

Mangrove history since 1,500 years B.P. at Dangmal, Baitarni-Brahmani Delta, Orissa, India

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ABSTRACT

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The paper embodies the results of fine resolution palynostratigraphy of a sediment profile dated 1,500 years B.P. from Dangmal, an area within Bhitarkanika wildlife sanctuary in Cuttack District, Orissa. It is second largest mangrove swamp in India covering an area of 142 sq km with thickets of mangrove forest. Bhitarkanika is famous for beautiful repository of mangrove constituents wherein 61 species out of the total 67 Indian species exist signifying the mangrove diversity. The bottom samples of profile exhibited rich occurrence of palynodebris such as pollen, spores, diatoms, dinoflagellate cysts, microforaminifera, *Pseudoschizaea*, etc. The core mangrove taxa encountered are *Rhizophora*, *Heritiera*, *Sonneratia*, *Avicennia*, *Excoecaria*, *Aegialitis*, etc. indicating conducive environment for growth and development of mangroves. However, the frequency of both core and peripheral mangroves declined in the middle and further reduced in the upper part of the profile. It has been found that there was comparatively low degree of mangal exploitation at Dangmal as compared to other investigated areas of Mahanadi Delta, Orissa.

Key-words— Palynostratigraphy, Mangrove, Environment, Dangmal, Orissa.

भारत के उड़ीसा प्रान्त के डांगमल अवस्थित बैतरणी-ब्राह्मणी डेल्टा का विगत 1500 वर्षों का मैंग्रोव सम्बन्धी इतिहास

आशा खण्डेलवाल एवं हरिपाल गुप्त

सारांश

प्रस्तुत शोध पत्र में उड़ीसा के कटक जिले में अवस्थित भीतरकनिका वन्यजीव अभयारण्य के अन्दर स्थित डांगमल क्षेत्र से विगत 1500 वर्षों की एक अवसादी परिच्छेदिका की उत्कृष्ट विभेदन परागाणुस्तरीकी के परिणामों को विश्लेषित किया गया है. यह भारत का दूसरा सबसे बड़ा मैंग्रोव अनूप है, जिसमें मैंग्रोव वनों के 142 कि.मी. का निकुंज क्षेत्र समाहित है. भीतरकनिका मैंग्रोव संघटकों की सुन्दर आधात्री के लिए विख्यात है, जिसमें भारत की कुल 67 प्रजातियों में से 61 प्रजातियाँ हैं, जो इसके मैंग्रोव वैविध्य का परिचायक है. परिच्छेदिका के अधस्तली प्रादशों में परागाणु मलबे, जैसे - परागकण, बीजाणु, घूर्णीकशाभ पुटी, सूक्ष्म फ़ोरेमिनीफ़ेरा, स्यूडोशाज़िया इत्यादि की प्रचुर उपस्थिति है. समागमित क्रोड मैंग्रोव वर्गकों के अन्तर्गत *राइजोफ़ोरा*, *हीरीटिएरा*, *सोनेरेशिया*, *एवीसीनिया*, *एक्सकोइकेरिया*, *ऐजायालाइटिस* इत्यादि आते हैं, जिनसे मैंग्रोवों की वृद्धि एवं विकास हेतु उचित वातावरण होना संकेतित होता है, फिर भी दोनों क्रोडों एवं परिधीय मैंग्रोवों की आवृत्ति परिच्छेदिका के मध्य में घट गई है तथा इसके ऊपरी भाग में यह और अधिक कम हो गई है. यह पाया गया कि उड़ीसा के महानदी डेल्टा के अन्य विवेचित क्षेत्रों की तुलना में डांगमल में मैंग्रोव उपयोग अपेक्षाकृत कम है.

सकेत शब्द—परागाणुस्तरिकी, मैग्रोव, वातावरण, डंगमल, उड़ीसा.

INTRODUCTION

BHITARKANIKA, locally meant for inner forest, is situated between $20^{\circ}40' - 20^{\circ} 80' N$ and $86^{\circ} 45' - 87^{\circ} 50' E$ at the confluence of Baitarni and Brahmani rivers in Orissa. It is bounded by Dhamara river in the north, Hansua river in the west, Bhitarkanika river in the south and Bay of Bengal in

the east (Fig. 1). Bhitarkanika, the most ideal tidal swamp on the eastern coast of Orissa near Chandbali town, is criss-crossed by several tidal creeks and covers a total area of 650 sq km and out of which 380 sq km is under forest cover which is colonised by both core and peripheral mangroves (Fig. 2). The ramifying estuaries, creeks, channels and distributaries in and

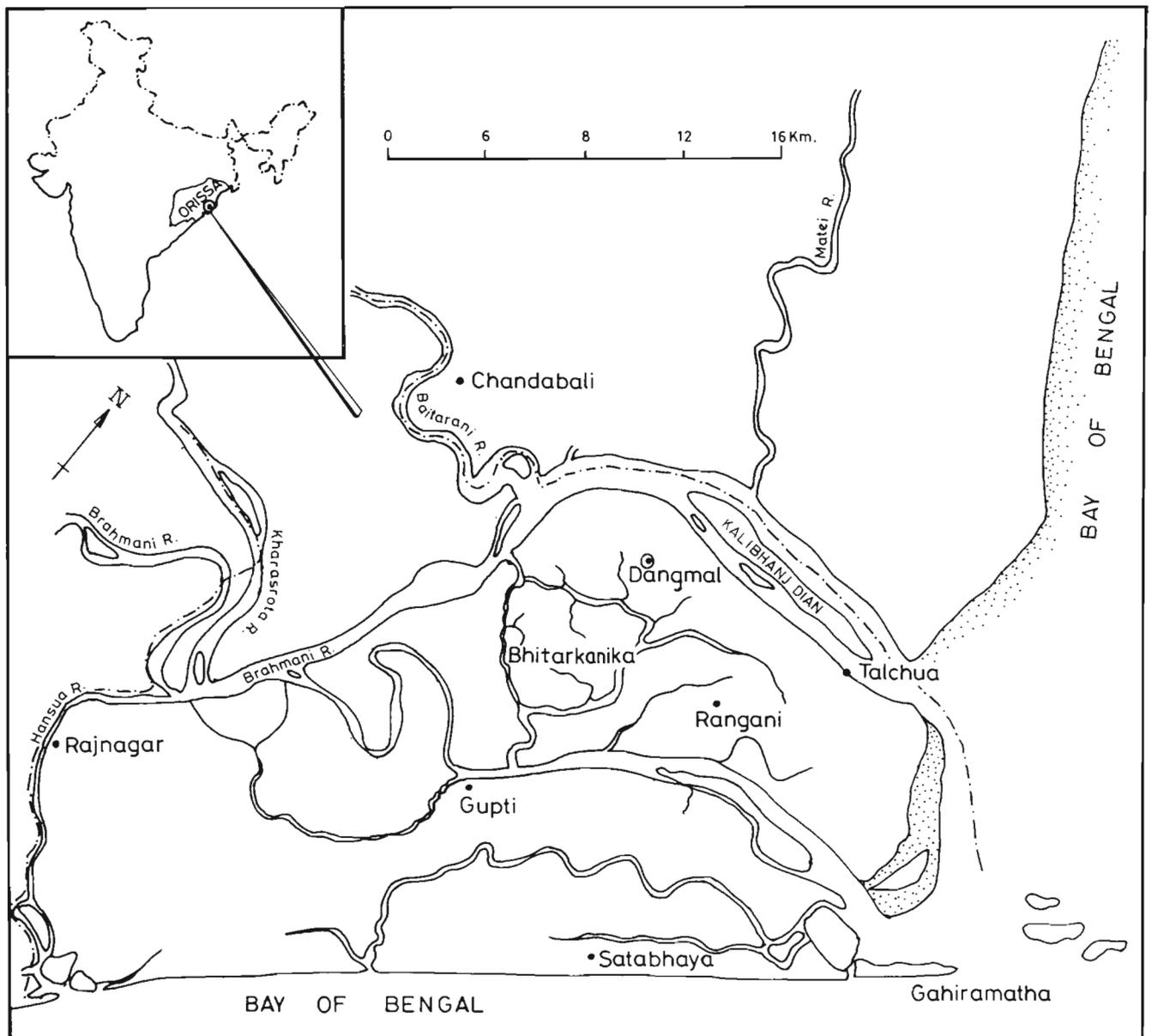


Fig. 1— Showing site Dangmal in Bhitarkanika (after Patnaik, 1990).

around Bhitarkanika provide congenial environment for the growth and proliferation of mangrove forest.

Dangmal, the investigation site, is situated on the bank of Baitarni river and is about 18.52 km inland from the present sea shore. The vegetation around Dangmal is comprised of both core and peripheral mangroves. The palynology of Dangmal area has been attempted for the first time. Nevertheless, such studies from elsewhere on Orissa coast have been conducted periodically. Caratini *et al.* (1980) pollen analysed six surface samples and two profiles of 70 cm and 90 cm deep from Kalibhanj Dian Island and Talchua Village within Brahmani Delta and envisaged that the pollen composition of the profile samples compares well with the present day vegetation of the respective areas. Gupta and Yadav (1990) studied eight surface samples and one 3 m deep profile from Jambu and Paradip islands in Mahanadi Delta and found that pollen composition of surface samples matches with the modern vegetation of the respective areas except for over representation of Rhizophoraceae and *Sonneratia*. The bottom samples of Paradip profile, deposited around 500 years B.P., recorded moderate occurrence of mangrove components and high values for midland/upland plant taxa depicting high discharge of riverine water in deltaic domain which continued till middle of the profile. The upper part of profile covering a time span of 200 years has recorded the dominance of mangrove taxa and just after that mangroves vanished from the scene. This event could be correlated with the construction of Paradip Port in the year 1960 and extermination of mangroves could be abused in the hands of man.

Palynology of Balugaon profile from the western flank of Chilka Lake has revealed the pattern of evolution of mangroves since 3,100 years B.P. (Gupta & Khandelwal, 1990). Dispersed organic matter (D.O.M.) study of Balugaon profile has aided in the determination and quantification of various stages of biodegradation and transportation of organodebris from terrestrial regime suggesting the deltaic depositional environment (Khandelwal & Gupta, 1994).

One 3.75 m deep profile from Nalabana, a muddy island within Chilka Lake, has been analysed (Gupta & Khandelwal, 1992) and the occurrence of salt marshes is highlighted since about 2,000 years B.P.

The Rambha profile from the southern flank of Chilka Lake has been pollen analysed and dated to around 3,800 years B.P. (Khandelwal & Gupta, 1993). The lower half of the profile has witnessed the existence of mangrove grove suggesting the proximity of the sea until 2,000 years B.P. and thereafter, a shift in vegetation has been recorded envisaging the degradation of mangroves.

Pollen study of 250 m deep bore-core from Sadanandpur in Mahanadi Delta is the first attempt to present the palaeorecords of marine palynology of Quaternary sediments

since the time of mid-late Pleistocene (Kohli, 1996). On the basis of pollen assemblage, 12 pollen zones and six intervening barren zones have been identified. The study has revealed that between 160-128 ka, core mangroves predominated and this feature of vegetation has revealed that during this time span the sea was about 35-50 km inland from the present sea margin and the sea level must have been around 5-10 m higher than at present. Thereafter, periodical regression and transgression have been recorded until 31,000 years B.P. Subsequent rise in the sea level accelerated the pace for the growth and proliferation of mangroves and this feature lasted till about 10,000 years B.P.

In addition, a profile each from Chandrapur, Solari and Geokhala around western flank of Chilka Lake was investigated and the study has established that the degradation of mangroves began around 1,800 years B.P. (Kohli, 1996).

GEOLOGY AND GEOMORPHOLOGY

Orissa coastline has an extensive spread measuring about 500 km in length and includes major parts of Balasore and small portions of Mayurbhanj, Cuttack, Puri and Ganjam districts. The main rivers which flow across the Orissa coast and pouring into the Bay of Bengal are Mahanadi, Brahmani and Baitarni forming a prograding triple deltaic complex.

A wide range of rock formations varying from ancient hard rocks to recent alluvial deposits have been recorded in Orissa. The Khondalites of Archean age occur as isolated hillocks within and on the margins of the delta. Khondalites are overlain by the Upper Gondwana sediments (Mahalik, 1983). Orissa coast provides an ideal condition to the Quaternary researchers to study the sediments up to 300 m deep laid down over the Khondalites and their estimated age comes around middle late Pleistocene (Kohli, 1996). The general topography of Mahanadi delta is marked by mangrove swamps abutting the sea shores but towards inland it is plain region traversed by the distributaries of Mahanadi river.

As regards the age of delta, the Chandbali deposits, a proposed ancient shoreline in Brahmani-Baitarni deltaic complex, was formed during the last 6,000 years synchronizing global rise of sea level (Mallick *et al.*, 1972). Niyogi (1971) delineated the ancient shoreline at the Orissa coast across Balasore and recognised various geomorphic processes. The geomorphology of the deltaic complex is marked by variety of land features such as estuaries, lagoons, spits, islands, salt marshes, mangrove swamps, beaches, coastal dunes, etc.

VEGETATION

Bhitarkanika has a typical equable climate with excessive humidity and receives about 1700 mm rainfall per annum. This area is prone to typhoons and cyclonic storms during summers

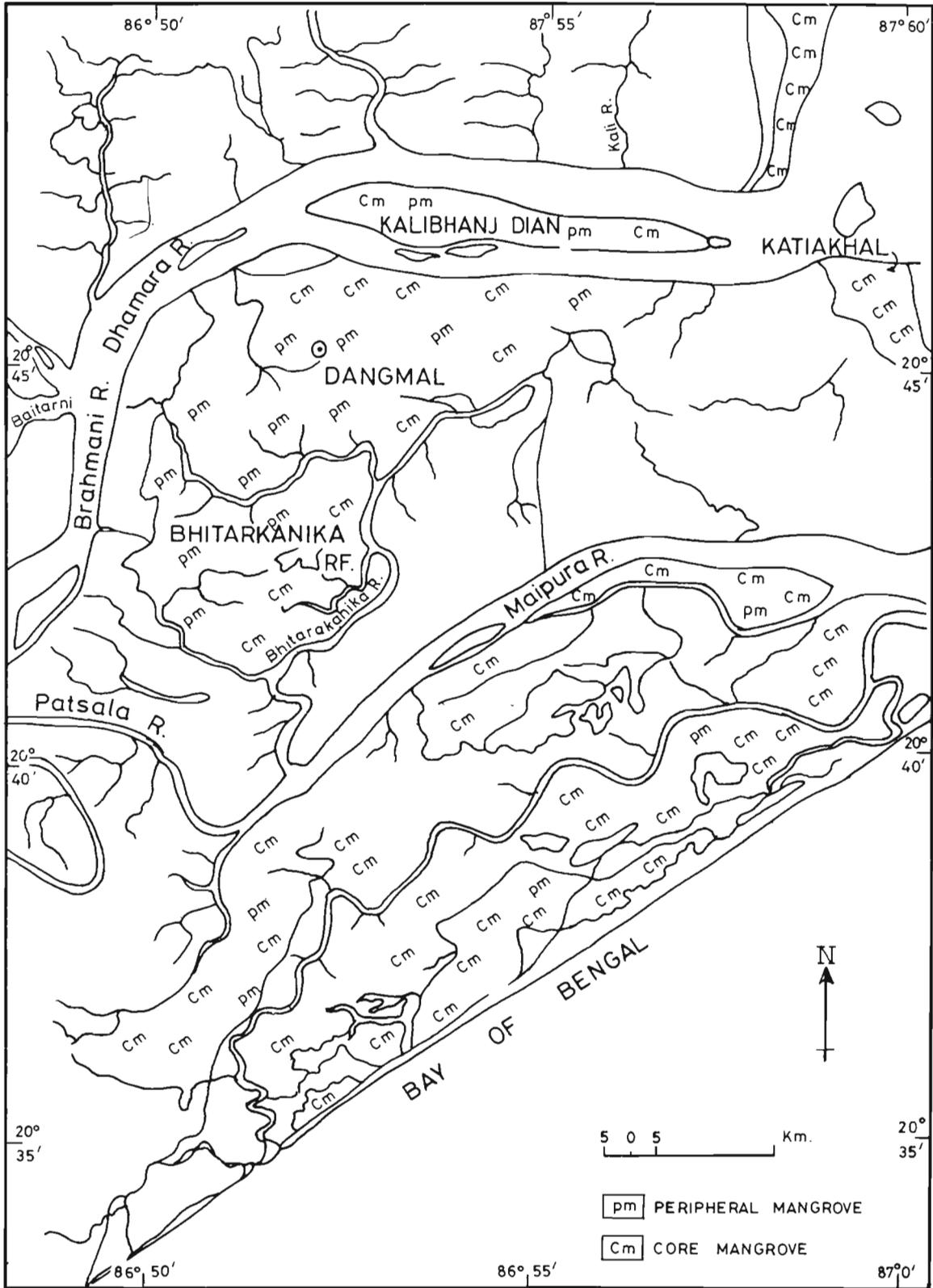


Fig. 2 — Showing distribution of mangroves Bhitarkanika (after Patnaik, 1990)

Fig. 3 — Pollen diagram from Dangmal, Orissa, India.



(mid February to mid June) with temperature rising to 45°C in April. However, winters are mild and the temperature often comes down to 12-10°C while mean maximum temperature is 27°C. Occasional rains and cyclones are experienced towards the end of summer. Thereafter, rainy season begins and extends up to October. The soil is often clayey loam and much slushy due to regular inundation. Owing to consistent accumulation of humus, the soil becomes quite rich and provides ideal environment for the growth of the vegetation.

The prevailing vegetation of Bhitarkanika is largely comprised of littoral and swamp forest along the estuaries. The forest components mostly exhibit physiological and mechanical adaptations characteristic of mangrove vegetation.

This area signifies richness in plant diversity comprising 61 species out of total 67 Indian mangrove species belonging to 27 families of flowering plants and ferns. A major part of the coastland is deprived of mangroves owing to excessive human pressure over the landscape which is now wholly transformed into heath land. Nevertheless, the fast receding mangrove vegetation from Orissa coast has caused severe damages to the life and property of the people and therefore, Orissa Government has notified 14 wildlife sanctuaries including Bhitarkanika. It is now adequately protected resulting in the diversification of mangroves.

Mangrove vegetation in the recent past had been widespread all along the coastline of India with characteristic flora varying from one coast to another. As per the previous estimates, the coastline in India was festooned with mangrove forest covering an area of about 7,000 sq km and the regional distribution was unequal (Sidhu, 1963). At present about 70% of the mangroves have been exterminated largely due to their abuse in the hands of man. The ecology and distribution of mangrove forest along the Indian coast have been periodically studied (Champion, 1936; Champion & Seth, 1968; Rao & Sastry, 1974; Rao *et al.*, 1973). The botanical studies of the mangroves of Orissa have been carried out by Chowdhury, (1984); Banerjee and Rao (1985) and Banerjee (1987). Two species viz., *Heritiera kanikensis* and *Merope angulata* are found to be restricted to Bhitarkanika only and not being reported from any other part of India.

The mangrove areas of Bhitarkanika could be divided into distinct zones based on proximity to the sea and distribution of mangroves. These zones are termed as proximal zone, middle zone and distal zone (Patnaik, personal commun.).

Proximal zone

This seaward zone is most unstable and faces great physical stress. *Porteresia coarctata*, a marine grass is seen as pioneer species which helps to stabilize the underlying slushy soil from erosion. *Rhizophora mucronata*, *R. apiculata*, *Ceriops decandra*, *Kandelia candel* etc. are seen on

depositional sites. The other associates of this zone, particularly at places where fresh water discharge is more, are *Avicennia officinalis*, *Aegiceras corniculatum*, *Xylocarpus granatum*, *Sonneratia apetala*, *S. caseolaris*, etc. *Myriostachya wightiana* and *Excoecaria agallocha* occupy the landward position in *Rhizophora* grove.

Middle zone

This zone is closer to riverine system in delta having prevalence of brackish water conditions. The dominant elements of this zone are *Sonneratia apetala*, *Heritiera fomes*, *Avicennia officinalis*, *Excoecaria agallocha*, *Aegiceras corniculatum*, etc. The erosional banks are dominated by *Porteresia coarctata*, *Myriostachya wightiana* and *Brownlowia tersa*. The peripheral mangroves of this zone are *Cerbera manghas*, *Intsia bijuga*, *Bruguiera gymnorhiza*, *Dalbergia spinosa*, *Derris trifoliata*, *Phoenix paludosa*, *Tamarix dioica*, etc.

Distal zone

This zone is at considerable distance from sea-shore and is not directly influenced by sea tides. It is often considered as midland or upland area. The important taxa belonging to this zone are: *Diospyros malabarica*, *Manilkara hexandra*, *Strychnos nuxvomica*, *Pongamia pinnata*, *Launea coromandelica*, etc.

MATERIAL AND METHODS

One 1.85 m deep profile was collected from Dangmal situated on the bank of Baitarni river. The materials for pollen analysis and radiometric dates were collected with the help of Hiller's peat-auger. The sediments are black humified organic mud with moderate plant debris. The method employed for extraction of pollen and spores from the matrix is the same as suggested by Erdtman (1943, 1952). The arrangement of pollen taxa in pollen diagram has been designed in a way to highlight different groups of plants viz., core mangroves, peripheral mangroves and upland plants as main components and other palynomorphs as ancillary.

POLLEN DIAGRAM AND ITS COMPOSITION

Based on the palynoflora recovered from the 1.85 m deep vertical sediment profile from Dangmal, a pollen diagram has been prepared by plotting the relative frequencies of pollen/spores taxa alongwith the lithocolumn (Fig. 3). The pollen diagram, based on subtle changes in the vegetation development, has been graded into four pollen zones in ascending chronological sequence and are prefixed with the site initials viz., D-I to D-IV to express biostratigraphic units in terms of palaeovegetation and secondly to recognise significant bio-

and climatic events since the time of deposition of the sediments. Each zone has been discussed and interpreted separately.

The radiometric dating of the basal portion of the profile has enabled to assume that total accumulation of 1.85 m deep sediments at Dangmal would have been deposited in a time span of about 1,500 years B.P. and the age extrapolated for each zone is approximative. The sediments of this profile are mostly dark black organic mud which indicates that the deposition might have taken place in ponding environment. The deposition seems to be uniform throughout the profile and thus rate of deposition has been estimated to be around 1 cm per 10 years.

Pollen Zone D-I (1.85-1.65 m) *Avicennia-Excoecaria agallocha-Sonneratia- Chenol/ Ams-ferns assemblage*

This zone, spanned for about 150 years, is characterized by high values of *Excoecaria agallocha*, *Sonneratia* and *Avicennia* whereas Rhizophoraceae remained in low profile throughout the zone. Chenol/Ams and ferns also enjoyed high values throughout. Amongst upland taxa, Myrtaceae, *Acacia* and Fabaceae were quite significant. Poaceae remained subdued but Utricaceae was recorded in high values. Freshwater plant taxa such as *Potamogeton*, *Myriophyllum*, *Typha* and *Lemna* were present in low values but showing upward inclination. Dinoflagellate cysts, Microforams and *Pseudoschizea* were infrequently encountered but all showed upward improvement in their values.

Although the vegetation development of this zone records the prevalence of core mangroves, the *Rhizophora*, *Xylocarpus*, *Aegialitis rotundifolia* and *Heritiera* constituting the first tier core mangroves in the order of mangrove stratigraphy, however, remained either sporadic or in low values. The peripheral mangroves such as *Lumnitzera*, *Phoenix paludosa*, *Borassus*, *Palmae*, *Barringtonia* also remained low. *Casuarina* - an alien taxon and *Acrostichum aureum* were also recorded in low values.

Pollen Zone D-II (1.65-1.05 m) - *Rhizophora-Xylocarpus-Heritiera-Sonneratia-Avicennia assemblage*

This zone, covering a time span of about 500 years, is marked by a substantial rise in the values of first tier core mangroves. *Rhizophora* has remarkably improved values from 5% in the preceding zone to 20% in this zone and formed a peak of 45% at the close of this zone. *Xylocarpus* has improved but remained discontinuously high showing its maximum values in the centre. *Aegialitis rotundifolia* and *Heritiera*, have improved than before but remained in low profile throughout the zone. *Sonneratia*, *Excoecaria agallocha* and *Avicennia*

are present throughout the zone with slight improvement than before. The peripheral mangroves did not show any change than before and remained subdued. Upland plants remained low throughout as in the preceding zone.

Chenol/Ams maintained the same high values as in the previous zone except its values showed evident spurt at the close of the zone maintaining 25% values. The ubiquitous taxa like Malvaceae, Caryophyllaceae, Brassicaceae, Asteraceae, *Artemisia* and *Tribulus* did not record any change than before and continued in low profile.

Poaceae and Cyperaceae are present in fluctuatingly high values and so also is with the fresh water plant taxa. Ferns have considerably improved but present in low values throughout as compared to the preceding zone. Dinoflagellate cysts and *Pseudoschizea* are present in much improved values than before. The frequency of fungal remains had risen in the beginning and close of the zone whereas in the centre it remained in low values.

Pollen Zone D-III (1.05-0.50 m) *Sonneratia-Excoecaria agallocha-Avicennia-Lumnitzera assemblage*

This pollen zone, lasted for about 400 years, has exhibited a steep fall in the values of *Rhizophora* making almost *Rhizophora* free zone and sharp rise in the values of *Sonneratia*, *Excoecaria agallocha*, *Avicennia* and *Lumnitzera*. Rest of the taxa including both peripheral mangroves and upland taxa continued in low values as before.

Chenol/Ams has also experienced slight fall whereas Poaceae continued in moderate values as before. However, Cyperaceae has recorded higher values in the upper half of the zone. There is an overall slight improvement in the fresh water plant taxa. With the decline of *Rhizophora*, ferns have sharply improved and continued throughout although fluctuating. Dinoflagellate cysts, Microforams and *Pseudoschizea* made their presence richer than before.

Pollen Zone D-IV (0.50-0.00 m) *Excoecaria agallocha-Avicennia-Casuarina assemblage*

This pollen zone covers a time span of about 400 years and is marked by total disappearance of *Rhizophora*. *Sonneratia* has also reduced as compared to the preceding zone. However, values for *Xylocarpus*, *Aegialitis rotundifolia*, *Heritiera*, *Excoecaria agallocha* and *Avicennia* remained almost the same as before. *Brownlowia tersa*, although sporadic, has made its first appearance in the middle of this zone. *Lumnitzera* has relatively reduced than before but present throughout the zone. *Borassus flabellifer*, *Palmae*, *Barringtonia* remained sporadic or in low profile. *Terminalia* and *Casuarina* have experienced improvement in their values. Most of the upland taxa such as *Emblia officinalis*, Myrtaceae,

Meliaceae, Rubiaceae, *Acacia arabica* and *Justicia* are all present with enhanced values than before.

Cheno/Ams pollen curve does not exhibit any evident change than the preceding zone and continued in moderate values throughout. Malvaceae, Caryophyllaceae, Brassicaceae, Utricaceae, Asteraceae, *Artemisia*, Poaceae, Cyperaceae and Liliaceae have recorded slight improvement than before. There is an evident improvement in the values of fresh water plants and ferns. Dinoflagellate cysts, *Pseudoschizea* and Microforams continue in moderate values.

DISCUSSION AND CONCLUSION

The palynological investigation of Dangmal profile unfolds the events which had occurred within the framework of around 1,500 years B.P. An overview of vegetational development emerged out from the study has exhibited the predominance of core mangrove taxa wherein *Sonneratia*, *Excoecaria agallocha* and *Avicennia* were significant but rest of the taxa of this group such as *Rhizophora*, *Xylocarpus*, *Aegialitis rotundifolia* and *Heritiera* were represented in low profiles.

The mangrove associates viz., *Lumnitzera*, *Phoenix paludosa*, *Borassus flabellifer*, *Palmae*, *Barringtonia*, *Terminalia*, etc. are either represented sporadically or inconsistently low in values. Fabaceae and *Acacia arabica*, the representatives of upland plant taxa are present in higher values as compared to the mangrove associates.

Cheno/Ams being an inhabitant of saltmarsh is represented in good values. Poaceae, Cyperaceae and fresh water plant taxa are present in low values. However, fern spores and dinoflagellate cysts are present in higher values but *Acrostichum aureum* is feebly present.

The above pattern of vegetation assemblage of Zone D-I envisages the marginal sea conditions with more fresh water discharge in and around the area between 1,500-1,350 years. B.P. and this type of environmental feature encouraged the profuse growth and expansion of salt tolerant brackish water plants.

The succeeding zone D-II, lasting for about 500 years, advocates the rise of *Rhizophora* and *Xylocarpus* along with *Heritiera*, *Sonneratia*, and *Excoecaria agallocha*. The mangrove associates in general have registered a slight uptrend. The upland plant taxa have proportionately decreased and the same trend was shown by Cheno/Ams. except that it rose at the close of this zone coinciding with the peak formation of *Rhizophora*. Both monolete and trilete fern spores have substantially declined but *Acrostichum aureum* and dinoflagellate cysts have proportionately improved.

The vegetational scenario of the zone D-II has depicted the advancement of the sea and therefore, direct sea influence in and around Dangmal has been interpreted. This aspect of environment was quite congenial for the development of frontline core mangroves.

The palaeofloristics of the succeeding zone D-III, covering a time span of about 400 years, portrays steep decline in the values of *Rhizophora* bringing it to fractions in the upper part. With the declivitous nature of *Rhizophora* curve, the pollen curve of *Sonneratia* rose substantially in the upper half of this zone whereas *Excoecaria agallocha* has relatively dwindled down. The sympathy rise has also been recorded by *Aegialitis rotundifolia*, *Heritiera* and *Avicennia*.

The mangrove associates and upland plant taxa have also registered a token improvement in general. Cheno/Ams curve has also been slightly reduced than before. No recognisable change has been encountered in the values of Poaceae but Cyperaceae has gained reasonably in the upper half of this zone. The fresh water plant taxa have moderately improved but fern spores and dinoflagellate cysts have substantially improved their values.

The palaeovegetation of this zone depicts that the direct influence of sea in and around Dangmal was ceased and fresh water flow increased causing an evident damage to the *Rhizophoras* which prefer constant depths of sea water to thrive and reproduce.

The last zone D-IV of vegetation development at Dangmal in Baitarni Delta envisaged the total disappearance of *Rhizophoras*. *Xylocarpus*, *Aegialitis rotundifolia* and *Heritiera* maintained low values as did in the preceding zone D-III. *Sonneratia* and *Avicennia* have been recorded declivitous trend upward in their pollen curves but *Excoecaria agallocha* has experienced slight improvement in its values as compared to the preceding zones. Mangrove associates and upland plant taxa have shown the increasing tendency but most of them remained sporadic or maintained incongruous low pollen curves. However, *Casuarina* has improved its values than before and is represented by continuous moderate pollen curve.

Poaceae has slightly improved but Cyperaceae comparatively declined as compared to the preceding zone. Fern spores and fresh water plant taxa continued to experience upward trend in their values. Dinoflagellate cysts, Microforams and *Pseudoschizea* do not display any noticeable change in their values than before.

The evaluation of vegetation mosaic of this zone signifies that the direct sea influence was considerably restricted and the deltaic environment developed. The reduction in the tidal magnitude and the progressive recession of the coastline arrested inundation of Dangmal area with sea water and this feature of environment jeopardised the growth and develop-

ment of frontline core mangroves on one hand and encouraged the proliferation of salt resistant brackish water taxa, peripheral mangroves, upland plants, ferns and fresh water plant taxa on the other.

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