# STRATIGRAPHY AND PALYNOLOGY OF THE MANGROVE SWAMPS OF BOMBAY

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## ABSTRACT

The mangrove swamps in Bombay and Salsette islands are made up up to 5 m of dark and brown mud filling undulating rocky basins. Pollen analysis has revealed statistical insufficiency of pollen grains, the identification of which permits us to infer broadly an increase of Rhizophorae (*Bruguiera* and *Ceriops*) in the top samples; *Avicennia* was poorly present and there are indications of the presence of the other important mangrove genera among which pollen grains of *Sonneratia acida* outnumber those of others. The sediments have been found to abound in microplankton and microforms, and the latter have indeed escaped the destructive effects of the acetolysis method. The lack of organic matter and poverty of pollen have not permitted the building up of radiocarbon dated pollen stratigraphy for these mangrove swamps. The possibilities for the prevalence of relatively moister climate in the past have been discussed.

## INTRODUCTION

BOMBAY, situated on the west coast of India between Lats. 18°55′N and 19°20′N, Longs. 72°45′E and 73°0′E, is made up of seven islands now welded into one. Separated from the mainland, it covers an area of 169 square miles, lying along a north-south axis extending from Ghodbunder in the north to Colaba Point in the south, and its northern limit in the Salsette Islands is much broader than the tapering south.

The Ulhas River flowing into the Bassein Creek and the Thana Creek separate the islands of Bombay and Salsette from the mainland, and the Mahim Creek separates them from each other. The coastal margin along the west is indented by smaller creeks, while the Harbour waters surround Bombay on the east. Extensive tidal flats separate the island of Trombay from Bombay and the Salsette Islands, the latter being the largest of all the islands.

The sea bordering the islands of Bombay and Salsette is shallow, and rocks, mud, sand or shingle are exposed at different places along the shores. The soils in these islands are derived from basalt and rocks of felsic and ultrabasic composition associated with trap and from the intertrappeans made up of yellow, green or black often laminated or stratified pyroclastic shelly material.

The climate is of the monsoon type, with a rainless and comparatively cool period from November to February; a hot dry season from March to May and a very wet season during June to September. The average annual precipitation is 220 cm with a maximum of 350 cm and a minimum of 156 cm.

The upland forest, the best example of which occurs in the neighbourhood of the Kanheri Caves is the Deciduous Monsoon Forest, described by Champion and Seth (1968) as the Southern Tropical Moist Deciduous Forest. Remains of the original forest also occur on the eastern slopes of Trombay Hill and on the chain of hills between the Agra Road and the Vehar and Tulsi lakes. No tree in the undisturbed forest is more than the 15% of the total. Common trees in these forests include *Acacia chundra* Willd., *Syzygium cumini* Skeels, *Erythrina indica* Lamk., *Butea monosperma* Taub., *Bauhinia racemosa* Lamk., *Ficus* spp., *Manilkara hexandra* Dub., *Lannea coromendalina* Merr., *Terminalia crenulata* Roth., *Pongamia pinnata* Pier., *Morinda tinctoria* HD.f., *Wrightia tinctoria* RBr., *Salmalia malabarica* and species of *Trema, Adina, Grewia, Bridelia, Mitragyna, Sterculia, Garuga, Gmelina, Dalbergia* and *Mangifera indica*. Among the less common species are of *Schleichera, Diospyros, Hymendictyon, Gardenia, Casearia, Anogeissus, Randia,* etc. Most of the tree species are insect-pollinated and of the others the pollen grains lack distinguishing criteria — the pollen being

3-colpate or 3-colporate with more or less smooth walls. The climbers and the shrubs in the forest are also largely insect-pollinated.

The mangrove vegetation in the tidal marshes consists of *Avicennia alba* which is the chief and dominant component together with *Avicennia officinalis, Acanthus ilicifolius, Ceriops candolleana, Aegiceras majus, Bruguiera gymnorhiza*, species of *Sonneratia* and *Rhizophora, Salicornia brachiata, Clerodendrum inerme, Lumnitzera racemosa* and *Excoecaria agallocha*.

During the course of field work in 1962 by one of us (Vishnu-Mittre), and in 1969 by both of us *Avicennia alba* was found to be the dominant element occurring either pure or mixed with *Acanthus* and other species. Both *Rhizophora* and *Bruguiera* occur only rarely. The succession of plant communities from the coast moving inland studied and described by Navalkar (1956) and modified by us, is given below:

a) *Rhizophora mucronata* community is nearest the sea, abutting on mud and sand along the edge of the creek at Ghodbunder and also on the edge of the Bassein Creek. Even in these two areas there is now considerable reduction in the number of *Rhizophora* trees.

b) *Avicennia alba* community. Behind the *Rhizophora* community, an almost pure community of *Avicennia alba* is seen in many places (Colaba, from Sewri to Trombay, Vadalla, south of Chembur, Madh Island, etc.), with occasional small bushes of *A. officinalis* and a few clumps of *Acanthus ilicifolius*. At other places, such as at Mahim, *Ceriops candolleana, Bruguiera gymnorhiza* and *Sonneratia apetala* also occur, though rarely, in the *Avicennia* community.

c) *Acanthus ilicifolius* zone fringing the *Avicennia* Community.

d) *Aeluropus villosus* zone outside the *Acanthus* zone. This is either a pure distinguishable zone or more often it is also populated by *Suaeda fruticosa, Sesuvium portulacastrum* and *Clerodendrum inerme*. The individual colonies of these species are found intermixed in the zone.

e) Approaching dry soil, *Clerodendrum inerme* forms a conspicuous belt together with grasses (species of *Sporobolus, Panicum paspalum*) and sedges such as *Cyperus compressus* and *C. rotundus* and species of *Fimbristylis*. *Clerodendrum* also grows on the bunds beyond the reach of the sea water.

Both the mangrove and the upland vegetation have been intensely affected by biotic factor, to provide fuel and fodder and land for cultivation, for roads, for housing estates. Several badly disfigured trees are a witness to this. More specifically the branches of *Butea* trees are cut off and burnt to provide ash on the rice fields; *Alangium* and *Manilkara* are cut to make walking sticks; *Sterculia urens* is damaged by incisions to obtain gum.

Human interference with the mangrove vegetation to collect fuel and provide fodder for cattle, the browsing of buffaloes and bulls on the foliage and flowers of *Avicennia* spp. and *Acanthus ilicifolius* (Navalkar, 1956) have resulted in the stunted and bushy forms of these species, which are rarely allowed to attain a height above 2 m. These biotic factors have also contributed substantially to the selective decline of certain species, the relative increase of others and have arrested vegetational succession at the *Avicennia alba* stage, if not deflected it. The upland forests have become bare of undergrowth, and elsewhere their ruthless destruction has induced such light-demanders and waste land species as *Bambusa arundinacea* and *Lantana* to invade the cleared areas. Certain trees which were spared during clearance have increased, thus changing the vegetational pattern.

The tidal marshes being waterlogged and badly aerated are suitable situations for pollen analytical investigation in order to build the history of the mangrove vegetation and of the upland forests and to infer therefrom a sequence of climatic changes. The pollen analytical work was, therefore, undertaken of some of these marshes so as to expand our knowledge of the environmental background of early man in the Bombay region and to assess correctly the role of environmental changes in shaping the various human cultures of which archaeological evidence has been found.

Briefly, the archaeological succession in this area covers the Early, Middle and Late Stone Ages. The Middle and Late Stone Age tools have been found by Tod (1939), Malik (1959), Sankalia (1962) and by one of us (Statira Guzder). These are observed both in the nala sections at Borivili and Kandivili and on the surface

TABLE 1 — COMPARATIVE DISTRIBUTION OF MANGROVE PLANT SPECIES OF BOMBAY AND SALSETTE ISLANDS

| | Colaba | Mahim | Bandra | Versova | Madh | Manori | Ghod-bunder | Bassein | Vadalla | Sion | Chembur | Kurla | Trombay | Thana |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Avicennia alba* | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| *A. officinalis* | – | + | – | – | – | – | + | – | – | + | + | + | – | – |
| *Acanthus ilicifolius* | – | + | – | – | + | + | + | – | + | + | – | – | – | + |
| *Bruguiera gymnorhiza* | – | – | – | – | – | – | + | – | – | – | – | – | – | – |
| *Ceriops candolleana* | – | + | – | – | – | + | + | + | – | – | – | – | – | – |
| *Clerodendrum inerme* | – | + | + | – | + | + | – | – | + | + | – | – | – | – |
| *Aegiceras majus* | – | – | – | – | – | – | + | – | – | – | – | – | – | – |
| *Excoecaria agallocha* | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| *Lumnitzera racemosa* | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Rhizophora mucronata* | – | + | – | – | – | – | + | – | – | – | – | – | – | – |
| *Sonneratia apetela* | – | – | – | – | – | – | + | – | – | – | – | – | – | – |
| *S. acida* | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| *Sesuvium portulacastrum* | – | + | + | – | + | – | – | – | + | – | – | – | – | + |
| *Bruguiera caryophilloides* | – | + | – | – | – | – | – | – | – | – | – | – | – | – |
| *Suaeda fruiticosa* | – | + | + | – | + | + | – | – | + | – | – | – | – | – |
| *Atriplex stocksii* | – | – | – | – | + | – | – | – | – | – | – | – | – | – |
| *Salicornia brachiata* | – | – | – | – | – | – | + | – | + | – | – | – | – | – |

of the coastal headlands at Erangal, Manori and Gorai. If the strata in which the M.S.A. tools are found can be correlated with or found to terminate at the base of the raised beach deposits, it will be possible to place these tools in a known chronological horizon.

The discovery of a submerged forest at Prince's Dock, Bombay (La Touche, 1919) and the occurrence of raised beaches along the Konkan coast are suggestive of sea level changes. It is also intended to date these events and to determine whether they resulted from eustasy, isostasy or tectonic movements and to relate these events to stages of forest evolution, climatic change and human cultures.

## STRATIGRAPHY

Bore holes have been dug at various places with the help of a Hiller-type sampler. It must be admitted that beyond a particular depth (generally 4 metres) it was impossible, even with extra force, to push the borer deeper.

In 1962 borings were made by the senior author accompanied by his assistants, at Kurla, Ghodbunder, Thana Creek, Meet Bunder, Mahim Creek and Madh-Marve. The sediments were found to consist of a silty mud of dark ? or blue colour with occasional woody fragments (roots and rootlets of modern vegetation). The sediments were of a homogenous nature throughout, except for the overlying 30-90 cm of brown mud.

At Kurla, the bed rock was encountered at a depth of 130 cm; the top 75 cm were of brown mud and the rest dark ? mud. The section at Ghodbunder extended to a depth of over 5 m. The details of the boreholes at Kurla and Ghodbunder are shown below:

| *Kurla* cm | | *Ghodbunder* cm | |
|---|---|---|---|
| Brown mud | 0-75 | Brown mud | 0-90 |
| Dark mud | 75-130 | Dark mud | 90-150 |
| Rock | | Blue mud | 150-510 |

At the other sites the brown mud varied in thickness from 25 to 80 cm and the rest of the profile consisted only of blue mud.

The depth of the profiles varied between 3 and 4 m. In the marginal sections only and not towards the centre of the swamps it was possible to strike the bed rock. No horizon of organic deposit such as peat or a submerged forest was encountered. The borings revealed that the floor of the basin was undulating.

In 1969 we conducted borings in the marshes at Madh Island (Bandholi) 72°46′5″ E, 19°19′N and at Bassein (Naigaon) 72° 48′E 19°19′N. The overlying brown mud of varying thickness was noted here too, below it the blue mud varies between 3 to 5 cm and overlies a dark, grey impenetrable plastic clay. Its thickness remains undetermined. Shell fragments and fabricated plant tissue, sometimes carbonized, have been detected at varying depths.

## POLLEN ANALYSES

Samples for pollen analysis were collected at intervals of 5 cm throughout the profile, but from Manori and Aksa they were spaced at 10 cm and 2·5 cm intervals. The samples were treated with 10% KOH, then HF, subsequently acetolysed and finally mounted in glycerine. The coarse debris left on the sieve after alkali treatment was examined under a low-power binocular microscope. No seeds or fruits were found. But for a few indeterminate fragments or shreds of cuticles and several microforaminifera, nothing else was found. Organic material derived from plants was extremely poor*.

To support the identification of subfossil pollen and spores, pollen slides of modern mangrove plant species prepared by the acetolysis method were examined and their morphological details drawn up in the form of a workable key to assist identification. The key was enlarged by incorporating morphological details of the pollen of all the marine, estuarine and fresh water plants of India. A similar broadly based pollen key was prepared of some wind-pollinated species of the deciduous forests of Bombay.

The only information available on the modern pollen content at Bombay is the unpublished annual pollen calendar constructed by Miss Olive Anchen at the K.E.M. Hospital, Bombay which shows an over-all poverty of pollen on the slides. Pollen grains of neither the mangrove species nor those of the deciduous forest are present in the aerial pollen content. This could be due to dominance of insect-pollinated species in the forest or to low pollen production or else the circulation of wind currents being unfavourable for the dissemination of pollen within the city. The pollen content of modern surface and water samples in relation to the composition of forest remains to be worked out. For the relative amount of pollen grains produced by mangrove plants we have largely depended upon the observations of Muller (1964). *Rhizophora*, *Ceriops*, and *Bruguiera* are high pollen producers. *Sonneratia* spp. with large and showy flowers also produce large amounts of pollen grains, while *Avicennia*, the most common mangrove plant, produces little pollen. Among the other members, *Acanthus ilicifolius*, *Clerodendrum inerme* and *Sesuvium* are insect-pollinated. The members of Chenopodiaceae are high pollen producers.

This distribution of species of Mangrove plants (Table 1) in the Bombay marshes reveals that *Rhizophora* is found at three sites: Ghodbunder, Bassein and along the Kamdevi River, but more profusely at Ghodbunder than at the other two sites. *Sonneratia* occurs more profusely at Ghodbunder than at Mahim. *Bruguiera* and *Ceriops* occur sporadically both at Ghodbunder and Mahim. Thus, the large pollen producers are extremely rare in Bombay today. *Sonneratia* is abundant on the eastern side of the Elephanta Island, and extends over a much wider area than that covered by *Avicennia*. *Rhizophora* has recently been discovered there (F. R. Bharucha, personal communication).

## RESULTS

The lack of sufficient pollen in the Bombay marshes was discovered by one of us (Vishnu-Mittre) in 1962-63. Detailed analyses now carried out have confirmed these observations. The total number of pollen grains recovered in each sample even after attempts to concentrate the pollen content was under

*That is why the samples collected for $C^{14}$ assay did not yield sufficient carbon for dating.

100 and in many samples it was less than 50 — quite insufficient for any statistical evaluation. In view of our inability to construct a pollen diagram, only the following comments based on small numbers of pollen grains are possible.

1. Pollen grains of *Rhizophorae*, increase in the top samples. Pollen of *Rhizophora mucronata* has not been recovered. Probably *Bruguiera* and *Ceriops* are the species represented.

2. *Avicennia* type pollen is poorly present in spite of the dominance of *A. alba*.

3. Mangrove vegetation also consisted of *Excoecaria agallocha*, *Carallia* sp., *Sonneratia acida* and *Acanthus ilicifolius*, as indicated by small numbers of their pollen grains. Among these the pollen grains of *Sonneratia acida* are comparatively more numerous than those of the others.

4. Pollen of Chenopodiaceae suggests the former occurrence of *Suaeda maritima* and *Atriplex* spp.

5. Pollen of marine angiosperms has not been found.

6. Pollen grains of the upland vegetation suggests the former presence of Malvaceae (*Salmalia malabarica*), Myrtaceae, Leguminosae, Euphorbiaceae (*Phyllanthus*), *Holoptelea*, Meliaceae and Urticaceae, together with ground vegetation comprising Compositae, Cruciferae and Gramineae. Their pollen grains are, however, extremely poorly present.

7. Large-sized grass pollen (82-100 μ) encountered at a depth of 140-145 cm in the profile from Madh Island is interesting. It could be of Maize (*Zea mays* L.), now held to have been introduced into India in pre-Columbian times. The possibility cannot be overlooked that it might have been derived from a wild grass producing large-sized pollen (Vishnu-Mittre, 1973).

8. Among the fresh-water species, a single pollen grain of *Typha* has been found in a bottom sample.

9. A few pollen grains of *Abies/Picea* have been found in the lowermost sample in the Madh profile at a depth of 3·90-4·00 m. These two genera today occur in the Himalayas and their pollen in Bombay is obviously due to long-distance transport. However, since they are encountered only in a single slide, the possibility of laboratory contamination cannot be overruled.

### Microforaminifera

A comparatively large number of microforaminifera have been observed on the slides, despite HCl and HF treatment. They are abundant in the upper part of the profile. A slight decrease is noted at 1·5 m. They are absent below 3 m. Their size ranges from 25 μ to 160 μ. Biserial and the close-coiled forms are the dominant ones; next in the order of abundance are the *Globigerina*- type and the loose-coiled forms. The Uniserial types and Ostracods are poorly represented.

It is unusual for Foraminifera to escape destruction by the acetolysis method — but their presence in these slides and their small size, are factors, similar to those recorded elsewhere by Wilson and Hoffmeister (1952), Wetzel (1957), van Veen (1957), Muller (1959). The present concensus of opinion would indicate that these are the chitinous inner linings of the tests of marine foraminifera. Their relatively small size, however, distinguishes them from more common genera, hence the term microforaminifera, referring to " these small but sometimes fully grown representatives of a restricted group of genera " (Muller 1959).

Dr S. N. Singh and Dr P. Kalia of the Geology Dept., Lucknow University very kindly processed, without any acid treatment, a part of a sample given to them and identified the following species of foraminifera in it: *Bolivina* sp., *Bulimina* sp., *Textularia*, *Ammonia* sp., *Rotalia* sp., *Discorbis* sp., *Cibicides* sp., *Elphidium corispum*, *Florilus scaphum*, *Hastigerina*, *Orbulina universa* and *Spiroloculina indica*.

They are of interest in this study from the point of view that their presence is certainly indicative of salt-water conditions and their relative increase/decrease may be found to coincide with the rise/fall of sea level. We are indeed incompetent to undertake study of microforms in this regard.

### Microplankton

As many as seven types of microplankton were observed of which Types I and V are dominant in the lower samples and Types II and III are dominant in top samples. In the absence of any detailed studies they have been tentatively indentified cf. *Paleaohystrichosphora* and cf. *Baltisphaeridium*.

## CONCLUSION

The lack of sufficient pollen grains in the marshes of Bombay has vitiated the object of building a pollen sequence from them. We can hardly draw any conclusion from the small numbers of pollen grains recovered, since the indications of species can not be properly assessed in relation to low and high pollen production. *Avicennia* pollen is inadequately present in spite of *Avicennia* being the dominant community in the region. This may perhaps be due to its low pollen production and the biotic influence — removal of young flowering shoots for fodder. Pollen of *Rhizophora* has not been identified, indicating its extremely poor occurrence in the past as at present. High values of other Rhizophorae perhaps suggests that they were more profusely present in the past. *Sonneratia acida* was also more abundant in the past than it is today. The presence of *Excoecaria agallocha*, *Carallia* sp., and *Acanthus ilicifolius* is also recorded. Both *Suaeda* spp. and *Atriplex* also occurred.

Indications of the upland forest have also been obtained. Pollen of Gramineae could have been derived from the grasses on the drier areas surrounding the mangroves or from the forest. If large sized pollen at a depth of 140-145 cm is really that of maize this level can not be considered older than 1500 A.D. (Vishnu-Mittre & Gupta, 1966).

Pollen of *Typha* is decidedly from the fresh water swamps in the vicinity but the conifer pollen appears to have been derived from the Himalaya, almost from an areal distance of over 1500 km.

The paucity of pollen and spores in these sediments may be due to low pollen production of these species, to the destruction of pollen in these sediments or to the high rate of sedimentation in these swamps.

The soils of the modern marshes of Bombay bearing mangrove vegetation are characterized by a chloride content (0·78 to 3.47) almost as high as in sea water (0·91-3·59) (Bharucha & Navalkar, 1942), though rainfall and temperature cause fluctuations in this concentration. We are as yet ignorant of whether a high concentration of chloride in the soils has a destructive effect on pollen grains in general and on those of mangrove plants in particular. Nevertheless pollen of terrestrial plants has been recorded in marine sediments. Koreneva's observations on the palynology of bottom sediments from the Pacific Ocean (Koreneva, 1964) are indeed revealing in this respect. She finds the greatest concentration of pollen grains in argillaceous silts, high concentrations in depression sediments of sub-marine relief and in coastal regions where coarsely aleuritic and arenaceous fractions occur. But there is a sharp drop in the pollen-spore content in sediments of amorphous silica which reflects rapid accumulation of diatoms. The proportion of fine sand and silt in the mangrove soil of Bombay varies from 68% to 71·3% while the coarse sand is only 3-5% (Navalkar, 1941).

Alkalinity of the soil may be responsible for the destruction of pollen. The soils of the Bombay mangrove swamps are more or less neutral with pH 6·81 in cold season and pH 7·03 during the Monsoon. The sea water however is distinctly alkaline with pH more than 8 (Navalkar & Bharucha, 1948).

Surprisingly it has been discovered that the mangrove soils in spite of their waterlogged condition and poor aeration — suitable environment for the deposition of organic matter, are very deficient in humus. The humus content varies between 1 and 2% in the Bombay mangrove soils (Navalkar & Bharucha, 1949). It is believed by Navalkar and Bharucha that the decaying organic matter is probably washed out by the tides, hence the low humus content. If this is true then this could be one of the factors responsible for lack of sufficient pollen in these sediments. Their (Navalkar & Bharucha, *op. cit.*) observations are substantiated by our findings of lack of sufficient organic matter in samples collected for C-14 assay.

If the inference of increased occurrence of *Sonneratia*, *Bruguiera* and *Ceriops* in the past from the meagre pollen record be considered reliable then it may indicate different environmental conditions in the past. The chloride content of the cell sap of these species has been found to be much lower (2·52-2·81) than that of *Avicennia alba* (3·11-4·40). The present dominance of *Avicennia* is held to be due to the higher chloride content of its cell sap than of the sea water, consequently the other species with a lower content are not able to thrive. The chloride content of sea water is 3·17-3·59 during the cold and 3·43-3·50 in the hot seasons and it ranges between 0·91 and

2·83 during the rainy season. For the frequent occurrence of the species *Rhizophora, Ceriops* and *Sonneratia* the decreased chloride content during the monsoon should be most suitable and this would require a higher and more equally distributed precipitation throughout the year. From this it appears that the former abundance of these species in Bombay where today they are extremely rare was due to the prevalence of moister climatic conditions.


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