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PALAEOBOTANICAL RESEARCHES IN INDIA : RETROSPECT AND PROSPECT

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Though the known records of fossil plants in India go back to the later part of the 18th century (Sonnerat 1782), yet the first illustration of a fossil plant appeared only in the beginning of the 19th Century (Warren 1810). Adolphe Brongniart described a few species of fossil plants from the coal-bearing formations of Raniganj Coalfield (1828-1837). Around the same time, the first fossil *Chara* from India was reported (Sowerby 1840). During the next two decades, a number of reports on Indian fossil plants was published, mostly in Transactions of the Geological Society of London. With the establishment of the Geological Survey of India in 1847, the work on fossil plants recovered from Gondwana sediments got an impetus. The first plant fossil, infact the first fossil, officially illustrated by the Geological Survey of India is *Zamia theobaldi* (now *Ptilophyllum acutifolium* Morris) from the Early Cretaceous of Rajmahal Hills (McClelland 1850, pl. 12, figs 1,2). During 1863 to 1886, a number of illustrated accounts was published in the Palaeontologia indica, mostly by Ottokar Feistmantel.

Professor Birbal Sahni initiated extensive research in palaeobotany and, with sustained efforts, was able to develop a centre of advanced studies at the Lucknow University. Birbal Sahni was born on 14th November 1891 at Bhera, now in Pakistan. He graduated from Punjab University in 1911 and obtained the DSc degree of London University in 1919. He joined Lucknow University in 1921 where he rose to be the Dean, Faculty of Science in 1933. In 1943, he accepted the additional charge of Head of the newly established Department of Geology. He was of the opinion that a student who had studied both botany and geology would make a better palaobotanist (Rao 1952). His areas of research were varied; he specialized on the fossil plants from the Rajmahal and Deccan Intertrappean beds and made valuable contributions to discussions on theory of Continental Drift, Himalayan Uplift, Permian floral provinces, age of Saline Series, etc. He also made valuable contributions to the knowledge on structure, affinities, geographical distribution and evolutionary aspects of extant plants.

Sahni had the rare foresight to realize the importance of plant microfossils in solving stratigraphical problems. He initiated research investigations on fossil spores and pollen (Virkki 1937) which laid the foundation of stratigraphical palynology in India. Palaeopalynology, that started as an offshoot of palaeobotany, has now become a very valuable aid in search for the fossil fuels; though sceptics may believe otherwise. Palaeopalynology can even help in resolving problems concerned with hydrocarbon reservoir continuity.

The Birbal Sahni Institute of Palaeobotany, Lucknow, founded in 1946 through his efforts, continues to be the core group for palaeobotanical and palaeopalynological researches in India. The research programmes cover Origin and early evolution of Life, Patterns of evolution in plants and floras in time and their distribution in space, and application of accrued knowledge to biostratigraphy, particularly in relation to exploration for fossil fuels. Research investigations on different aspects of palaeobotany are also being carried out at Allahabad, Bangalore, Bombay, Burdwan, Calcutta, Jodhpur, Kashmir, Kolhapur, Lucknow, Mysore, Osmania, Poona, Punjab and Utkal Universities, besides Geological Survey of India, Oil and Natural Gas Commission, Institute Francaise, Pondicherry, Institute of Science, Nagpur, Wadia Institute of Himalayan Geology, Dehradun, Maharashtra Association for Cultivation of Science, Pune and many other institutions. The two palaeobotanical associations in the country are the Palaeobotanical Society and Indian Association of Palynostratigraphers, as well as the Palynological Society of India.

The following account summarizes our knowledge about plant life through the ages in India. Geochronometric dates of rock units given in million years before present (Ma BP) are only approximate (cf. Cowie & Bassett 1989).

THE EARLY LIFE

Early life forms discussed in several publications are simple sphaeromorphs or filamentous types to which a plethora of names has been given. The number of records that have been accepted as genuine is not very large.

Presence of silicified cyanobacteria in the 2,600 million-year old Sandur black cherts, and of fossil eubacteria in the Kudremukh Formation (Naqvi *et al.*, 1987, Venkatachala *et al.*, 1986) has proved the existence of biogenic and photosynthetic activity during that period.

Stromatolites were first discovered in the Fawn Limestone Formation (>1000 Ma BP) of Vindhyan Supergroup in the Mirzapur District. Stromatolites recently reported from the 2,600 million-year old rocks of Shimoga Schist Belt are amongst the oldest records (Vasudev *et al.*, 1989; Venkatachala *et al.*, 1989). So far, more than 20 species/forms are known from Lesser Himalaya, Aravalli, Vindhyan, Pranhita-Godavari, Cuddapah and Kaladgi basins.

Most of the Precambrian records of the Dasycladaceae need authentication. For example, the "microscopic verticillate Dasycladaceous algae with slender jointed stalk terminated by a globular head" from the Vindhyan is not an alga. Indubitable records of the Dasycladaceae are known only from Upper Cretaceous Niniyur Group of Tiruchirapalli District.

Filamentous algae which show heterocysts and other characters typical of the Cyanophyceae (Nostocaceae) are reported from Ganga Valley sediments around 700 Ma BP (Shastri *et al.*, 1972). Sheet algae (metaphytes) have recently been discovered in 950 million-year old sediments of Vindhyan Supergroup (Shukla *et al.*, 1989). Acritarcha, a comparatively more diversified group comprising cyst-like or spore-like biomorphotypes of unknown, possibly algal, origin is also known from the Precambrian-Cambrian rocks of India.

EARLY VASCULAR LAND PLANTS

There have been sporadic reports of the occurrence of remains of vascular plants, such as, spores and tracheids in the sediments of Precambrian-Cambrian age. Due to lack of reproducibility of the data, such records are not considered to be authentic. The triradiate mark recorded in some of these spores is only tetragonal compression mark like the one in spores of some primitive plants (Bhardwaj & Venkatachala 1960). Even the cuticles with cellular structure (but without a stoma) may belong to some algae. The discovery of microfossils in the Saline Series of Salt Range by Sahni (1944) caused much debate and discussion, and stimulated research by forcing a reconsideration of opinions and inspiring new field-work' (Halle 1952).

In India, probable remains of early vascular plants are known only from the Upper Devonian of Spiti Valley (Sahni 1953) and Kashmir (Singh *et al.*, 1982). These remains have been compared with *Taeniocrada, Protolepidodendron* and *Hostimella.* So far, tracheids, stomata and acid-resistant spores have not been recorded.

Definite vascular plants are known from the Lower Carboniferous of Spiti Valley (Gothan & Sahni 1937) and Kashmir (Singh *et al.*, 1982). The Lycophytopsida are represented by remains of aerial axes of the Order Lepidodendrales (Cyclostigmaceae, Lepidodendraceae), and Protolepidodendrales (Archaeosigillariaceae, Sublepidodendraceae). The specimens are only small pieces and hence do not give any idea about the height of the plant. A specimen from Po Formation of Spiti has been examined by us and seems to represent an arborescent lycopod.

Fern-like fronds also contribute a sizeable part of the assemblage. All the known forms, both from Spiti and Kashmir, represent the sterile stage and hence no idea can be formed about their phyletic affinity. Some of these forms may represent foliage of the Order Pityales of the Progymnospermopsida (Arnold 1970) or of the orders Calamopityales and Lagenostomales of the Ginkgoopsida (Meyen 1987). Microspores have been recovered from the upper part of the Po Formation (Khanna & Tiwari 1983). Preservation is poor and therefore, a comparison with microspores of lycopsids or progymnospermopsids is not possible. No megaspores are so far known from this level though elsewhere a free-sporing heterosporous condition was attained in some plants by basal Upper Devonian.

No records of Middle-Upper Carboniferous vegetation in India have been preserved. In the northern hemisphere, luxurious forests thrived during this period and major coal measures were deposited.

ADVENT AND DECLINE OF GLOSSOPTERIODS

In India, the Upper Carboniferous (310-290 Ma BP) was a time of the great glaciation that also covered most of the Gondwana Supercontinent. The vegetation cover must have been drastically reduced, plants surviving in protected niches. The glaciation initiated the deposition of a great thickness of sediments, primarily in a fresh-water environment. These sediments - the Gondwana - were recently discussed in great depth at a Workshop (see Venkatachala & Maheshwari 1988). The age of the Indian Gondwana was earlier generally accepted as Late Carboniferous to Early Cretaceous (both inclusive). Recently, it has been suggested that the term Gondwana in India should be restricted to fresh-water sediments of Permian to Triassic age, with occasional marine interbeds (Venkatachala & Maheshwari 1991). Accordingly, the concepts of two-fold or a three-fold classification of the Gondwana rocks are no more relevant. The vegetation of this period is known as the Gondwana Flora or the Glossopteris Flora. Study of Gondwana plants formed a substantial part of Birbal Sahni's research interests.

So far no mega- or micro-fossils are definitely known from the glacial period that initiated the Permian Period in India, though plant-remains have been reported from beds directly overlying the glacial boulder bed in the Karanpura Coalfield (Jowett 1925) and spore-pollen have been reported from the Talchir boulder bed in Jayanti Coalfield (Lele & Karim 1971). The earliest known Permian mega-remains from India are gymnospermous and represented by the leaf genera *Gangamopteris* and *Noeggerathiopsis* (Feistmantel 1879). From the same level gymnospermous monosaccate pollen have also been recovered (Lele 1966).

From the genus *Gangamopteris* started a great lineage of plants that dominated the vegetational scenario of India and other countries of the Gondwana Supercontinent for almost forty million years, i.e., althrough the Permian Period. It was also during this period that the great coal deposits of the country were laid down. The leaf of *Gangamopteris* was simple, tongueshaped, non-petiolate and with entire margin. A number of vascular bundles entered the base, repeatedly dichotomized and anastomosed to form a net-venation pattern. In slightly younger sequences an almost similar leaf appeared. This leaf which had a definite midrib instead of a central strand of vascular bundles has been named *Glossopteris*. Simultaneously appeared a new morphoform of gymnospermous pollen which was bisaccate and had taeniae on the proximal face of the corpus or the central body (Potonie & Lele 1961).

The glossoptefids started diversifying in the Early Permian itself and reached their zenith in the Late Permian. The generic and specific identification of the glossopterid leaves is based on their overall morphology (Maheshwari 1966, Chandra & Surange 1979). Sometimes, features of the epidermis are also taken into account for taxonomic delimitation (Chandra 1974). The leaves were borne in tight spirals, almost simulating whorls.

The trees of this period had pycnoxylic wood, basically of Araucarioxylon-type. A number of genera of fossil wood are recognized on the basis of characters of pith and primary xylem (Krausel *et al.*, 1962). A very characteristic form of woody axis is *Vertebraria* which is known from all the Permian sediments of the Gondwana Supercontinent. This axis is now considered to be a root. The seedling had two, forked cotyledons (Pant 1987).

Although the first glossopterid leaf was described as early as 1828, a fructification definitely assignable to the plant that bore such leaves was reported only in 1956, from South Africa. Similar but detached fructifications were earlier thought to be fern pinnules (Feistmantel 1880). Maheshwari (1965) showed that Dictyopteridium-type of fructification is a linear, dorsiventral body with net-venation on one surface and oval scars on the other surface. This organisation has been confirmed in a cross-section of a permineralized fructification from Australia. From the late Late Permian in India, another very characteristic seed-bearing fructification, *Lidgettonia*, is known; here, in the axil of a bract-like leaf arises a pedicel that gives off 2-3 pairs of lateral branches, each branch terminating into an orthotropous ovule. The ovuliferous pedicel is fused with the median region of the bract for about 1/2 the length. *Glossotheca* and *Eretmonia*, the two genera of pollen-producing organs assigned to the glossopterids also have basically the same organisation as in *Lidgettonia*. De'ached seeds and sporangia, some of these related with the glossopterids, have been described by Pant and Nautiyal (1960). Two families based on fructifications have been recognised, viz., Dictyopteridiumaceae and Eretmoniaceae. The fructifications though apparently arose from the midrib yet, were possibly axial to the subtending leaf. It seems that the group represents an independent branch of the gymnosperms (Maheshwari 1990).

Other gymnospermous leaves associated with the glossopterids have been referred to Cordaitales, Cycadales, Coniferales, and Ginkgopsids. The dichotomously branched fructifications *Utkalia* (Chandra 1984), *Veekaysinghia* and *Birbalsahnia* (Bajpai & Maheshwari 1991) have not been found in organic connection with an axis or a leaf, hence their affinities remain uncertain.

The pteridophytic content of the Permian floras is rather low. *Cyclodendron leslei* is the only species of lycopsid megafossils known from the Middle Permian, and possibly also from the upper part of Late Permian. However, lycopsid megaspores have been recorded from all the Permian sediments. Though six genera of sphenopsids are known, their distribution is very irregular. Most comon forms are *Phyllotheca* and *Trizygia*. The reported connection between *Trizygia* and *Vertebraria* (Maithy 1978) is based on inadequate observation. There is no organic connection between the two; it is just chance overlapping.

The earliest known fern-like frond from India is referred to the genus *Botrychiopsis*. Foliage apparently similar to the pteridospermous fronds of the Euramerican Flora occurs in the Middle-Late Permian but its fertile stages have clearly indicated affinities with the ex-indusiate ferns (Lele *et al.*, 1981).

The Permian flora from Kashmir that contains definite elements of the glossopterids also shows the presence of the sphenopsid *Lobatannularia* and the ginkgopsid *Psygmophyllum* (Singh *et al.*, 1982). The former is a characteristic element of the Cathaysian Flora, and the latter of the Angora Flora. *Kashmiropteris meyenii* (Kapoor *et al.*, 1992) possibly is related to the cycadopsids. Birbal Sahni apparently did not support the hypothesis that the northern elements migrated into India at a later period. He rather believed that these forms could have survived the Ice Age in niches on the Gondwana Supercontinent.

The glossopterids started declining during the uppermost Permian. The Triassic megafloras of India being poorly known, levels of changes in the vegetational scenarios are not clearly decipherable. The genus *Glossopteris* continued atleast into the basal Triassic though there are reports of occurrence of this genus in the Late Triassic, too.

Elsewhere in the Gondwana Supercontinent, for example, in the Molteno Formation of South Africa, the Late triassic is characterised by the predominance of presumed pteridospermous plants belonging to the families Peltaspermaceae and Corystospermaceae. These families are mostly known by their foliage, i.e., *Lepidopteris* and *Dicroidium*, respectively. Fertile organs have been ascribed to them, on the basis of regular association. In India, the only definite *Dicroidium* is known from the Late Triassic (Feistmantel 1882). Recently the taxon has also been reported from presumed Early Triassic of Orissa. *Pteruchus*, the pollen-producing organ of the Corystospermaceae, is reported from the plant-bed of probable Late Permian age exposed near Nidhpuri in Sidhi District (Pant & Basu 1973). *Dicroidium*-like fronds are also reported from this bed but in the absence of the characteristic forked rachides, the presence of this genus is yet to be confirmed. Though these fronds have a fern like habit and venation, yet they posses an acid-resistant cuticle and hence belong to a group of gymnosperms.

The presence of pteridophytic micro- (Maheshwari *et al.*, 1978) and mega-spores (Maheshwari & Tewari 1988) reflects on the occurrence of a fairly varied pteridophytic undergrowth during the Triassic. The coniferous foliage *Pagiophyllum* and *Elatocladus* that forms an important constituent of the Upper Mesozoic vegetation appeared in the Late Triassic (Pal 1984).

The Gondwana vegetation probably arose from the pre-existing Carboniferous stock through saltations. The glacial episode could have acted as a catalyst for rapid genetic reorganisations in the parent populations resulting in newer morphophysiological types. Birbal Sahni (cf. 1937) was of the opinion that the Ice Age was somehow causally connected with the origin of the Gondwana Flora. In the basal Permian, the plants were small and simple that could tolerate the rigours of an arid climate. During the late Early Permian, the plants had relatively thick cuticle indicating restricted availability of water. During the Middle Permian, the precipitation probably was very high. A temperate climate is indicated by the presence of growth rings in the trees. In the Late Permian, the climate was warm-temperate with comparatively high wind velocities (Maheshwari *et al.*, 1990). The climate became arid during the Triassic as is indicated by reduction in leaf size and by the presence of papilae overhanging the stomatal aperture in most cases.

LIFE AND TIME OF PENTOXYLON

The Jurassic (205-135 Ma BP) was a period of virtual nondeposition of fresh-water sediments on the Indian peninsula and scanty vegetation of that period has been preserved. The Hartala Formation in the South Rewa Basin that has been assigned an Early Jurassic age represents the younger aspect of Late Triassic Tiki Formation. Middle Jurassic age assigned to the Kota Formation is not confirmed. However, spores-pollen of Jurassic Period have been recovered from marine sediments of Rajasthan. The basal Jurassic sediments show the presence of conifer polen, e.g., *Callialasporites* (Podocarpaceae), *Araucariacites* (Araucariaceae), *Classopollis* (Chirolepidaceae), etc. (Venkatachala 1972). From slightly younger sediments in the same area, petridophytic spores such as *Cyathidites, Osmundacidites,* etc. are also known.

In the Early Cretaceous (135-120 Ma BP) appeared a very unique group of plants that combined characters of many groups. This group, the Pentoxylales (Sahni 1948), is represented by permineralised stems, leaves, ovule-bearing organs and male flowers. The reconstruction of the *Pentoxylon* plant is based on inferred connection between these organs; they have not been found in organic connection. The discovery of stem *Pentoxylon,* with an anatomy superficially similar to that of *Medullosa* and *Rhexoxylon,* was first announced in 1935 by B.P. Srivastava, a student of Professor Birbal Sahni. The leaf *Nipaniophyllum* was deciduous, with taeniopteroid venation and anomocytic sunken stomata. *Sahnia,* the male flower, was terminal on a short shoot; the microsporangiophores were borne on a collar-like structure formed by raised margin of the receptacle. *Carnoconites,* the ovuliferous cone, was probably also borne terminally. The *Pentoxylon* plant probably had a shrubby habit (Bose *et al.,* 1985).

The *Pentoxylon* plant thrived more or less in seclusion, in the Rajmahal Hills region of Bihar during the Early Cretaceous. During the same period, the Bennettitales, another unique but more or less cosmopolitan group of gymnosperms, attained its acme in India. Elsewhere, for example, in the Yorkshire Flora of England, this group reached its developmental peak in the Late Jurassic. Guided by this information, most of the Upper Mesozoic floras of India were dated as Middle-upper Jurassic (Bose 1974), inspite of radiometric dates of around 110 million years, i.e., late Early Cretaceous. The most common bennettitalean leaf is *Ptilophyllum.* The male and female flowers are named as *Weltrichia* and *Williamsonia,* respectively, while the stem is known as *Bucklandia.* Sahni (1932) reconstructed a bennettitalean plant which he called as *Williamsonia sewardiana.* Incidentally, this was the first reconstruction of a fossil plant from India.

The araucarioid conifers that made their appearance in the Late Triassic became an important constituent of the Early Cretaceous vegetation. The pycnoxylic secondary wood with araucarioid pitting on the radial walls of the tracheids that appeared during the Early Permian is also found in the Mesozoic wood. It, however, does not imply that the Permian and Early Cretaceous plants with such a secondary wood were closely related. The leafy twig *Pagiophyllum* resembles that of *Araucaria. Brachyphyllum* is another type of leafy twig. Cones and seed-scales of the Araucariaceae have been described as *Araucarites* or even *Araucaria.* Pollen of Mesozoic Araucariaceae are dominant elements of the Early Cretaceous palynofloras (Venkatachala 1972). By the end of the Cretaceous, the family almost disappeared from India. There are stray reports of araucarioid remains from the Palaeocene (cf. Ramanujam 1980).

The podocarpaceous conifers were also common in the Early Cretaceous flora of India. They are represented by wood *(Podocarpoxylon)*, leaves *(Elatocladus)*, ovuliferous cones *(Stachyotaxus, Nipaniostrobus)*, and pollen-producing organ *(Podostrobus)*. The pollen is 2- or 3-winged. The family had a drastic decline during the Tertiary. Infact, the gymnosperms in general and the conifers in particular formed an insignificant part of the Indian Tertiary flora (Sahni 1931).

Another group of plants that was inhabiting the Upper Mesozoic seas is the Pyrrophyta - the dinoflagellates. These unicellular, mostly planktonic, algae have a combination of primitive prokaryotic features as well as more advanced features, and thus hold a key position in the evolution of life. These algae, which formed an important source for liquid hydrocarbons probably appeared in pre-Mesozoic. The same seas were also inhabited by minute algae that secreted calcareous skeletons and are referred to the Class Chrysophyceae. In India, the oldest records of the Pyrrophyceae (dinoflagellates) and Chrysophyceae (calcareous nannophytoplankton) are from the Middle Jurassic of Kutch Basin (Garg *et al.*, 1988). The phytoplankton now form a critical area of research at the Birbal Sahni Institute of Palaeobotany, Lucknow, for dating sediments and for deciphering ancient environments of deposition to facilitate the search for more oil.

DECCAN VOLCANISM, RISE AND SPREAD OF ANGIOSPERMS

In India, the oldest fossil presumed to have angiospermous affinities is a permineralised corroded pollen-like body, *Sporojuglandoidites*, from the Early Cretaceous of Rajmahal Hills (Mittre 1956). The authors do not confirm this attribution. New evidence, however, has recently been found that indicates the appearance of angiosperms in the first intertrappean of the Rajmahal Basin (105 ± 10 Ma BP, Tripathi & Tiwari 1991).

The Deccan Intertrappean beds of central India have yielded a number of petrified angiosperm remains including flowers and fruits. Though the occurrence of fossil plants in the Deccan intertraps had been known since 1837, yet an impetus to the study of this flora was provided only after Birbal Sahni started taking interest in it. The influence, if any, of the Deccan volcanic activity on the Early Tertiary vegetational scenario is yet to be clearly understood. At the terminal Cretaceous, a large scale but selective extinction of animals, e.g., dinosaurs and ammonites is believed to have taken place the world over. It is not yet clear if the plant kingdom also faced a crisis at this period of time. Atleast the flora from the Deccan Intertrappean beds does not support the occurrence of such a crisis in the Indian region. Similarly, no major extinctins are noticed of the dinoflagellate taxa across the Cretaceous-Tertiary boundary in Meghalaya.

Some of the Deccan intertrappean sequences must have been laid down in deltaic swamps as is indicated by the occurrence of marine algae *Peyssonnelia* and *Distichoplax* and the palm *Nypa*. Marine algae have also been reported form Tertiary sediment of Kuch (Lakhanpal et al. 1984). At the same time, fresh-water algae belonging to the Chlorophyceae and Cyanophyceae were not uncommon. The Charophytes which made their first appearance in the Early Createceous proliferated during the Deccan Intertrap period and about 24 species referable to 7 genera are known. A number of species of the Charophytes are also known from the Siwalik Formation of post Micene (5.3 Ma BP) age. There are sporadic reports of bryophytes also. The pteridophytes that constituted a major part of the Mesozoic floras are rather poorly represented by megafossils during the Tertiary Period. The water-fern *Azolla* that made its first appearance in the Maastrichtian of Meghalaya and Tamil Nadu continues, and forms referable to *Regnellidium* and *Salvinia* appear (Sahni & Rao, 1943). *Regnellidium* is now restricted to South America. Most of the gymnosperms known are conifers. the ginkgoalean type of leaves which were not infrequent in the Early Cretaceous and were represented even in Triassic and Permian disappeared by the time angiosperms appeared on the Indian scene.

Some of the fossil taxa, e.g., *Simarouboxylon* and *Cyclanthodendron* resemble *Simarouba* and *Cyclanthus* presently growing in South America. Other apparently resemble *Eucalyptus, Tristania* and *Callistemon - Melaleuca* presently native of Southeast Asia and Australia. If the identifications are authenticated, the presence of these taxa in the Indian Tertiary floras will need some explanation, particulary with regard to the route of migration in either direction.

The Angiosperm flowers known from the Deccan Intertrappean beds indicate the presence of both zygomorphy and actinomorphy. *Musa*-Like fruits (Jain 1964) and presumed myrtalean flower *Raoanthus* (Chitaley & Patel 1975) depict zygomorphy. The flowers of *Sahnianthus* assigned to the Sonnerativaceae (Mahabale & Deshpande 1957) and *Sahnipushpam* possible belonging to Araceae (Prakash & Jain 1964) were actinomorphic. Fossils of fruits/flowers referable to families Guttiferae, Malvaceae, Lythraceae, Pandanaceae, Poaceae, Arecaceae and Araceae are also known. Many more families are represented as petrified wood which are the most common fossils (Bande *et al.* 1988).

The tropical Tertiary sediments are replete with a diversity of pollen types. Distributional anomalies of these taxa in east coast and west coast basins hold key to provincialism, endemism and migration patterns of vegetation in the subcontinent.

The extinction pattern at the terminal Eocene in India may be related to drifting of continents and shifting of palaeoenvironmental regimes. The qualitative and quantitative representation of palms is reduced. Similarly, megafossils resembling species of *Dryobalanops, Gonystylus* and *Sindora* and some species of *Anisoptera, Shorea, Hopea, Mangifera, Gluta, Parinari, Barringtonia* and *Alangium* that grow today in Malaysia have been recorded from Miocene of south India (Awasthi, 1974, Awasthi & Panjwani 1984). This indicate that some plants migrated to Malaysia from India during post-Miocene period, too.

By the beginning of the Miocene (23 Mp BP), the angiosperms acquired a modern look. It is possible to relate them to extant counterparts, with a greater degree of confidence allowing for more accurate conclusions regarding palaeoclimate and palaeoecology. Members of Dipterocarpacea which presently occur only in tropical evergreen forests of Assam, Karnataka, Kerala and Andamans were widely distributed all over India during the Miocene thus indicating the existence of luxuriant evergreen rain-forests over a large part of the Indian subcontinent (Awasthi 1980).

Prospects

The early life on the earth was dominated by prokaryotes which were mainly fermantative. The advent of oxygen necessitated development of a new biological strategy- the eukaryotes. When did the eukaryote appear in time is a question that needs to be answered. There are positive evidences of metaphytes and metazoans at 950 million-year before present. One has now to look for even older forms.

Whether the Gondwana Flora evolved from earlier plant communities that survived in niches during glaciation or whether it is derived from plants that migrated to the Gondwana Supercontinent from other phytochorias after glaciation is a problem that is yet to be solved. It is also not known as to exactly in which region of the Gondwana Supercontinent the Gondwana Flora originate.

Species of plant megafossils are usually identified on the basis of gross morphography. In recent years, features of the cuticle have also been taken into consideration. However, subjective approach of different investigators has brought about an element of uncertainity in the identification of taxa because similar specimens with and without cuticles have mostly been assigned to different species. A co-ordination between two groups of species is desired so that not only these species will become biostratigraphically significant, even dispersed cuticles could be used for stratigraphical correlation and dating at levels where other microfossils are not known. For this purpose it is also necessary that the palaeobotabists avoid vague statements about the stratigraphical and geographical location of their material. Exact posititioning of the samples can only help both in biostratigraphy and evolutionary studies.

Most Tertiary palaeobotanists now assign their fossil specimens to extant taxa. Some go to the extent of instituting new species within modern genera for dispersed parts of plants. e.g., wood, leaf or pollen. the latter trend needs ot be discouraged as it will create two sets of species within genera based on extant plants, i.e., (i) almost always based on complete morphophysiological information, (ii) usually based only on partial knowledge about an unconnected organ.

Similarly, an indepth study of *in situ* spores and pollen can provide requisite data on variable and consistent characters for different taxonomic groups. Study of ultrastructure of the exines should provide much useful information regarding affinities. Once palynological taxa are objectively circumscribed, they can be used with a higher level of confidence for zonation and correlation as well as to understand evolutionary patterns.

In the recent past there have been major discoveries of early angioperma from the Cretaceous sediments of Europe and America but the occurrence of authentic Cretaceous plant megafossils is yet to be recorded in the Indian sediments. Angisoperm pollen are only sporadically known from the Upper Aptian. High resolution character assessment of dispersed pollen is required to trace the antiquity, relationship and evolutionary aspects of early angioperms in time and space. This study would also necessitate development of information on the possible favoured regimes, environment and climates in which the early angiosperms appeared, flourished, diversified and rose to position of dominance. The Tertiary flora of India witnessed several changes during the Palaeocene-Eocene times ; several taxa either became extinct or migrated. The relative position of India and Malaysia may have facilitated intercontinental migrations. The available palaeobotanical and palaeopalynological data need to be reassessed in global perspective to trace the possible migration routes, particularly keeping in view the geographic position of Greater India. The problems of regionalism, endemism and migration/extinction of floras in response to geomorphological and climatic factors need to be worked out to uravel the history of the modern flora of India.

The tree-ring studies offer an exciting opportunity for lengthening and extending the special coverage of high resolution information which will specially be useful in studying decadal to century scale climatic variations. Conifers have distinct annual growth rings which show a high degree of environmental sensitivity. In tropics, teak has the potential for the reconstruction of past precipitation. These studies may provide information about the glaçial/interglacial phases of the recent past and their probably feedback link to the monsoon climate. High resolution palynostratigraphy can help work out history and causes of deterioration of the mangrove ecosystem and its impact on receding shorelines.

Fossil fuels are non-renewal resources and need planned exploration and exploitation. Most of our coalfields are confined to the Paleozoic and Tertiary basins whereas most of the known oilfields are restricted to the Upper Mesozoic-Tertiary horizons only. Palynofossils and other vegetal remains of the past help interpret ancient environmental conditions favourable for organic matter accumulations and their conversion to fossil fuels by transformation and susequent thermal alteration. Quantitave distribution of palynofossils mostly determines the approximate location and configuration of nearshore marine deposits in which hydrocarbons are formed and accumulated. Thus, high resolution palynology needs to be developed as an effective tool in stratigraphical geology for tapping organic fuel resources.

Concluding Remarks

The last hundred and odd years have seen a remarkable progress in techniques, methodology and practical applications of palaebotanical investigation. Yet, many problems remain unsolved or only partly solved. More information is required towards solving such problems and also to meet societal obligations by creating R&D information base for user agencies engaged in exploring fossil fuels, ground water, forestry and environment. A synergistic approach involving inter-institutional and inter-disciplinary collaborations is called for, as a Palaeobotanists can no more afford to work in isolation.

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