PALAEOBOTANY IN INDIA—QUO VADIS* ?

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I am thankful to the Palaeobotanical Society for inviting me to be the Chief Guest and deliver the *Inaugural Address* of the *Sixth Indian Geophytological Conference*.

I chose this topic to share with you some of my views on the future direction of researches in the Sahni Institute. I am sure palaeobotanists and colleagues working in allied disciplines would like to ponder over and interact with us on areas of common interest and for mutual benefit.

Often, one hears the comment that *Palaeobotany is a descriptive science*. Do we acknowledge that *we do not want* to grow out of this state of complacency or that we are satisfied ? Each descriptive science passes through this phase and grows out of it; let us also grow. I see a great potential for growth in palaeobotany. Origin and antiquity of life; land plant origin and spread; significance of mixed floras; animal-plant relationships; origin of angiosperms and their development and spread; floral provinces of Cretaceous and Tertiary—their inter-relationship; provincialism of Late Cretaceous pollen floras; form function and meaning of plant organs; differential fossilisation and preservation; development of ecological models; significance of hermomegathic apparatus in Gondwana pollen; whole plant and vegetational reconstructions and continental drift/plate tectonics are some of the important areas where we could concentrate and I am sure can make meaningful contributions. Concentrated efforts are needed in the study of phytoplankton, calcareous reef building algae, organic matter diagenesis and such other emerging fields within Palaeobotany. These are only some examples where data is available and it is now necessary to analyse them and interpret. Let us take stock of our achievements so far and set future goals and objectives.

Historic Perspective

The first documented record of plant fossils in India dates back to the later part of the eighteenth century when Sonnerat (1782) reported the occurrence of petrified angiosperm logs in the Cuddalore Sandstone. Warren (1810) an amateur naturalist illustrated (what probably is the first illustration of a fossil plant in an Indian scientific journal) petrified logs from Cuddalore sandstones exposed around Tirruvakerrai and concluded that they were those of tamarind trees. The first scientific investigation of an Indian fossil plant may be credited to Brongniart (1828) who described and illustrated *Glossopteris browniana* var. *indica* and *Glossopteris angustifolia* from the Raniganj Coalfield. About a decade later, Royle (1833-39) illustrated first specimens of the genera *Vertebraria* and *Trizygia* and some of *Glossopteris*, also from the Raniganj Coalfield. Morris (1840) illustrated Indian Mesozoic plants and reported *Ptilophyllum*, *Lycopodites* and *Fucoides*. More Mesozoic plants were recorded by McClelland (1850) from the Rajmahal Hills under the names *Zamites*, *Taeniopteris* and *Poacites*. He also recorded some Palaeozoic plants from the Raniganj Coalfield. In the years prior to the establishment of Geological Survey of India, scattered papers were also published in the *Transactions of Geological Society of London* (Sower-

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by, 1840) and *Quarterly Journal of the Geological Society of London* (Hislop & Hunter, 1855; Bunbury, 1861).

The Geological Survey of India in the later half of the nineteenth century started publication of a series of memoirs under the title "Palaeontologia indica" (Oldham & Morris, 1863; Feistmantel, 1876-1886) which can be regarded as the take off point for Indian Palaeobotany. Ottokar Feistmantel, not only undertook an exhaustive and intensive morphographic study of Gondwana plants but also used the information for age determination and palaeobotanical zonation. He propounded the three-fold division of the Gondwana Sequence which formed the basis for recognition of Glossopteris Flora, Thinnfeldia Flora and Ptilophyllum Flora. Later workers gave geological age connotations to these floras and put the transition of floras at Permian-Triassic and Triassic-Jurassic boundaries. The matter, however, remains controversial and needs further attention.

After Feistmantel's monumental efforts, only sporadic work was done on Indian fossil floras till the time Professor Birbal Sahni took this up as his life's mission. In his Presidential Address to the 8th Session of Indian Science Congress held in 1921 at Calcutta, Sahni presented a State-of-the art report and outlined his future programme of research in Indian Palaeobotany. While Sahni's own researches centred around a gamut of megafossil studies, he initiated and encouraged palynological investigations. Though, much of the palaeobotanical research during his time had a botanical bias, he laid emphasis on biostratigraphical, palaeoenvironmental and palaeogeographical aspects. He also encouraged colleagues and students to undertake palaeobotanical investigations and with their help and support established the Institute of Palaeobotany at Lucknow which now proudly bears his name. Sahni's ideals are being ably carried out by his colleagues and successors who also founded new centres of palaeobotanical research in other places in India.

Precambrian-Cambrian biota

Scientists and philosophers have ever been contemplating on questions like how life began? How it evolved into its present form and what are its pathways? It is in the search of an answer to such questions that Precambrian biology assumes importance. The documentation and analysis of Precambrian records help to decipher earth's early atmosphere and conditions during advent and development of early life.

The role of micro-organisms in the formation of rocks and minerals of economic importance needs emphasis. Bacteria play a major role in the formation of iron, manganese and other minerals. Uranium and copper ores are also considered products of microbial interaction. This adds to the importance of the study of biotas in these sediments. Bacterial leaching has been reported from Copper, Zinc, Nickel and Uranium deposits.

Morphological and biochemical studies of extant organisms reveal that the earliest living forms were unicells, procaryotic (anucleate) micro-organisms that led a heterotrophic mode of life. The Lower Precambrian records contain primitive anucleate cyanophycean algae.

Organised biological structures reported from the oldest sediments in Isua Supra Crustal belt-3.7 Ga (Pflug, 1978) are now regarded non-fossils; however, carbonaceous matter-particulate kerogen is indigenous to the Isua sediments. The biological origin of this kerogen needs to be established. Evidences of biological activity in sediments older than 3.2 Ga have been found in Early Precambrian carbonaceous cherts and shales of Swaziland System (Ulrych *et al.*, 1967).

Some of the Indian records of earliest life forms are : micro-organisms in Sargur Complex, Karnataka—3.0 Ga (Viswanathiah *et al.*, 1976); stromatolites and other structures from Iron Ore Supergroup, Orissa—3.2 Ga (Awasthi, 1980); Sandur Schist Belt—2.5-2.9 Ga (Murthy & Reddy, 1984) and acritarchs and algae from the Dharwar Supergroup—2.4-2.6 Ga (Viswanathiah & Venkatachalapathy, 1980). The record of biota from stromatolitic cherts of Sandur Schist Belt is significant (Venkatachala *et al.*, 1986). The biotas recorded from Sargur Schist and Banded Iron Formation of the Bababudan Group need careful restudy and confirmation.

Extreme caution is needed when dealing with fossil blue-green algae, bacteria and other organisms. These though belonging to dynamic groups have not evolved much since the time they first appeared in the Precambrian. It, therefore requires diverse techniques to recognise them and distinguish extinct from extant.

Early Proterozoic to Cambrian biotas have also been reported from the Archaean complex of Chitaldurg Schist Belt (Gowda & Srinivasa, 1969) and Dharwar-Shimoga Schist Belt (Venkatachala *et al.*, 1972), Kaladgi Group (Venkatachala & Rawat, 1973; Viswanathiah *et al.*, 1975), Badami Group (Viswanathiah *et al.*, 1977) and Bhima Group (Venkatachala & Rawat, 1972; Viswanathiah *et al.*, 1976, 1979).

Ghosh and Bose (1955) in a paper entitled "Did vascular plants exist in Cambrian times?" discussed the antiquity of vascular plants and traced it back to Precambrian-Cambrian, based on biota from Salt Range. However, earlier to this Sahni and Shrivastava (1954), based on the same material, had concluded that the Salt Range biota is of Tertiary age. A perusal of the photographs published by these authors affords assignment of these "fossils' to extant floral elements. M. R. Sahni and Shrivastava (1962) reported lycopsid and sphenopsid spore types from the Cuddapah sediments and postulated that vascular plants originated as early as Precambrian. These records are also not considered authentic.

Since the first report of small discoidal carbonaceous fossils from the Suket Shale of Vidhyan Supergroup by Jones (1908) many workers have attempted palaeobiological studies from these horizons. Maithy (1969) described acritarch and algal remains from the Suket Shale (Upper Vindhyan) of Madhya Pradesh. He dated the Suket Shale as Ordovician and further concluded that the entire Vindhyan Sequence is not Precambrian in age. Salujha *et al.* (1969, 1970, 1971) studied the Vindhyan sediments exposed along Son Valley in Uttar Pradesh and Madhya Pradesh, Karauli and Kota areas in Rajasthan and their equivalents (Bhima in Karnataka, and Kurnool in Andhra Pradesh) and recorded an assemblage consisting of a variety of acritarch as well as few trilete and fungal spores. On the basis of this data, they concluded that the Vindhyan Sequence ranges from Early Cambrian to Early Silurian in age. The palynofloral contents of Bhima and Kurnool sediments are similar to those recovered from the Vindhyan sediments dated as early to late Cambrian and thus are considered to be their equivalents. A restudy of palynological data allows an age assignment of Precambrian-Cambrian to the Vindhyan sediments. The conclusion is based on the absence of complex spinose acritarchs, absence of true Chitinozoa which are common in Ordovician and absence of true trilete spores with morphological complexities which also appear in the Ordovician and diversify in the Silurian.

Maithy and Shukla (1977) recorded algal taxa, viz., *Aphanocapsiopsis*, *Myxococcoides*, *Palaeoanacystis*, *Oscillatoriopsis*, *Eomycetopsis* and *Neoscytonema*. They also reported the presence of acritarchs, such as *Orygmatosphaeridium*, *Nucellosphaeridium*, etc. and assigned an Early Riphean age to these sediments. M. R. Sahni and Shrivastava (1954) suggested an algal affinity for the genus *Fermoria* recovered from the Vindhyan sediments. Some algal structures were also reported from the Fawn Limestone (Lower Vindhyan) of

Mirzapur District (Mathur *et al.*, 1962). Maithy and Shukla (1984) concluded that *Fermoria* and other allied remains, such as *Krishnania acuminata*, *Tawuia* and *Vindhyania* are morphologically similar to the genus *Chuaria* Walcott. However, they were assumed to be distinct at species level due to difference in exine structure.

Extra-peninsular records include microbiota from the Calc Zone of Chamoli in Lesser Himalaya (Prakash, 1974); cyanophytic algae and acritarchs belonging to Sphaeromorphitae and Acanthomorphitae groups (Nautiyal, 1978, 1980); chitinozoans from Satpuli area, Garhwal Himalaya (Nautiyal, 1978, 1979); and cryptarchs from Shali Formation near Mandi (Singh, Tiwari & Gupta, 1978). The authenticity of these records needs confirmation. Raha (1980) reported filamentous and spherical microbiota from the Riasi Limestone.

Problems and perspective of the study of Precambrian biota

Precambrian biota comprises simple sphaeromorphs and filamentous types with little or no morphological and structural differentiation. A plethora of names has been used to describe them. However, a close study reveals that the taxonomic treatment employed needs thorough revision as diversification of morphoform had not taken place during this period, or was in its inception. It is only in the later part of the Precambrian-Early Cambrian that the ornamented spheres appear. Distinctly ornate forms with simple spines are recorded only from the Late Cambrian.

The problem of contamination by younger biota poses a serious challenge. The source of contamination may be *in situ* or in the laboratory. The *in situ* contamination may be due to ground water seepage, soil algal or fungal flora, spore/pollen contamina-
tion and rootlet and other extant plant remains penetrating into the cracks. The labo-
ratory sources of contamination are: (i) growth of extant biota on rock surface if stored in wet/damp conditions; (ii) air-borne elements; and (iii) recent algal and fungal elements as water contaminants.

The records of vascular plants (monolete and trilete spores, tracheids and other such remains) from the Vindhyans are not acceptable. The positive evidences of land plants are only in the Tremadocian. The spores with triradiate marks recorded from the Precambrian-Cambrian sediments (Venkatachala & Rawat, 1972, 1973) do not belong to vascular plants. The triradiate mark recorded in some of them is only a tetragonal compression mark and like the ones recorded in *Protosalvinia* and other primitive fossil plants (Bharadwaj & Venkatachala, 1960) and not a true trilete aperture.

Some of the forms referred to various acritarch genera are also, in fact, contamina-
tions from recent biota, perhaps through subsurface waters. Pollen grains of Compo-
sitae and Graminae have also been attributed to acritarchs. Fungal fruiting bodies have been commonly identified as *Leiosphaeridium*, *Leiofusa*, *Granomarginata*, etc.

The common contaminants, such as fungal spores, sieve plates derived from sieve-tubes, tannin cells, mesophyll cells, epidermal cells, water storage tissue, and mesophyll cells with large scale pitting can be easily mistaken for fossil cryptarchs, chitinozoa and other fossils (Venkatachala, 1986). It is necessary for the Precambrian biologists to take note of such major sources of contamination and acquaint themselves with the modern algal and fungal floras. It is either due to over-enthusiasm or due to the thrill of the credit associated with such finds that such reporting is increasing. Earlier workers were handicapped due to lack of literature and experience but it is not justifiable to commit such mistakes now with presently available advanced instrumentation, methodology, knowledge and experience. If only we could interact with algologists and mycologists such erroneous identifications would be rectified.

Modern contaminated vegetal remains can easily be distinguished from the fossil ones by differential absorption of safranin 'O'. Recent vegetal remains of nonfungal origin take better stain; *per contra*, the fossil material takes little or no stain depending on the thermal alteration the matter has undergone. Precambrian-Cambrian biota show generally darker hues of brown and do not easily accept safranin 'O'. The degree of transparency is also useful to recognise modern contamination. Recent material shows high degree of transparency as compared to fossil material. Fluorescence microscopy and fluorochrome staining are additional tools which need to be increasingly used to recognise modern contaminants. Fungal material does not accept safranin 'O', thus needs more caution and different techniques to identify them.

Animal remains and problematic fossils

Records of animal remains in the Precambrian-Cambrian sediments need our attention. Misra (1949) reported microscopic verticilliate algae with a slender jointed stalk terminated by a globular head from the Rohtas Formation. Vologdin (1957) considered it to be an *Archaeocyatha* and named it as *Misracyathus*. Tandon and Kumar (1977, recorded an annelid *Katania* and an arthropod from the Rohtas Formation. Later, Maithy and Gupta (1983) also reported *Ajacicyathus* from the Inoti Limestone and *Tubocyathus* from the Nagod Limestone exposed around Chandrahat. Prakash (1966) recorded shell-like forms from shell-limestone bed within Kajrahat Limestone; these forms have the appearance of broken cast of brachiopod. Sisodiya (1982) recorded impression of Jelly fish in Nimbehara Limestone. Another jelly fish *Ramapuraea* was described by Maithy and Shukla (1984) from the Suket Shale Formation.

Among problematic fossils, mention may be made of the ring-shaped structure, named *Coleolella* and circular to subcircular calcitic bodies, called *Allotheca*. Both these forms have been reported from the Suket Shale Formation in Madhya Pradesh by Maithy and Shukla (1984). The organic plates reported by Venkatachala and Rawat (1971, 1972, 1973) from Dharwar, Kaladgi and Bhima sediments could perhaps represent Metazoan remains. Viswanathiah *et al.* (1975, 1976, 1977) also recorded similar plates from Kaladgi, Badami, Bhima and Cuddapah basins. These reports of animal plates and possible record of animal remains from sediments older than 700 Ma indicate that metazoan activity started much earlier than accepted so far.

Stromatolite studies

Stromatolites are organo-sedimentary structures with narrow, tall, erect, branching columns that are formed by sediment-binding activities of successive mats of cyanophycean algae through a process in which fine detritus is often trapped and calcium carbonate precipitated. These structures and oncolites occur more in carbonate rocks than in cherts. The oldest known stromatolite (3 Ga) in India is from the sediments of Koira Group of Orissa (Awasthy, 1980).

Since the first record of stromatolite-like structure by Auden (1933) very little work was done till 1960 and as yet no definite picture has emerged on the stratigraphic value of stromatolites in India. Valdiya (1969) correlated carbonates of Lesser Himalaya and Vindhyans on the basis of stromatolites. Later, Banerjee (1971), Burman *et al.* (1978) and Chauhan (1978) attempted stromatolitic biozonation of Aravalis. Srikantia (1978) made stromatolitic correlation of Lesser Himalaya and Raha (1978) established stromatolitic biozones in Jammu Limestone. Indian workers have used different styles and techniques to describe stromatolites which cause difficulty in comparison. Standard techniques need to be adopted. Instead of directly attempting age correlation on the basis of stray records it is necessary to build stromatolite successions in each basin for interbasinal and other correlations.

Palaeozoic Floras

There are no definite pre-Devonian records of land plants in India. Sahni (1953) recorded possible psilophytic remains from the Silurian of Spiti. Later workers have questioned the affinities of these fossils and suggested animal affinity (Pant, 1978). The Palaeozoic floras of India are chiefly represented by the Glossopteris Flora. In the peninsula there are no pre-*Glossopteris* records. However, in the extra-peninsula scanty plant remains of older age have been recorded in sediments exposed at Kotsu Hill and Diuth Spur in Kashmir (Singh *et al.*, 1982). Though fragmentary in nature, they are interesting because of their being the only records of Devonian plants in India. It is one of the areas where much work remains to be done and the B Member of Aishmuqam Formation needs particular emphasis.

Earlier, a Lower Carboniferous flora was known from Po Series of Spiti. In recent years a well-preserved flora has been worked out from Member C of *Syringothyris* Limestone Formation and Member A and C of *Fenestella* Shale Formation in the Kashmir Valley. While the assemblage from *Syringothyris* Limestone is poor in contents the *Fenestella* Shale assemblage is characteristic and very similar to the one known from the Po Series. Infact, this assemblage is closely comparable with a number of Visean-Bashkirian plant assemblages known from different parts of the world. This perhaps shows an uniform global climatic pattern during the Lower Carboniferous, which can only be possible if all the localities containing this flora were situated within a common latitudinal belt.

No Upper Carboniferous flora is known from India so far. Some workers have placed a part of the Talchir Formation of the Gondwana Sequence in the Upper most Carboniferous. However, as of today, there is no floristic evidence in its support.

Gondwana Floras

The Indian peninsula witnessed deposition of a huge succession of fresh water sediments ranging in age from Early Permian to Early Cretaceous. These sediments termed as the Gondwana Sequence bear remains of three distinct floras, Glossopteris Flora Dicroidium Flora and Ptilophyllum Flora.

Whether the Gondwana deposits extended into extra-peninsula and if so, to what extent, is a debatable point. Leaf impressions simulating those of the genera *Trizygia*, *Gangamopteris* and *Glossopteris* are recorded from the Lower Permian of Nishatbagh and Mammal formations of Kashmir. However, *Gangamopteris* and *Glossopteris*-like leaves have been recorded not only from Lower Permian of Siberia but also from Jurassic of Oxaca, Mexico. Even the species of the so-called leaves of *Glossopteris* from Kashmir are different from the Gondwana species. The Kashmir flora does not indicate the presence of typical Gondwana elements, e.g. *Raniganjia*, *Dizeugotheca*, *Asansolia*, *Botrychiopsis*, *Rubidgea*, *Buriadia*, etc. or of typical Cathaysian elements, such as *Calamites*, *Gigantopteris*, *Cathayseopteris*, etc. Therefore, it is a mute point whether the Cathaysian elements occur in Glossopteris Flora of Kashmir or Gondwana elements occur in the Cathaysian Flora of Kashmir.

The concept of "mixed floras", such as the one mentioned earlier, has been used to disprove the idea of Continental Drift. However, one should never overlook the possibility of mis-identifications and parallel evolution (homoplasy). In the same way Gondwana affinities of the flora from Qubu Formation, southern Tibet are suspect. Interestingly, the original work on Qubu Flora used this evidence to support the concept of continental drift. But a couple of years later the same data was used to drown this concept in the Tethys. Further, not a single glossopterid fructification or even the genus *Vertebraria* is on record from these formations. On the other hand, *Parasphenophyllum thonii, Trizygia sino-coreanum, Lobatannularia ensifolia, L. ligulata, L. sinensis* var. *curvifolia, Rajahia mamalensis, Ginkgophyllum haydenii, G. sahnii*, etc. have Cathaysian affinities. Hsü (1976, p. 141) remarked—"The recent discovery of the Glossopteris Flora from the Qubu Formation of southern Tibet and the Gigantopteris from Shuanghu of northern Tibet shows no relationship with each other. This strongly supports the view of continental drift that the Indian block drifted............". But Ahmad (1978) speaks "This distribution takes away almost the very plank on which the theory of continental drift was, to start with, supported".

Much work, of late, has been done on the fertile organs associated with *Glossopteris* remains. The sporangial organisation and the *in situ* spores have clearly shown that not a single northern Permian pteridophyte occurs in India or even elsewhere in Gondwanaland (Lele *et al.*, 1981; Pant, 1976). Both polliniferous and ovuliferous organs related to the glossopterids have been worked out in detail at Birbal Sahni Institute and also by Department of Botany at Calcutta (Surange & Maheshwari, 1970; Chandra & Surange, 1979; Banerjee, 1969). An organisational model of the glossopterid female fructification as a cone has been provided. Findings of petrified material from Australia (Gould & Delevoryas, 1977) may provide additional evidences to improve on it.

Recent investigations have immensely advanced and crystallized our knowledge about the glossopterid group and a reconstruction of a typical plant with *Vertebraria* root, *Araucarioxylon*-complex stem, *Glossopteris* leaf, *Ottokaria-Cistella* female fructification, *Glossotheca-Eretmonia* male fructification, *Arberiella* sporangium, taeniate disaccate pollen and *Stephanospermum* seed is possible. However, whether this group formed a class into itself (Maheshwari, 1976) or had pteridospermous affinities (Chandra & Surange, 1979) is yet to be deciphered and should take a lot of serious thinking and research, including comparative studies on modern gymnosperms. The anatomy of the glossopterid wood indicates a humid temperate climate. Scanning Electron Microscopy has confirmed the presence of "torus" in Permian wood (Bajpai & Maheshwari, 1984), a feature so far not recorded from Indian pre-Jurassic woods. The Sahni Institute has also carried out anatomical studies on Permian wood from Antarctica (Maheshwari, 1972) and a great resemblance has been observed, to the chagrin of anti-drifters, with those known from XVIII coal seam, Kharkhari Colliery, Jharia Coalfield. On the other hand, some data have been found to show that all the Indian species of *Glossopteris* are endemic (Chandra & Surange, 1979), a good point for the anti-drifters to revolve around. However, this concept is still in the formative stage and must be very closely scrutinised as opinion to the contrary also exists (Rigby *et al.*, 1980).

Mesozoic Floras

Feistmantel advocated a tripartite division of the Gondwana Sequence on the basis of floristic changes. But whether the change from a Glossopteris Flora to a Dicroidium Flora coincided with other stratigraphic changes is highly debatable. The Panchet sediments and even the Nidhpuri (Nidpur) beds of the Tiki Formation have not yielded typical dicroidia. The genus *Glossopteris* rather continues to be the main plant of the Panchet sediments. Definite *Dicroidium* remains are recorded only from the Parsora Formation. Therefore, with the present status of our knowledge, the boundary is to be drawn below the Parsora Formation. If the emergence of the genus *Dicroidium* can be taken as a criterion for distinguishing a major subdivision, the emergence of other genera such as *Botrychiopsis* and *Buriadia* should also be given the same eminence to distinguish many floras or subdivisions.

The leaf size in the genus *Glossopteris* becomes comparatively reduced, for the same species, in the Panchet Formation. This seems to have climatic implications to meet ecological needs. This aspect necessitates further research (Maheshwari, 1974 a, b). The stomata of the leaves are mostly sunken with over-hanging papillae. This character must again reflect a xeric climate of the period. This aspect has been examined only very cursorily. Systematic taxonomy is no doubt very important, but it is the time that more attention is paid to environmental reflections exhibited in the morphology of these fossils. An understanding of the form and function of vegetative organs would certainly help to reconstruct past vegetations, climate and environment. The same also applies to the Jurassic-Cretaceous floras. The Jurassic and Cretaceous floras have been investigated to a large extent from the Rajmahal Hills, Son River Basin, Satpura Basin, Krishna-Godavari Basin, Cauvery Basin, Palar Basin, Rajasthan and Gujarat. It has been observed that cycadophytic leaves are more common in the Jurassic than Lower Cretaceous. But what is our standard sequence for comparison? The Euramerican Flora! Such far-fetched correlations could have led conclusions that need rethinking. The Rajmahal Flora (or floras) has been variously dated by palaeobotanists as Lower, Middle or Upper Jurassic. But we have absolute dates and these are not older than 105 Ma, i.e. Lower Cretaceous (Klootwijk, 1971 & others). These naturally have resulted in comparative palaeobotanical dating of other Mesozoic horizons because Rajmahal Flora has been taken as a base for comparison. Another problem that has not been examined in the Rajmahal Formation is the different assemblages associated with various lava flows.

The Bhuj Formation of Kutch has been generally accepted as a fresh-water deposit on the basis of occurrence of fossil *Isoetes*. Other important evidences such as the occurrence of dinoflagellates and other marine indicators have to be considered. The Bhuj flora is not an *in situ* flora and hence the possibility of upland plants being transported to a brackish-marine depositional site should also be examined. It is reported that root markings have been seen in shale beds at some localities suggesting their *in situ* nature (Bose & Banerji, 1984). There are records of transported roots also; like *Vertebraria* roots in the Lower Gondwana sediments - shales, coals, sandstone and petrified peat.

Ecological perspective should not be ignored. When I was discussing with a young doctoral student about his work on East Coast Gondwana Flora, he talked to me about the occurrence of sunken stomata, the leaf structure and related morphological manifestations indicating xeric conditions—yet the Mesozoic floras are called tropical. We have to start understanding, I restate, meaning and form of plant organs.

The problem of East Coast Gondwana needs reevaluation. Negative evidence, i.e. absence of the genera *Onychiopsis* and *Weichselia*, has been used to date these sediments as Late Jurassic. It is interesting to note that the Bansa Formation, which has been dated as Lower Cretaceous due to the occurrence of the genus *Weichselia* (Bose & Dev, 1959) has a palynological assemblage (Maheshwari, 1974) more resembling that of the Jhuran Formation of Late Jurassic age (Venkatachala *et al.*, 1969) whereas, the Jabalpur Formation, which is dated as Late Jurassic due to absence of *Weichselia*, has a palynological assemblage (Bharadwaj *et al.*, 1972) closer to that of the Bhuj Formation of Early Cretaceous age (Venkatachala, 1969a, b, 1972). Foraminiferal evidences also support an Early Cretaceous age. Now why this discrepancy between palaeobotanical and palynological and foraminiferal evidences ? Is it because plant megafossil assemblage, though distinct, might not be representative or complete ? or in age determination other evidences - such as palynological, faunal and absolute dating have not been considered. The incompleteness of evidence, either faunal or floral, is a reality and should be ascribed to our inability to find fossils rather than their actual absence. Therefore, all stratigraphic evidences have to be seen as a whole and not in isolation. Fossil records are already fragmentary. Let there be no further fragmentation or, there will be a leaf fossil age, a wood fossil age, a root fossil age, a fructification age, a spore-pollen age etc. ! Do we want to subscribe to this methodology ! It is not a happy prospect and I would advocate and plead for a synergistic approach.

Jurassic-Cretaceous floral assemblages have been reported from Ladakh (Sharma *et al.*, 1980), Bhutan (Ganesan & Bose, 1982) and Nepal (Barale *et al.*, 1978). The assemblages from Bhutan and Nepal have no characteristic fossils which would throw light on their genetic affinities. These, however, have been compared with the floral assemblage of the Jhuran and Rajmahal formations respectively. The plant megafossil assemblage from Fukche in Ladakh has definite Tethys-Karakoram floral relation; it does not have any Gondwana affinity. These evidences need to be further evaluated to see if the Kashmir and Ladakh area in reality did form a part of Gondwanic India.

Trap activity and associated floras

Basalts of Jurassic-Cretaceous-Tertiary age are known both in the exposed and subsurface sequences. The Sylhet, Rajmahal and Deccan Traps are the most prominent and their age has long been debated. Fossil as well as radiometric data has to be integrated and re-evaluated and tied up for a better understanding. Fossil evidences for dating of traps should be reconsidered in the light of recent studies. Age determinations on the basis of foraminiferal and palynological data fiom the subsurface sequences have been analysed by Sastri (1981).

The Sylhet and traps met within the subsurface of Baghmara (Meghalaya) as well as the traps met within the Bengal Basin are considered Lower Cretaceous and thus are equal to the Rajmahal Trap. The age of Rajmahal Trap is controversial. K-Ar ages on the Rajmahal Trap range from 109 to 69 Ma. Klootwijk (1971) also assigns Early Cretaceous (100-105 Ma) age. Besides, palynological data also confirms a Neocomian age (Venkatachala, 1978). Intertrappean sediments met within the subsurface of Mahanadi Basin are also Neocomian in age (Jagannathan *et al.*, 1983). Several wells drilled by the Standard Vacuum Oil Company in the Bengal Basin met Trap sequences up to 987 m thick (Bolpur Well). These are of Lower Cretaceous age and equal to Rajmahal Traps (Biswas, 1963).

The Deccan Trap found in some wells of Cambay Basin and in the Offshore of West Coast of India are Cretaceous to Eocene or perhaps Oligocene in age while those in the Krishna-Godavari Basin are Upper Cretaceous-Lower Eocene. The trap sequences met within the Offshore of Cauvery Basin are dated Upper Cretaceous. The same is true of the sequence met within the north-west offshore of Sri Lanka.

The Deccan Traps in central India range from Upper Cretaceous to Oligocene. Rama (1964) on the basis of K-Ar determinations dates volcanic rocks around Bombay as 42-45 Ma (Oligocene). Fossil evidences from Gurumatkal also point towards an Oligocene age (Shivarudrappa, 1981). Late Palaeocene (57 Ma) Intertrappean sediments are known from the western flank of the Laccadive-Chagos Ridge (Site 220-JOIDES). A well drilled at site 221 encountered an unfossiliferous layer within the basalt interval. The sediments above the cherts are dated 46 Ma. Upper Palaeocene volcanic breccia and highly altered vesicular trachy basalts are known from the well drilled at Site 223 on Owen Ridge (Rao, 1975). Records of traps from western India, Arabian Sea, Pakistan, eastern India (Cauvery Godavari and Mahanadi and Bengal basins) broadly fall into Upper Cretaceous-Oligocene time interval.

The occurrence of basalts extending from Hyderabad, Sind (Pakistan) to Baghmara in the northeast and Palk strait in the southeast to the west flank of Laccadive-Chagos Ridge in the Arabian Sea confirms that the trap activity was more extensive than indicated by the present outcrop distribution. Pepper and Everhart (1963) believe that the traps also extended into the Indo-Gangetic plains. The positive gravity anomalies of Laccadive Islands according to them may indicate a centre of flow in that area. The Palaeocene-Lower Eocene Fullers' earth deposits of Rajasthan are considered to be derived from volcanic ashes belonging to Deccan Trap volcanic activity and bentonites of Pakistan may also be of similar origin (Rao, 1967).

The Deccan Intertrappean sediments have also been investigated for their floral contents for more than a century. They contain an inexhaustable treasure. The occurrence of these floras at the Mesozoic/Cenozoic boundary gives an added importance to their study. The origin and spread of Angiosperms is also attributed to this period. The intertrappean sediments contain remains of angiospermous woods and fruit-fossils, some of which are comparable to Australian forms (Bande, Mehrotra & Prakash, 1986). An indepth study is needed to understand the implications of this finding and its relationship with Australian floras. Marine algal fossils attributed to *Peyssonelia*, *Distichoplax* and *Lithophyllum* are recorded from the Intertrappean sequences from Chhindwara in central India. This is a very important find as it indicates the presence of an arm of sea near the Nagpur-Chhindwara area (Bande, Prakash & Bonde, 1981).

Palynology of Gondwana and associated sediments

The initial encouragement to palynological researches in Indian subcontinent was given by Professor Birbal Sahni who stressed on the importance of palynological correlation of coal-seams and called for a thorough study of spores and cuticles of the Indian fossil plants, particularly from the Lower Gondwana. In his opinion such a study could also throw light on the early traces of Glossopteris Flora coexistent with the Lower Gondwana glaciation (Sahni, 1922). In response to this Chinna Virkki (1939, 1946) made a beginning by studying the spores and pollen from the Early Permian sediments of the Indian subcontinent.

During the later half of fifties and in the sixties, the foundation for taxonomy of palynofossils was laid by palynologists of the Sahni Institute. Persistent efforts have been made to understand the fine structure of exine, the nuances in sculpture and the overall organisation. As a result a plethora of new taxa also came into existence due to over-enthusiasm of authoring new finds in a virgin area. It is, however, obvious that this phase was also inevitable, as during that period not much data was available on the variability of morphographic features. Recent studies on the development of exine structures have revealed that the array of sculpture patterns as well as structure are controlled by endoplasmic reticulum (Stanley & Linskens, 1974) and that finer structural differences have genetic expressions. The separation of genera *Plicatipollenites*, *Parasaccites* and other monosaccate pollen on the basis of saccus attachment from apparently similar *Nuskoisporites*-group of pollent; the differentiation of *Callumispora* from *Punctatisporites;* and circumscription of *Lahirites*, *Striatites* and other taeniate (striate or grooved) pollen are some of the examples which exhibit significance of organisation and fine structure in delimitation of taxa. Similarly, the significance of harmomegathic apparatus to combat environmental stress and strains in certain grooved pollen genera including *Ephedra*, and the separation of sexine from the nexine in thick leathery and spongy subsaccus as exemplified in *Schizopollis* to fully blown saccus in order to enable the pollen to become airborne have also been studied and need further critical investigation. Further, the initiation of morphologic character simulating a saccus in Lycopsid spores such as *Endosporites* and *Playfordiaspora* and the manifestation of equatorial exoexine during the Triassic in *Kraeuselisporites* and *Lundbladispora* exhibit distinct morphologic adaptation in response to environment.

During the last decade and a half palynological information has been extensively applied for solving stratigraphical problems. In this pursuit, different formations of the Gondwana Sequence, including stratotypes, have been investigated and standardised at the Sahni Institute. The Oil and Natural Gas Commission have studied surface and subsurface sequences of offshore and onshore sedimentary basins of India. All these researches have resulted in generation of a large amount of information on Indian sedimentary basins.

Conventionally Gondwana sedimentation is believed to have commenced in the Upper Carboniferous-Permian concluding in the Lower Cretaceous. The Talchir Formation is characterised by an abundance of trilete-bearing radial monosaccate pollen similar to the palynological assemblages from the *Eurydesma* and *Connularia* horizons of Umaria and Manendragarh (Lele & Chandra, 1972) which shows that the Talchir sedimentation commenced in the Permian. Bap fauna also consisting of *Eurydesma* and *Connularia* is found in association with such a radial saccate pollen assemblage (Venkatachala & Rawat, 1985) confirming a Permian age to the boulder bed in Rajasthan. The discovery of *Leiosphaeridia* in association with this radial monosaccate pollen assemblage from Palar Basin (Venkatachala & Rawat, 1973), West Bokaro Coalfield (Lele, 1975), Do-Dhara, Satpura Basin (Bharadwaj *et al.*, 1976), Bap Formation, Rajasthan (Venkatachala & Rawat, 1984), Penganga Valley (Lele, 1984) are significant records of the early Glossopteris Flora coexistent with the Gondwana glaciation and marine transgressions during the Early Permian (Talchir).

Palynological investigations seem to indicate another glacial phase during Upper Karharbari. A third cooler phase, probably due to a minor glaciation, is presumed to have prevailed at the beginning of Panchet sedimentation (Bharadwaj, 1977). This needs support from sedimentological studies. Palynofossils across Raniganj-Panchet boundary show that the lithological boundary "almost" coincides with the palynological boundary. The palynoflora of the Kamthi Formation in Godavari Graben (Bharadwaj *et al.*, in press) shows this unit to be time transgressive, ranging from Upper Permian to Lower Triassic. It is interesting to note that coal beds have been taken as a part of the Kamthi Formation in this study. The stratotype of Kamthi Formation istotally devoid of coal and hence this study needs an indepth analysis.

An isolated exposure in Gopad River near Nidhpuri is reported to contain Triassic plant mega- and microfossils. Palynological studies of stratigraphically controlled samples can also confirm this age determination.

The records of Permian spores in the Tertiary lignites of Cannanore by Potonié and Sah (1960) and in Jabalpur sediments of Sehora by Sukh-Dev (1961) were first doubted as contamination. However, of late, such occurrences have commonly been observed in the Mesozoic sediments of Kutch, Palar and Krishna-Godavari basins and Tertiary sediments of Assam and are ascribed to reworking. These reworked spores in younger sediments can, however, be distinguished by fluorescence microscopy or even differential staining techniques. Venkatachala (1970) studied these reworked assemblages in detail and opined that the Lower Gondwana sediments, once extensive throughout the country, have been eroded and subsequently redeposited as younger sediments. The occurrence of Permian palynofossils in the Mesozoic sediments of Kutch Basin is particularly interesting because so far no Palaeozoic sediments have been deciphered in that basin, either in surface or in subsurface. However, Triassic sediments have been identified in the subsurface on the basis of palynofossils (Koshal, 1975).

Palynology of sediments equivalent in age to Upper Gondwana in Cauvery, Krishna-Godavari and Palar basins have been studied extensively during the last decade at the Sahni Institute, various laboratories of ONGC and some University centres in Calcutta, Jadavpur and Osmania. So far, no evidence is forthcoming to support the occurrence of Jurassic continental Gondwana assemblages in these basins.

The age and stratigraphical position of Dubrajpur Formation in the Rajmahal Basin are critical questions. The formation generally contains Upper Permian plant mega-fossils (Sah & Maheshwari, 1969) but in one area, i.e. Khatangi Hill, there is no lithological change between Permian sediments and overlying sequences containing *Ptilophyllum*. The Dubrajpur Formation contains a palynoflora ranging from Upper Permian (Raniganj) to Late Jurassic in age while Intertrappean bed between Trap 2 and Trap 3 of the Rajmahal Formation shows Lower Cretaceous palynoflora (Tiwari *et al.*, 1984). The unconformity between the Late Permian and Late Jurassic is to be defined and the limits of Dubrajpur and Rajmahal formations circumscribed. It is necessary to work out the entire exposed and subsurface sequences.

The Sriperumbudur Formation in Palar Basin palynologically shows Lower Cretaceous affinity and has been found to rest over the Talchir sediments with an unconformity (Murthy & Ahmed, 1969). A similar stratigraphic control is envisaged in Athgarh area of the Mahanadi Graben. Jurassic sediments could not be found in the subsurface of Karaikudi area of the Cauvery Basin where Sivaganga beds are exposed. With these observations the presence of Jurassic sediments on the east coast remains debatable.

There is an ongoing debate on the definition and scope of the term Gondwana. Whether the Gondwana Sequence comprises only fresh water sediments with minor marine transgressions or it can also be used for marine sequences with minor continental deposits? What is the horizontal and vertical distribution of the Gondwana Sequence in India? Can some of the extra-peninsular sediments be called Gondwana simply because they contain fossils apparently having affinities with those found in peninsular sediments? These questions need to be answered for an indepth analysis of the problem. The term Gondwana has a purely lithological connotation and it is hardly justified to identify a sedimentary sequence as Gondwana simply because it may have a few floral elements apparently similar to those of the *Glossopteris*, *Dicroidium* or *Ptilophyllum* floras.

Tertiary palynostratigraphy

Tertiary palynology has gained importance due to oil exploration endeavour in the country. Most of our known oilfields are in the Tertiary, i.e. Cambay Basin, Assam Shelf and Bombay Offshore. Exploratory efforts in Andaman-Nicobar, Bengal, Cauvery, Jaisalmer, Kutch, Krishna-Godavari, Mahanadi, Saurashtra, Tripura-Cachar basins and Himalayan foot-hills have established occurrence of hydrocarbons. Palynostratigraphic and palaeoecologic and source rock studies in these basins as well as other Tertiary basins in the country have helped to establish a large data base. The available information has been reviewed periodically (Sah, 1984; Venkatachala, 1978 & others).

Proliferation of taxa both at generic and specific levels, use of different parameters to circumscribe taxa and nomenclatural inconsistencies are the main problems of Tertiary palynology. The earlier workers used, and to my dismay some even now use, supra-generic categories like *Monocolpites*, *Tricolpites*, *Tetracolpites*, *Pentacolpites*, *Octacolpites*, *Monoporites*, *Diporites*, *Triporites*, *Tricolporites*, etc. to name pollen taxa, while others identify genera with extant pollen on only superficial resemblances. Examples of the latter are many and too well known. Realising this, researchers in Indian and African Tertiary palynology got together in Pondicherry in 1983 to discuss both taxonomical and nomenclatural problems which resulted in an Atlas "Selected Tertiary Angiosperm pollens from India and their relationship with African Tertiary pollens" (Thanikaimoni, Caratini, Venkatachala, Ramanujam & Kar, 1984). Tropical Tertiary sediments are replete with a rich diversity of pollen types. Only some of them are useful as stratigraphical and ecological markers. The need of the day is to tag these marker fossils and catalogue them with annotated stratigraphical and ecological notes. A word of caution—let us not get lost in listing and describing many fossils that occur—which would be an endless and a non-profitable exercise. Stratigraphically and ecologically important taxa have to be separated out. Fifty three important taxa were restudied in Pondicherry Atlas. A concentrated programme to continue this exercise is underway at the Sahni Institute. Stratigraphic range tables and zonation available for each of the sedimentary basins have to be critically re-examined to bring about precision. Distributional anomalies of taxa in east and west coast basins need to be analysed for deciphering provincialism, endemism and migration patterns of vegetation in the subcontinent. Many vegetational elements of Malaysian and Indo-Burmese origin occur at different stratigraphic levels in different sedimentary basins.

The time scale in vogue is built up on evolutionary lineage and distribution of marine biota. It is of utmost importance to tie up spore-pollen zones with the already established zonation based on marine biota. Marginal marine biozones play an important role in correlating continental zonation with those of marine ones. Phytoplankton (including diatom) research need to be stepped up to meet this goal.

Cuddalore Sandstone and associated lignites

The Cuddalore Sandstone, exposed in the western part of the Cauvery Basin, comprise gritty to pebbly and ferruginous sandstones considered as Mio-Pliocene in age and continental in origin. The well-known Neyveli lignite deposits occur within these sandstones. Eames (1950) considered the age of Cuddalore Sandstone as Pontian on the basis of the occurrence of *Mesembrioxylon schmidianum* in the Tirrvakkerrai grits (Sahni, 1931). The other fossil records that influenced Eames are the occurrence of *Anadara granosa* from beds of Yellada odai which Foote (1883) doubtfully referred to Cuddalore Sandstone and *Crocuta* sp. by Rao (1932) from Sendurai. Sahni (1931) also recorded that the age may range from Eocene to Pliocene. Yet, later workers (Ramanujam, 1968 & others) have assigned a Miocene or post-Miocene age. Venkatachala (1972, 1973) and Deb *et al.* (1973) pointed out that typical Eocene palynofossils recorded from the subsurface of the Cauvery Basin (Venkatachala, 1972) occur in the Neyveli Lignite and that the lower age limit of the Cuddalore Sandstone may extend to Eocene and the formation may be time transgressive. In some of the shallow wells drilled in the Vedaranyam and Mayavaram areas, Cuddalore Sandstone with lignite lenses dated as Oligocene in age has also been recorded. A 32 m thick shell limestone of Eocene age has been met within Sangoli Kuppam well-10 which contains distinct *Nummulites*, while a well drilled near Bahur contains 9 m thick lignites of Pliocene age.

It will be worth while to also study Ratnagiri and Kerala lignites on the West Coast and those contained within the Rajahmundary Sandstone in the Krishna-Godavari Basin for correlation and broad palaeogeographical reconstructions.

The records of mangrove and associated coastal pollen in the Neyveli lignite negates their attribution to continental type of deposition. It has also been taken for granted that absence of phytoplankton and other marine elements indicates a continental deposition; however, it is necessary to use ecological perspectives before arriving at such conclusions. The possibility of large scale reworking from older sediments in allochthonous deposits should also be considered before age conclusions are drawn. Many of the "Eocene markers" found in Neyveli, Warkali, Cannanore and Ratnagiri lignites and associated deposits may, in fact, be reworked from older deposits.

Do Eocene sediments occur in Arunachal Pradesh?

The presence of sediments of Eocene age in Arunachal Pradesh has been a subject of controversy. Karunakaran and Rao (1979) are of the opinion that Palaeogene sediments do not occur in the eastern Himalaya. Acharya *et al.* (1975) recorded the existence of Palaeogene-Lower Neogene sediments along the frontal zone and further north below the pre-Tertiary sediments. Tripathi *et al.* (1978 a, b, 1981) also recorded fossiliferous Early Eocene sequence along the right bank of Siang River. Singh and Singh (1983) discovered another outcrop of late Early Eocene sequence about 19 km southeast of Yinkiyong in Yamna Valley. Tripathi *et al.* (1978) named these sediments as Renging Formation. Overlying this are the rocks of Late Early Eocene named by Tripathi *et al.* (1981) as Yinkiyong Formation. The occurrence of Eocene sediments in Arunachal Pradesh has not been accepted by many geologists. Biostratigraphical evidences including palynology can play a major role in solving this crucial problem.

Ninety East Ridge

Palynological study of the Tertiary sediments from Ninety East Ridge has been worked out by Kemp (1974), Harris (1974) and Kemp and Harris (1977). The palynological assemblage recorded from site 214 in northern part of the ridge is Palaeocene in age whereas that recorded from site 254 at southern extremity is of Oligocene age. The flora is comparable with other Lower Tertiary floras from southern hemisphere, particularly from Australia and New Zealand. This is probably due to greater proximity of the ridge sites to these southern landmasses in the Early Tertiary in comparison to their present position (Kemp & Harris, 1975). During that period India was far to the north of Island sites of the Ninety East Ridge and perhaps because of that Ninety East Ridge flora lacks similarity with the Indian Tertiary flora. It will be worth while to take up detailed comparative studies of Palaeogene floras of Andaman Basin and East Coast basins of India including Assam with those of Burma and the Sumatran Arc.

Environmental interpretations

Every type of sediment continental to deep marine has a distinctive palynofossil assemblage and organic matter content. Plants occupy all conceivable habitat and the tolerance of the species and nature of physical environment are criteria important for palaeoenvironmental conclusions. Environmental interpretations which are derived from a group of species forming a natural ecological association are far more reliable than the one based on a single dominant taxon. It is therefore necessary to consider the entire palynofossil assemblage rather than use single dominant species. Certain species are specifically adopted to distinctive environments, for example the halophytes, the mangrove plants, the sand-dune vegetation and others. These associations are useful indicator assemblages. Major plant communities can be outlined by an intelligent assessment of a group of characteristic species. Palaeoecological interpretations have to be attempted on the basis of modern analogues as guide. Various types of organic matter logged for use in organic matter typing can also be used for palaeoecological reconstructions.

Each one of the different depositional realms, such as the hinterland or the upland representing the erosional plain, flood plain, coastal plain including the lower deltaic plain and estuary, lagoon and coastal swamp, sandy beach and barrier island, mangrove and back mangrove representing the depositional plain and marine realm has a characteristic assemblage.

Environmental interpretations need quantitative assessment of a large amount of palynological data. It is necessary to consider the following factors also while interpreting this data:

i) Pollen productivity—large pollen producers like *Pinus nigra* (*ca* 225,000,000 pollen per inflorescence) and *Rumex acetosa* (*ca* 393,000,000 pollen per inflorescence) have to be weighed against low pollen producers like mangrove plants. Entomophyllous plants produce less pollen than anemophyllous ones.

ii) Mode of transport of spores and pollen and sorting before and during fossilization.

iii) Ecological control and local factors effecting fossil quantities.

iv) Identification of autochthonous elements from allochthonous ones.

v) Negative evidences such as absence of phytoplankton—mostly coastal mangrove deposits contain little or no phytoplankton. Sediments not containing phytoplankton but with mangrove pollen have erroneously been interpreted as continental deposits.

vi) Identification of reworked assemblages for recognition of unconformity surfaces and shore lines.

Hinterland or Montane

The hinterland represents the erosional plain and is the non-depositional phase. Pollen of this vegetational unit are represented in the flood plain and coastal plain sediments.

Flood plain — The flood plain sediments are generally deposited in the lower reaches of rivers and have many distinctive environmental regimes like ox-bow lakes, marshes, back and fresh water swamps and levees. These deposits are laid down during excessive floods and inundation by rivers.

Among the vegetational complexes the fresh water, water edge and swamp assemblages are most commonly encountered along with a fair mixing of upland and lowland elements. The lowland vegetation surrounds the flood plain and is represented by various distinctive spores. Structured terrestrial matter as well as spores and pollen are most abundant. Charcoal and woody particles are rare to common. Biodegradation of organic matter takes place more in the lower realms and depending on the nature of deposition biodegraded organic matter is common to dominant sometimes resulting into the formation of a fair amount of amorphous organic matter. Grey amorphous organic matter is almost absent. Some algal remains are encountered but are rare and phytoplankton are totally absent. Lacustrine sediments contain an abundance of fresh-water plant representatives and algae. Other plant complexes represented are mostly material transported either by wind or water from the hinterland sources. The organic matter content in lake sediments is abundant with fair contribution of structured terrestrial organic matter, spores, pollen and charcoal. Biodegradation of organic matter is evidenced by microbial and fungal action resulting into a large amount of biodegraded cuticles and woody matter. Though algae and other aquatic elements are common, they are soon biodegraded. Amorphous matter is rare to common.

Coastal plain—The coastal plain is built up by the activities of the fluvial system and the intertidal marine realm. This includes various features, such as transitional zone between the continental and tidal mangrove swamp, estuary, lagoon, coastal swamp, sandy beach and barrier islands. The transitional zone between marine tidal mangrove swamp and continental flood plain is distinctive. Intermixing of pollen of vegetational complexes is recorded at this interface.

Coastal swamps

These form the most interesting unit and have distinctive mangrove vegetational associations which are tidal forests occupying the littoral habitat. The important factor is the brackish environment. The mangrove belt extends both into the estuarine formations as well as in the deltaic regime. They also border lagoons. These swamps have relatively few species of plants and have characteristic pollen that can be easily recognised. A large amount of plant debris accumulates in association with marine phytoplankton; microforaminiferal remains are also common. The back mangrove deposits contain fresh water algal representatives, such as *Pediastrum* and the like, showing fresh water influences. A certain amount of pollen of fresh water swamp and water edge plants associated with lowland forest types are also encountered in these sediments along with other allochthonous elements.

The organic matter in this realm contains mostly an abundance of terrestrial organic matter of both structured and biodegraded nature. Spores and pollen are common to abundant. Charcoal is also common and sometimes abundant, along with wood-remains, which in some samples are dominant. This is a result of wet oxidation and as wood and charcoal are buoyant, they almost form a linear distribution pattern along the water edge. Marine tidal fluctuations bring in phytoplankton which are trapped along with sediments by pneumatophores, the root system of mangroves. The phytoplankton percentages vary from area to area depending on local factors. This ecological realm is most interesting and many stages of biodegradation of organic matter are present. Palaeocene-Eocene subsurface sequences in the Krishna-Godavari Basin afford a very interesting material where this type of environment has been interpreted on the basis of palynological and organic matter studies. Detailed studies of organic matter transformation from well-preserved cuticle and wood pieces to those where they are completely biodegraded into amorphous organic matter are recorded. The grey amorphous organic matter also is abundant to common. There is much bacterial action which results into formation of amorphous matter.

By a study of the organic matter and that of different plant ecological complexes it is also possible to investigate the extent of development of mangrove vegetation in an area. Excellent examples are available in the study of subsurface sequences in Narasapur (Krishna-Godavari Basin) and Cambay black shale (Cambay Basin) sequences wherein the initiation, growth and development of the mangrove complexes can be interpreted.

Mud flats and beaches

There is little accumulation of organic matter in mud flats and beaches. The plant constituents are mostly of Chenopod-Amaranth group associated with palms. Phytoplankton are rare to common. Though most of the organic matter types are present they are poor in quantity. Amorphous and grey amorphous organic matter are absent and biodegraded organic matter is very rare. Charcoal is most dominant and the structured terrestrial matter is abundant to rare depending on the site of deposition. The material representing a lagoonal environment is rich in organic matter of the mangrove and fresh-water swamp types. As this represents both closed or silted basins or with marine openings, the phytoplankton and amorphous types of organic matter vary in abundance. This is also associated with pyrite and a large amount of organic matter of bacterial origin. Mangrove swamps generally are associated with lagoonal complexes also and the inflow of fresh water through rivers determines the vegetation in and around the swamp. Fresh-water swamps are also common around the stream mouth bordered by mangroves but depend on the salinity. The pollen assemblages show this mixture with fresh-water algae, microforaminifera and phytoplankton. Palms and other barrier island type of vegetation are also common associates. Organic matter concentration and types vary depending upon the site of deposition in the lagoon. At the estuary and river mouths the structured terrestrial organic matter and fresh water ecological vegetational complexes are abundant while phytoplankton are absent. While in the other area of the lagoon phytoplankton are common to abundant with varying abundance of grey and amorphous organic matter types; charcoal is present throughout this environment.

Delta and estuary

The palynological and organic matter contents of deltaic and estuarine sediments are closely comparable. Deltas are a complex network of interconnecting tidal channels and river distributaries while the estuaries consist of one major channel surrounded by mangrove and fresh-water swamps. There is not much of variation in the plant communities of these two sub-environments.

The delta front has various types of mangrove elements represented but the back mangroves are rare. In this type of sediment a fair and sizable amount of pollen types of fluvial plains are seen as the river system brings in a large amount of terrigenous material. Microplankton are abundant and form a sizable representation. The organic matter types dominant are the structured terrestrial and biodegraded material. Charcoal is common. Amorphous organic matter of both grey and amorphous types is common. The prodelta area has almost the same variety of organic matter content as that of the delta front except for a large representation of marine organic matter types. Mangrove vegetation still continues in isolated patches between distributaries and their pollen are encountered here.

MARINE

Concentrated deposition of pollen grains is unlikely in high energy areas of the continental shelf. An impoverished assemblage may be recorded which mostly contains some mangrove pollen, like—*Zonocostites* and other smaller pollen. Phytoplankton occur abundantly. The most common organic matter type in this realm is the grey amorphous organic matter; small quantities of spongy amorphous type are also present. Further offshore, the clastics of the continental slope contain very little organic matter.

Concluding remarks

I have discussed several important aspects that concern Indian Palaeobotany and endevoured to bring out the necessary emphasis on certain areas where we need to collaborate and contribute significantly. Some of these problems, I know, are engaging your attention. I am sure this Conference will deliberate on these issues and come up with a significant programme. To conclude I once again stress that *synergy* is the need of the hour. Let us work with this spirit in our mind and heart.

संगच्छध्वं सवदध्वं सं वो मनांसि जानताम्
समानो मन्त्रस्समितिस्समानी
समानं मनस्सहचित्तमेषाम् ।
समानी व आकूतिस्समाना हृदयानि वः ।।
समानमस्तु वो मनो यथा वस्सुसहासति ।।

ऋग्वेद-X. 191.2-4.

Be united;
Speak in harmony;
Let your minds apprehend alike;
Common be your methods;
Common be the end of your assembly;
Common be your resolution;
Common be your deliberations.
Alike be your feelings;
Unified be your hearts;
Common be your intentions;
Perfect be your unity and understanding.

Rig Veda-X. 191.2-4

I have great pleasure in inaugurating this CONFERENCE.

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