

A note on the ancient mangroves of Goa, central west coast of India

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Organic peat deposits were observed 1.5 to 2.5 m below hinterland coastal plains, 20 km inland from the open sea coast. Red mud overlies peat. Sedimentological and mineralogical data revealed that peat was deposited in protected areas under calm marine conditions which were conducive for plant growth. The area appeared to have been colonized by mangrove populations as evidenced by wood fragments and a reddish brown tree stump encrusted with wood borers. Considering the utility of *in situ* mangrove peats as markers of past sea levels and paleoshorelines, the present study revealed that the hinterland of Goa was once occupied by luxuriant mangrove swamps under shallow water, low energy, sheltered environments during the recent geological past when the sea level was 1 to 3 m lower than at present.

Mangrove trees had evolved by Middle Cretaceous and have fringed tropical coastlines for the last 120 million years¹. However, since the growth of these trees is dependent on climate and sea level position, the intensity of mangrove growth has varied drastically throughout the geological time scale². Geological studies of modern mangrove swamps and associated organic sediments are vital as they provide information on the evolution of ancient coastal swamps which serve as stratigraphic markers with which the position of past sea levels can be fixed². Geomorphologically, mangrove swamps trap fine sediments and thus build up land along low coasts; but owing to the complexity, remoteness and difficult working conditions, mangrove swamps have not received attention that their geological importance warrants.

Organic sediments with vegetal debris (termed as peat) are being reported for the first time in Goa. In this paper, an attempt has been made to reconstruct past climate, sea levels and the existence of paleoforests based on the sedimentological characteristics of organic sediments within the coastal plains, in relation to geomorphic changes brought by climate induced processes.

The coastal plains of Goa are intersected by estuarine river systems and comprise an intricate system of wetlands and lowlands, tidal marshes, intertidal beaches, canals, bays, lagoons and creeks, features which are governed regularly by 2-3 m

tides. These geomorphic features support mangrove colonies which extend far into the hinterland; several mangrove islands and swamps can be presently identified within the estuaries³. The study area (Fig. 1) comprises lowlands within a network of canals, lagoons and backwaters pertaining to the Mandovi-Zuari estuarine system. It is bounded by evergreen hills on the west and east; the N-S trending Combarjua canal lined with mangroves runs in between and opens into the river Zuari in the south.

Organic sediments (peat) were sampled at five locations along a 15 km stretch from Banastarim in the north to beyond Cortalim in the south (Fig. 1).

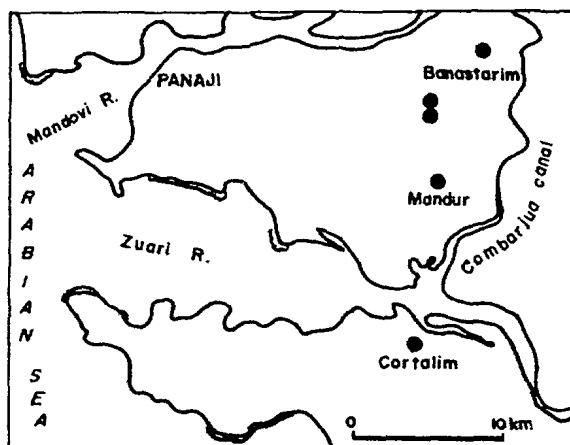


Fig. 1—Map showing locations where organic peat deposits were identified.

Peat occurs in the form of black clay with abundant vegetal debris; a meter long log buried in clay was recovered at one of the sites (Mandur). Peat occurs 1.5 to 2.5 m below surfaces which, at present, are almost at sea level (Fig. 2). These hinterland sites are located about 20 km from the open sea coast.

The organic sediment samples were analyzed for various sedimentological parameters⁴, organic carbon⁵, clay and bulk sample mineralogy by X-ray diffractometry⁶ and coarse fraction analyses so as to ascertain their nature and composition.

Grain size studies reveal that organic peat samples are dominantly composed of clay fraction which varies from 64% (minimum) to 69% (maximum). Silt varies from 30 to 35% while sand sized material is almost negligible (around 1%) (Table 1). Nevertheless, wood pieces and fragments were identified in peat samples collected from all the sites. More importantly, a reddish brown log more than a meter in length, resembling a tree stump, was found to be full of burrows; it

was encrusted with wood boring organisms. Organic carbon content in peat was found to be between 2.6 and 3.2% which showed variations among samples. The presence of sulfur in the samples is indicated by a yellow powdery material with its characteristic odor. Clay minerals comprise of smectite, kaolinite and illite in decreasing order of abundance. X-ray diffractometry revealed inorganic minerals such as feldspar, quartz and calcite.

Peat is a sedimentary organic deposit derived from plant products. Humid climate, abundant precipitation, large source of plant debris, retardation of organic decomposition and low influx of inorganic material⁷⁻⁹ are some of the prerequisites which favor plant growth, peat formation and its accumulation. In the tropics, mangroves are the most remarkable and the only intertidal trees which inhabit coastal embayments influenced by seawater. The permanent establishment of mangroves over conducive substrates are limited to areas under favorable physiography and optimal environmental conditions such as calm waters, sheltered habitats, a gently sloping intertidal area and a stable sea level¹⁰. These plant communities have been found to be the most prolific producers of peat over a period of time^{10,11}. Since the organic components generally originate from plants growing within the wetland environment, autochthonous peats have been regarded as indicators of paleoenvironments, paleoclimates and also as markers of paleo sea levels and paleoshorelines^{10,12,13}.

Sedimentological data from the study area revealed that fine grained sediments of silty clay grade, rich in smectite, were deposited in the region under calm conditions. Since smectite is a product of weathered volcanic rocks found along the coast of Maharashtra in the north, it is obvious that this

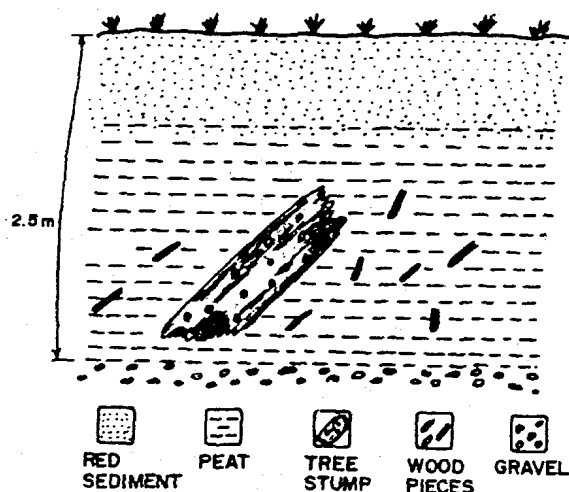


Fig. 2—A typical section showing peat with wood fragments stratified within coastal plain sequences.

Table 1—Sedimentological characteristics of plant-rich peat deposits, found below the surface, at various sites along the coastal plains of Goa

Site	Sample	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Org C (%)	Sediment type
Banastarim	BN-1	2.0	1	35	64	2.83	Peat / black clay / plant debris
Carambolim	CR-2	2.0	1	30	69	3.20	Peat / black clay / plant debris
"	CR-1	2.0	-	-	-	-	Peat / black clay
Mandur	MN-2	2.5	1	33	66	2.62	Peat / black clay / tree stump with wood borers / plant debris
Cortalim	CL-1	1.5	-	-	-	-	Black clay

mineral species has been introduced in this area via the sea. This also means that this entire area (Fig. 1) was once directly connected to the sea. The presence of calcite in these sediments also points to the marine influence¹⁴. This area must have been a sheltered one as it is bounded by hill ranges to the east and west. The only possible connection with the sea could be to the north but more certainly to the south where the present Combarjua canal opens in the river Zuari. Since the organic sediments are found at a depth of 1.5 to 2.5 m below ground level, it could be concluded that the study area once comprised a large intertidal zone, probably under a shallow water lagoon and a low energy environment.

The organic clayey sediments which showed the presence of significant plant remains also indicate that the entire area became a site conducive for plant growth even before the Combarjua canal acquired its present form. The major trees that could have existed in such a shallow marine environment are only mangroves which colonized the area thus making it a luxuriant mangrove swamp. This is evidenced by a mangrove tree stump recovered from the peat unit (Fig. 3). The characteristic reddish brown color of the preserved tree stump is due to tannin, a compound which can be found in mangrove tree species. Moreover, the encrusted wood borers which belong to the category of *Martesia* and attack mangrove wood exclusively (Shantakumaran, pers. comm.), and thus confirms the mangrove stump hypothesis. Continuous litter supply from these mangrove trees thus resulted in the preservation of plant debris leading to the production of peat. Sulfur would indicate an oxygen deficient marshy environment⁷ which retarded organic decomposition and hence favored peat accumulation. From the preceding discussion it can be postulated that the coastal plains of Goa were conducive for forest growth and was therefore the scene of widespread mangroves swamps during the recent geological past.

Mangroves being intertidal, the position of sea level has to be considered to study the plant rich sediments which were deposited under marine conditions. It is well established that the global sea level was low (-120 m) at 18,000 years BP and rose rapidly since then¹⁵. Along the west coast of India, the eustatic sea level rose at a very high rate from 10,000 to 7,000 years BP after which it almost stabilised¹⁶. The horizons where peat was deposited



Fig. 3—Part of a meter long tree log encrusted with wood borers.

are now found at 1.5 to 2.5 m below present sea level. Therefore, the paleo sea level was around 1 to 3 m below the present sea level; the time when the sea level had reached this position during Holocene was between 7,000 and 6,000 years BP.

Mangrove debris has been identified below coastal plains near Karwar¹⁷, Coondapur¹⁸, Tellicherry¹⁹ and Changanacherry¹⁹ along the west coast of India; these deposits range from 7,230 to 6,000 years BP. Similarly, a plant-rich horizon, 1.5 to 2.5 m below present sea level, was identified along the coast at Colva (Goa). Fossilized wood and twigs within this black layer yielded an age of 6,430 years BP²⁰. Considering the proximity of this site, and since the organic debris identified in this study are also found at identical depths below present sea level, peat studied may be assigned the same age (around 6,430 years BP).

In conclusion, the geomorphic configuration of the coastal plains of Goa was altogether different during mid-Holocene. The sea level was 1 to 3 m lower and the climatic conditions were wet and humid. The coastal zone was the scene of luxuriant mangrove forests. Organic-rich plant-bearing sediments therefore reflect mangrove colonization over the area that was subsequently filled by lateritic detrital sediment when the sea level attained its present position.

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