south in the well at K20 it is 11, which is the lowest count in this area. On the Purnagad plateau at P6 and P7 the count is 42 and 43 respectively. The count decreases to 11 at P12 in southwest and 16 at P3 in the north. In both the cases the general pattern of distribution is similar to that suggested by other constituents.

Table 5.4 : Amber count in lignite samples

<table>
<thead>
<tr>
<th>No.</th>
<th>Kolambe</th>
<th>Purnagad</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10</td>
<td>K1, 2, 12, 14, 21, 22</td>
<td>P1, 2, 5, 10, 13, 14</td>
</tr>
<tr>
<td>10 – 20</td>
<td>K3, 4, 8, 17, 19, 20</td>
<td>P3, 8, 11, 12</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>K5, 6, 7, 9, 10, 11, 13, 15, 16, 18</td>
<td>P4, 6, 7, 9</td>
</tr>
</tbody>
</table>

(Per sample of 1 cubic foot)

All the aspects of the lignite discussed above are associated with the actual mangrove vegetation. The composition of lignite itself is also a significant aspect. For growth of mangroves the percentage of sand has to
AMBER COUNT IN LIGNITE DEPOSITS

Plateau margin

FIG. No. 5.7
be minimum, as silty clayey substratum favors rich growth of mangroves (Davies, 1977). The percentage of sand in lignite samples therefore can provide more information about the type of bed material or the nature of the substratum. So also it can speak for the dominance of marine or fluvial sedimentation processes.

Over the northern Kolambe plateau, percentage of sand in the well at K9 is only 8%. It is 9% at K6, K15 (Table 5.5). These are the areas of relatively low sand content (Fig. 5.8). The percentage of sand increases towards the margins of the plateau. It increases slowly towards east, (in the well at K7, K10, K13, K16 percentage of sand in samples is 19, 21, 22, and 19 respectively). The increase in the sand percentage is more towards the coast and the estuary. The northern well K2 has 31% sand, the western K19 has 30% of sand and southern K20 has 26% of sand. Similarly the southern Purnagad plateau has sand percentage as low as 8 and 9% (P6, P7) respectively. This increases to 24% at P3 in the north, 21% at P12 in southwest and 23% at P11 in south.

The trend in the percentage of sand is inverse to other aspect i.e. sand increases away from the central part indicating that the central areas were conducive for the growth of mangroves and the substratum was unfavorable for the growth towards the margins.

The various aspects, which are indicative of the paleo-environment and its composition and variation, can be integrated and the sites can be
Table 5.5 : Proportion of sand

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Kolambe</th>
<th>Purnagad</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20</td>
<td>K2, 3, 4, 8, 10, 11, 12, 13, 14, 19, 20, 21, 22</td>
<td>P1, 2, 3, 4, 5, 10, 11, 12, 13, 14.</td>
</tr>
<tr>
<td>10 – 20</td>
<td>K5, 7, 16, 16, 18</td>
<td>P8, 9.</td>
</tr>
<tr>
<td>0 – 10</td>
<td>K6, 9, 15</td>
<td>P6, 7</td>
</tr>
</tbody>
</table>

classified according to the suitability of paleo-environment for the growth of mangroves. The sites were given scores based on the classification of the distribution of different aspects (Table 5.6). Depending upon the value of different aspects score were assigned. The scores were then grouped in three groups namely, sites that are not suitable, moderately suitable and most suitable. Over the northern plateaus sites K9 and K15 have highest scores and suggest that the area was conducive for the growth of mangroves (Fig. 5.9). Well K5, K6, K18, K16 belong to most suitable group. Moderately suitable sites are K 4, K 8, K11, K17, K19, K20, K13, K10, and K 7. Sites K1, K2, K 3, K12, K14, K21, K 22, were not conducive for the growth of mangroves. On Purnagad plateau near P6, P 7 and P9 the environment was most suitable. Area near P4, P8 was moderately suitable while that near P1, P2, P3, P5, P10, P12, P13, and P14 was not favorable for the growth of mangroves.
SUITABILITY OF TIDAL ENVIRONMENT
FOR MANGROVE GROWTH
(Based on scores)
Table 5.6: Sites of dug wells, indicative of Paleo-existence of mangrove swamps

<table>
<thead>
<tr>
<th>Suitability for mangrove growth</th>
<th>Kolambe plateau</th>
<th>Purnagad plateau</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not suitable</td>
<td>K1, K2, K3, K12, K14, K21, K22</td>
<td>P1, P2, P3, P5, P10, P11, P12, P13, P14</td>
</tr>
<tr>
<td>Moderately suitable</td>
<td>K4, K7, K8, K10, K11, K13, K17, K19, K20</td>
<td>P4, P8</td>
</tr>
<tr>
<td>Highly suitable</td>
<td>K5, K6, K16, K18</td>
<td>P9</td>
</tr>
<tr>
<td>Most suitable</td>
<td>K9, K15</td>
<td>P6, P7</td>
</tr>
</tbody>
</table>

The most suitable areas on both the plateaus were intertidal in nature. Isolated areas were not favorable or were always away from tidal influence.

Late Holocene Scenario (around 3000 YBP)

In addition to lignite other features help in knowing the chronology of events especially in later part of Holocene. Occurrence of beach rock or ‘Karal’ is one of them. The association between the beach rock and the sea level change has been discussed by Karlekar (1981), Deswandikar (1993), Keskar (1996) etc. along the Konkan coast in general and area under investigation in specific. Beach rocks are actually lithified sands of the ancient beaches and dunes. The location of these in present day...
topography especially with respect to the HTL is important in the reconstruction of earlier environment.

In the study area beach rock is found at Waingani and Ganeshgule. The beach rock at Waingani is a rock of dune and beach origin and occurs at the base of present day dune and is exposed in a small tidal inlet. The elevation of this formation near the exposure is 1.2 m. ASL. The rock is flaky and undergoing erosion by tides. At Ganeshgule the rock is exposed at many places along the base of the dune. Here, its elevation is 2 m. from present HTL. The continuation of the same is found in the tidal inlet towards south. Here it assumes a form of pile of slabs of lithified sand with a gentle dip. It is massive and hard. To the south of Ganeshgule near Gulekarwadi, beach rock is found along 3 North-south trending lines. The uppermost is behind the present day dune and has elevation of about 3m from present HTL (Photoplate 5.3). It is hard and compact. The present day dune is undergoing lithification as is evident from the storm cut at the base of the dune. Many shells are found embedded within this dune. The third row is represented by intertidal beach rock, which extends from upper beach to low tide line (Photoplate 5.4). It is not continuous but patchy. At places it is raised by 32cms over the present day beach. It is undergoing alteration due to present day wave and tidal action. The beach rocks in the area are backed by a narrow terrace behind the present dunes. The elevation of terraces 3m ASL suggests the earlier higher sea level.
5.3 SHORE PARALLEL BEACH RIDGE AT GANESHGULE

5.4 INTERTIDAL BEACH ROCK AT GANESHGULE
According to Karlekar (2001) these beach rocks are about 1800 to 2100 years old and thus represent the sea level at that time. They suggest regressions of sea during last 2000 years.

**Shoreline terraces**

In the area, narrow, flat, shoreline terraces are found at Kurli, Kasop, Waingani (Fig. 5.10) and Ganeshgule. These terraces are small and parallel to the coast. Kurli village is located on a small terrace backing the beach. The terrace has elevation of about 3m from HTL. It is narrow and elongated. The terrace at Kasop is comparatively wider. It stretches between two streams to north and south. The orientation of this terrace is north south and borders a gravel beach (*Photoplate 5.5*). The water table on the terrace is relatively shallow and helps vegetable farming. The height of the terrace is 3 to 5 m. ASL. To the south of Kasop at Waingani there is a wide terrace at an elevation of 3 m. ASL. The terrace is fronted by sandy beach and a lithified sand dune. Along Kolambe plateau, the terraces are seen at Kurli, Kasop and Waingani. Along the Purnagad plateau there is an extensive terrace at Ganeshgule. This is a very wide terrace in the area. The irregularly shaped terrace is fronted by a long sandy beach. A tidal inlet to the south is a scene of dense mangroves. Peculiarity of the terrace is that along its seaward margin a thin section of fossil beach rock is exposed. The elevation of the terrace is not uniform everywhere. It varies from 5m to 1.7 m.
5.5 LATERITIC GRAVEL BEACH AT KASOP

5.6 SHORE PLATFORM AT GANESHGULE
SEDIMENTARY ENVIRONMENTS
(THE BEACH AND TERRACE AT WAINGANI)

INDEX

Cliff
Lower Upper Beach
Ilmenite bands/placers
Dune-Fossilised
Exposed Beach Rock
Terrace
Beach
Feet Hill Material (Colluvial)

FIG.No. 5-10
The morphology and the configuration of these terraces undoubtedly point to their marine origin and defunct nature due to a slight drop in sea level. Steep banks of the channels of small streams, which cut across the terraces, suggest an increase in fluvial activity, subsequently after these terraces were developed. The lower reaches of the streams very close to the shore are necessarily tidal and have a meandering pattern that can be attributed to a very recent, slight rise in sea level.

A sharp and abrupt contact of terraces with the inland plateau edges is also very striking. Recently reported salinity increase of well waters on the terraces, is an indication of slowly rising sea in the area.

**Cliffs**

Sea cliffs in the area show a striking similarity in their vertical exposure. They are convex with near vertical basaltic lower section. The profiles suggest the change in the sea level. Their contact with the shore platforms is sharp. At places these cliffs have caves and notches at the base (*Photoplate 5.6*). Various aspects such as their distance from high water, gradient, caving and height above sea level and their degradation and erosion are significant.

Sea cliffs at Bhatye are about 54m inland from present high water line. It is only during the tidal surge that the water reaches to the base of these cliffs. Similarly cliffs to the north of Ganeshgule are 7m inland from present high water mark. (Fig. 3.5)
Sea caves developed on cliffs are found at Ganeshgule headland (Fig. 5.11) at a height of about 6 m ASL (Photoplate 5.7). Similar caves are seen in nearby area normally at a height of 9m. The caves at higher levels are more intact as they are not under the direct impact of present day waves. The caves that are observed near the base are only half a meter above the shore platform. The notches also have similar appearance. Today the high water rarely reaches up to these caves and notches, except in spring and surges.

Similar to the cliffs on the shore platforms some features suggestive of regression could be seen. The shore platforms at Ganeshgule and Ranpar are wide and there are stump like features on the platform (Photoplate 5.8) that are actually the remnants from the earlier higher platforms. The height of these rock protrusions varies from 29 cm. To 42 cm. at Ganeshgule. Their frequency is very high and striking. At high tide they are surrounded by high water. The shore platforms are covered with the material of disintegration and quarrying of cliff slopes. The amount of such material covering the platforms is very high especially near Kasop, Waingani, Ganeshgule and Mervi. The modern waves have not been able to completely remove the material, as it is out of reach of waves, due to a slight drop in sea level.
THE CLIFF AND SHORE PLATFORM MORPHOLOGY

KASOP

Lateritic Cap
Weathered Section
Parent Rock

GANESHGULE

FIG. No. 5.11
5.7 DEFUNCT NOTCHES AND ELONGATED CAVING AT GANESHGULE

5.8 STUMP 52cm HIGH ON SHORE PLATFORM AT GANESHGULE
Table-5.7 : Evidences Suggestive of Former higher Sea level.

<table>
<thead>
<tr>
<th>Place</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhatye</td>
<td>Defunct sea cliff</td>
</tr>
<tr>
<td>Kurli</td>
<td>Terrace raised at 3 M. ASL.</td>
</tr>
<tr>
<td>Kasop</td>
<td>Terrace raised at 3 – 5 m. ASL., Down cutting of terrace by stream in the lower course, Geo like formation.</td>
</tr>
<tr>
<td>Waingani</td>
<td>Terrace raised at 3 m. ASL., Down cutting by stream, Tidal water inundating the lower stream course, Beach rock at the base of the dune.</td>
</tr>
<tr>
<td>Ganeshgule</td>
<td>Terrace raise from 1.7 –5 m. ASL., Down cutting by stream, Tidal water inundating the stream, Three parallel ridges of beach rock from dune to inland, Geo like formation, Low tide cliff.</td>
</tr>
<tr>
<td>Ganeshgule</td>
<td>Terrace raised at 3 m. ASL., Beach rock backing present dune, Sea caves raised by 3m. on the present sea cliff, Low tide cliff.</td>
</tr>
</tbody>
</table>

(Ref. Map 3.4 for location of places)

On the shore platforms towards the cliff edge there are Geo-like cuttings (*Photoplate 5.9*), orthogonal to the coast. The depth of these Geos corresponds to that of low tide cliff bordering the seaward margin of platform. Such cuttings are seen near Kasop and Ganeshgule. Near Kasop these vertical narrow cuttings on shore platform are 1.6m wide and 1m deep. At Ganeshgule they are 8m long and 1.7m wide and 1.6m deep. Waves run up through these gaps and form spray near their head. The seaward edges of the shore platforms have steep small 1 to 1.7 m. high low tide cliffs, all along the coast from Kasop to Ganeshgule (*Photoplate 5.10*).
5.9 NEARSHORE HEADLAND OUTLIER AT GANESHGULE SHOWING WIDE SHORE PLATFORM

5.10 GEO LIKE FEATURES DEVELOPED ON SHORE PLATFORM AT GANESHGULE
<table>
<thead>
<tr>
<th>Geological period</th>
<th>Tentative Date (MYBP)</th>
<th>Terrain feature/Geomorphic processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>1</td>
<td>Sea level regression, shore platforms, terraces, Beach rock, Lateritization of coastal plains, stable sealevel, Development of drainage, Burial of landforms and Land facets (Estuaries, creeks, etc.)</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>2</td>
<td>Formation of low-level Laterites.</td>
</tr>
<tr>
<td>Pliocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miocene</td>
<td></td>
<td>Periods of relatively stable sea level, Development of coastal plains, minor regressions, Incision of valleys.</td>
</tr>
<tr>
<td>Oligocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paleocene</td>
<td></td>
<td>Formation of High level Laterites, Rift/ Faulting/ Formation of W. Ghats/ Headward Retreat</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>65</td>
<td>TRAP ROCKS</td>
</tr>
</tbody>
</table>