ABSTRACTS

Challenges in Indian Palaeobiology

Current Status, Recent Developments and Future Directions

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Theme–Emerging Trends in Palaeobiology, Session C–Advent of angiospermous characters, pollination and fruit dispersal

ANGIOSPERMOUS FOSSIL FRUITS/SEEDS FROM THE TERTIARY SEDIMENTS OF INDIA

Anil Agarwal

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A number of fossil fruits/seeds are known from different Tertiary sediments of India ranging from the Maastrichtian-Danian (Palaeocene) to the Pliocene-Pleistocene. In the present study, well known fossil fruits/seeds from the Indian Tertiary have been listed and an attempt has been made to throw light on their palaeoecological, palaeophytogeographical and evolutionary significance. Most of the known fossils belong to the monocots, particularly the family Arecaceae from the Maastrichtian-Danian Deccan Intertrappean beds of India. The fossil fruits/seeds of family Lythraceae are described only from the Palaeocene -Eocene while the fabaceous fruits/seeds are described in large number mostly from the Oligocene to Miocene. The families, viz. Arecaceae, Burseraceae, Combretaceae, Nyssaceae, Polygonaceae, Rhamnaceae, Rubiaceae and Sapindaceae occur in the Neogene sediments. The paucity of fossil fruits/seeds precludes any definite analysis/ comments on their palaeobotanical characteristics. However, most of the fossil fruits are drupaceous or capsular while fabaceous fruits are lomentum or legume. The fibrous mesocarp of the fruits suggests their dispersal by water and the plants to which they belong must have been growing in the coastal areas or near other water bodies. The capsules or fruits with thin pericarp might belong to the inland terrestrial plants. Many fruits of uncertain affinities, e.g. *Sahniocarpon, Wingospermocarpon, Enigmocarpon* and *Viracarpon* pose interesting questions about the evolution of angiosperms. Further investigation is needed to tag the fruits/seeds hitherto reported to respective parent families.

UNVEILING PAST ENVIRONMENTS AND LANDSCAPES USING MODERN TOOLS AND APPROACHES – VALUE-ADDITION THROUGH CONTEMPORARY ECOLOGICAL STUDIES AND THE APPLICATION OF REMOTE SENSING IN POLLEN STUDIES

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Pollen analysis is a powerful tool for reconstruction of the past vegetation patterns. Conventionally, pollen analysis and interpretation follow the well established approaches used in temperate environments where Quaternary palynology was first initiated, as early as 1916 (Faegri & Iverson 1989). However, tropical ecosystems are characterized by a greater diversity and complexity and moreover, their dynamics are quite different. From the point of view of pollen analyses, these systemic and environmental variations have meant differences in different parameters, starting from the number, distribution and variety of palaeosites to qualitative and quantitative differences in the preserved proxy record, significant to its interpretation.

While some studies from the neo-tropics take into account these additional dimensions (for example, Binford *et al.* 1987, Bush 1995, 2001), this is not common to studies in the Indian tropics. This paper addresses the need for such an approach with illustrative examples from ongoing studies on palaeoenvironments of peninsular India. Ecological studies serve at least two purposes: first, in tandem with modern pollen studies, they are very useful to help delineate pollen-vegetation-climate relationships; second, they can help to enhance the accuracy of the palaeoclimatic interpretation of palynological data from sediment cores or sections, by providing additional information regarding the functional adaptations of one or more "pollen taxa markers" in the record.

Results from ongoing studies on the modern and fossil pollen from the Eastern Ghats and southern Tamil Nadu are used in illustration. There are three additional aspects in our palynological study of modern surface samples. First, the modern pollen sampling sites are selected using remote sensing. The satellite image of the proposed study area is subjected to RS analyses and forest areas under different stages of degradation are delineated. A broad selection of points, representative of the different classes of degradation, is done and ground-truth is used to make a smaller selection from within these points, in order to obtain a spatial coverage along a gradient of increasing disturbance. Second, in addition to conventional vegetation typology quantitative vegetation studies are being carried out at the modern pollen sampling sites. In each site, a plot was laid with a dimension 5m x 100m = 500m^2, with subplots of 5m x 5m dimension. Various age and habit classes were enumerated and measured for their Girth at Breast Height (GBH) in 20 subplots, that were enumerated for plants following the methodology set forth by Anupama *et al.* (2002). The third aspect involves field and laboratory measurements of plant parameters relevant to the classification of plant species in terms of their functional types (PFT classification). As the proxy pollen data are obtained in terms of "pollen types" rather than species, their ecological significance is better interpreted by adopting the plant functional type classification (PFT). This classification allows us to compare different species belonging to the same functional groups, each functional group being related to climatic parameters. Among the various plant traits of significance, the most important is that of leaves. Hence, leaf trait measurements have been carried out at these selected sites. Leaf samples from species occurring in various sites were collected for measuring their trait variation in various sites. Twigs, that were fully exposed to sunlight, were collected and leaf thickness was measured using a dial thickness gauge. Leaves were dried and dry mass and specific leaf area were measured in the laboratory.

There are further applications of RS because of its synoptic and temporal coverage. Satellite RS coupled with GIS tools is of immense help in narrowing down the study area and identification of suitable sites for sediment coring as explained briefly. There are very few undisturbed natural lakes in peninsular India which is however uniquely characterized by several natural and man-made irrigation reservoirs (tanks) that act as repositories of sediment from the surrounding slopes and catchments. These sites appear on satellite images as "water bodies". To shortlist the water bodies listed from the recent (Awifs-2004) Awifs sensor imagery, old MSS sensor imagery (MSS-1973, 1974) was compared. The land use pattern since 1970 is recorded faithfully by satellite imagery. While delineating the palaeoclimatic effects from tank sediments the effect of land use (human intervention) can be eliminated using inputs from imageries. Old toposheets are also used in the process of short listing suitable sites and from an initial list of over 100 water bodies all along the Eastern Ghats from Orissa to Tamil Nadu, around 15 were short listed for ground truth and final selection.

In palaeoclimatic interpretation the pollen results are supplemented and complimented by other newer studies, like environmental magnetic, chemical and geomorphological studies. These, together with newer dating techniques, like OSL, will give a wholesome story of the palaeoclimates and palaeoenvironments.

Our studies show that by adopting a truly inclusive multidisciplinary approach to the reconstruction of past environments, complementary enhancements, feedbacks and enrichments, both basic as well as applied, are achieved in the different disciplines.

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PALAEONTOLOGY, A MULTIPLE SCIENCE

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Life is immensely attractive because of its movement, colour, size, shape and many other aspects. In the same way, the natural happenings in the past life evince interest in the society as our perception of evolution of life changes with every fossil discovery. Any discovery holds enormous information and contributes to the study of past life. Such a study is compounded and made into a series of progressive works that has been compiled to palaeontology. This science encompasses ancient evolution, ecology, geography and deposition of sediments in lakes, rivers and seas. The deductions based on fossil study enable us to unravel secrets of nature. Somehow, the word palaeontology has become synonymous with dinosaurs as these huge demons roamed the earth in the past and left their imprints in the rocks. Their mere size makes us diminutive. Apart from this popular group, echinoids, ammonites and plants, including fossil wood, steal the show. Totally unable to create awe in the minds of man, microfossils such as, foraminifera, ostracoda, diatoms, dinoflagellates, spores and pollen contributed to the progress of palaeontology by providing precise correlation due to their abundance in sediments of far lying rocks. A careful tabulation of their occurrences that may suggest the nature of their ecological niche in layered sequence was utilized in petroleum exploration to find the source and reservoir rocks. Apart from their utility to find mineral deposits, the beauty of fossils in their pristine luster is valued by the collectors of rare items be it an ancient amber with insect inside, a coral or an ammonite.

EARLY EVOLUTION OF ACRITARCHS IN INDIA AND THEIR BIOSTRATIGRAPHIC SIGNIFICANCE

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The intracratonic, crescent shaped Chhattisgarh Basin is developed over the Precambrian basement in central India. A thick sequence of unmetamorphosed, tectonically least disturbed Meso-Neoproterozoic sediments belonging to Chhattisgarh Supergroup is exposed is Chhattisgarh state. This supergroup, consisting of shales, siltstones, sandstones and limestones is classified into different formations belonging to three groups (Das *et al.* 1992). An assemblage of organic-walled microfossils of unknown and probably varied biological affinities (acritarchs) is structurally well preserved and has been studied both in petrographic thin sections and macerated residue of black carbonaceous shales, siltstones and associated chert of different formations.

The recovered dark brown to yellow brown planktonic forms (acritarchs) are not so diversified in present assemblage. They are simple, moderate thick walled, ornamented and spinate forms ranging 10-120 µm and belong to two subgroups of acritarchs, i.e. Sphaeromorphida and Sphaerohystrichomorphida. The recovered acritarchs of Sphaeromorphida subgroup are leiosphaerids and cymatiosphaeroides. *Micrhystridium*, protected by a hyaline sheath, and *Tappania* like forms of Sphaerohystrichomorphida subgroup are also present. This assemblage compares with the known assemblages of Mesoproterozoic sediments exposed in other parts of the world.

The acritarchs show morphological changes through time and hence have been used as a tool for biostratigraphic analysis in absence of radiometric dating since 1966 (Timofeev 1966, Downie 1984, Fensome *et al.* 1990) and in determining the palaeoenvironment during sedimentation by others (Javaux *et al.* 2001).

Recently, the explosion and diversification of eukaryotic forms (acritarchs) including morphological complexity have been recognized on the basis of available data belonging to Mesoproterozoic (1200 Ma) / Neoproterozoic boundary (Butterfield & Rainbird 1998, Knoll 1994, 1996, Vidal & Moczydlowska 1997, Xio *et al.* 1997, Yin 1997). The four stages of acritarchs have been categorized based on the morphological features and size of acanthomorphs (Yin and Gao 1995) from the Precambrian sediments exposed in different regions of China. Variations in genera and their species depend upon the nature and duration of abiotic factors as genes are usually affected by these conditions (Javaux *et al.* 2001).

The obtained low diversity of acritarchs (6-60µm) and low amount of eukaryotic origin substance steranes (chemical fossils) have been reported from the Mesoproterozoic sediments of Bangemall and Roper groups, Australia (Peat *et al.* 1978, Summons *et al.* 1988, Buick & Knoll 1999). The morphologically complex protist fossils are currently unknown from the rocks older than 1650 Ma but leiosphaerid acritarchs occur in succession that stretched back towards the beginning of Proterozoic Eon (Sun & Zhu 1998). The analysis of the recovered acritarchs and available radiometric data suggest ±1200 Ma for Rehatikhol Formation that is the oldest formation of Chhattisgarh Supergroup.

The discovery of planktonic forms (acritarchs) of two subgroups from the oldest formation (Rehatikhol) of Chhattisgarh Supergroup is very significant for Proterozoic eon regarding the evolution of acritarchs, as given in the following new approach.

The phenoptical analysis based on the quantitative analysis and morphological features (shape, size and ornamentation) of recovered acritarchs from the Rehatikhol Formation shows the 2nd filial generation (F2) in present assemblage based on Mendel's law of inheritance because of the short duration of life cycle of these microbiological entities which might be immediately formed new progeny without any alterations in genes by abiotic factors. The evolution of the new progeny is the result of the interplay of many diverse factors (genes). These factors (genes) are themselves subjected to change accordingly. The environmental condition is not a criterion for divergence of organic-walled microfossils (Anabar and Knoll 2002).

It is assumed that the first filial generation (F1) was much older than latest Mesoproterozoic time, which probably started from the earliest Mesoproterozoic. This is a preliminary and new approach, which is being taken up for the first time in the field of Proterozoic micropalaeontology in India for understanding the significance of acritarchs. The present/such type of observation is untouched till today for the organic – walled microfossils in India. The aim of the present paper is to provide such information regarding new approach as taken from the acritarchs based on Mendel's law of inheritance in place of taxonomic description of acritarchs.

The present observation on the recovered acritarchs belonging to Sphaeromorphida and Sphaerohystrichomorphida subgroups suggests that the acanthomorphs were originated much before the Mesoproterozoic in India. So, it is suggested to search the acritarchs from the Palaeoproterozoic and Mesoproterozoic boundary sediments exposed in India.

The challenging problems in acritarch studie are: (i) to ascertain affinities of the acritarchs; (ii) to know the relationship between the spiny acritarchs and dinoflagellate; (iii) to search organic biomarker and isotopic signatures through time; and (iv) to know the differences between acritarchs of shales and cherts through the ages.

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Theme–Interface of Palaeobiology with other disciplines

EVOLUTIONARY TRANSITION OF MAMMALS FROM LAND TO SEA: CURRENT PERSPECTIVE

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Profound ecosystem changes resulting from the gradual shallowing of the Tethys Sea following the initiation of India-Asia collision around 55-60 million years ago, provided sheltered environments, routes for faunal migrations and abundant food resources. These changes are currently under study in the excellent Eocene sedimentary sequences in the Indian subcontinent, extending from the Pakistani sections in Punjab, Baluchistan and NW Frontier Province and the Indian localities in Gujarat and the Lesser Himalayan regions of Himachal Pradesh and Jammu & Kashmir. Major biotic changes associated with the India-Asia collision include the origin and radiation of new mammalian communities in the Indian subcontinent, particularly whales and associated mammals.

The origin of aquatic mammals, particularly cetaceans (whales, dolphins, porpoises), from a four-footed land ancestor is considered to be one of the best examples of biological evolution, and one of the few where macroevolution is documented by fossils. It is also becoming a text-book example of macroevolution. Recent data from India and Pakistan clearly establish this landmass as the centre of origin and early experiments in whale evolution. Research in this remarkable evolutionary transformation is currently in an explosive phase involving multiple lines of evidence, with several new techniques being applied to address new questions. An overview of the recent advances made in this field is presented here, with emphasis on its interdisciplinary nature.

Based on recent fossil finds from India and Pakistan, the outline of the evolutionary transformation of whales has been exposed, and efforts are being made to reach the level of sophistication that allows for a study of the evolutionary processes. Many of the fine patterns and their underlying causes are now being studied, especially for the organ systems that underwent the most striking changes in the transition from land to water, i.e. osmoregulation (saltwater vs. freshwater drinking), balance, hearing, locomotion and feeding. Recent work has clearly shown that the morphological data can provide exceeding valuable information when seen in conjunction with additional, independent lines of evidence, particularly sedimentology, isotope geochemistry and embryology.

Sedimentology is a prime indicator of the changing environment and it is imperative in understanding the physical habitat in which the terrestrial to marine transition took place. Recent data show that many gross morphological and isotopic inferences related to the whale origins need to be evaluated in the context of depositional environments.

Because mammals secrete hydroxyapatite that has an isotopic composition very similar to that of the water and food they ingest, this composition has proved to be a useful tracer of habitat shift. Based on an innovative approach using the stable isotopic ratio of oxygen (O^{18}/O^{16}) as preserved in the enamel of fossilized teeth, it has been possible to trace the origin of saltwater drinking in archaic whales and to document the physiological transition from fresh to salt water in fossil forms. This work has demonstrated for the first time that the Kutch Eocene whales preserve some of the earliest stages in the acquisition of this ability to ingest seawater, an ability that subsequently made these marine animals colonize all of the oceans.

Insight into the balance perspective was gained by studying the semicircular canal, the organ of balance, preserved in the fossilized inner ears of fossil whales. Fossils preserving such delicate structures are extremely rare; hence the CT scanning techniques were used to study the semicircular canals. This work, based on the Indo-Pak Eocene whales as well as a large number of modern mammals, made it possible to understand how whales became capable of aquatic existence by way of acrobatic swimming, as early as approximately 45 million years ago.

Recently, in a very significant study based on the outer and middle ears of fossil whales as well as those of modern mammals, both marine and terrestrial, it has been possible to uncover the evolutionary patterns that took place in the transition of land-based sound transmission to one based on aquatic hearing. The data show that sound transmission mechanisms change early in whale evolution and pass through a stage in which hearing in both air and water is unsophisticated.

One of the most exciting areas of modern evolutionary studies is the rapidly growing field dealing with the interaction of regulatory genes and the evolving organ systems. It is only rarely that developmental patterns can be shown to match the actual (fossil-documented) transitions. Limb loss in whales is such a case, and it has been studied from a developmental perspective. Pilot work, based on the recently acquired series of embryos of a modern dolphin, has shown that it is possible to test the developmental control of genes in the cetacean limb loss. Similar studies integrating palaeontological and embryonic data are also planned for other organ systems.

In addition, fossil data on the earliest representatives of a group provide significant constraints for evaluating the hypotheses proposed by molecular biologists concerning the time of origin of that group on the basis of the modern fauna. The discovery of the oldest known fossil whale (53.5 Ma, from the Indian Himalaya) is a case in point.

In summary, the evolutionary transition of mammals from land to sea is documented in a rigorous phylogenetic context in the Eocene fossil record of the Indian subcontinent. It is a dynamic field of research, which represents a model system for understanding the patterns, and processes that underlie a macroevolutionary phenomenon in response to a profound tectonic event.

Theme–Interface of Palaeobiology with other disciplines

IMPORTANCE OF ULTRASTRUCTURAL STUDIES IN PALAEOBOTANY

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In continuing quest to explore structure of an organism or its various organs at a very high resolution and to relate the structural organization to functional significance, electron microscopy is now a relatively routine research tool in most areas of palaeobotany. The electron microscopes allow observations at real magnifications which are up to a couple of hundred times that of light microscope, and thus have proved to be very potent tools for ultrastructural and micro-morphological studies. A combination of light microscopy (LM) with scanning electron microscopy (SEM) and transmission electron microscopy (TEM) is often most informative in the study of palynofossils and fossil cuticles, as well as fruiting bodies. Digitally captured images can now be stored on a zip disk or on compact disc, printed on conventional laser jet printers or dye-sublimation printer (for photographic quality prints), and shared with researchers through the Internet.

In recent years palaeobiological studies have developed into a technically advanced and intellectually attractive field, with ramifications applicable to phylogeny, evolution, taphonomy and palaeoclimate. Often surface details, which can be seen only through SEM, provide evidence of taphonomic processes. For example, eroded micro-topography or scratches indicate transport in an abrasive context. Electron probe microanalysis (EPMA) done on the SEM is a non-destructive technique used to map the distribution of elements present in the fossil. Analytical TEMicroscopy works on a similar principle and has the ability to derive chemical and crystallographic data from extremely small samples. TEM and SEM analyses of acritarchs in Mesoproterozoic shales show promise for elucidating eukaryotic cell wall ultrastructure in ancient samples if the results could be verified from comparisons with modem analogues. However, there are technical challenges in imaging modem microbes by conventional electron microscopy. Using environmental SEM (which allows high resolution imaging of uncoated, delicate and hydrated samples) fresh microbial cultures can be imaged directly and then surface morphology can be compared with that of the fossil microbes. Using this tool, role of taphonomical factors in alterations in an organism, or an organ, or a layer, at ultrastructural level can be assessed with a very high degree of confidence. For example, some acritarchs possess a similar reticulate texture, which has been recognized as a taxonomic feature. Micro-morphological studies on the other hand suggest that this texture could be a result of digenetic processes, such as, compaction or desiccation, and hence may not be a taxonomic feature. One may also study the role of bacteria in conversion of structured mass to unstructured one and its capabilities to act with various minerals in the sediment. Small fossilised cyanobacteria (single-celled, sometimes organized in colonies - prokaryotes, which lack internal organelles, a discrete nucleus and the histone proteins) have been extracted from Precambrian rocks and studied through the use of SEM and TEM.

The investigation of ultrastructure of fossil spores and pollen provides information, hitherto unavailable, about the biology and evolution of past biota. Ultrastructural investigation of fossil spores and pollen reveals important proxy records of structure useful for deciding functional relationships by comparison with modem analogues. Supplementary data from ultrastructural studies can help to resolve a number of problems concerning the interpretation of morphology of fossil spores and pollen, and provide new significant data about the systematics, development and biology of fossil spores and pollen. For example, ultrastructural studies show that the surface sculpture of Jurassic cycad *Androstrobus szei* strikingly resembles that of *Ginkgo biloba,* a resemblance considered to be homoplasious. SEM study has shown that the spore walls have a colloidal crystal organization, and that self-assembly is a key element in spore wall development. The presence of tapetal membranes in association with orbicules as observed in the TEM study of Mesozoic pollen *Classopollis* has demonstrated the developmental pattern of the final wall ornament of the pollen wall. Ultrastructural studies of spore-containing plant fragments from Late Ordovician rocks of Oman have shown that these represent earliest bona fide land plants, of liverwort affinities.

The cuticle, a continuous extra-cellular membrane, plays the important protective role, and shows considerable variations in its thickness, degree of development and chemical composition between different species. It is highly resistant to chemical or physical degradation and is often fossilised. Most of the features that appear in extant plant cuticles also can be found in fossil cuticles. Studies of fine structure of fossil cuticles can be directed at determining the degree of cuticle preservation, organization of structural components, and as a character in interpreting the physical environment in which the organisms lived and thrived. For example, the epidermis of xerophytic plants may consist of very thick, cutinised outer walls, deeply sunken stomata, and a dense layer of trichomes. The structure and function of these xeromorphic features may be studied with electron microscopes. A recent study of sun and shade leaves of the Jurassic leaf *Komlopteris nordenskioeldii* has revealed four distinguishable categories of cuticle, according to their thickness; sun upper, sun lower, shade upper and shade lower. In addition, cuticle ultrastructure may also be important as a taxonomic feature. Cuticle micro-morphology of fossil *Gingko* leaves is quite similar to that of modern *Ginkgo* leaves, yet the chemistry is drastically altered. Specimens, which cannot be coated (e.g. type specimens), can be imaged using low vacuum SEM, though the resolution of this device is presently limited to x500 - x1000 magnifications. Ultrastructural studies of fossil plant cuticle may also reveal the presence of delicate structures such as infection pegs formed as a result of fungal infection or changes in the ultrastructure of the cuticle proper due to fungal infection. In the cuticle of *Rhizophora* a cork-wart structure has been identified, which is interpreted as modification of stomata for exudation of excess salt to balance the physiology of the plant. One of the most exciting examples of the importance of ultrastructural studies of fossil plants is the report of grana stacks, starch deposits, nuclei and plasmodesmata in a Miocene leaf.

SEM study of Late Cretaceous fusainised angiosperm flowers has enabled most of these to be identified in terms of modern orders and families, thus greatly improving our knowledge of angiosperm evolution and, radiation. SEM study of fossil charcoals (fusain) has revealed the past role of wildfire and ancient fire-prone plant communities. Charcoal is formed commonly under natural conditions when vegetal matter is heated in oxygen-depleted conditions during wildfire, and is abundant in the fossil record, archaeological sites and recent sediments.

OVERHAULING OF THE PALAEONTOLOGY SYLLABUS: SOME COMMENTS

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In technologically advanced countries, career in palaeontology is considered academically profitable and challenging. This is not true for Indian institutions of learning. The root cause is the continuation of an obsolete method of teaching and taking undue pride for an age-old syllabus, which most of us followed in early sixties of the last century. Geology syllabus, and in particular the palaeontology syllabus in most Indian universities have not been revised for three decades or more. A few years ago, a committee of University Grants Commission proposed a model syllabus for our universities, taking into account the differing standards of teaching in different parts of the country. This syllabus was whole heartedly adopted by some, while most universities rejected it outright, without suggesting an alternative. But, this made the ball rolling. The purpose of presenting a 'model syllabus' was to start a healthy discussion. And discussion did start, with several notes of dissent, without any consent for preparing a new document. Most of these institutions felt that there is no need for a change. Most 'teachers' failed to keep pace with the modern developments in their subject field, hence remained reluctant to introduce new topics in their syllabi. Topics like modes and methods of fossil preservation, distribution of major taxa and species in different continents and their time significance, should be relegated to general science school curriculum and should be read and understood by every one. No B.Sc. level geoscience course should have any of these topics as part of their syllabus. Similarly, entire systematic identification of major genera and species should be completed in the undergraduate level without extending it to the Master's course. In recent years, modern courses in animal and plant sciences have been drastically modified with total emphasis on molecular and nano-aspects of organic life. Keeping tune with this trend, modern geobiological course should place emphasis on these molecular aspects and evolve a suitable syllabus which will equip our M.Sc. level students to understand complex nuances of organic life, their origin, their destruction, their preservation in the rock records and their utility in understanding the history of the earth.

This is a challenge for all practising palaeontologists of the country. I will be watching the development as a bystander.

FATE OF ORGANIC LIFE: DROWNING IN THE SEDIMENTARY RESERVOIR

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There is a general agreement that the life processes are characterized by their preferential interactions amongst a selected suite of elements like C, O, H, N, S, P with some discreet functional structures representing their morphological expressions with inherent capability of proliferation by means of identical reproduction. Given suitable condition in their sedimentary burial grounds, dead organisms leave fossilized record in sedimentary rocks which tend to withstand the onslaught of time and persevere through billions of years until tectonically or metamorphically obliterated or destroyed. Incorporation of key elements mentioned above in the living system or biochemical processing in the widest sense entails sizable isotopic fractionation as a result of thermodynamic and kinetic effects imposed on the principal metabolic pathways. Through encoding a wealth of palaeontological and biochemical evidence, sediments are a highly selective store of palaeobiological data which is particularly true for Precambrian times, dominated by microbial biosphere of mostly prokaryotic affiliations with low preservation potential. In spite of its inherent shortcomings, the sedimentary record constitutes the sole source of empirical evidence related to the origin and evolution of the biosphere.

After initial burial of the organism, subsequent geological conditions should be capable of preserving it within closed physico-chemical system. These depend upon the kind of rock in which the material was originally entombed. Impervious, non-porous rocks reveal a better preservation of the organisms and the organic derived matter and are liable to less alteration. The organic matter originally available for preservation in the sediments varies for several reasons. These include, the nature and source of original organic matter, the degree of autochthonous versus allochthonous material admitted in a particular environment, the extent of degradation and the physico-chemical and biological milieu at the site of preservation.

Palaeontologists *per-se* study various aspects of the biosphere including its changing modes, on the basis of morphologically preserved fossils. On the other hand, sedimentologists interested in the evolution of the biosphere not only make use of these direct, mega and microscopically observable proxies of life, but also make reading of the chemical records of life whose principal information is stored in the reduced carbon constituents of the sedimentary rocks. Long ago, Lord Byron pronounced that ‘the Dust we tread upon was once Alive’. This philosophical paradigm finely reflects the omnipresence of a vast reservoir of reduced carbon in the sedimentary records, reflecting the end product of the life process. Fossil manifestations of benthic microbial ecosystems date back to some 3.5 Ga ago but the isotopic fingerprinting of autotrophic carbon fixation extends beyond this time. Since the manifestations of biologically mediated geochemical activity are preserved in sediments, the respective features were propagated into the rock section of the geochemical cycle which allowed them to be traced into the geological past. It is now common knowledge that the oxidized carbon is recorded as carbonate rocks while the reduced carbon occurs in various forms. The commonest amongst these is the kerogen, which is the acid insoluble, polycondensed end product of digenetic alteration of organic substance. It is produced as a result of carbon fixation by one of prime, life sustaining activities of the living bacteria and green plants called photosynthesis.

When organic constituent is preserved in the sedimentary record, biological isotope fractionations are basically retained and the effects are reflected in the rocks where they leave their signatures on the crustal inventories of the respective elements mainly in the case of carbon and sulphur. Continuous biological processing of these two elements is responsible for the characteristic duality of their fluxes into the crust caused by photosynthetic carbon fixation and bacterial sulphate reduction, leading to crustal depositories of organic carbon and bacteriogenic sulphide.

Association of organically derived sediments with metallic and non-metallic minerals has been studied in almost all the continents. A vast majority of economically exploitable deposits have been linked either directly to specific group of organisms or organic matter produced directly or indirectly by organic activity. Well known associations of prokaryotes and bacteria with the palaeoproterozoic Witwatersrand gold in S. Africa, iron ore in parts of Orissa and regions near Noamandi, Kudremukh iron ore in Dharwar are some key examples of organism-metal association. Non-metallic mineral deposits of stromatolitic phosphorite, layered magnesite and evaporites have several examples all over the world which show well documented links with the organic matter, quite often directly derived from the inter-layered autochthonous as well as allochthonous fossil debris. Peat, coal and petroleum source rocks and humus in the modern and ancient soils are perhaps the most undisputed examples of sediment- organism interactions.

Theme–Integrated approaches to Palaeobiology and Sedimentology

MICROBIALLY ORIGINATED BLACK SHALE IN PALAEOPROTEROZOIC KAJRAHAT FORMATION AND ITS SIGNIFICANCE

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Microbe-sediment interaction is well documented from Proterozoic carbonates. Microbial mat influence has been documented in recent years from modern siliciclastics and attempt has been made to search microbially originated features in Proterozoic siliciclastic record. Microbial mat features are relatively easier to recognize in Proterozoic sandstones as the features are mesoscopic in nature. In contrast, the microbial features are mostly microscopic to sub-microscopic in scale in Proterozoic shales. Microbial filaments are rarely preserved in siliciclastics as the original microbial cover gets decomposed during diagenesis. Indirect evidences, however, can be used to infer the microbial mediation in Proterozoic shales.

The Palaeoproterozoic Kajrahat Formation of the Vindhyan Supergroup is dominantly shelf-originated and characterized by a thin (up to 12 m) black shale horizon in its type area near Kajrahat which overlies the Arangi Shale and passes upward to Kajrahat Limestone. Organic-rich black shales (TOC up to 3.1%) are used to alternate with thin beds (2-10 cm) of dolomite. Black shales exhibit conspicuous wavy and crinkly laminated microfabric defined by the carbonaceous laminae alternating with submilimeter-scale clayey laminae. Pyrite grains are used to follow the wavy carbonaceous laminae. Proportion of carbonaceous and clayey laminae within the shales may vary causing different types of microfabric. Quartz silts are found to be sprinkled through the carbonaceous laminae whereas alternating clay laminae are devoid of quartz grains. Size and proportion of the quartz silts may be highly variable within the shales. Clusters of quartz silts are occasionally found within the black shale. At places, the carbonaceous laminae are found folded and contorted. Wavy and crinkly, pyriteferous carbonaceous laminae are suggestive of microbial mat growth. The wavy laminated fabric is a typical feature of microbially originated shelfal Proterozoic black shale. In contrast, the Phanerozoic black shale exhibits planar laminated fabric and represents deep basinal product. Variable amount of quartz silts within the black shale possibly represents trapping and binding actions by microbial filaments. Cohesive behavior of such shale is reflected by the folded and contorted appearance of the carbonaceous laminae at places. Sticky nature of the microbial cover possibly created the aggregated quartz clusters. The black shale horizon of the Kajrahat Formation, thus, appears to be microbially originated like many other contemporaneous organic-rich shales. Curtailment of siliciclastic is a prerequisite for prolific microbial mat growth. The overall depositional scenario identifies the black shale horizon as a possible condensed zone deposit which can be considered as a key sequence stratigraphic element within the Vindhyan sedimentary succession.

MESOZOIC MEGAFLORA: EVOLUTION, DIVERSIFICATION AND EXTINCTION

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Mesozoic flora, spanning over the period of 249 Ma to 65 Ma, shows gymnosprmous predominance throughout the globe. It comprises two distinct floras in peninsular India: (i) Triassic flora, which flourished from 249 Ma to 199 Ma and had pteridosperm dominance; and (ii) Jurassic-Cretaceous flora (199 Ma to 65 Ma) dominated by cycadophytes and conifers. Three major floral changes have been observed during the entire Mesozoic Era. The first, during the Triassic, has been marked by the decline of Glossopteris flora and gradual emergence of Dicroidium flora, i.e. appearance of Corystospermales and Peltaspermales. The second change in flora is observed with the decline of Dicroidium flora and appearance of Ptilophyllum flora, i.e. emergence of Bennettitales, Caytoniales and Pentoxylales. The third and the most significant change is the appearance of angiosperms in the Early Cretaceous and gradual disappearance of Ptilophyllum flora. Megafloral change during the Mesozoic Era is quite interesting because it shows extinction of three major plant groups, i.e. Pteridospermales, Bennettitales and Pentoxylales and also appearance of Corystospermales, Peltaspermales, Caytoniales, Bennettitales, Pentoxylales and angiosperms.

Triassic flora of India is characterized by the predominance of pteridosperms comprising mainly two families, i.e. Corystospermaceae and Peltaspermaceae. The family Corystospermaceae is represented by *Dicroidium, Xylopteris* and *Pteruchus,* whereas Peltaspermaceae is represented by *Lepidopteris.* Detailed systematic study of various assemblages identified the presence of major plant groups, viz. Phycophyta, Bryophyta, Pteridophyta, Pteridospermophyta, Cycadophyta, Ginkgophyta and Coniferophyta.

Various Triassic megafloral assemblages, identified from India, have been recorded from: (i) Nonia Nala and Neel Factory region, Raniganj Coalfield, West Bengal (Lower Triassic); (ii) Deobar and Tubed, Auranga Coalfield, Bihar (Lower Triassic); (iii) Ledhonala and Karamdiha, Ramkola-Tatapani Coalfield, Madhya Pradesh (Lower Triassic); (iv) Daigaon, Karkati and Salaia, South Rewa Basin (Lower Triassic); (v) Sarimunda Pahar, Talcher Coalfield, Orissa (Lower Triassic); (vi) Nidpur, Sidhi District, Madhya Pradesh (Middle-Upper Triassic); (vii) Pathargarh, Talcher Coalfield, Orissa (Upper Triassic); (viii) Ghiar and Harai, Shahdol District, Madhya Pradesh (Upper Triassic); and (ix) Kamtadand, Parsora, Beli and Chicharia, South Rewa, Madhya Pradesh (Triassic – Rhaetic).

Comprehensive study shows that the onset of *Dicroidium* - an index genus of Triassic flora, was in the later phase of Early Triassic, it proliferated and diversified in the Middle-Upper Triassic and declined in the Upper Triassic-Rhaetic. Significant genera of the Indian Triassic flora are - *Dicroidium, Lepidopteris, Pteruchus, Xylopteris, Yabiella, Sphenobaiera, Baiera, Sidhiphyllites, Elatocladus, Desmiophyllum* and some fructifications, viz. *Bosea, Nidia, Nidistrobus, Satsangia* and *Nidhpuria.* However, exact affinity of some of the taxa needs confirmation.

The Jurassic-Cretaceous flora flourished from 199 Ma to 65 Ma and is dominated by cycadophytes, followed by conifers. Pteridophytes are the most diversified group during this period. In the peninsular India, Jurassic was a period of non-deposition for fresh water deposits except in a few areas such as

Dubrajpur Formation (partly Late Jurassic) in the Rajmahal Basin, Jhuran Formation (Late Jurassic) in Kutch Basin, Hartala Formation (Early Jurassic) in South Rewa Basin and Kota Formation (Middle Jurassic) in Pranhita- Godavari Basin. The Early Cretaceous flora recorded from various localities in India is cited below:

1. Early Cretaceous flora of East Coast: (a) Athgarh, Cuttack District, Orissa, Mahanadi Basin; (b) Gollapalli, Raghvapuram, Ellore District and Vemavaram, Ongole District, Andhra Pradesh, Krishna-Godavari Basin; (c) Sripurumbudur, Chingleput District, and Satyavedu, Ramnad District, Tamil Nadu, Palar Basin; (d) Shivaganga, Tamil Nadu, Cauvery Basin; and (e) Gangapur, Adilabad District, Andhra Pradesh, Pranhita Godavari Basin.

2. Early Cretaceous flora of Rajmahal Basin, Jharkhand.

3. Early Cretaceous flora of Seoni – Malwa, Hoshangabad District, Sehora and Imjihri, Narsinghpur District, Chui Hill, Jabalpur District, Bansa, Chandia and Patparha Shahdol District, Satpura and South Rewa Basin, Madhya Pradesh.

4. Early Cretaceous flora of Kachchh Basin, Gujarat.

5. Early Cretaceous flora of Kathiawar Basin, Gujarat.

6. Early Cretaceous flora of Cambay Basin, Gujarat.

7. Early Cretaceous flora of Himmatnagar Sandstone, Sabarkantha District.

8. Early Cretaceous flora of Habur, Jaisalmer District and Sarnu, Barmer District, Rajasthan.

9. Late Cretaceous flora of Dongargaon, Chandrapur District, Maharashtra.

The Late Jurassic-Early Cretaceous flora comprises various groups of plant remains belonging to algae, bryophyta, pteridophyta (comprising fossil remains of Equisetaceae, Selaginellaceae, Isoetaceae, Marattiaceae, Osmundaceae, Matoniaceae, Weichseliaceae, Dipteridaceae, Aspidiaceae, Cyatheaceae, Dicksoniaceae, Dennstaediaceae, Gleicheniaceae, Schizaeaceae, Azollaceae and Marseliaceae), pteridosperms (Caytoniaceae and Corystospermaceae), Cycadophyta, Ginkgophyta, Pentoxyleae and conifers (mainly Araucariaceae and Podocarpaceae). The Early Cretaceous flora in India is well diversified and marked by the presence of certain significant taxa, viz. *Weichselia, Onychiopsis, Ruffordia, Matonidium, Phyllopteroides, Gleichenia, Sagenopteris, Nipaniophyllum, Pachypteris, Cycadopteris, Allocladus,* etc.

Detailed analysis of the Early Cretaceous floral assemblages recovered from various deposits indicates that pteridophytes were well diversified group during this period. Almost all the modern families of ferns were evolved during this period. Amongst Filicales, Weichseliaceae disappeared in the Late Cretaceous, while amongst Gymnosperms, Pteridospermales, Bennettitales and Pentoxylales gradually disappeared from the scenario. However, conifers diversified and were mainly represented by Araucariaceae and Podocarpaceae, which continued up till now. Angiosperm is the most significant and advanced group of modern flora evolved during the Early Cretaceous Period and radiated during the Cenozoic in India.

Extensive study and analysis of the Early Cretaceous flora indicated that shift in floral vegetation is primarily dependent upon the environmental factors (mainly climate), which is well reflected by the compositional changes of the different plant groups. On the other hand, the change due to secondary factors, i.e. local ecological factors, is also depicted by change of the community structures of vegetation in space. However, the preservation of plant parts and recovery of the fossils also depend upon environment of deposition.

PROXIES AND METHODS FOR RECONSTRUCTING GLACIAL AND CLIMATIC HISTORY OF ANTARCTICA SINCE LGM

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Polar regions are the integral component of the Earth System and are linked to global climate system, sea level, biogeochemical cycles & marine ecosystems. The interplay of the ocean, atmosphere and the cryosphere in the polar region makes this region key in producing 'rapid' climatic change. It is one of the best climatic archives of the past and future with terrestrial sediments, polar ice covering the last 0.2 million years and marine sediments covering millions of years and even older areas of ancient continental rocks. Coal beds and plant fossils were reported in the trans-antarctic mountain by Shakleton and Scott, which clearly indicates that the Antarctica was not always covered with ice. After its final detachment from Australia, about 40 my ago, Antarctica settled into its present polar position and began to cool dramatically.

Climate changes have a significant effect on periglacial regions in front of the large inland ice masses of Antarctica and Greenland. As a consequence, information on environmental changes during the recent history of the earth is stored in the deposits found there. The terrestrial and lacustrine deposits like moss bank, lake sediments, microbial mats, algal flakes, glacial clay varves are valuable source of palaeoenvironmental data. The age control on glacial and climatic events since the LGM in Antarctica is primarily through radiocarbon dating (C^{14}, AMS). Both marine and terrestrial/lacustrine material often yield ages that appear too old in comparison with the conventional terrestrial based radiocarbon time scale. A requirement for understanding the dynamics of the Antarctic glacial system is to have a reliable chronology for both terrestrial and marine materials as there are also a number of sources of contamination when dating bulk sediments, microbial mats, aquatic mosses from Antarctic lake basins, often resulting in ages that are too old.

Long Antarctic ice core provides long, low resolution proxy records of ice volume changes for the past 0.45 million years and inferred information on summer temperatures and ice thickness. The long Vostok record shows a strong correlation with the global isotopic records and has been taken to indicate strong linkage between northern and southern hemisphere ice sheets. There are, however, large discrepancies between late Quaternary glacial and climate history as reconstructed from geological evidence from coastal terrestrial or offshore records and ice core records. The summary focuses on the stratigraphical terrestrial and offshore geological record as the most reliable proxies for the glacial history of Antarctica. It also gives a unique access to the past concentration of a wide range of atmospheric parameters like trace gasses, soluble / insoluble aerosols, volcanic compounds trapped in the ice. Study of stable isotopes is also useful for various palaeoconditions, viz. ä ^{18}O provides indication of palaeotemperature, ä ^{11}B preserves palaeo pH, ä ^{13}C derives dissolved inorganic carbon and Cd/ Ca ratios provide palaeoproductivity.

Most studies suggest that the LGM ice was considerably thicker and more extensive than present during the LGM, with ice extending off the present shore around most of Antarctica. Some minor coastal areas may have remained wholly or partly ice-free. LGM ice extended onto the mid to outer shelf areas off western Antarctica, Antarctic peninsula and in the Ross Sea. In East Antarctica, the LGM ice reached its maximum extent at mid shelf positions in some areas, whereas, in other areas it only expanded less than that. The age of the last circum Antarctic maximum extent of ice is poorly constrained by radiocarbon dates that broadly range between 24-14 ka BP, and there is data suggesting that there might have been an earlier glacial event of considerably more extensive glaciation onto the continental shelf areas. However, reconstruction of the glacial and climatic history of Antarctica since the LGM is hampered by the scarcity of available archives, low resolution in many datasets and chronological problems. Therefore, any synthesis must be regarded as a tentative description of the environmental development.

Fossil pollen evidence, supported by many radiocarbon dates, indicates that the severe maximum of the last glaciation or its final stages occurred broadly at the same time at such widely separated sites as Marian Island, the Argentine basin, southern and tropical South America, central and east Africa and Europe. Then the definite amelioration of the climate, which marked the end of the post glacial in Europe, sets in the southern hemisphere at about 10000 years BP but at ±12000 years BP in the Argentine basin, ±12500 years BP at Marian Island and ±14000 years BP in New Zealand. In retrospect it is evident that the Quaternary climate had a profound influence on the biogeography of the entire Antarctic land, the surrounding oceans and continents as well. Despite all these, it is still debating the relative role of biogeographical and ecological factors in determining distribution in the southern hemisphere. More fossil and genetic data is needed and catching the organisms in the act of dispersal is most valuable.

QUATERNARY PALYNOLOGICAL SCENARIO OF INDIA AND ITS FUTURE PERSPECTIVE

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Duly considering the limitations and shortcomings, palynological data has now been accepted as an established proxy record for the palaeoenvironmental and palaeoclimatic reconstruction during Quaternary. In India, pollen analytical studies were started in the early part of nineteenth century and first site was explored from Kashmir. These pioneer analyses and several subsequent studies established the potentiality of this tool in palaeoclimatic and palaeoenvironmental reconstructions in the tropical region. These earlier studies though brought out significant contributions but lacked fixed chronology, as these were not supported by absolute dates. With the progress of palynology and with additional support of absolute dates, application of this proxy data towards palaeoclimatic analyses got expanded. A good amount of information has now accrued with high temporal and spatial coverage, i.e. covering almost entire Quaternary; and extending from Himalayas (western, central and eastern) at the north to Thar Desert, Ganga plains, peninsular region, and oceanic sediments, both from Bay of Bengal and Arabian Sea to the south. These analyses have brought out a synoptical glimpse of climatic scenario of India especially changes in temperature and precipitation as broader aspect, i.e. in terms of cool/warm or moist/dry. In spite of large number of studies made, the available climatic reconstruction especially from the continental sediments is not sufficient to understand climatic changes covering major time span of Pleistocene and Holocene even in time resolution of 1000 years. It has been recorded that in correlation of these reconstructed climatic data there is coherence in climatic variability in longer time scale but such comparisons may be out of phase in shorter timescale in many sites. These discrepancies in correlations have been recorded in some studies even in local scale. This temporal non-synchronity of climatic changes recorded in these studies may be due to several reasons. One possibility may be the validity of dates which got interpolated; there are many cases with one radiocarbon date in the profile and the rest dates were extrapolated ignoring the sedimentary sequence. Moreover the C^{14} dates used in many studies have not only large error range but also even may be erroneous due to hard water effect. Further, interpretation of fossil pollen spectra in the pollen diagrams in terms of extant vegetation needs extensive supportive evidences, which are often ignored. In most palynological studies climate considered to be the only controlling factor of the change of vegetational history and the role of other factors like amount of rainfall, quantum of rainfall, anthropogenic effects, some natural calamities like forest fire, earthquake, pest, etc. have been overlooked, due to which we only have a generalized record of palaeo-events and a gap in our present knowledge of past climate exists. So, towards the better understanding of the past global climatic scenario a multi-disciplinary approach in the analysis of pollen is felt necessary. With the synergistic approach and climate modeling techniques it could be used as a very reliable tool for the resolving climate during glacial/interglacial changes, sea level changes, monsoon dynamics etc. The most important task to be researched through palynology would be the understanding of monsoon dynamics and its teleconnections to other climatic phenomena. To understand this, long, high resolution climatic records, based on pollen in both temporal and spatial scale, will be of great importance from the both continental and marine sediments. However to achieve these objectives proper sampling strategies, site selection and precise dating controls (AMS C^{14} dates) are essential.

INDIAN FOSSIL MONOCOTYLEDONS: CURRENT STATUS, RECENT DEVELOPMENTS AND FUTURE DIRECTIONS

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Monocotyledons, comprising about 25% of the angiosperms, include 112 families and about 59,300 species. The record of fossil monocotyledons is very meagre in comparison to the number of extant members and also to the dicotyledons. They are preserved as permineralizations, impressions and compressions and are assigned about 20 families, viz. Agavaceae, Alismataceae, Amaryllidaceae, Araceae, Arecaceae, Commelinaceae, Cyperaceae, Dracaenaceae, Hydrocharitaceae, Juncaceae, Juncaginaceae, Liliaceae, Najadaceae, Pandanaceae, Poaceae, Potamogetonaceae, Scitamineae (Cannaceae, Heliconiaceae, Musaceae, Strelitziaceae, Zingiberaceae), Smilacaceae, Sparganiaceae, Typhaceae and Xyridaceae. Of these, only four families extend back to the pre-Cretaceous horizons. *Sanminguelia lewisi, Alismaphyllum victor-masoni* Berry and *Propalmophyllum liasimum* Lignier are the leaves and others are pollen grains. The poor record of monocots may be because majority of them are herbaceous plants which do not readily get preserved. However, the Deccan lntertrappean flora (Maastrichtian) is very rich in monocotyledonous remains along with the dicots in comparison with the other Cretaceous or early Tertiary horizons. In India, the monocotyledons are dominated by Arecaceae followed by Scitamineae, Poaceae, Araceae, Liliaceae, Cyperaceae, Agavaceae and Pandanaceae. Palms, dominating the monocotyledonous fossil flora, are represented by organ genera for stem, root, leaf, inflorescence axis, rachilla, flower, fruit, seed and pollen grains. Permineralized palm stems have been assigned to the form genus *Palmoxylon* Schenk with about 200 species throughout the world, including more than 60 species from India. It might comprise many natural genera of palms as Palmae is a very large family comprising about 212 genera and 2800 species of woody plants distributed in 5 subfamilies living today. The species of *Pa1moxylon* are created on the basis of highly variable characters such as form and distribution of fibrovascular bundles, type of bundle sheath (sclerenchyma), number of metaxylem vessels, structure of vessel endplate, size and shape of phloem, presence of fibre bundles, nature of ground tissue, etc. Some of these characters are highly variable even within the genus and hence are of little taxonomic importance. Moreover, the petrified stem fragments representing to outer or inner region, basal or apical region exhibit variations in these characters resulting into creation of large number of *Palmoxylon* species. Some of them could be other woody monocots belonging to the families Pandanaceae, Scitamineae, Araceae, Agavaceae, Poaceae, Cyperaceae, Velloziaceae and Boryaceae. Knowledge of external morphology and anatomy of these members is required for the resolution of the artificial organ genera erected for the stem, petiole or inflorescence axis. In order to understand the diversification of monocotyledonous flora utmost care is required to be taken, especially during the field work to look for entire herbaceous plants or woody baby plants comprising roots, stem, leaves, inflorescence, flowers, infructescence, fruits and seeds in organic connections or the flowering and fruiting organs as they are highly conservative in their characters and hence taxonomically more reliable for phylogenetic and environmental interpretations.

The significant elements include *Palmoxylon (Cocos) sundaram* Sahni which is the first reconstruction of a 4.5 metre tall trunk with aerial stem and rooting region comparable to coconut palm. *Mahabalea* *phytelephasii* Bonde is a 15 cm tall permineralized juvenile palm axis with roots, short obconical stem crowned with a rosette of leaves in trimerous phyllotaxy suggesting its affinity with *Phytelephas* restricted now to northern South America whereas *Appamahabalea uhli* Bonde is a 46 cm tall matured soboliferous acaulescent phoenicoid palm. *Sabalocaulon* Trivedi & Verma, *Parapalmocaulon* Bonde, *Phoenicicaulon* are petioles; *Amesoneuron borassoides* Bonde, *Palmacites khariensis* Lakhanpal *et al., Sabalites microphylla* Sahni, *Livistona wadiai* Lakhanpal & Guleria are leaves; *Sabalophyllum livistonoides* Bonde, *Palmostroboxylon* Biradar & Bonde are inflorescence axis; *Arecoideostrobus* Bonde is a rachilla; and *Cocos sahnii* Kaul, *Hyphaeneocarpon* Bande *et al., Nypa hindi* Sahni, *N. sahnii* Lakhanpal, *Eugeissonocarpon* Shinde & Kulkarni, *Arecoidocarpon* Bonde are fruits. *Deccananthus savitrii* Chitaley & Kate is a flower comparable to that of Palmae. The reconstruction of *Cyclanthodendron sahnii* Sahni & Surange indicates it as a soboliferous monocotyledonous plant suggesting its affinity with Scitamineae than Arecaceae, Pandanaceae, Cyclanthaceae or Araceae. The combination of the characters of Strelitziaceae, Heliconiaceae and Musaceae suggests its Proto-Scitaminean ancestry. *Musophyllum indicum* Prakash *et al.* is a musaceous leaf whereas *Cannaites intertrappea* Trivedi & Verma is a pseudostem of *Canna. Musa cardiosperma* Jain is a triangular multi seeded syncarpous berry comparable to the seeded banana fruit. *Pandanaceoxylon kulkarnii* Patil & Datar is a rhizome, *Pandanas eocenicus* Guleria & Lakhanpal is a leaf and *Pandanusocarpon umariense* Bonde is a fruit of Pandanaceae. *Rhodospathodendron tomlinsonii* Bonde is a viny aerial axis resembling extant *Rhodosaptha* of Araceae. *Viracarpon* Sahni is a infructescence of uncertain affinities probably belonging to Araceae. *Glycerioxylon mohgaoensis* Trivedi & Bajpai is a culm comparable to that of *Glyceria, Festrucophyllites intertrappeanse* Patil & Singh and *Elymus deccanensis* Patil & Singh are the pseudostems comparable to hydrophytic member *Festucaovina* and *Elymus* respectively, *Culmites eleusineoides* Bonde is a gramineous stem with thin culm, swollen node and dormant bud comparable to *Eleusine* and *Gramineocarpon mohgaoense* Chitaley & Sheikh are the caryopsis type of gramineous grains, *Cyperaceoxylon intertrappeum* Chitaley & Patel is a cyperaceous axis with stem, roots and leafsheaths where as *Scirpusoxylon indicum* Shete is a rhizome comparable to *Scirpus. Eriospernlocormus indicus* Bonde is the first record of a monocotyledonous corm comparable to *Eriospermum* of Liliaceae. The family is also represented by the inflorescence with inaperturate, monosulcate to trichotomonosulcate pollen grains resembling fossil pollen grains *Matanomadhiasulcites. Monocotylostrobus bracteatus* Lakhanpal *et al.* is a inflorescence showing its resemblance with Liliaceae and Arecaceae. *Neyvelia awasthii* Reddy is a monocot axis comparable to *Dracaena* of Agavaceae. The fossils assigned to Amaryllidaceae, Juncaginaceae, Typhaceae, Sparganiaceae, Smilacaceae and Xyridaceae need reinvestigations for their affinities with the extant members.

Theme–Emerging Trends in Palaeobiology, Session D–Proxies and parameters in Palaeoclimate assessments

CARBON ISOTOPIC COMPOSITIONS OF COMPRESSION FOSSIL FROM THE CRETACEOUS SEDIMENT OF BHUJ FORMATIONS, GUJARAT.

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Stable carbon isotope analysis of fossil leaves from the Bhuj Formation exposed on the northern bank of Korawadi river section near Dharesi, Gujarat was carried out to explore its potential for studying the prevailing environmental conditions. Some compression fossil leaves, such as *Ptilophyllum* sp., *Dictyozamites* sp. were retrieved from Bhuj Formation (Aptian). Isotopic analysis was carried out on different parts of these leaves to infer the isotopic variability along the length of the leaf. The overall variability shows a mean value of -24.58 ±0.38‰. The pattern of the variation implies that there is no systematic change along the leaf axis or between the above mentioned two genera. The carbon isotopic compositions are likely to be controlled by the carbon isotopic values of atmospheric CO_2 and high O_2 levels during the Cretaceous, organic constituent of the plant fossil and environmental parameters, such as salinity, temperature, etc. With limited analysis, it is difficult to identify the causes that are responsible for such kind of ä^{13}C values. However, these values match with that of a fossil plant collected from the Flat Rocks of the same age (Aptian) in southeastern Australia (Grocke 1998). This most probably implies that the isotopic composition of these extinct plant fossils from this area is well preserved and could be used to investigate the environmental conditions during the Cretaceous. The stomatal index measured for this fossil plant (~22) appears to be higher relative to other plant fossils that were available during this time (Royer *et al.* 2001). More work is warranted to ascertain these values and investigate their relationship with the CO_2 partial pressure.

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Theme–Interface of Palaeobiology with other disciplines

SHIVA IMPACT, DECCAN VOLCANISM, AND DINOSAUR EXTINCTION AT THE CRETACEOUS-TERTIARY BOUNDARY, INDIA

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Considerable evidence exists for a giant asteroid impact on the Mumbai offshore Basin on the western shelf of India. The Shiva crater is largely submerged on the passive continental shelf and is buried by 7 km thick strata of post-impact Cenozoic sediments. It is the largest impact crater known on the Earth, about 500 km in diameter and a rich source of oil and gas. It has the morphology of a complex peak ring structure with a multiring basin. Four different ring structures have been identified, where the inner peak ring represents the central uplift of the Bombay High Area with a core of Neoproterozoic granite. We speculate that the Shiva bolide (~40 km diameter) crashed obliquely on the western continental shelf of India around 65 Ma, excavating the crater, shattering the lithosphere, initiated the rifting between India and the Seychelles and caused the sudden northward acceleration of the Indian plate in the early Tertiary. The K/T boundary sections of India have yielded several cosmic signatures of the Shiva impact such as iridium anomaly, iridium-rich alkaline melt rocks, shocked quartz, nickel-rich spinels, sanidine spherules and high-pressure fullerenes. Although Deccan eruption was close to the Shiva crater, impact did not initiate volcanism because of conflict of timing. Recent work suggests that both the Chicxulub impact in Mexico and the first phase of the Deccan volcanism preceded the K/T boundary by 400 Kyr and cannot be the proximate cause for the K/T mass extinction, whereas the Shiva impact occurred precisely at the K/T boundary. Moreover, dinosaur bones and their eggs have been found in intertrappean beds interlayered with the Deccan flows indicating that dinosaurs were thriving when Deccan lava was erupting. The biotic effects of the Shiva impact would have instantaneous devastating effects globally with climatic calamity, collapsing the ecosystems, which killed the dinosaurs and caused the mass extinction of many other organisms at the K/T boundary.

BIODIVERSITY OF GLOSSOPTERIS FLORA OF INDIA

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During Carbo-Permian times all parts of Gondwanaland were in the grip of a widespread glaciation, which is believed to have begun in the upper Carboniferous and persisted up to the Lower Permian. This is regarded as the greatest ice age, the world has ever witnessed. Immediately after glaciations there arose a distinct vegetation in the southern land mass known as Glossopteris flora due to prevalence of tongue shaped leaves of *Glossopteris*.

During glaciations, in cold climate some stunted forms of *Gangamopteris*, *Noeggerathiopsis* and some herbaceous pteridophytes like *Schizoneura* were present in isolated and protected areas. Later, when conditions became gradually favourable the Glossopteris flora diversified in different geological formations of India. A large number of megafossils of pteridophytes and gymnosperms have been reported from the Lower Gondwana of India. Out of these, about 82% are gymnosperms, 17% pteridophytes and 1% bryophytes but all the bryophytes reported so far are doubtful. In gymnosperms, the members of Glossopteridales are most abundant and they contribute about 59% of the total gymnospermous flora. Other gymnosperms present are members of Noeggerathiopsidales 4%, Ginkgoales 3%, Coniferales 2% and 32% are of unknown affinity which are grouped under *incertae sedis*. Of these 32% *incertae sedis* are permineralized woods, 13% dispersed seeds, 2% leafy forms like *Caulophyllites, Cheirophyllum, Pterophyllum*, *Pteronilssonia* and 1% fructifications like *Birbalsahnia* and *Veekaysinghia* whose relationships are unknown. Thus, the members of Glossopteridales had enough plasticity to spread over larger ecological niches. They lived in periglacial environment, diversified in subtropical to tropical climate with warm and humid atmosphere.

In peninsular India, the Glossopteris flora is present in Talchir, Karharbari, Barakar, Barren Measures, Raniganj and Kamthi formations. Talchir Formation is the basal most formation of Lower Gondwana of India where well preserved *Schizoneura, Neomariopteris, Gangamopteris, Noeggerathiopsis, Glossopteris, Paranocladus, Euryphyllum, Vertebraria* and *Arberia* are reported. Chandra (1995) also reported some bryophytes like *Bryothallites talchirensis*, *Hepaticites umariensis*, *Talchirophyllites indicus, Saksenaphyllites saxenae* and *Umariaphyllites accutus* but the bryophytic nature of these genera needs further confirmation.

The Karharbari Formation follows the Talchir. The Karharbari Formation shows a greater generic and specific diversity as compared to the Talchir Formation. The important pteridophytes are *Botrychiopsis, Cyclodendron, Giridia, Phyllotheca, Schizoneura* and *Sphenophyllum*. The gymnosperms described from here are Arberia, *Birsinghia, Birsinghpuria, Bulbospermum, Buriadia, Cheirophyllum, Caulophyllites, Cordaicarpus, Dolianitia, Euryphyllum, Gangamopteris, Glossopteris, Lanceolatus, Noeggerathiopsis*, *Ottokaria, Otofeistia, Palaeovittaria, Paliandrolepis, Psgmophyllum, Rhabdotaenia*, *Rubidgea, Samaropsis* and *Vertebraria.* The *Gangamopteris* and *Noeggerathiopsis* had achieved their maximum diversity during this formation. Monosaccate pollen continued to dominate in Lower Karharbari assemblage. Lower Gondwana beds in Kashmir specially Nishatbagh, Mamamal, Vihi and Marhoma are referred to the Karharbari Formation but it has some unique forms like *Ahmadia, Chiguites, Cycadites, Kawizophyllum, Lobatannularia, Rajahia* and *Vinaykumaria* which are not present in peninsular India.

Barakar Formation lies above the Karharbari and flora of this formation is characterized by the dominance of the genus *Glossopteris* and decline of *Gangamopteris* and *Noeggerathiopsis*. Pteridophytes are represented by *Annularia, Barakaria, Chitraphyllum, Giridia, Lelstotheca, Neomariopteris, Palasthalia, Paracalamites, Phyllotheca, Rajmahaliastachys, Tulsidabaria, Saharjuria* and *Santhalitheca*.

Some unique forms like *Diphyllopteris* and *Deogarhia* which are regarded as the possible seedlings of *Glossopteris* are also reported from Barakar Formation. The Barakar Formation has a few fructifications of glossopterids like *Dictyopteridium, Lanceolatus, Ottokaria* and *Eretmonia*.

Barren Measures Formation lies over the Barakar and has a poor assemblage of plant fossils. Pteridophytes became rare and are represented by *Cyclodendron* and *Neomariopteris*. The important gymnosperms are *Glossopteris, Gangamopteris, Rhabdotaenia, Noeggerathiopsis* and *Vertebraria*.

Raniganj Formation represents the climax of the Glossopteris flora. Megafossils of this formation include the lycopsids, sphenopsids, pteropsids, glossopterids, cycads, conifers, ginkgophytes, many dispersed seeds and petrified woods. Among Sphenopsids are *Bengalia, Lelstotheca, Phyllotheca, Raniganjia, Schizoneura* and *Sphenophyllum*. Fern genera are *Angiopteridium, Asansolia, Cuticulatopteris, Damudopteris, Damudosorus, Dichotomopteris, Leleopteris, Trithecopteris, Dizeugotheca* and *Neomariopteris*. The only lycopsid reported is *Cyclodendron leslii*.

The glossopterids are most dominant and *Glossopteris* attained its zenith in this formation. Other taxa related to *Glossopteris* are *Gangamopteris, Belemnopteris, Palaeovittaria, Rhabdotaenia, Euryphyllum, Gondwanophyllites* and *Sagitophyllum*. Some compound leaved gymnosperms like *Pseudoctenis, Pteronilssonia* and *Pterophyllum* are comparable with pinnately compound leaves of cycads. *Vertebraria* is very common element of this formation. Glossopterid fructifications became more diversified and abundant which are represented by *Bankolia, Dictyopteridium, Eretmonia, Jambadostrobus, Kendostrobus, Lanceolatus, Mahudia, Ottokaria, Plumsteadia, Plumsteadiostrobus, Senotheca* and *Venustostrobus*. Conifers are represented by *Searsolia* and *Walkomiella*, the ginkgophytes by *Ginkgoites* and *Rhipidipsis*. Dispersed woods are *Araucarioxylon, Arauspiropitys, Australoxylon, Chapmanoxylon, Damudoxylon, Kaokoxylon, Kendoxylon, Megaporoxylon, Palaeospiroxylon, Paracatervoxylon, Parapalaeospiroxylon, Protophyllocladoxylon, Ranoxylon, Trigonomylon* and *Zalesskioxylon*. The diversity in the flora of Raniganj Formation indicates the presence of warm, humid, subtropical climate with intermittent rainfall.

The Kamthi Formation is present above the Raniganj Formation. The floral assemblage is more or less similar to that of Raniganj Formation but the diversity of glossopterid fructifications shows a peak during this formation. These fructifications include *Denkania, Dictyopteridium, Eretmonia, Glossotheca, Hirsutum, Jambadostrobus, Kendostrobus, Lidgettonia, Mahudia, Ottokaria, Partha, Plumsteadia, Plubstreadiostrobus, Scutum* and *Utkalia*. Leafy forms include *Glossopteris, Palaeovittaria* and *Sagittophyllum*. Pteridophytes reported are *Cyclodendron, Phyllotheca, Raniganjia, Schizoneura, Sphenophyllum, Stellotheca, Benlightfootia, Asansolia, Neomariopteris* and *Pantopteris*.

Petrified dispersed woods are also reported from Kamthi Formation. These are *Araucarioxylon, Australoxylon, Dadoxylon, Damudoxylon, Kamthioxylon, Kaokoxylon, Nandarioxylon, Parapalaeoxylon, Prototaxoxylon, Sclerospiroxylon, Taxopitys* and *Zalesskioxylon*. The variety of Kamthi flora indicates warm and humid climate, which is quite favourable for plant growth. The red bed facies of the ferruginous sandstones marks seasonal dry spells and semi-arid conditions in a year.

Glossopteris flora declined gradually from Kamthi Formation to the Triassic Period. The climate of the area seems to have become unfavourable due to further increase in temperature and loss of humidity.

Although a large number of fossil genera and species are attributed to the Glossopteris flora of India, our knowledge is still incomplete and fragmentary. The need to study better preserved and complete specimens for correct identification of the species still remains to be worked out and continued efforts are required to discover new elements.

VEGETATION, CLIMATE AND HUMAN HABITATION IN THE CENTRAL GANGA PLAIN SINCE EARLY HOLOCENE

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The Ganga Plain, one of the major alluvial plains of the country, extends from the Aravalli-Delhi ridge in the west to the Rajmahal hills in the east, Himalayan foot hills in the north to the Bundelkhand-Vindhyan plateau-Hazaribag plateau in the south between 24^0 and 30^0 north latitudes and 77^0 and 88^0 east longitudes. This region abounds with a large number of potential extinct and extant lakes of varying dimensions for the palaeoclimatic studies. However, this aspect has not yet received the due attention, except for some scattered information from the central Ganga Plain. Interestingly, the lakes in the vicinity of the early archaeological settlements are potentially important to infer the human activities, during the changing vegetational and climatic scenario in the remote past. Appending with the generation of archaeological information at these settlements, the palynological approach is rewarding to reconstruct the models of early land use and subsistence strategies in the region. Quaternary palaeoclimatic studies have recently been initiated on some of such lakes with an objective to reconstruct the vegetation scenarios and monsoon trend as well as inception and the subsequent course of agricultural practices in relation to cultural history of this region.

The investigation on three lakes, viz. Lahuradeva, Sant Kabir Nagar District, Basaha, Unnao District and Misa Tal, Lucknow District, all located close to ancient settlements, has been carried out and the results are considerably important. The pollen sequence from the Lahuradeva Lake, situated close to a Neolithic-Chalcolithic (about 9000-3200 yr BP) site, has revealed that between 9500 to 8700 yr BP, open vegetation mainly comprising grasses, Cheno/Am, *Artemisia*, etc. together with scanty trees of *Aegle marmelos*, *Holoptelea*, *Terminalia* grew in the region under cool and dry climate. The record of pollen of aquatic plants indicates the existence of lake. Between 8700 to 5700 yr BP, due to amelioration of climate the invasion of a few more trees of *Bombax*, *Emblica officinalis*, *Syzygium*, *Lagerstroemia*, etc. becomes evident. The progressing abundance of *Botryococcus* and other aquatic taxa implies that the lake became wider in expanse owing to increased monsoon rain. Amazingly, the appearance of characteristic cerealia pollen in the levels dated 6700 yr BP depicts the early activities of man associated with some sort of cereal-based agriculture. During the time bracket between 5700 and 2600 yr BP, increase in *Bombax*, *Madhuca indica*, *Holoptelea*, etc. demonstrates the establishment of forest groves as a consequence of increased precipitation on account of enhancement in active summer monsoon. The further expansion of agricultural practices is reflected by well marked and consistent presence of cerealia along with other culture pollen taxa. The pollen of *Trapa* (shinghara) suggests that its fruits would have been consumed by the ancient settlers. Between 2600 and 1400 yr BP, increase in *Madhuca indica* together with *Holoptelea*, Sapotaceae and swampy element of *Barringtonia* in the forest groves implies further increase in monsoon rainfall. Acceleration of further agricultural practices is witnessed by the more frequent occurrence of culture pollen taxa. Since 1400 yr BP onwards, the arboreals became sparse in the forest groves with the onset of dry climatic conditions. The lake gradually shrunk and attained the present ephemeral status during the succeeding phase. However, the agricultural practices continued with more or less same intensity as before, perhaps due to technological advancement.

The studies on two other lakes in the vicinity of settlements, viz. Basaha Jheel and Misa Tal in the districts of Unnao and Lucknow respectively have provided the proxy signals on the short-term climatic variability and contemporary vegetation in the much later phases during 3300 yr BP to present. The pollen sequence at the Basaha Jheel, suggestive of open vegetation, indicates the fluctuating trend of arboreals, viz. *Bauhinia*, *Holoptelea*, Sapotaceae, *Acacia*, aquatics such as *Myriophyllum*, *Potamogeton*, *Botryococcus*, etc. and cerealia along with culture pollen taxa. Around 3300 yr BP a semi-humid climate prevailed with moderate agriculture practice. During 3200 to 2800 yr BP, the climate changed to humid as indicated by increasing frequencies of arboreals in the pollen record. Simultaneously, the gradual increase in cerealia and other culture pollen taxa, reveals ongoing agricultural practices. Thereafter, sudden decline in the trees and culture pollen taxa between 2800 and 2200 yr BP suggests the onset of dry climate and depletion in the agricultural practices. From 2200 yr BP onwards, further decline in trees, aquatics and total absence of cerealia pollen demonstrate reduction of monsoon rainfall and consequent increase in alkalinity of the soil. With the prevailing adverse climate and edaphic condition, the inhabitants of the area abandoned their settlement.

The pollen analysis of sediment profile from Misa Tal in Lucknow has furnished the evidence of vegetational changes, low rainfall and the occupancy of agriculture as deduced from the scanty pollen of trees, aquatics and culture pollen during 2000 to1850 yr BP. Broadly, this time duration encompasses the ruling of Kushanas in historical account. Subsequently, during the rulings of Gupta, Turkic and Mughal dynasties spanning from 1850 to 300 yr BP, the climatic conditions improved as shown by the rise of trees and aquatics. Prosperity in agricultural practices is also reflected by the better representation of cerealia and other culture pollen taxa. The British period faced the reduction in rainfall and agricultural prosperity, until the independence of the country.

There is plenty of scope for extending the Quaternary palynological studies on the lakes lying in the close proximity of settlements in the other sectors of the Ganga Plain. This approach will enable us to reconstruct a very precise and comprehensive picture of past landscape, climate and agricultural activities of this region in the cultural perspective during the Holocene.

ALGAL STROMATOLITES IN THE EASTERN CHHATTISGARH BASIN: THEIR BEARING ON SEQUENCE ANALYSIS

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The lithologic succession in the Neoproterozoic Chhattisgarh basin, covering a large part of the Bastar-Bhandara Craton, is characterized by remarkable facies variations in space and time. The basin exhibits highly variable stratigraphic architecture and relationships and had a complex history of evolution. The complexities in stratigraphic architecture are manifested by highly divergent lithostratigraphic successions built up by different workers in different parts of the basin. The differences in stratigraphic columns are marked not only by the local development of a number of formations, but also by the numbers of disconformities or hiatuses in different sections. The regionally variable lithostratigraphy points to uneven rates of subsidence and creation of accommodation in different parts of the basin and the differences do not appear to be reconcilable within the framework of lithostratigraphic correlation. Sequence stratigraphic analysis of the succession in the eastern part of the basin was attempted to obviate the problems of lithostratigraphic correlation. The analysis was made along the Seraipalli< ; Raigarh profile, on the basis of recognition of major nconformities, detailed facies analysis for environmental interpretation and identification of several markers for changes in sea level and system tracts.

In eastern Chhattisgarh, three major unconformities are recognized: (i) between the sedimentaries and the underlying crystallines of the basement complex; (ii) within the Neoproterozoic succession; and (iii) between the Neoproterozoics and the overlying Gondwana succession. These divide the Chhattisgarh succession into two major unconformity-bound sequences. The lower sequence comprises a sandstone-shale dominated assemblage and overlying limestone-red shale dominated assemblage, the Chandarpur and Raipur groups respectively. Both the assemblages comprise several transgressive-regressive cycles, representing smaller order cycles and multiple events of sea level rise and fall. The most convincing evidence for maximum flooding during the deposition of the Raipur sequence, an apparently monotonous alternation of limestone and red shale, is recorded by a regionally persistent thin horizon of black shale within the lower limestone build-up, the Sarangarh Limestone. Two separate events of sea level fall are indicated by the occurrence of small stromatolite bioherms along two narrow intervals; one in the upper limestone build-up, the Rotopalli Limestone and the other at the upper part of a monotonous red shale, the Churtela Shale that occurs between the two limestone sequences. The algal stromatolites define two biostratigraphic markers and also two events of low-stand sea level.

The bioherms in the Churtela Shale could not develop into large continuous bodies because of high rate of influx of siliciclastic shale. However, the strings of mounds formed an incipient rim along the sea-ward margin of a muddy shelf giving rise to a muddy shelf lagoon on the land-ward side. The mounds occur as elongate bodies, each comprising smaller elongate bodies separated by red shale. Many of the elongate bodies are composed of linear stromatolite structures of high length : width ratio, whereas several bodies comprise both elongate structures and columnar structures with circular to slightly ovoidal planar sections. Despite the dominance of shale in the system, the interareas between the stromatolite structures are filled up with brown lime-mud. The stromatolite structures, on all different scales, exhibit a very persistent, WNW to ESE trending linearity, the direction of tidal currents and a very subtidal to intertidal depositional environment.

MANGROVES AS INDICATOR OF LATE QUATERNARY SEA LEVEL AND CLIMATIC FLUCTUATIONS IN THE SOUTHEAST COAST, INDIA

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The marine sediments mostly constitute particles of inorganic or organic matter that generally settle through water column and accumulate in a loose unconsolidated form. The physical processes involved are accumulation rate, depositional environment, range of particle size, continental slope and effect of currents. Biogenous accumulation, its qualitative and quantitative status, composition, etc. in a sedimentary soil sequence correspond to existing habitat. Terrigenous sediment load is generally eroded and carried through streams to ocean depending on transport mechanism, distribution and rate of accumulation. Analysis of the above parameters through a sedimentary soil data with the help of mangroves and the associated palynotaxa served as potential palaeoenvironmental indicator. Changes in the pollen/spore assemblages during Holocene are equated with climatic and relative sea level changes as they indicate the conditions under which they exist. The two main approaches adopted for environmental reconstruction are: (1) the individualistic- indicator species approach. With knowledge of the present day ecology and tolerance of an individual, the ecological and climatic conditions under which they exist in the past environment were reconstructed. (2) The assemblage approach. Fossil pollen assemblages were used to reconstruct past environments by the use of transfer functions, which relate present day environments to present day pollen assemblages.

Generally, mangroves are trees and bushes growing below the high water level of spring tides. For this study, the existing estuaries, lakes and lagoons were identified along the south-east coast of India. Number of sedimentary soil profiles were collected from four sites (i.e. Kolleru lake, Pulicat lagoon, Adyar estuary and Pichavaram estuary) in a cross section from west to east covering 16 to 25 km inland for the palynological study. The evidences of mangrove pollen in the strata bound soil sediments along the east coast reflect the records of palaeoshoreline and associated ecology. Plants being able to tolerate and flourish in saline mud and others that withstand frequent inundation by sea water are their respective indicators.

Palynochronostratigraphical record reveals that the mangrove forests covered sheltered coastlines all along the east coast formed by major or minor river deltas that include the Ganges, Mahanadi, Krishna and Godavari, Penner, Adyar, Couum and Cauvery rivers. Results indicate good quantitative and qualitative diversity of mangroves and associated coastal vegetation until later half of middle Holocene. The middle Holocene sea highstand reached several kilometres inland during this period and the climate was warmer and humid than present. The palynological succession also indicates the trends of ecological and deltaic evolution since ~7000±300 yr BP. Such changes are generally induced by climate and relative sea level in the near shore coastal areas. However, the direction and magnitude of sediment accretion and tectonic related hydro-isostatic adjustments brought about abrupt configurational changes in the above studied estuaries and lagoons, between 2400 to 1600 yr BP affecting the ecology and mangroves since middle Holocene. The evidences of mangroves on land indicating middle Holocene palaeoshoreline match well with the global time period of maximum transgressive event. But, the position of marine evidences in the lithology varies at different places, suggesting the land subsidence or upliftment in the past that could have played a major role in the evolution of south-east coastal land forms and mangrove vegetation.

It is inferred through palynological succession that mangrove formations, due to their situation along the coast, were constantly controlled by marine and terrestrial factors such as, coastal erosion or accretion by the sea or by rivers, tidal waves, high salinity, water-logged soils and other edaphic characteristics. These, together with the distance from the sea, the frequency and duration of inundation and tidal dynamics, govern the local distribution of mangrove tree species and their succession. The best development of mangrove forest is found at locations with deep soils, rich in organic matter and low in sand, usually in river estuaries. The east coast of India is bestowed upon with number of full flowing rivers and streams that are charged seasonally bringing sediment load and therefore, have a direct relation to climatic conditions. Consequently, they leave their impact on the vegetation as well. The imprints of these changes are buried in sedimentary soil sequences and the palynological succession allowed the reconstruction of past vegetation indicating the magnitude, duration and direction of the deltaic evolution and the associated vegetation.

Up welling and down welling are seasonal important vertical circulations in the Bay of Bengal, being created by monsoon winds. The persistence of monsoon, especially from the southwest and the orientation of the coasts, cause up welling to occur along most of the east coast of India. However, vertical movement of water and its duration and intensity play a pivotal role in the appearance or disappearance of opportunistic flora and fauna. They do have a profound effect on the productivity of the coastal ecosystem. Palynological results show high productivity along the near shore region and are also attributed to the above reasons.

The study enables us to understand the landscape of the coastal zone and to identify those aspects likely to impose upon society in the future. The bio-tools developed to illustrate the forces and patterns inducing evolutionary trend in coastal landforms, drainage systems and the vegetation relative to coastline would assist in interpretation and understanding of the coastal dynamics. The study provides additional insights into geomorphological development in the modern deltaic areas. The rate of vertical change is of the same order as the changes recorded globally. Development of a process for modeling differential land movements, vegetation pattern, its local extinction and migration, etc. will therefore also be useful for predicting future coastal emergence or submergence and their impact on plant diversity. In combination with geological, palynostratigraphical and hydrological informations, it may also be possible to model future long term river migration, erosion and siltation and to deduce land use options.

POTENTIAL OF DINOFLAGELLATE CYSTS AS A PROXY FROM MARINE SEDIMENTS FOR QUATERNARY PALAEOCLIMATIC STUDIES IN INDIA

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Reconstruction of past climate/ environmental changes require retrieval of proxy biotic records from various continental and marine domains. Amongst microfossil proxies, foraminifera from marine sediments and pollen-spores from continental records are the most commonly used parameters in Quaternary palaeoclimatic studies in India. Dinoflagellate cysts, which constitute a significant component of the marine palynological assemblages from coastal and shelf sediments, also have a strong potential in high resolution studies for palaeoclimatic interpretations and sea level fluctuations. However, studies on Quaternary dinoflagellate cysts from the Indian region are severely limited, though extensive investigations have been carried out in other parts of the world (Wall *et al.* 1977, Head & Wrenn 1992, Dale 1996, Mudie & Harland 1996, Head 1996, Marret & Zonneveld 2003 and references therein).

Dinoflagellates are aquatic organisms constituting a major part of the primary producers in the marine realm. They have both autotrophic and heterotrophic feeding strategies and occur mainly as acid-resistant organic-walled cysts (dinocysts) in shallow as well as deeper marine sediments, although few calcareous and siliceous forms are also known. Being strongly influenced by environment, organic-walled dinocysts provide excellent proxy records of past climatic changes. Specific dinocyst associations are known to characterize coastal, neritic and oceanic environments and changes in cyst communities have been related to temperature/salinity gradients, coastal proximity (inshore-offshore trends) and monsoon/upwelling related (palaeo) productivity.

The Arabian Sea sediments are important recorders of the climatic variability, which is closely linked to the Indian Monsoon system. The Arabian Sea is characterized by high surface water productivity, intense upwelling, a mid-depth oxygen minimum zone (OMZ) and organic matter rich sediments. Studies on dinoflagellates in the western Arabian Sea demonstrate that main variance in cyst distribution in surface sediments are assignable to monsoon related environmental characteristics (Zonneveld 1996 1997). Groups of species having comparable relationships with temperature/ salinity gradients in the upper water mass are recognized. The down core occurrences of dinocyst associations have the potential as indicators for palaeo SW and NE monsoon and upwelling (Zonneveld *et al.* 1997). Variations in cyst concentrations of heterotrophic dinoflagellates may be potentially useful as palaeoproductivity indicators and in assessing bottom water oxygenation (Reichert & Brinkhuis 2003). In the eastern Arabian Sea, dinocyst data is effectively used to decipher palaeomonsoon phenomena from subsurface sediments off the western coast of India (van Campo 1986, Caratini *et al.* 1991, 1994). Conceptual models for cyclicity in monsoon rainfall on the Indian subcontinent have been proposed based on foraminifera from eastern Arabian Sea sediments (Nigam *et al.* 1995, Naidu & Malmgren 1996). It is presumed that dinoflagellate cyst data will substantially add to the palaeoclimatic interpretations during Late Quaternary in this region. Preliminary studies on dinoflagellate cyst distribution patterns on the surface sediments off the Karwar-Marmagao coast have revealed significant patterns in the distribution of organic-walled cysts and calcareous dinoflagellates, which seem to be related to depth, productivity and salinity variations.

Western Indian margin is a potential key area to undertake dinoflagellate based integrative palaeoclimatic studies on Arabian sea sediments to investigate an important, yet not fully explored, parameter for proxy records of past environmental (palaeomonsoon) changes and sea level studies. Building up of datasets on biogeographic distribution patterns of dinocysts from marine surface/ core sediments (coast to slope transect, especially OMZ) is required to identify palynological proxies suitable for area near river mouths and coastal/ shelf regions for their application in past climatic interpretations.

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Theme–Biodiversity: Past and Present

BIODIVERSITY MANAGEMENT IN INDIA: A TYRO'S CONCEPTION

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The vast geographical area, diverse climatic conditions coupled with topographical variations of India have resulted in enormous ecological diversity supporting about 8% of the world's biological diversity on 2% of the earth's surface making it one of the 12 megadiversity countries in the world. At present on our earth approximately 5-30 million species of living forms exist. Amongst these, about 1.5 million species have been identified. India having a geographical area of about 329 million hectares is remarkably rich in biodiversity with a substantial percentage of endemic flora and fauna. This species richness is owing to enormous variety of climatic and altitudinal conditions along with diversified ecological habitats. In general, tropical climatic condition is characterized by high species diversity. In tropics, the diversity of species was conserved over the geological time owing to low rates of extinction. In the present scenario drastic loss of biological diversity is a global crisis. Extinction of life has been a natural phenomenon in the earth's history through ages. However, the rate of extinction was very low, i.e. approximately one species in thousand years in the geologic past. Gradually human activities accelerated the extinction rates and at present the estimated extinction rate is one species every year. Apart from human's intervention, several other ecological factors accompanied by socio-economic as well as political factors are responsible for the extinction of plant and animal species. The development policies and projects have rarely been sensitive to the need for biodiversity conservation in developing countries like India. The conservation methods of biodiversity include both *in situ* and *ex situ* conservations. Presently, India has a well-developed institutional infrastructure for *ex situ* conservation of plants, forest trees, farm animals and fishes. Indian Council of Agricultural Research has established National Bureau of plant, animal and fish genetic resources. Besides its network of 12 regional stations and base centres in different agroecological regions in India, it has strong links with various national research institutes, universities, government departments, non-government organizations, research foundations and private sector research and development programmes. However, there is urgent need for all-India coordinated project on biodiversity. In view of this, awareness of public, their participation and woman empowerment are essential factors for the proper management of biodiversity in a developing country like India.

EMERGENCE OF NEWLY PROPOSED TAXONOMIC PERSPECTIVES FOR FOSSIL CORALLINE ALGAE

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As an outcome of major studies by various phycologists remarkable changes in the taxonomy of living species of coralline red algae (Corallinales, Rhodophyta) have taken place since 1960 (cited in Johansen 1981). The taxonomy of fossil coralline red algae is under the process of revision and modification since 1993. Prior to 1993 it was believed that several diagnostic characters used in present day coralline red algae were unpreservable in fossil coralline algae. As a matter of fact, Wray (1977), Pongniat (1984) and several other palaeoalgologists opined that fossil and extant coralline algae have to be classified in different manners and consequently different diagnostic characters were used for the identification of fossil and present day coralline algae.

Traditionally, the generic and suprageneric taxonomy of present day coralline algae were based upon the characteristics of tissues and reproductive structures, which could be easily recognized in fossil material. On the other hand, taxonomy of fossil coralline algae was solely dependent upon the calcified characters with high fossilization potential. According to Wray (1977) diagnostic suprageneric criteria for extant as well as fossil material included: (i) type and location of conceptacles; (ii) character of hypothallium (core or primigenous filaments in recent literature); (iii) character of perithallium (peripheral or postigenous filaments in recent literature); and (iv) presence or absence and arrangement of heterocysts (trichocytes).

Bosence (1991) raised some important questions regarding the preservation of taxonomic characters and relationships between fossil taxa and groups of extant taxa. He emphasized the significance of reassessment and revision of well known fossil taxa along with detailed measurements and statistical analysis because many of the fossil coralline taxa were suffering from excessive splitting only on the basis of very few characters.

Discovery of interfilamental cell connections (Johansen 1969) as an important taxonomic criterion for characterizing subfamilies of extant coralline algae and later on use of this important character in both suprageneric and generic taxonomy of extant corallines by a number of renowned phycologists in Europe and Australia were widely accepted by the phycologists all over the world working with extant corallines. Apart from this, some other diagnostic features, e.g. shape of epithallial cells as a significant feature in identifying some genera (Adey 1970), number of epithallial cells as an important character at generic level (Johansen 1976) and pattern of cell elongation in recognizing suprageneric taxa (Woelkerling & Irvine 1986 and others) were employed for the taxonomy of extant coralline algae by the phycologists. Many of these characters were not utilized earlier (prior to 1993) in the taxonomy of fossil coralline algae. However, since 1993 extensive work by Spanish (Braga & Aguirre), English (Bosence), Austrian (Rasser & Piller), Italian (Bassi), German (Nebelsick) and some other groups of palaeoalgologists led to the view that some key features, e.g. cell-connections, cell-fusions, characteristics of epithallial cells and meristems, can also be recognized in fossil corallines using light microscopy as well as appropriate SEM techniques (as specified by Braga *et al.* 1993). It has been widely accepted by the palaeoalgologists that unification of taxonomy for extant and fossil corallines is essential for the accurate interpretation of phylogeny, palaeoecology and palaeobiogeography. It may be mentioned here that phylogenetically the corallines are very important as they represent a major evolutionary line within red algae as evidenced by the studies (Bailey & Chapman 1996, Bailey 1999) on 18S rRNA gene sequences. Distribution of corallines is also very widespread as they occur from tropics to polar region and from intertidal down to more than 200 m water depth.

Woelkerling (1988) extensively analyzed the genera and subfamilies of extant coralline algae and proposed a classification scheme based on number of diagnostic features, many of which can be observed in fossil material with bright field and Scanning Electron Microscopy. Based on these key features, Woelkerling (1988) classified Corallinaceae into subfamilies Amphiroideae, Corallinoideae, Metagoniolithoideae, Chreonematoideae, Lithophylloideae, Mastophoroideae and Melobesioideae. Amongst these, Amphiroideae, Corallinoideae and Metagoniolithoideae were considered as geniculate corallines. Verheij (1993) instituted the family Sporolithaceae to separate the genus *Sporolithon* from rest of the corallines. Fossil record of this family is represented by the genera *Sporolithon, Kymalithon* and *Hemiphyllum*; however, till date there is no fossil record of the extant genus *Heydrichia* belonging to family Sporolithaceae. Later on, Harvey and Woelkerling (1995) erected a new subfamily Austrolithoideae (nongeniculate coralline) belonging to the family Corallinaceae. 18S rRNA gene sequence analysis (Bailey 1999) recommended close affinity of the geniculate Amphiroideae and the nongeniculate Lithophylloideae. Re-evaluation of coralline algal taxonomy, using ultrastructural studies, also supports that Amphiroideae and Lithophylloideae should be included in a single subfamily Lithophylloideae. Considering these findings a modified scheme has been introduced by Braga (2003) in the suprageneric taxonomy of Woelkerling (1988), based on the contributions of Verheij (1993), Harvey and Woelkerling (1995) and Bailey (1999). In this classification, three subfamilies of Corallinaceae, viz. Metagoniolithoideae, Austrolithoideae and Chreonematoideae have not been recorded as fossils till date.

A number of publications on fossil corallines by European group of palaeoalgologists highlighted the application of newly proposed taxonomic criteria for the fossil species following the taxonomy applied to present day corallines. A latest analysis (Aguirre & Braga 2005) of data obtained from 600 publications from the year 1871 to 2003 revealed that at least 703 species of non-geniculate coralline red algae have been described from the Late Jurassic-Early Cretaceous to Pleistocene. These species have been included in 27 genera and the species richness of these genera is extremely variable, with 4 genera, viz. *Lithothamnion, Lithophyllum, Sporolithon* and *Mesophyllum* representing 84.8% of the total species. But, validity of hundreds of species described before 1993, based only on traditional taxonomic criteria, is under scanner and very much doubtful.

The present review deals with the remarkable changes that have taken place since 1993 in the taxonomic scenario of fossil coralline algae and the current trends of research in this aspect. In India, very few workers are actively engaged in this important field of palaeontology and there is urgent need to revise and reassess (employing new taxonomic perspectives) the type specimens figured or described by earlier authors from the Indian subcontinent. However, in many instances the type collections may not be available. In that case collection of fresh materials from the type locality and examination of thin sections may produce some useful and valuable contributions towards the extinct coralline algal flora of India.

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TERTIARY FLORA OF INDIA: ITS DEVELOPMENT, SIGNIFICANCE AND FUTURE CONSIDERATIONS

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A time span, ranging from 65 my to1.8 my, constitutes the Tertiary Period, which has broadly been divided into Palaeogene and Neogene. This is the most important period for tracing the antiquity, history and evolution of modern Indian flora. The present paper is based on the Tertiary plant megafossil records, of which the angiosperms provide the bulk of data and are represented by various plant parts such as woods, leaves, fruits, flowers, etc. The modern flora of India is one of the richest and most diverse floras of the world. The roots of extant flora of India can be traced back to the Tertiary Period. The development or history of the Tertiary flora in India can be divided into three phases, viz. (i) pre-Sahni period, (ii) Prof. Sahni's period, and (iii) post-Sahni period.

(i) Pre-Sahni Period (1782-1920):

This period can be called as the age of colonial or pioneer explorers. It was a period when Tertiary plant fossils were largely collected as curios or they were viewed with a purely geological bias.

(ii) Prof. Sahni's Period (1920-1950):

It was the most momentous period in the history of Indian palaeobotany in general and Tertiary palaeobotany in particular. Prof. Birbal Sahni, soon after returning from Cambridge, took stock of the existing position of palaeobotany in India (Sahni 1921). Prof. Sahni did considerable work on the Deccan Intertrappean megafossils and evinced keen interest in the fossil plants of Karewa beds of Kashmir. He trained many of his students to work on plant fossils and laid the foundation of Indian Tertiary palaeobotany. Under his able guidance, the work on Tertiary microfossils and cuticular studies was also carried out. Initiation of systematic taxonomic work on the Tertiary plant fossils from various parts of India was the major achievement of this period.

(iii) Post-Sahni Period (1950 onwards):

Indian palaeobotany suffered a big jolt due to sudden demise of Prof. Birbal Sahni in 1949. However, his devoted team of students and successors carried forward successfully work on palaeobotany. During this period, Indian palaeobotany made far reaching progress in all spheres. A large amount of data was accumulated and synthesized for the proper evaluation of the Tertiary flora.

The Indian Tertiary flora can be divided into Palaeogene and Neogene floras.

(1) Palaeogene or Early Tertiary flora:

The Deccan Intertrappean flora has largely been considered to be basal Tertiary (late Maastrichtian-early Palaeocene) and is well documented from intertrappean beds of Madhya Pradesh, Maharashtra, Andhra Pradesh and Gujarat. Lately, some additions have been made to the equivalent infratrappean flora of Madhya Pradesh and Maharashtra. The Deccan Intertrappean flora is unique in the sense that it includes a large number of plant fossils, representing almost all groups of the plant kingdom.

This flora can be considered as the parental stock of the modern Indian flora. Some of the important taxa reported from the intertrappean beds are:

Rajahmundry area

Algae - *Halimeda, Dissocladella, Terquemella, Acetabularia, Neomaris, Holosporella* and *Acicularia*. The occurrence of estuarine algae, along with *Cocos (Palmoxylon sundaram)* and *Sonneratia,* indicates near-shore, tropical conditions.

Central India (Mandla, Chhindhwara, Sagar, Nagpur-Wardha areas)

Marine algae, viz. *Peyssonnelia, Distichoplax* and *Solenopora*; pteridophytes, viz. *Acrostichum, Azolla, Salvinia, Marsilea* and *Rodeites* cf. *Regnellidium*; gymnosperms, viz. *Araucaria-Agathis* and *Podocarpus*; and angiosperms, viz. *Agalia, Ailanthus, Amoora, Anamitra, Aristolochia, Artocarpus, Atalantia, Barringtonia, Bursera, Canarium, Cocos, Dracontomelum, Elaeocarpus-Echinocarpus, Eucalyptus, Evodia, Flacourtia, Garcinia, Gmelina, Grewia, Heterophragma, Homalium, Hydnocarpus, Hyphaene, Lagerstroemia, Leea, Livistona, Lophopetalum, Mallotus, Melaleuca-Tristania,, Musa, Nymphaea, Nypa, Polyalthia, Simarouba, Sonneratia, Stemonurs* (=*Gomphandra), Sterculia, Syzygium, Walsura,* etc. and a number of palms.

Kachchh, Gujarat

Homalium, Hydnocarpus, Stemonurs (=*Gomphandra), Bischofia, Mallotus* and some palms.

Significant conclusions derived from the above data are: (i) the recorded fossil taxa were inhabitant of tropical forests, as most of the genera exist in the evergreen to semi-evergreen forests of Western Ghats and north-east India; (ii) the abundance of variety of palms (a characteristic features of the tropical vegetation) in the intertrappeans and other moisture loving dicotyledonous taxa, together with those confined and belonging to Gondwanaland continents of tropical America, Africa and Australia *(Regnellidium,* a water fern of Brazil, *Simarouba, Cyclanthodendron* cf. *Cyclanthus, Hyphaene, Chrysalidocarpus, Ecualyptus),* provide strong evidence to infer that palaeoposition of the Indian landmass during the deposition of intertrappean beds was within the equatorial zone south of equator; and (iii) an analysis of the intertrappean woods has shown that they possess more primitive anatomical features than the Neogene woods.

Other Palaeogene floras

Upper Palaeocene flora of India is known from Meghalaya, Eocene flora from Rajasthan and Gujarat, late Eocene-early Oligocene flora from Ladakh and Manipur and Oligocene flora from Assam and Arunachal Pradesh. The Palaeogene flora from north-east India, Rajasthan and Gujarat shows presence of estuarine or littoral elements, such as *Avicennia*, *Barringtonia, Calophyllum, Cocos, Nypa, Pandanus, Terminalia catappa, Sonneratia, Rhizophora* and palms along with other moist tropical taxa indicating swampy, littoral/deltaic depositional conditions with close proximity of sea as for deep in the north-east as Dibrugarh in Assam, Tirap District of Arunachal Pradesh and near Barmer in the west. The occurrence of tropical palm genus *Livistona* in the Hemis Conglomerate of Ladakh indicates that climate of Ladakh was tropical till the Oligocene epoch. The composition of the flora shows that it is largely a continuation of the Deccan Intertrappean flora.

(2) Neogene or Late Tertiary Flora

The Neogene flora of India is fairly well known and consists of typical hardwood assemblages of broad leaf types and, in many instances, showing close resemblance to existing species. Neogene flora of peninsular India is known from western India (Gujarat, Rajasthan, Konkan and Kerala), East Coast (Rajahmundary and Tamil Nadu), north-east India, central India and Andaman and Nicobar Islands. On the other hand, Neogene flora of extra-peninsular India is known from pre-Siwalik, Siwalik and Karewa sediments.

A survey of the Indian Neogene plant fossils and their comparison with the extant taxa, which are largely distributed in lowland evergreen, semi-evergreen to moist deciduous forests, indicates that the Neogene flora was more or less uniform indicating the prevalence of tropical moist climate throughout the Indian landmass. The flora also shows immigration of plants from the south-east Asia *(Anisoptera, Dipterocarpus, Dryobalanops, Eugeissona, Hopea, Koompassia, Swintonia,* etc.), Africa and Arabia *(Baphia, Chlorophora, Entandrophragma, Khaya, Isoberlinia,* etc.) and from the north *(Prunus, Trachycarpus)*. The flora remained nearly unchanged in its overall composition until the close of Pliocene.

Significant conclusions derived from the Indian Neogene floral studies are:

(i) all the floras from different basins show close similarity in their composition as most of the genera are common to them;

(ii) the wide distribution of the tropical rain forest family Dipterocarpaceae, along with other associated genera, indicates more or less uniform tropical moist climate throughout the Indian landmass during the Neogene;

(iii) there were large scale migrations and admixture of floras over Malaysia, India, Arabia-Africa and North during the Neogene due to establishment of land connections; and

(iv) The presence of some families and genera such as Dipterocarpaceae, Ebenaceae, Sapotaceae, Rosaceae, *Afzelia-Intsia, Gluta, Swintonia* and dominance of legumes distinguishes the Neogene flora from the Palaeogene flora of India.

Thus to understand the history and evolution of the modern flora of India and its phytogeography it is important to study and build up the Tertiary flora of India.

Future Considerations

(i) The question of marine influence in the Deccan Intertrappean sediments of Mandla, Amarkantak, etc. deep inside central India has to be settled by reassessing the occurrence of reported marine or coastal taxa belonging to higher plants, such as *Acrostichum, Cocos, Nypa, Sonneratia* and the algal taxa *Peyssonnelia Distichoplax* and *Solenopora*. This is particularly warranted in the absence of any definite palaeontological and sedimentological supporting evidences.

(ii) Exact affinities of some of the reported problematic taxa in the intertrappean sediments need be traced.

(iii) Emphasis should be given on the investigations of amber (fossil resin) found in Tertiary lignite mines.

(iv) To evaluate climate and temperature changes on the basis of megafossil studies through the Tertiary, vis-á-vis changes seen in global context.

(v) To study the evolution and establishment of monsoon system.

(vi) To study stomatal frequency responses in fossil leaves.

(vii) In view of the occurrence of a large number of petrified flowers and fruits in the Deccan Intertrappean sediments, special emphasis need be laid on the study of floral anatomy.

(viii) Efforts should be made for molecular studies and extraction of DNA from the mummified leaves found in Tertiary sediments and to integrate fossils into molecular phylogenies.

(ix) To assess Tertiary vegetation in broader biological and evolutionary perspectives.

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CLIMATE ASSESSMENT OF HIMALAYA – MULTIDISCIPLINARY APPROACH

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There is a general trend to undertake one discipline and to interpret past climate on the basis of single parameter. Quaternary sediments from Himalaya have been analyzed palynologically since the beginning of last century and past climate is deciphered on the basis of reconstructed vegetation. Recently multidisciplinary approach has been undertaken and temperate zone of Kumaun (neglected earlier) is analyzed. Present contribution deals with geochemical, palaeontological and palynological investigations of lacustrine sediments from Nainital district, which have revealed past climate of the region since Early Holocene (8700±170 years B.P., based on radiocarbon dating).

Geochemical analysis shows that in Early Holocene investigated area had high representation of total organic matter and low total carbonate contents - reflecting existence of humid climate in the region. Subsequently, in Middle Holocene, organic matter became low and carbon contents high - indicating change in climate towards dry conditions. Thereafter, in Late Holocene, organic matter again became high and carbonate contents low - reflecting restoration of humid climate in the region.

Palaeontological investigation reflects that in Early Holocene to Middle Holocene the investigated area had no molluscs - reflecting climatic conditions of the region not suitable for molluscs. Near onset of Late Holocene numerous molluscan shells (planispiral gastropods, conispiral gastropods and bivalves, etc.) came into existence - indicating change in climate to suitable humid conditions.

Palynological analysis reveals that in the beginning of sequence, area had predominance of nonarboreals with pine in or around the region and rare broad-leaved arboreals. Spores are encountered (at upper part of zone) but aquatics are absent. Such scenario reflects that open type of vegetation existed in the region with cold and less humid climate. Subsequently, area enjoyed marked enhancement of arboreals (particularly of broad-leaved elements) with corresponding fall in nonarboreals. Change in vegetation pattern indicates establishment of mixed oak forest with warm and humid climate. During Middle Holocene broad-leaved arboreals declined with proportionate rise in *Pinus* and nonarboreals. Floristic change reflects that mixed oak forest became loose with deterioration in climatic conditions. At the onset of Late Holocene were broad-leaved arboreals again showed increase with fall in *Pinus* and nonarboreals, except culture which taxa enhanced abruptly. Such change reflects restoration of mixed oak forest with amelioration in climate.

Data generated from different disciplines broadly corroborates each other. Multidisciplinary investigation of more profiles in time and space shall be of paramount importance in order to interpret past climate more precisely and more authentically.

JURASSIC - CRETACEOUS GYMNOSPERMS OF INDIA

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Gymnosperms, the naked-seeded flowering plants, attained their zenith during Jurassic-Early Cretaceous due to the availability of favourable climate. But their decline started from Middle Cretaceous onwards from where they could never recover. This group was the major floral constituent of Jurassic-Early Cretaceous and widely recorded from Indian peninsula. Indian fossil gymnosperms are described under following major groups.

Bennettitales is known from Middle-Upper Jurassic where it attained its climax and is known by following genera: leaf (*Ptilophyllum, Otozamites, Nilssoniopteris, Anomozamites, Dictyozamites* and *Pterophyllum),* male flower (*Weltrichia*), female flowers (*Williamsonia*), bisexual flower (*Amarjolia*), detached scale leaves or perianth scales (*Cycadolepis*) and stem (*Bucklandia*). Of these, leaf genus *Ptilophyllum,* with its 16 species, is the most common and has been recorded from almost all Upper Gondwana localities. However, its rarity or absence has been noticed in definite Lower Cretaceous beds. *Otozamites*, with its six species, is known from Jabalpur Stage, East Coast, Kachchh and Athgarh Sandstone. Four species of *Dictyozamites* have been recorded from Rajmahal Hills. Fragmentary specimens of *Dictyozamites* from Bhuj Formation in Kachchh and *D. gondwanaensis* from Gangapur Formation in Andhra Pradesh have been recorded by Bose and Banerji (1984) and Sukh-dev and Rajanikanth (1988) respectively. Two species of *Nilssoniopteris,* are known from Kachchh only. While revising cycadophytic fronds, Bose and Banerji (1981) recognized 9 species of *Pterophyllum* and 5 species of *Anomozamites* in India. *Pterophyllum* is common in Rajmahal flora. Five species of *Weltrichia* and 12 species of *Williamsonia* are known mostly from Rajmahal Hills and Kachchh. Five species of *Cycadolepis* too, are known from Rajmahal Hills and Kachchh. *Amarjolia dictylota* and *Bucklandia* are known from Rajmahal Hills.

The short-statured modern *Cycas*-like reconstruction of *Williamsonia sewardiana* by Sahni (1932a) bearing terminally *W. sewardiana* type flower on short branched lateral shoots composed of *Bucklandia indica* type of stem bearing *Ptilophyllum cutchense* type leaves, has been doubted by Bose (1974) in the absence of any organic connection and non-coexistance in the field.

Cycadales - The detached leaves grouped under *Pseudoctenis, Morrisia* and *Taeniopteris* are known from different Upper Gondwana localities and may be cycadean in nature. But their exact affinity can be confirmed on the basis of cuticles only. *Pseudoctenis fragilis* is the definite cycadean frond from Kachchh.

Ginkgoales in India is represented by 5 species of leaf genus *Ginkgoites* from East Coast, Rajmahal Hills and Rajasthan, and two wood genera *Baieroxylon* from Kota Formation and *Ginkgoxylon* from Gangapur Formation in Andhra Pradesh.

Pentoxylales - Sahni (1948) instituted a unique group of plants - the Pentoxylales, consisting the stem *Pentoxylon sahnii* and *P. guptai,* leaves *Nipaniophyllum raoi* and female cones *Carnoconites compactum* and *C. laxum*. The group is unique in possessing the characters of pteridosperms, Cycadales, Bennettitales and Coniferales. Vishnu-Mittre (1953) described a male cone *Sahnia* from Nipania, Rajmahal Hills and attributed it to this group. The genus *Pentoxylon* includes stems of dimorphic nature - thick long shoots with a few leaf scars and short shoots with dense coverage of foliage and leaf scars. It has 3 to 9 (mostly 5) steles with eccentric secondary growth towards peripheral side.

The petrified leaf genus *Nipaniophyllum raoi* (Sahni 1948) resembles superficially *Taeniopteris spatulata* (Sahni 1932b), has been worked in detail by Rao (1943) and found cycadalean feature in having diploxylic bundles and slightly sunken stomata. *Sahnia* as well as *Carnoconites* are borne terminally on separate short shoots only.

Coniferales - In India, the conifers have attained their maximum development during Upper Jurassic-Lower Cretaceous Period. The conifer remains include sterile and fertile shoots, male and female cones, petrified woods and dispersed pollen grains. The affinities of Indian conifers have been found either with Podocarpaceae or with Araucariaceae. Though affinity of certain forms has been shown with Taxaceae or Taxodiaceae but their exact affinities are still uncertain (Florin 1940).

Podocarpaceae - Three species of *Nipanioruha*, a petrified coniferous shoots with needle shaped leaves borne spirally on pycnoxylic woody stem, are known from Rajmahal Hills (Rao 1947, Vishnu-Mittre 1959). The majority of leafy twigs are known as *Elatoclatus* which were earlier described by Feistmantel as *Palissya* or *Taxites* from different Upper Gondwana localities and it has 12 species in India. Vishnu-Mittre (1959) described 3 species of *Indophyllum*, another type of foliage from Nipania. *Nipaniostrobus,* a loosely arranged seed bearing cone from Nipania (Rao 1943, Vishnu-Mittre 1959), *Mehtia,* an ovuliferous cone with erect ovules found in organic connection with vegetative shoots from Rajmahal Hills (Vishnu-Mittre 1959), *Stachytaxus,* a megastrobilus found with *Elatocladus conferta* type of foliage from Onthea, *Siltholeya,* an ovuliferous shoot from Rajmahal Hills are the different fertile podocarpaceous cones known from India. Petrified woods, which were earlier described under *Podocarpoxylon*, *Phyllocladoxylon* and *Paraphyllocladoxylon*, were transferred to *Mesembrioxylon* by Seward (1919),

a genus instituted by him. Bose and Maheshwari (1974) preferred to retain the validly published name *Podocarpoxylon* Gothan (1905) for its priority over *Mesembrioxylon*. Nine species of this genus are known from Rajmahal Hills and East coast. *Circoporoxylon amarjolense*, another type of petrified wood, is also known from Rajmahal Hills (Krausel & Jain 1964).

Araucariaceae - The sterile shoots, *Brachyphyllum* with its 6 species and *Pagiophyllum* with its 10 species, have been recorded from almost all Upper Gondwana localities of India. *Desmiophyllum indicum* is known from Raghavpuram shales and Jabalpur stage. In the genus *Araucarites,* cones as well as detached cone scales and leafy shoots have been described from most of the Upper Gondwana localities of India. Petrified cones are known from Rajmahal Hills only. Silicified woods with araucarian affinity are known from Rajmahal Hills, Kutch and East coast under the generic names *Dadoxylon* and *Araucarioxylon*, but the later name is preferred (Maheshwari 1972) and has 13 Indian species.

Taxales is represented by detached leafy shoot known as *Torreyites* recorded from East Coast and Rajmahal Hills and petrified woods known as *Taxoxylon* from Rajmahal Hills. The nature of this petrified wood was later considered to be abietanaceous by Krausel and Jain (1964).

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PERMIAN PALYNOLOGY IN INDIA – PAST, PRESENT AND FUTURE

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In India, of all the geological periods, it is the Permian which has attracted the attention of palaeobotanists and geologists because of vast coal reserves of economic importance occurring in Permian strata. Permian rocks are rich in pollen and spores. The credit to start palynological studies in India goes to Virkki (1937), who on initiation by Prof. Birbal Sahni, undertook the studies and first described some bisaccate pollen grains from Permian sediments and published “Spores from the Lower Gondwana of India and Australia”. This opened a new area in the field of Permian palynology in India. Sahni (1940, 1948) actually realized the importance of these microfossils in fossil fuel exploration and emphasized for palaeobotanical studies of coal seams in India. Later, various workers (Sen 1944, Mehta 1945, Ghosh & Sen 1948, Pant 1950) continued the study of pollen and spores but a systematic approach was given to this branch of science by Bharadwaj (1962). In early phase of work more emphasis was on morphology and the spores and pollen were categorized as- Type A, Type B or Type 1, Type 2 or one winged, two winged, trilete, etc. This categorization was not much effective and morpho-taxonomic understanding of dispersed spores was preliminary. Pant (1954) proposed a system for classification and nomenclature of fossil spores and pollen grains. Potonié and Lele (1961) and Bharadwaj (1962) emphasized for their detailed morphographic studies and introduced advanced taxonomy by providing their systematic description. These investigations initiated intensive characterization of morphological features, viz. germinal aperture, exine ornamentation and stratification, striations, taeniae, saccus structure and organization, etc. and introduced binomial nomenclature for naming them in accordance with the International Code of Botanical Nomenclature. Various genera and species were instituted on the basis of different morphological characters (Bharadwaj 1962, Lele & Maithy 1964, Tiwari 1964, 1965, 1968, Kar 1968, Lele & Makada 1972). In later phase, the distribution of these pollen and spores at various levels was studied in order to understand palynological succession through Lower Gondwana (Permian: Talchir to Raniganj) of India. Thus, palynology became fast growing science in view of wide possibilities of its application to geological problems.

Since then a large number of areas, covering both time and space, have been studied extensively in India particularly at Birbal Sahni Institute of Palaeobotany, Lucknow. Palynosequences of Permian strata in all the basins, viz. Damodar, Son- Mahanadi, South Rewa, Satpura and Wardha-Godavari, are now well established. Palynological studies in Permian sequences of extra-peninsular region have also been carried out in solving the geologiocal problems (Srivastava & Dutta 1977, Srivastava & Bhattacharyya1990, 1992). The intensive and extensive researches on the applied aspect of Permian palynology carried out during last five decades have established the potentiality of these palynomorphs as an important tool for dating and correlation of strata.

Morphoevolutionary trends, cladistic analysis, species based zonations, palynoevent stratigraphy, bacterial degradation and taphonomy have ushered in to finer aspect of age determination and correlation of coal-bearing strata (Vijaya 1990, Vijaya & Tiwari 1992, Tiwari & Tripathi 1992, Tiwari

1996). Significance of presence or absence, appearance or disappearance and range of certain taxa in time, etc. have added knowledge to understand the magnitude of complexity pattern of these microfossils through time.

Wealth of good data in this discipline has been accumulated but most of the work dealt with the classical palynology, i.e. taxonomy and /or biostratigraphy. Practical application of computer technology is must for rapid identification of taxa and comparative analysis of assemblages. Biodiversity and evolutionary trend during Permian should be studied. One should explore the application of palynological correlation to CBM exploration. Permian palynologists must widen the scope of palynological topics in exploring new field of knowledge and starting close collaboration with various branches of earth and other sciences. Innovative ideas, aided by newer instrumentation can make this parameter more effective as well as authentic in the study of fossil fuel/ hydrocarbon exploration.

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DOMESTICATION OF PLANTS: SOME INSIGHTS FROM PALAEOBIOLOGY

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Domestication of plants is an exceedingly complex, multifaceted and man-aided evolutionary process. Factual evidence for domestication of plants started appearing from archaeological sites and relatively recent geological sites (ca. 10,500 B.C.-6000 B.C.) in different parts of world. It has been a continuous ongoing process and certainly not a one-time event. The initial cultural, physiological, geo-environmental and phytosociological factors in various natural ancient ecosystems of the world started showing up evidences of man-preferred characters in changed forms, at time against the processes of natural selection.

It is well established that the prehistoric process involved human association, intensification, selection and perpetuation of useful characters (incipient cultivation), cultivation and genetic change (domestication) beneficial to mankind, which may or may not have been accompanied by distinct morphological change. Had there been no domestication of plants and animals, there would have been hardly any development towards human civilization and scientific development. Domestication of plants occurred side by side with animal species with ecological and social pre-disposition (e.g. wheat, barley vis-a-vis sheep-goat, cattle) in some regions like Fertile Crescent zone. Whereas in Europe, reindeer domestication seems to have proceeded much earlier. In South America, domestication of maize (*Zea mays*) and new world beans (*Phaseolus* spp.) took place non-synchronously with animals.

Domestication of plants and animals produced revolutionary effects on human societies by ushering change from hunting and food collection to food production, leading to initially surplus food, population growth, leisure for part of population intellectual developments, socioeconomic differentiations, development of civilization, greed for overexploitation of natural resources leading to man-induced environmental, landform, microclimate change and at times even the economic downfall of civilizations. In the symbiotic process of domestication of plants and animals at the hands of man, plants and animals greatly lost their natural ability of self-perpetuation, but at the same time man also got himself bound (domiciled) to the terrain and emotionally attached to the landscape. Domestication resulted in expansion of natural eco-geographical range of crops and weeds, decline of wild putative ancestral species with useful disease/wilt resistant characters, (over) dependence on lesser and lesser numbers of food species, monoculture and genetic erosion of natural biodiversity, especially during the last century.

The palaeobiological indications of domestication can be gleaned through sub-fossil seeds, fruits, pollen, phytoliths, coprolites, animal bones, etc. Taking insights from chronology, place of primary origin and expansion of domestication processes of plants and animals, it is possible to honour and preserve intellectual property rights of the people and also look for new sources of future food/ other utility plant products in the wake of increasing human populations during 21st century. Thus, domestication studies, albeit appearing academically fundamental, are potentially useful for linking past with present and future of regions in various parts of the globe with strong biological and cultural heritage.

Theme–Emerging Trends in Palaeobiology, Session A–Early life on Earth and signatures of Extra Terrestrial Life

ORIGIN OF LIFE ON EARTH AND SEARCH FOR EXTRA TERRESTRIAL LIFE

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During the last few decades experimental and theoretical evidences led us to believe that life on earth must have evolved as a result of several complicated reactions that occurred among the primitive substances present on the Earth. Attempts are also in progress to detect life elsewhere in the universe, but till today no positive results have been achieved. Presence of hematite on Mars, spectroscopic detection of several biomolecules in the interstellar space and in comet's tail and presence of a bulk of organic molecules on Titan lead us to believe for the existence of life somewhere in the outer space. In this talk, results of some important experimental approaches towards chemical evolution and origin of life will be discussed.

POPULARIZATION OF PALAEOBIOLOGY AND ROLE OF EARTH SCIENCE SOCIETIES AND INSTITUTIONS

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Palaeobiological studies have been in the forefront in earth sciences in India during the last hundred and seventy-five years. Leading organizations in the field are Geological Survey of India, Birbal Sahni Institute of Palaeobotany, Wadia Institute of Himalayan Geology, Oil and Natural Gas Corporation and National Institute of Oceanography. Academic work in the field is mostly carried out in the university and college departments of geology. Results of research investigations are published in regular and specialized journals, besides some house journals of reputed organizations.

During the late fifties of the twentieth century, Government of India initiated a programme to popularize earth sciences, including palaeobiology, under the "lay man consciousness of minerals". The programme encouraged local residents to search for minerals and extinct life forms in their particular areas, a search which could follow, if necessary, detailed exploration by a specialist organization. The programme also involved distribution of pamphlets covering geology, mineral resources and fossil biota of selected districts of different states by the Geological Survey of India during various regular and mobile exhibitions, lectures in universities and colleges, and selected fares. Geological Society of India is bringing out publications on the geology of different states to popularize and familiarise general public. Government agencies have also undertaken establishment of fossil parks, for example, the Saketi Sivalik fossil park. It is an outstanding example where fossil sites have been marked and preserved, and a small museum with fossils and models of selected forms has been established. Fossil parks on similar lines are also being established at a few other sites in Jharkhand, Rajasthan, Tamil Nadu, Modhya Pradesh, etc.

For guidance of students and scholars, Geological Survey of India and Birbal Sahni Institute of Palaeobotany have also published a number of catalogues, inventories, etc. with relevant literature citations. Though a couple of atlases on fossils have been brought out, there now seems to be an urgent need to bring out an atlas of index fossils of India.

Palaeontological researches in the country suffered a severe jolt when one of the renowned palaeobiologists was found to have played truant by transplanting 'imported' fossils on to the Indian sites and claimed credit for exiting discoveries. In the process, this palaeontologist also smeared the reputation of many a palaeobiologist who were roped in by him as co-authors. However, of late it has been realized that the research is more important than a particular person, and the research interests would be better served by 'outcasting' the research of this fellow and-carrying on further from that point.

Palaeobiology is of interest not only to the earth scientists (geologists), but also to biologists (both zoologists and botanists). The latter need the data from palaeobiology for comparative studies and evolutionary trends and deciphering biotic groups. The subject, though has been researched for more than a century and half, yet needs a large number of specialists aided by lay public for locating and exploring fossiliferous sites. The area is vast, opportunities are ample, and the applications are exiting. The common person is naturally interested, but only if he is properly guided and educated about different facets of palaeobiological researches, which concern him directly or indirectly.

Official and private institutions working in the field of palaeobiology are contributing to the subject, but in a sort of specialized structure that often is not understood by the lay public, because it is more research oriented application-wise. The common man is more interested in knowing what this kind of research means to him in an economic or social or educational field. Here the academic societies can play a very important role as a go between the researcher, whom they support and publish, and the common man, whom they understand. The country has several learned and academic societies in the field, for example, The Palaeobotanical Society, The Palaeontological Society of India, Geological Society of India, Indian Association of Palynostratigraphers, Geological Mining and Metallurgical Society of India, Indian Association of Geologists, Indian Gondwana Society. Some of these societies have sufficient funds, while others work on shoe-string budgets. Thus, a few, if not all, of these academic societies can contribute towards popularizing palaeobiology.

Popularization has a real utility as stated by Pasteur "Fortune favours the prepared mind". Therefore the spirit of palaeobiologist members of learned and academic societies has to be awakened so that they understand that besides earning credits for their research efforts, they also have a duty towards the society, which funds their researches, to educate it about the importance of their work in simple language. The common man thus educated may in turn help the palaeobiologist as did K.P. Sinor, a construction engineer, who discovered the Umaria Marine bed, or the professor-engineer duo of Falconer and Cautley of Roorkee, who while digging a canal discovered vertebrate fossils in Himachal Pradesh.

It need not be reemphasized that different societies must work in tandem so as to avoid duplication of efforts. Some societies can undertake publication of popular literature on palaeobiology, while others may organize popular lectures, still others may put up educative stalls at scientific conference sites or exhibitions. Palaeobiologists on their return from field may prepare travelogues and guide books, which can be published by the academic societies. This would generate interest in the public and students who go in site seeing in different parts of the country. Below are listed some of the activities that may be undertaken, as far as possible in vernacular, by the palaeobiological and earth science societies.

(i) Preparation of palaeobiogeographic maps of different geological stages – a collaborative attempt between palaeobiologists and stratigraphers.

(ii) Identifying established biotic sections and initiating attempts to preserve and maintain these sections for students.

(iii) Preparation of guide books for important fossiliferous localities, which may lead to development of palaeontological tourism, attracting both national and international traffic.

(iv) Preparation of booklets, in vernacular, listing and illustrating fossil biota at district level.

(v) Establishment of life-size models of extinct biota in zoological and botanical parks.

(vi) Preparation of video clips, documentary films, TV serials, etc. on the fossil biota, the environment in which it lived and thrived. The film Jurassic Park and its sequels created an immense interest in lay public about past life of this planet.

(vii) Establishment of fossil galleries in state and district level museums.

(viii) To encourage schools and colleges to maintain an inventory of important fossils to satiate the curiosity of middle and college level students.

POPULARIZATION/DISSEMINATION OF PALAEOBIOLOGY THROUGH DIFFERENT MEDIA AND ITS IMPACT ON INDIAN MASSES

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Palaeobotany and the myriad forms of life, be it animals or man, have been in association since long. Therefore, even the common masses ought to be told about the evolution of life encompassing the story of the ascent of man, of the vegetation and the change in bio-diversity. Birbal Sahni Institute of Palaeobotany is the only institution exclusively focused on palaeobotany and has a wonderful museum with collection of a large number of specimens. There is a need of extending it and also of having its branches may be as displays in other museums of country.

It is possible to seek support of various governmental and non-governmental institutions of the country in popularization of palaeobotany. These institutions include *Vigyan Prasar*, NCSTC and various educational channels like *Gyan Darshan*, DD Bharati, Central Institute for Educational Technology, NCERT and the state centres. Along with them, one may network the 28 science centres/ museums of National Council for Science Museums with the world's biggest science centre NETWORK. These centres are very relavent as they display a large number of specimens of prehistoric period and other items also.

Publishing a series of popular books on palaeobotany will be a meaningful initiative in this direction of dissemination of palaeobotanical knowledge. News and features on palaeobotany may also be published regularly in the monthly publications of NCSTC, *Vigyan Prasar* and science pages of newspapers.

It will be a fruitful exercise to prepare mobile fossil exhibitions and take them to the various cities and villages. Another place where palaeobotanical knowledge would be relevant is the National Agriculture Museum at Pusa.

The population touched by present science popularization efforts is still limited. For a common man, structure of the earth, changes in biodiversity, earth, fire, water and sky are not part of the real world. In such a scenario, palaeobiology can play an important role in explaining the mysteries of earth's evolution in a very effective manner. Radiocarbon dating is another important approach that complements the study of fossils by providing dates.

Making science centres and museums important points on the tourist maps will go a long way in promoting palaeobotany awareness in particular and science awareness in general.

AEROBIOLOGY: ASPECTS AND PROSPECTS

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Aerobiology is the scientific discipline focussed on the study of the passive transport of organisms and particles of biological origin in the atmosphere. It deals with source of organisms or materials, released into the atmosphere, dispersion, deposition and impact on animal, plant or human systems. It includes the study of viruses, cells and spores of bacteria, actinomycetes, fungi and associated metabolites, spores of bryophytes and pteridophytes, pollen grains of higher plants, mites and their body parts and fecal pellets; proteins released from plants and animal cells during industrial processing and products of biotechnological processes (Mandrioli & Ariatti 2001). In recent past, Scientific Committee on Antarctic Research (SCAR) has organized air-monitoring programme to protect the natural environment of Antarctica from air pollution. Similarly, International Geosphere Biosphere Programme (IGBP) has provided additional opportunities to aerobiologists to detect change of world climate (Benninghoff 1991).

Aerobiology both as a tool and discipline

Aerobiology has been used as a discipline as well as a tool for other disciplines such as medicine (allergology – both human and animal diseases, immunology, occupational hygiene), agriculture (plant pathology, pest management, arthropod dispersal), forestry and gene ecology, meteorology, climatology, biometeorology, microbiology, biodeterioration, indoor air quality, air pollution, industrial aerobiology, cultural heritage, palaeobotany, etc. In fact, aerobiology is a limitless science.

Aerobiopollutants and allergy

(i) Annual pollen and fungal spore calendars and their importance: Aerobilogical studies have gained significant importance in the recent years because of their application in the diagnosis and treatment of allergic disorders such as allergic rhinitis, bronchial asthma, atopic dermatitis and urticaria, etc. In general, allergic rhinitis, also called "hay-fever", ranges from 6% to 12% in USA, Canada, Finland, New Zealand and Australia. Preliminary statistics available from India suggests that nearly 10% of the population suffer with this syndrome.

First systematic aerobiological work in India was carried out in Kolkata by Cunningham (1873). Later on, two important centres, viz. S.M.S. Medical College, Jaipur and Vallabhbhai Patel Chest Institute, Delhi inititad the aerobiological investigation with particular emphasis on clinical relevance of air-borne pollen. Now the aerobiological studies have its own national network at many centres in the country such as Kolkata, Bangalore, Gwalior, Chennai, Hyderabad, Imphal, Gorakhpur, Pune, Aurangabad, Delhi, Nagpur, etc.

The survey of atmospheric pollen grains at the Birbal Sahni Institute of Palaeobotany, Lucknow, was initiated by Lakhanpal and Nair (1958). In the year 1969, the analysis of aeromycoflora was incorporated along with pollen studies in order to complete the picture of the aerobiota (Vishnu-Mittre & Khandelwal 1973). During the year 1976-77, the survey of air-borne fungal flora of Lucknow University area was conducted in relation to plant and surface mycoflora (Wadhwani 1979). A two-year (1980-81) survey of air borne pollen alone was carried out in the National Botanical Research Institute, Lucknow (Chaturvedi *et al.* 1987-88). The qualitative and quantitative evaluation of important pollen grains and fungal spores of year 1969-70, 1970-71 and 1983-86 have been found useful for ready assessment of daily fluctuations in their frequencies (Vishnu-Mittre & Khandelwal 1973; Khandelwal 1991, 1992). The aerobioogical data generated over a period of four years in All India Coordinated Project entitled "Aeroallergens and Human Health: Aerobiological studies" at the Birbal Sahni Institute of Palaeobotany, Lucknow employing three internationally recognized samplers, viz. Burkard, Rotorod and Andersen could not be compared with earlier records due to changed methodology and sampling site. However, forty-three types of pollen grains, forty types of fungal spores and thirty-six types of fungal colonies were registered. The qualitative and quantitative variations in number and composition of airspora have been recorded from both urban and suburban areas (Khandelwal 2001). The pollen grains of family Poaceae, fungal spores of *Cladosporium* and fungal colonies of *Alternaria alternata* were found dominant almost from all the investigated sites. Co-dominance was recorded by pollen grains of families Chenopodiacae/Amaranthaceae, fungal spores of *Alternaria*/'small round spores' and colonies of *Fusarium oxysporum* /*Penicillium funiculosum*. The Burkard air sampler has also been used for monitoring the Antarctic air (Bera and Khandelwal 2003).

The pollen spore calendars are useful in identifying allergies against particular airborne pollen and fungal spore types. However, the limitation of pollen calendar is the occurrence of year to year variation in both number and time of appearance of each type of pollen grains and fungal spores. The emphasis has been laid for continuous periodical monitoring at different sites in a given area in order to provide specific zonal data to local clinicians/allergists. The standard record of aerospora of Lucknow assembled so far is being utilized as a 'ready reckoner' for periodic biopollutant predictions required for the treatment of various allergic disorders caused by air-borne pollen grains and fungal spores.

(ii) Aeroallergenic pollen grains & fungal spores of Lucknow: The significant aeroallergens of Lucknow area, based on clinical investigation carried out at King George Medical College, Lucknow, are: *Alstonia scholaris, Amaranthus spinosus, Azadirachta indica, Chenopodium album, Cynodon dactylon, Cyperus rotundus, Holoptelea integrifolia, Prosopis juliflora, Putranjiva roxburghii, Ricinus communis, Alternaria alternata, Aspergillus flavus, A. fumigatus, A. nidulans, A. niger, A.terreus, Cladosporium cladosporioides, Curvularia lunata, Fusarium oxysporum, Helminthosporium spiciferum, Monilia* sp., *Penicillium citrinum, Phoma* sp., *Rhizopus* sp., *Trichoderma virde,* etc. (Agnihotri & Singh 1971, Khandelwal 1974, Jamil *et al.* 1981, 1986, Wadhwani *et al.* 1986). Besides the role of intact pollen grains, microaerosols originating from the same or different taxa contributing towards total allergenic load are yet to be thoroughly studied.

Aerobiology: Vision 2005 and beyond

(i) Global aerobiological network: There is a need for the establishment of global network for aerobiological monitoring. Air monitoring is of great significance in weather forecasting. Identification and prevalence of clinically significant aerobiopollutants are the prerequisites and then dissemination of generated data in difference parts of the world where such data is not available.

(ii) Integrated and Co-ordinated National Programme: In India, there is no integrated and co-ordinated national program as yet on different aspects of environmental pollution, which is a serious lacuna in the promotion of better hygiene and health. The utility of existing dataset, predictive models of specific pollutant are required for better understanding and proper management.

(iii) Storage of Data: At present, there are no means for keeping the account of acquired data of current efforts in Indian aerobiology other than the efforts of the overseas centres. The International

Association of Aerobiology exchanges information but there are no arrangements for data storage. It was felt that the SAROD (Storage and Retrieval of Atmospheric Data) and EPA (Environmental Protection Agency) should also handle the aerobiological data of other countries as well. Establishment of data retrieval centre and computer based forecasting system are important for avoidance strategies.

(iv) Standardization of methods and procedures: Characterization of different pollen allergens for their allergenic components is inadequate and efforts should be made to characterize and standardize most of the pollen allergens on global basis.

(v) Education: Unfortunately, aerobiology is not officially taught at Indian universities, except for a very few states, where it has been recently introduced in science courses at graduation and post-graduation levels. The need for aerobiology to be identified both in universities as an academic discipline and in governmental institutes as a scientific discipline is strongly felt by the aerobiologists actively engaged in this field.

(vi) Forecasting System: Most of the advanced countries have devised an efficient integration of aerobiology with the early warning system for forecasting plant and human diseases by using mass-media such as newspaper, television, radio, electronic media, etc. A similar pattern of warning and prediction system should be evolved in our country, which might contribute towards a more direct and immediate benefit for local population in general and allergic patients in particular.

The analysis of environmental biopollution is an important issue related with health hazards of living systems. It is hoped that prevention and control of environmental biopollution would be within our reach and command to achieve health for all living systems in near future.

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INDIAN ANTARCTIC PROGRAMME: SCOPE FOR PALAEOBIOLOGY AND FUTURE CHALLENGES

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Antarctica is a pristine and natural laboratory which enables the scientist to study, detect and monitor global phenomena, such as those related to oceanographic, atmospheric and meteorological parameters. Glaciological, geological and geophysical researches provide clue to the evolutionary history of the continents and the palaeo-climate of the earth. In addition, Antarctica provides a singular window for studies on solar-terrestrial interaction, geomagnetism and plasma processes. The adaptation techniques of organisms, including those of the human beings, in the cold and isolated environment can at best be addressed from this remote and icy continent.

The Indian Antarctic Programme has been designed to take advantage of the unique site and environment of Antarctica for understanding the key global processes by undertaking thematic research in different aspects of Polar Science. The first Indian Antarctic Expedition which was launched in 1981 under the able leadership of Dr. S.Z. Qasim, heralded entirely new era of the Indian science. Subsequently, it proved India's capability to undertake Antarctic explorations at par with other global partners. Our continuous pursuance of science has been the driving force for the successful launching of 24 annual scientific expeditions to Antarctica. Besides, four specific expeditions (namely Waddell Sea expedition, Krill expedition, Southern Ocean expedition and Total solar eclipse expedition) have also been launched.

India's presence in Antarctica has been well recognized within the Antarctic Treaty System. The sustained interest and proven capabilities to conduct front ranking Antarctic science paved way for country's admittance to the Antarctic Treaty System (ATS) on 19 August, 1983 and soon thereafter, achieving a Consultative Status on 12 September, 1983. In this year the first permanent station, *Dakshin Gangotri* was established. This was followed by the second station *Maitri* which was set up in 1988-89. In October 1984 India was also admitted to the Scientific Committee on Antarctic Research (SCAR) and later in 1986, became Member of Council of Managers of Antarctic Programme (CONMAP) and Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). India's commitment to uphold the principles of the Treaty System was lately demonstrated through the ratification of Protocol on Environment Protection to Antarctic Treaty in April 1996. This protocol, for which India was one of the original votaries in 1991, is designed to preserve and safeguard the pristine nature of unique continent.

The scientific framework of the Indian Antarctic research activities has been constantly evolving and is designed to address topical issues of global concern with particular emphasis on those aspects which have a direct relevance to the country. Several national institutions, organizations and universities participate in Antarctic Research Programme by pooling together their inter-disciplinary knowledge and expertise. Till date, about 1500 personnels, drawn from nearly seventy organizations, have participated in these expeditions. The logistic support to these expeditions is rendered by the Indian Army.

Contemporary scientific programmes in the field of atmospheric, earth, biology, human physiology, environment, engineering and communication are being conducted in accordance with the national priorities and international commitments.

True to the spirits of Antarctic Treaty System, the Indian Antarctic Programme, is embarking upon mutually beneficial scientific collaborations with various Treaty nations. These collaborative missions are directed towards understanding issues of global relevance which have been identified by SCAR. Joint research projects in different domains of Polar Science with Argentina, France, Germany, Italy, Peru, Malaysia and Poland are being finalized.

Future challenges for palaeobiology: The lakes of Antarctica are the major features of the Antarctic landscapes and sediments of these lakes assume a pivotal role in palaeoclimatic and global change investigation. Antarctic lakes receive their sediment supply during warmer periods of spring and summer when ice melts. It is well known that the sediments and palaeobiology (fauna/ flora) contained therein are influenced by climatic changes. Therefore, the core retrieved from the lakes will be utilized for sedimentological, mineralogical, geochemical, trace elements, stable isotopes and biological, diatoms, palaeomagnetic study to decipher the climatic changes that have occurred in the immediate geological past in Antarctica. The water mass characteristics of lakes can be an added advantage to compare the biological changes among lakes of Schirmacher Oasis. However, in order to collect the sediment core from Antarctic lake one of the initial requirements is the bathymetric map and an estimation of the distribution, thickness and stratigraphy of the sediments underlying the lake. This aids in locating the coring sites and conducting the overall basin analysis. Acoustic techniques, such as echo sounding and sub-bottom seismic reflection profiling are commonly employed for lake-bottom and sub-bottom characterization. The data allow the detection and mapping of geologic features such as irregular and rocky sea floor, nature and distribution of surface and subsurface sediment characteristics, etc. Therefore, it is proposed, for the first time, that an Indian approach will be made to carry out geophysical survey of the Antarctic lakes. Based on the analysis of geophysical data the availability of sediment and its thickness will be located on bathymetric chart that would help us to provide the exact location for sediment coring of lakes. The proposed approach can drastically reduce the number of attempts made in order to retrieve the sediment core and therefore, can save the valuable time, energy and resourses spent in Antarctica for coring purposes. In future the data generated can also be effectively utilized for various other scientific purposes for collecting the samples for biological/ environmental study.

The objectives of the Indian Antarctic Programme are: (i) to carryout detailed bathymetric survey of Antarctic lakes using single/ dual echo sounder and prepare bathymetric charts of lakes frequency at geographically distinct locations; (ii) to determine sediment thickness of Antarctic lakes using sub-bottom profiler; (iii) to study palaeoclimatic history recorded in lake sediments using microlife and other parameters like, sedimentological, geochemical, etc; (iv) hydrographical assessment of various lakes using portable CTD and other methods; (v) nutrient dynamics in various lakes; and (vi) botanical/ zoological aspects of various lakes.

THE EDIACARAN PERIOD: ITS LOWER AND UPPER BOUNDARIES IN INDIA

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The Ediacaran Period, a new addition to geologic time scale for terminal Proterozoic, begins with the termination of the last great global glaciation (Varanger) of the Neoproterozoic Era, and is characterized by the Ediacaran fossil assemblage that gave the period its name. 'The beginning and the end of the Ediacaran Period are also marked by remarkable negative excursions in the carbon isotopic records, unusual biogeochemical events recognized globally in both carbonate rocks and sedimentary organic matter'. The base of the period is defined by "cap carbonate" that conformably overlies the Varanger /Marinoan glacials and the initial GSSP is marked at the base of the Marinoan cap carbonate (Nuccaleena Formation) in the Enorama Creek section of the central Flinders Ranges, Adelaide Rift Complex, South Australia. No precise carbon isotopic data to constrain the age is available but recent 635 Ma U-Pb zircon age for an ash bed within glacial strata in Oman and Pb-Pb age of 599±4 Ma for post-glacial phosphorites in southern China suggest an age for the GSSP younger than 635 Ma, but older than 600 Ma.

The initial GSSP for end of the Ediacaran Period and beginning of Cambrian is located in the Chapel Island Formation, Fortune Head, southeast Newfoundland, Canada and the boundary placed between the trace fossil Zone-I (*Harlaniella podolika Zone*) and Zone-II (*Treptichnus* (*Phycodes) pedum Zone*), 2.4 m above the base of the formation. The radiometric dates of the point are not available. However, U-Pb age from Oman coinciding with the negative carbon excursion has given an age of 542 Ma.

In India, Ediacaran sequences form part of a continuous sequence, which rests unconformably over the oldest platform sequences (Meso-Neoproterozoic II) in many parts of Lesser and Tethys/ Higher Himalaya and grades into Cambrian. Of the various sections studied in detail in different parts of Himalaya for demarcation of the boundaries, the Baliana-Krol-Tal succession in the Krol Belt, Lesser Himalaya is found to be the best. Of these, the Maldeota section was one of the candidates for selection of GSSP for Ediacaran Period. The lower boundary of the Ediacaran period is marked at the base of red-green shale and pinkish lenticular dolomite (Member-G) forming the topmost bed of the Blaini Formation. There is a marked change in assemblage of acritarch and cyanobacteria within upper part of the Baliana Group with appearance and extinction of Ediacaran fauna in the overlying Krol. This change is also accompanied with a significant depletion in $d^{13}C$ values in the 'cap carbonate'. The upper boundary could not be precisely demarcated in the absence of record of boundary diagnostic trace-fossils. However, a significant depletion in $d^{13}C$ values is recorded in the upper part of the Krol Group with appearance of spiny and processed acritarch (acanthomorphs), scaphomorphs and hercomorphs, small shelly fossils, trace fossils and trilobites of Early Cambrian age in the overlying Tal, which is considered to mark the boundary. The paper discusses in detail both boundary problems and attempts at the correlation with GSSP.

Theme–Emerging Trends in Palaeobiology, Session D–Proxies and parameters in Palaeoclimate assessments

DISPERSED ORGANIC MATTER: A PROXY INDICATOR FOR ASSESSMENT OF DEPOSITIONAL ENVIRONMENT

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Plant derived organic matters buried in sediments provide direct or indirect means to assess the status and trends of depositional factors. Microscopic analysis of these biological entities isolated from sediments by chemical processes highlight significant information about productivity, composition, transportation and accumulation at depositional sites. For understanding their role, a better apprehension of their diagnostic features and properties are essential, which help to identify various environmental factors involved during deposition. The characterization and frequency analysis of such organic matter can be utilized as a reliable proxy data for reconstructing the provenance, compositional variability, heterogeneity, diagenesis and rate of sedimentation in time and space. The organic matter analyses also focuses at variabilities in depositional structures that have been influenced by fresh water or marine ecosystems. Their contents in a particular bed can be demonstrated by identifying their status of preservation and biodegradation indicating the potentiality of microbial activity in relation to the sedimentary section. The fate of various types of organic matter in a bed is solely dependant on the duration of its burial time and involvement of biological, mineralization and lithification processes, which also reflects its association with lithotypes and pore water condition. The density of organic matter in a stratum is based on the rate of supply, sedimentation, sharing with anoxia and degree of preservation and biodegradation processes that occur in a particular lithotype. Therefore, analyses of organic matter characteristics of a sequence reflect the trends of organic facies deposition. These studies thus, generate a more useful proxy data to evaluate the depositional condition of organic rich sediments.

PALAEOCLIMATE SIGNATURES OF MANGROVES FROM THE NEOGENE AND QUATERNARY SEDIMENTS AND THEIR IMPLICATIONS IN PALAEOMONSOON STUDY

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Mangroves and their deposits are extremely important in palaeomonsoon studies as India has an extended coastline of 6,500 km with a mangrove cover estimated to be 4,87,100 ha. Mangroves help trap fine grained sediments including spores and pollen because of their unique and intricate horizontal root network system. Due to high rates of accretion, mangrove sediments may turn out to be very useful for palaeomonsoon studies. Preservation of such sediments in the geological column helps to yield information on the ambient sea level, presence and extent of backwater bodies, lagoons, swamps and marshes. Observations suggest that the mangrove deposits can be excellent indicators of palaeoclimatic events such as rainfall variations. Excess rainfall leads to massive erosion within the catchment areas. Sediments deposited by such large-scale floods can cause phenomenal changes in the substrate lithology. More significantly in regions of low subsidence, estuaries and lagoons eventually get silted up and become marshes beyond the reach of tidal waters. Thus, the important conditions required for the survival of mangroves, namely salinity and substrate can become non-existent following excessive rainfall. On the contrary, deficient rainfall over a long period of time, can turn the coastal landforms that support the mangroves into progressively more saline areas intolerant to mangroves. Reduction in rainfall also affects the fluvial sediment supply to the mangrove swamps. As observed in several places in south Kerala, aeolian deposits can bury lagoonal sediments. However, signals of environmental changes can be complicated by fluctuating sea levels and tectonics, especially in areas undergoing subsidence.

Until now, palaeomonsoon changes have been studied using isotopic and foraminiferal proxies from the Arabian Sea. Sedimentological and palynological studies of lake deposits in the Himalayas and in Nilgiri highlands of southern peninsular India have brought out interesting new data in palaeomonsoon studies. However, mangrove sediments are seldom addressed in a palaeoclimatic perspective and palaeomonsoon studies in particular despite the sedimentary basins have massive and thick pile of sediments derived from the coastal ecosystem. As the sustenance of mangroves is dependent on hydrodynamics and sedimentology, the mangrove swamps form ideal storage sites for palaeomonsoon records.

As the climate of India is dominated by two monsoon seasons (southwest and northeast) and the rate of rainfall varies from north to south along both the coasts, the monsoonal records are expected to be stored in this specialized and sensitive environment located near ocean-continent interface where high rate of sediment accumulation takes place. Being the major component, the mangrove vegetation has a considerable role in the hydrodynamic and flushing processes and as such has tremendous influence on sediment accumulation. The root system of the pioneer species holds the sediment intact and enhances the accretion process in the mangrove swamps. Since these sediments are laid down under environmental conditions essentially influenced by the monsoon, the coastal deposits offer an opportunity to unravel the palaeoclimatic history. Accordingly, these swamps develop into potential storage sites with a huge pile of peats, black clays and silts.

One of the tools for studying palaeoecology and palaeoclimate is palynology, the science of study of pollen and spores. The mangrove vegetation produces large quantity of pollen grains which are liberated to the substratum where the conditions favour for their preservation and fossilization. Because of small size and highly resistant exine, the pollen are the most abundant plant remains in the sediments. As the vegetation is directly influenced by climatic, geographical and geological changes, palynological studies form the basis for the reconstruction of past vegetation and the changes of environmental conditions over time as well. Any minor or major sea level changes and the fresh water discharge subject the mangrove vegetation to stress conditions and affect its zonation pattern and their sustenance. Therefore, stratigraphical record of pollen of mangrove in a profile has its implications in understanding the different aspects of the coastal and climatic changes.

Peats and organic rich clay layers are valuable markers for environmental changes and form excellent stratigraphic units within the Quaternary sequence of Kerala-Konkan Basin. These organic matter enriched deposits vary from 0.5 to 6.0 m thick and are found at different depths in the boreholes between sandy clays and clayey sedimentary facies. Three generations of organic deposits have been identified; the younger ones are of Late Holocene (<4000 yr BP) and the Middle Holocene-Early Holocene-Late Pleistocene interval (4,540-10,760 yr BP). The older one is dated to be 40000-43000 yr BP and few beyond the dating range of radiocarbon.

Pollen analyses of samples revealed that the peats and organic rich sediments are mostly derived from the mangrove vegetation (Rhizophoraceae and Avicenniaceae) and mangrove swamps and few from coastal (*Acrostichum* and *Ceratopteris*) and upland evergreen forest (*Cullenia exarillata* of Bombacaceae and members of Euphorbiaceae). The other commonly recorded families in the mangrove swamps are Rubiaceae, Caesalpiniaceae, Lecythediace, Combretaceae, Myrtaceae, Verbanaceae, Sterculiaceae, Sonneratiaceae and Meliaceae. Some of the members of these families occur between the low tide and high tide areas where the soil is characteristically silty and clayey. The organic deposits of Late Holocene occur as discrete pockets, lenses of peat are found sporadically and pollen grains of mangroves are relatively poor. The scarcity and absence of mangrove pollen in the late Holocene sediments may be attributed to the decline of mangroves and phenological changes as the mangroves are under environmental stress.

The available data and radiometric ages of peats and organic matter enriched clays from west coast of India are far from precision due to wide geochronological variations. Accordingly, radiocarbon dates (^{14}C), including AMS dates, of different layers and those of sands and sandy clays by luminescence dating in a single core with close sampling are necessary to determine high resolution palaeomonsoon records. Further, environmental magnetism could complement palaeoclimatic study of the coastal deposits. The magnetic properties of the clay and silt rich mangrove sediments are expected to sensitively record past changes in rainfall intensity as the iron bearing minerals are very sensitive to pH and Eh conditions. Such changes make their formation and transformation available indicator for environmental changes such as rainfall, temperature, weathering and others. It is this link between magnetism and environment (climate) that is used in environmental magnetic measurements covering marine and continental realms. Since there is hardly any input of environmental magnetism study along with pollen analysis from the mangrove sediments of India for high resolution palaeoclimatic study, there is an integrated study in order to address the palaeoclimate of Late Quaternary. Thus, coupled palynological and mineral magnetic studies would provide invaluable information on vegetation response to monsoon change in India.

PRESENT STATUS OF PALAEOGENE PALYNOFLORA AND FUTURE DIRECTIONS

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The Indian Palaeogene palynodata generated so far is very rich and the palynofossils have successfully been utilized in palynostratigraphic zonation, correlation, age determination and in deducing palaeoclimate, environment of deposition and palaeoshorelines. Recently a few contributions have been made on the origin, evolution and dispersal of selected pollen taxa. These data have come mainly from the coastal areas of peninsula while information from the extra-peninsular region is meagre. Extra-peninsular palynoassemblages are known from the Subathu, Dras Volcanics and Dagshai sediments. In recent years information has also been accumulated from Andaman Islands, which reveals presence of some typical palynofloral elements in the Island, though a gross resemblance exists with the mainland contemporary floras. These assemblages are poor in palynomorphs and are not sufficient to build palynostratigraphy but throws light on palaeocurrent directions based on reworked palynofossils. The Deccan Trap country, occupying a large area of peninsula, though rich in megafossils of doubtful Palaeocene-Eocene age, has yielded negligible palynofossils to confirm this age constrain.

The palynoassemblages so far recorded from the Palaeogene sediments suggest true tropical to tropical-subtropical climate. The recorded assemblages also demonstrate vegetational changes during 21 Ma span of the Palaeogene. The continuous modification in the flora during this time interval is in response to northward movement of India. Palynoflora of the late Palaeocene and early Eocene sediments are very rich and diverse and have been worked out extensively. The lower part of the Palaeocene is almost devoid of palynofossils due to non-yielding nature of out-crop sediments. Consequently, there is a major gap in assessing character of early flora and its diversification. However, pollen data of the late Palaeocene suggest relationship with the African flora, e.g. presence of *Matanomadhiasulcites, Kielmeyerapollenites* and *Trilatiporites*. These taxa reached India through land route established during the late Cretaceous-Early Palaeocene. A few taxa like *Proxapertites* and *Spinizonocolpites* had global distribution in tropical areas, while *Dandotiaspora* and *Acanthotriletes* are typical of Indian flora. Excepting a few, majority of the late Palaeocene taxa persists in the early Eocene and a number of taxa evolved at this time. The palynoflora of the later part of the Eocene is comparatively less known. Palynoassemblages are not rich in variety though older sequences exhibit change in palynofloral composition from the early to late Eocene. At the onset of the Oligocene, the palynoflora takes modern look resembling extant families. Palynofossils suggest inclination towards terrestrial habitat from marshy/swampy conditions. They also reflect rise of land mass and thereby change in climate due to collision with the Asian plate. This climate change was not sufficient to support growth of cold loving plants like *Pinus*. Moreover, palynofossils demonstrate migration of flora towards S.E. Asia through land route established at the end of the Eocene.

Besides conventional studies, future investigations should focus on: (i) finding modern analogues of palynofossils to decipher palaeovegetation and palaeophytogeography; (ii) searching for and identifying palynofossils belonging to recorded megafossil genera; (iii) analyzing assemblages to demarcate palaeoshorelines; and (iv) evaluating reworked palynofossils to locate source and direction of sediments and multidisciplinary approach towards high resolution stratigraphy. Additionally, inconsistencies in designating taxa by different researchers should be avoided. This helps in precise stratigraphic correlation since identity of a taxon is the key for all inferences.

INTERACTION OF FUNGI WITH HIGHER PLANTS - SOME PALAEOBOTANICAL GLIMPSES

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Fungi are known to live, survive and multiply in diversified habitats. Out of 1.5 million fungi, 50% remain hidden. Out of 79000 fungi named, around 27000-29000 fungal species are reported from India. Graham (1962) and Tiffney and Barghoorn (1974) have stated approximately 500 fossil fungal species representing 280 genera are known in the literature which are from Cretaceous and Tertiary rocks. Oomycete like structures from Skillogalee Dolomite, Precambrian (Schoff & Barghooru 1969), *Palaeomyces,* non-septate hyphae terminated in vesicles, Devonion (Kidston & Long 1921), oogonium with oospore like structures associated with Pennsylvania - Upper Carboniferous (Stidd & Cosentino 1975), *Palaeancitrus,* Clamp connection bearing hypha like fungus (Dennis 1970) are some of the earliest evidences of fungi.

Arbuscular mycorrhizal fungal structures are described in the cortical tissues of underground pests as evidenced in Upper Carboniferous plant remains (Wagner & Taylor 1981). Similar structures were also reported in specimens collected from the Triassic of Antartica in host root cells of cycads (Stubblefield *et al.* 1987). They may belong to *Glomus* and *Sclerocystis.* Hyphae with clamp connections were reported in Upper Carboniferous coal ball material indicating basidiomycetous nature. Further, some fruit bodies such as *Sporocarpon, Dubiocarpon, Mycocarpon* and *Traquairo* resembling ascomycetous fungi were reported on plant deposits of Triassic age. Rothwell (1972) reported *Palaesclerotium* from Upper Carboniferous coal-ball materials, few fruit bodies resembling the modem earth stars and polypores such as *Geasterites* from the Tertiary and *Fomes* from Pleistocene (Andrews & Lenz 1947). Microthyriaceous fungi resembling the modem *Aslerima, Microthyrium* and others are reported from fossil angiosperms of Eocene. *Meliola* like *Callimothallus, Microthallites, Paramicrothallites* and *Parmathyrites* are some of the microthyriaceous fungi reported from Eocene.

Palaeomycologists have not given the needed importance of saprophytic fungi in the fossil record. Stubbfield *et al.* (1985) have reported mycelial pockets in the secondary wood of *Callixylon newberrys* from Upper Devonian.

Further identification of parasitic fungi has become a major problem due to the absence of symptom documentation in fossils. Dilcher (1965) has reported several epiphytic fungi in the Tertiary fossil material. Angiospermic diversity and fungal diversity at least during Carboniferous and Cretaceous or Tertiary seems to be similar even if you compare the modem fungi.

If the rate of nucleotide substitution is approximately constant for all lineages and if fossil evidence is available to calibrate the rate of nucleotide substitutions, then the percentage substitution between pairs of species can be used to estimate their times of divergence. Berbee & Taylor (2001) have reported an initial estimate of the divergence time for major groups of fungi based on 18 S rRNA gene sequences. Basidiomycetous fungi might have radiated after the Cretaceous.

Most Glomales, Endogonales, Ascomycetes and Basidiomycetes are associated with terrestrial plants. The most parsimonious assumption is that radiation of these fungi followed the origin of land plants. While the date of origin of the first terrestrial plants is uncertain, microfossils from 460 Ma

(Gray 1985) have been attributed to terrestrial plants. Conservatively placing the origin of land plants at 600 Ma, 140 Ma earlier than their appearance as fossils, provides an earliest possible date for terrestrial fungal radiation. Fossil spores and arbusculaes from about 390 Ma represent the most recent possible date for the origin of Glomales. A 290 Ma clamp connection (Dennis 1970) provides a most recent possible date for Basidiomycota.

Glomales or Endogonales divergences occurred about 600 Ma or even earlier. The tree from 18 S rRNA sequence data shows Ascomycota and Basidiomycota diverging from one another in the Palaeozoic, about 500 Ma.

As per rough estimate, 0.3 million angiospermic plant species are available in diversified plants. It is known that angiosperms originated just prior to the Cretaceous. Further, they were well preserved in Lower Cretaceous onwards. Though fossil angiosperms described are not many, still some data reported Tertiary fossils from Deccan Intertrappean flora of India stands for documentation.

Chitaley (1974), Prakash (1974) and Lakhanpal (1974) have published excellent reviews on fossil plants of Deccan Intertrappeon beds. Fungal spores and some microfossils have been recovered from oil-bearing sediments. Palaeoecological studies of fungi must deal interaction with the biotic environment provided by plants and animals. Host pathogen interaction is another aspect, which does not have basic information in the form of fossil evidences. In conclusion, the interaction of fungi with higher plants with reference to palaeobotanical evidences need to be documented in appropriate manner by exploring more fossil fungi and chemical and geological aspects.

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EDIACARAN BIOTA FROM KROL GROUP, LESSER HIMALAYA AND ITS STRATIGRAPHIC SIGNIFICANCE

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The Ediacaran biota includes soft-bodied metazoans mainly represented by primitive coelenterates, few arthropods, echinoderms, problematic taxa and trace fossils generally in the form of simple horizontal to subhorizontal burrows. The appearance of Ediacaran biota is believed to make transition in the evolution between the microbial communities that characterize the Precambrian and the shelly biota of Cambrian and younger Phanerozoic rocks. Before the appearance of Ediacaran biota, benthic communities had been dominated by prokaryotic micro-organisms alongwith some sheet-like and ribbon-like algae during Mesoproterozoic to mid-Neoproterozoic Period. The oldest known megascopic Ediacaran type remains occur in the Twitya Formation of northwestern Canada immediately below tillites. These tillites have been correlated with Varanger / Marinoan / Nantau / Blaini glacial deposits. Ediacaran biota diversified rapidly after the end of the Neoproterozoic glaciation and is now known from all the continents except Antarctica. The known stratigraphic range of Ediacaran biota is approximately 55 Ma (600-545 Ma), but diverse and complex fossils are known from the final 20 Ma of Neoproterozoic. The abrupt disappearance of Ediacarn biota may be attributed to competition and predation of early skeletal animals and global geochemical changes.

Ediacaran biota, viz. medusoids (*Kimberella* cf. *quadrata, Beltanella* cf. *gilesi, Cyclomedusa davidi, Conomedusites lobatus, Tirasiana* sp., *Medusinites asteroides, Sekwia* cf. *excentrica, Irridinitus* sp. and *Beltanelliformis* cf. *brunsae*), frondoids (*Charniodiscus* cf. *arboreus, Pteridinium* cf. *simplex* and *Zolotytsia biserialis)*. annelida (*Dickinsonia* sp.), ichnofossils (*Bilinichnus* sp.) and metaphytic algae (cf. *Proterotaenia Montana)* has been recorded from the Kauriyala Formation (Upper Krol) of the Krol Group, Lesser Himalaya. The underlying Jarashi Formation (Middle Krol) has yielded frondoid forms- *Pteridinium carolinaense* and *Charniodiscus* sp. cf. *arboreus* and trace fossil -*Harlaniella* sp. whereas the Mahi Formation (Lower Krol) has yielded medusoid -*Nimbia* cf. *occlusa.* This biota is generally cosmopolitan in nature except *Dickinsonia* which is restricted to Protogondwana. The Ediacaran biota is preserved at the interface of arenite / siltstone and shale which show ripple marks, rhythmic and lenticular bedding at places suggestive of tidal flat environment. The biota is preserved mostly as impressions/ moulds / casts on the lower surface of the arenite / siltstone. This biota is found generally associated with microbial mat structures which are inferred to be responsible for preservation of the biota.

The present fossiliferous horizon is characterized by $_{6}C^{13}$ values that vary from +1.3‰ to + 1.5‰ PDB. Similar isotopic signatures have also been described from other Ediacaran fossil bearing horizons from northwestern Canada, Namibia, Australia, China and north Siberia.

APPLIED PALYNOLOGY— TOWARDS A BRIGHT FUTURE

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Palynology is an important branch of palaeobiology, concerned with the study of organic walled microfossils found in the sedimentary rocks. Starting as a descriptive science confined to the study of palynomorphs (mainly spores-pollen and fungal remains) for botanical and biostratigraphic purposes, it has vastly diversified and has grown into an indispensable discipline due to their wide range of application in solving geologic problems and fossil fuel exploration. Palynology now covers a very broad spectrum of terrestrial and marine palynomorphs besides spores-pollen, e.g. dinoflagellate cysts, acritarchs, chitinozoans, scolecodonts, microscopic algae, etc.

Palynological study of the total particulate organic matter in the sediments has developed as an important field of research (palynofacies study) for reconstruction of depositional environment and evaluation of hydrocarbon source rock potential. With the development of sequence stratigraphy in sedimentary geology, palynology and palynofacies have emerged as important components in integrated multidisciplinary studies. Significance of palynomorphs has been amply demonstrated for characterizing various sequence components, correlation of terrestrial and marine deposits and relative sea-level fluctuations.

A vast amount of palynological data has been generated from the petroliferous sedimentary basins of India during the past five decades (see Mehrotra et al., 2002a, b, 2005 & references therein; Mehrotra & Aswal, 2003; Mehrotra & Singh, 2003). However, it is only during the last two decades that significant development with regard to the application aspects of palynomorphs and palynofacies have taken place due to the increasing emphasis on hydrocarbon exploration in different on-shore and off-shore sedimentary basins. Frontier fields of these applications are in the dating and correlation of sediments through identification of global bio-events (FAD and LAD), high-resolution integrated biostratigraphy for finer zonations, recognition of T/R cycles, reconstruction of palaeoenvironment and palaeoclimate, identification of sequence boundaries, maximum flooding surfaces, characterization of system tract components, deciphering relative sea-level changes, and better understanding of hydrocarbon source potential facies. Palynology has, therefore, proven its application in all the commercially producing sedimentary basins of India— Cambay, Mumbai Offshore, Krishna-Godavari, Cauvery and Assam (Mehrotra et al. 2002a, b, 2005). Based on the identification of globally recognized dinoflagellate cyst Biohorizons, a fine stratigraphic resolution of 0.5 to 1 Ma has been achieved in some of these basins. Analyses of terrestrial palynomorphs and dinoflagellate cysts have helped to develop palaeoenvironmental models useful in basinal studies. Palynofossils have been extremely valuable in providing age support in calcareous microfossils poor successions. These multifaceted approaches facilitated emergence of ‘Applied Palynology’ or ‘Industrial Palynology’ as a potentially viable tool in solving geologic problems and hydrocarbon exploration.

The fast growing energy requirement in the oil and natural gas sector and the gap between indigenous production and likely demand require constant striving to enhance hydrocarbon production in our country. With further expansion of exploration operations in the oil industry, demand for Applied Palynology is bound to increase manifold in the coming future. However, it is said that western countries may likely face a serious shortage of Industrial palynologists in the coming decade and urgently need active support from industry and academic institutions to work in closer alliance. This may seem to be true as in the present global scenario of integrative and productive research, expectation from scientists have immensely increased especially in terms of utility of the outcome of research for the benefit and development of the society. These changing situations and pressing demands, coupled with lack of funding, pushed palaeobotanical studies to the background in education centers world over. This led to an alarming decline in pursuing studies in palaeobotany in general and palynology in particular. In order to generate interest among education centers, vigorous training in Applied Palynology is required to meet the impending demands of the oil industry.

The Birbal Sahni Institute of Palaeobotany as a nodal centre of Palaeobotanical research and education can ideally serve in enhancing Academia-Industry interaction by pursuing studies in Applied Palynology.

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Theme–Emerging Trends in Palaeobiology, Session C–Advent of angiospermous characters, pollination and fruit dispersal

ANTIQUITY AND MIGRATORY PATHS OF ANGIOSPERMS IN INDIA

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Most of the herbivorous animals, including humans, depend heavily on the angiosperms or flowering plants for food and other useful products. Their utility to man has created interest in their origin, evolution and migration. Although it is difficult to define an angiosperm, ovules completely enclosed in a carpel, is considered as one of the most important characters for its identification. Though there are several records of pre-Cretaceous angiosperms based on the reticulate venation of leaves, poorly preserved flowers and fruits, monosulcate and reticulate pollen grains and woods having vessels, none of them shows definite characters of angiosperms and therefore are discarded. The earliest record of definite angiosperm named *Archaefructus* is known from the Lower Cretaceous sediments of Yixian Formation, Liaoning in north-east China. In India the Lower and Middle Cretaceous records of angiosperms are unfortunately very poor as compared to those in the other continents. A few angiospermous remains of uncertain affinities have been recorded from the Lower Cretaceous sediments of Rajmahal Hills, Bihar, but there is no further record of their presence before the Maastrichtian. Their definite records started appearing from the flora of the Lameta Formation considered as Maastrichtian in age. They can be seen as the most dominant element in the Deccan Intertrappean flora which is considered as Upper Maastrichtian to Danian in age. The reason of their sudden abundance during the Maastrichtian could be due to the link of India with Africa via Greater Somalia during the Campanian- Early Maastrichtian. A further influx of south-east Asian elements could be noticed in the beginning of the Neogene as Dipterocarpaceae, a native of south-east Asia, appears in the fossil records only after the Oligocene. It proves that the land connections between the Indian and Asian plates were completely established by the end of Oligocene/ beginning of Miocene after the collision of the former with the later at the end of Eocene, resulting in the formation of Himalayas. During their upheaval, temperate angiosperms, which were growing luxuriantly in the nearby areas of Tibet and south-west China, inhabited the area under the prevailing favourable conditions. This is the reason why India did not have any endemic flora despite the fact that it remained separated from the other continents for nearly 100 million years.

Theme–Interface of Palaeobiology with other disciplines

FINITE ELEMENT MODELLING IN PALAEOBIOLOGY: DEVELOPMENTS IN THE LAST DECADE

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Finite Element Modelling (FEM) is a mathematical technique to simulate the structural and mechanical parameters, such as stress, strain, load, displacement, etc. of any physical system. Due to advancement in computational power and availability of personal computers, FEM has become a powerful tool to analyse the problems in mechanical, civil and aeronautical engineering. FEM's application into biological areas, particularly in biomechanics, has been growing and recently, palaeontologists have also shown to use FEM as a research tool. In this survey article a brief summary of application of FEM in palaeobiology in the last decade has been described which suggests that FEM has potential to help in the analysis of several palaeobiological questions related to evolution, locomotion, form and function of extinct taxa. Additionally, a brief overview about fundamentals of finite element modelling techniques for a beginner palaeobiologist with common pitfalls and limitation of computer modelling has also been discussed.

Theme–Interface of Palaeobiology with other disciplines

RAT TO IGUANODON: COMPARATIVE STUDY OF BONE MICRO-ARCHITECTURE

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Bone micro-architecture primarily consists of osteon, Haversian canal, lacuna and canaliculi. Recent studies in palaeobiology have described the morphology of dinosaurian bones at osteon level. Therefore, in the present study a comparison has been made on the size of osteon and Haversian canal from bone specimen of a rat, rabbit, cat, dog, monkey, adult man and cow, with two specimens from dinosaur (Diadectes and Iguanodon). Furthermore, relationship between the size or weight of the animal with respect to the size of its osteon and Haversian canal has been explored by applying allometric scaling laws to the micro-architecture data.

The results indicate that in general osteon and Haversian canal size increases with increasing body weight however, the relative size of the osteon and Haversian canal decreases per unit body weight, i.e. rat osteons are large relative to human and dinosaurian osteon. Surprisingly, the ratio of osteon to Haversian canal diameters were in the range of 4 to 6 for all the animals (excluding rat) investigated in the present study including the dinosaurs. This suggests firstly, a close resemblance of dinosaurian bone micro-architecture to the mammals and secondly that osteon and Haversian canal sizes have been optimised for efficient transportation of nutrients and metabolites from the animal body to the bone cells. It may be explained by the concept that beyond a critical size an increase in osteon diameter actually reduces the efficiency of transportation of nutrients and waste products.

In summary, osteon size of four to six times of Haversian canal in bone structure appears to be optimum range for all living mammals and extinct dinosaurs to satisfy the requirements to minimise hydraulic resistance in lacunocanalicular network while fulfilling the increased nutritional demand due to increase in size/weight of the animal.

ENDOMYCORRHIZAL ASSOCIATIONS FROM THE EARLY DEVONIAN OF RHYNIE CHERT

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Early indubitable records of mycorrhizal associations in pteridophytes are known since Lower Devonian (about 400 million years ago), when plants were transmigrating from aquatic to terrestrial habitats. This is indeed regarded as the landmark event or rather 'turning point' in the saga of early land plant history. During this transitional period of terrestrialization, mycorrhizal symbiosis evolved and played a pivotal role in the co-evolution of these early vascular land plants. Both mycobiont and autobiont co-evolved symbiotically in the nutrient deficient palaeoecosystem and provided nutrient supply to each other. Kidston and Lang (1917-1921) published a series of epoch making papers and described the first unequivocal accounts of mycorrhizal associations in these Rhynie Chert plants. Subsequently, Merker (1958, 1959), Pant (1962), Boullard (1957, 1979), Boullard and Lemoigne (1971), Bhutta (1973), Hass *et al.* (1994), Taylor *et al.* (1995), Taylor and Taylor (1993), Sharma *et al.* (1993), Sharma & Tripathi (1999) and Misra *et al.* (2005, in Press) also contributed on this subject. Despite the ubiquitous occurrence of endophytic fungi in the Rhynie Chert fossils, the endophytes have not received reasonable attention either from workers of mycorrhiza or from the palaeobotanists and therefore endophytic morphology and anatomy remained unknown. Due to this reason, the present study was undertaken and numerous slides were prepared from the petrified material to study morphology and anatomy of these endophytes.

The endophytic fungus consists of inter- or intra-cellular hyphae of nonseptate and septate types. However, the nonseptate hyphae are more prevalent. The non-septate hyphae often form the dense clusters or coils inside the lumina of cells and produce characteristic arbuscules, thick or thin walled resting spores, chlamydospores or vesicles of varying sizes and shapes. Sometimes resting spores and hyphae are also seen in matrix. Dual infections of endophytes containing *Glomus* and *Rhizoctonia* have also been observed in some sections of the axes. The endophytes belonging to the Glomaceae and Endogonaceae are characteristically present in the axes of *Rhynia major (Aglaophyton major), Rhynia gwynne vaughani, Horneophyton lignieri* and *Asteroxylon mackiei.* On the basis of structure and size of spores, septate and non-septate hyphae and fine and coarse taxtures of the hyphal wall layers along with the presence of various kinds of vesicles and arbuscules, different mycorrhizal fungi, which are closely similar to the present day mycorrhizal fungi (Harley 1972, Harley & Smith 1983, Pant *et al.* 1995) have been assigned to the following genera of Phycomycetes (Glomaceae and Endogonaceae), viz. *Palaeomyces = Glomus, Gigaspora, Acaulospsora, Sclerocystis* or forms like *Milleromyces, Lyonomyces* and *Krisperomyces* of Chytridiales. Sporadic occurrence of *Rhizoctonia* of Basidiomycetes has also been recorded. Although all VAM endophytes are classified under the mycorrhizic category, the term mycorrhiza was applied by Frank (1885) to embrance all kinds of fungal associations found in roots, rhizomes, thalli and prothalli. These associations were kept under the century old term mycorrhiza, which covers associations of fungi with wide range of organs like roots, rhizomes, stems, tubers, thalli and prothalli of various plants. However, many authors like Rayner (1927), Kelley (1950), Boullard (1957, 1979) and Nicolson (1975) have deprecated the use of term mycorrhiza as far as its use for fungal associations with thalli, prothalli and rhizomes is concerned. They suggested that the term mycorrhiza is obviously a misnomer and it should be restricted to fungal assocations with roots only and the new terms like mycothalic (as coined by Gottschem 1858) and mycorrhizomic or mycorrhizomata (as coined by Dangeard 1890) as mentioned in Kelley (1950), should be used for associations of fungi with thalli or prothalli and rhizomes. These mycorrhizal associations appear to be symbiotic and beneficial both to host as well as to the fungus.

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TEACHING AND SYLLABUS OF PALAEOBOTANY IN INIDA

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India is well known for having its vast natural resources of fossil fuels of coal, petroleum and minerals. Hence, study of classical branches like palaeobotany or palaeontology and geology for Indian students is desired. The last few decades have witnessed a spectacular advancement in these areas of research in India. However, in spite of so many advances, these subjects particularly palaeobotany has not received reasonable attention in the curriculum of the Indian universities. Only in a few academic institutions, palaeobotany is taught by non-specialized teachers. There is an urgent need to frame a uniform syllabus for palaeobotany by the University Grants Commission. This dynamic and fascinating subject should also be taught to the students in their pre-university education. The study of palaeobotany should also be integrated with other subjects, viz. geology, zoology, environmental science, anthropology, chemistry, biochemistry and other modern subjects like bio-informatics and genomics. Palaeobotany now has become a multidisciplinary subject embracing above branches. It deals with the study of plant remains of the past vegetation in relation to their environment. The following should be included in the palaeobotany curriculum.

Geology with special reference to palaeobotany, general principles of stratigraphical geology, standard geological time scale, earth as a planet and its position in the universe, origin and age of the earth, structure and interior of earth, abundance of elements in the universe, earth crust, mantle and core, theory of continental drift, plate tectonics and sea floor spreading, elementary discussion on earthquakes and seismology, minerals and their deposition. igneous, sedimentary and metamorphic rocks, coal and origin, petrography, physical and chemical properties of Indian coal, petroleum, chemical, geological and biological evolution, fossils, kinds of fossils, origin and techniques for studying fossils, origin of life, prokaryotic and eukaryotic cells, amino acids and molecular evolution, early atmospheres and the problems of energy source for primitive life, O_2 levels, origin of photosynthesis, ecosystems of plant and animal interaction, distribution of life in time and space, palaeogeography, palaeobiogeography, palaeoenvironment, palaeomagnetism, geochemistry, palaeobiochemistry, palaeobioinformatics, experimental palaeobotany, applications of palaeobotany, its inter-relationships with other branches, etc. Since fossil fuels, like coal, petroleum and minerals, are of global prime importance and meeting the needs of energy to human beings, skilled and trained students of palaeobotany, palaeontology as well as of geology can be fully utilized by various government institutes, like Oil and Natural Gas Corporation, Geological Survey of India, Birbal Sahni Institute of Palaeobotany, Zoological Survey of India, etc.

A GROUP OF CRYPTIC FUNGI-THE TRICHOMYCETES ASSOCIATED WITH ARTHROPODS

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Trichomycetes are the cryptic group of zygomycetous fungi associated with arthropods (insects, crustaceans and millipedes). These fungi have unbranched or branched thalli attached by a holdfast to the gut cuticle. Trichomycetes reproduce asexually by arthrospores (Asellariales), sporangiospores (Eccrinales), or trichospores (Harpellales), that vary in shape, size and the number of appendages. Biconical zygospores in Harpellales are formed when the endobiont reproduces sexually. Zygospores are characteristic for different genera and their attachment to the zygosporophore varies from median, submedian, parallel, to polar.

The host-fungus relationship of Trichomycetes is not well worked out because of lack of experimental studies and the inability to culture the majority of species. Although most are commensulistic, a few are beneficial or deleterious to their hosts. In Harpellales, *Smittium morbosum* is known to kill many species of mosquito larvae. Blackflies and some other insects are rendered infertile due to fungal cysts that develop in their ovaries as a means of disseminating the fungus.

Currently, more than 55 genera and 226 species of Trichomycetes are known from all over the world, predominantly from the European and American continents. However, poor information is available from the tropical world, particularly from the south-east Asian region.

Molecular data have proved that *Amoebidium parasiticum*, a member of one of the traditional orders (Amoebidiales) of the class Trichomycetes, is a protozoan and not a fungus. It is challenging to see these fascinating cryptic fungi with their hosts in Indian aquatic and terrestrial environments. The present communication highlights some of these fungi from guts of Indian insects.

TERTIARY CALCAREOUS ALGAE OF INDIA AND THEIR BIOSTRATIGRAPHIC AND ECOLOGICAL SIGNIFICANCE

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The Tertiary rocks of India (Cauvery Basin, South India, South Shillong Plateau, N. E. India and Kachchh, western India) contain abundant well-preserved calcareous algae which are associated with deposits accumulated in different marine environments and preserve signatures in useful palaeo-ecological interpretation. The distribution patterns of the subgroups of the calcareous algae observed in these areas point to deposition in tidal flat and lagoonal to reefal environments. Besides the taxonomic content of the algal assemblages, the internal and external morphology of the coralline algal forms have also been found to indicate sea level, hydraulic energy and depth of deposition both in past and present environments. The coralline algae can grow from fragments or from spore settlement on any surface and thus may form a pioneer community to contribute to the development of reefs. Fragments and hard substrate may originate in the bed or be broken from nearby reefs and transported to the site of growth. They are important not only as frame builders but also as sediment binders and sediment contributors because rhodoliths commonly grow less than one millimetre per year and, like trees and corals, leave behind the growth bands.

Though biostratigraphically less significant, their chronological value can be evaluated by studying the associated fossil fauna, e.g. planktic foraminifera. Dasycladacean members, however, are important to some extent in the biostratigraphic context. In general, it has been observed that in the Palaeogene sequences of India, the melobesioid coralline algae constitute a dominant component of the fossil assemblage followed by dasyclades (Green algae) in some horizons. In the Neogene successions, the melobesioids decline and give way to mastophoroids which become dominant gradually thereafter. Articulated forms are also found, but they never reach sufficient diversity to be of use in biostratigraphy. In the Dwarka beds, the Pleistocene calcareous forms can be observed to be forming a thick crust on the substrate. Their living representatives show luxuriant growth on the modern coast line which is about 30-50 metres away from fossil deposits.

LAMETA (MAASTRICHTIAN) AND THEIR FOSSILS- INFUENCE OF DECCAN VOLCANISM ON CONTEMPORARY FAUNA AND FLORA: STRATIGRAPHIC CORRELATION OF INDIAN LATE CRETACEOUS NON-MARINE SEQUENCES

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The Late Cretaceous sedimentary sequences of central and western India are crucial mainly in context of: (i) its relevance to the most dynamic palaeogeogarphy of the Indian subcontinent; (ii) its association with an extensive Deccan Volcanic Event and to assess its effect on the contemporary sediments and biota; and (iii) to understand the end Cretaceous environmental and climatic changes. The Late Cretaceous sedimentary sequences are represented by Bagh Beds (Turonian-Santonian), Lameta Formation (infratrappean, Maastrichtian) and Intertrappean beds (Maastrichtian-Palaeocene). These sediments together with the associated biota offer an insight into the history of spatia-temporal changes in the depositional environments and climates. The sediments also record history of the early connection of the Indian subcontinent (India, Srilanka and Pakistan) to greater Gondwanaland through its drift northwards across the equator and to a later connection to Asia.

The sediments of the Lameta Formation are considered to be deposited in different rift-related inland basins in central and western India. Of these, the Lameta sediments of the Jabalpur- Mandla basin and Nand-Dongargaon (N-D) basin are the best studied sections for their detailed lithofacies and biofacies analysis. The sediments of Jabalpur region remained a matter of debate for over a couple of decades amongst the workers who favoured either marine or non-marine origin. But the recent integrated studies comprising sedimentological, palaeontological and isotope analysis of the sediments have favoured non-marine origin. Presently, a fluvial-palustrine-sheetwash environment of deposition is postulated for the Lameta sediments of Jabalpur region. On the other hand the Lameta sediments of N-D basin, based on lithofacies and biofacies analysis, are established as ailuvial-limnic deposits under semiarid climate having a strong seasonality. In India amongst all the Lameta basins, the N-D basin has a unique distinction of having a well-developed and uninterrupted lake sequence. Cyclic sedimentation induced by climatic fluctuations is observed in the lake sequence. Well-developed diatom (at least three species of *Aulacoseira)* bearing varved-clays have been observed at different levels within the lake sequence.

The sheer diversity of the fossils including lake biota, coupled with their excellent preservation including dinosaur nesting sites in the Lameta sediments provide an unmatched view of the Indian non-marine Maastrichtian biota. Different lithofacies representing over-bank, channel, palustrine and lake subenvironments having distinct fossil assemblages have been identified. The check-list of the Lameta fossils is exhaustive. A wide diversity is noticed in the fauna represented by vertebrates like dinosaurs, chelonian, ophidian, lizards, fishes and micromammals; invertebrates including ostracoda, gastropda and pelecypoda. The ostracoda fauna of the N-D basin has been observed to be distinctly different from the Jabalpur region and it may be owing more to the ecological variation.

It is important to note that though the central and western Indian Late Cretaceous sequences produced numerous and diversified vertebrate fauna, but excepting the fishes, it mostly produced only disarticulated forms. The few articulated skeletons reported so far are titanosauromorph sauropod *Isisaurus colberti,* abelisaurid *Rajasaurus narmadensis* and one unnamed snake.

The flora from the Indian Lameta sediments excepting that from the N-D basin is known scantily in comparison to the inter-trappean flora. In India a sole locality at N-D basin, has yielded well-preserved and diversified remains of angiosperms (monocots and dicot leaf impression and woods), gymnosperms (including *Araucarites),* pteridophytes and charophytes. A large collection of plant-bearing coprolites with comminuted and permineralised plant tissues of angiospermic, gymnosperemic and pteridophytic affinities has been made from the Pisdura in N-D basin. These coprolites have been attributed to titanosauromorph sauropods. The study of such coprolites has provided insight into the dietary habit of their producers and it has suggested that the titanosauromorph preferred to crop and feed on high nutrient soft tissue of plants and they avoided hard tissues befitting their jaw mechanism. The study of coprolites of different morphotypes and the associated vertebrate fossil (including chelonian and ophidian) from the Lameta sediments has offered a most potential tool to establish animal-plant and animal-animal interaction during late Cretaceous freshwater ecosystem. Recent finds of in situ freshwater diatoms and dinoflagellates may possibly offer a potential new tool for the stratigraphic correlation of Indian non-marine Late Cretaceous sequences which are separated in time and space.

The integrated study of the Indian Late Cretaceous sedimentary sequences (Lameta and inter-trappean beds) in the last one decade has indicated initiation of the Deccan volcanic activity during the Lameta time and implicitly suggested that there are inter-trappean sediments which were contemporarily deposited with the Lameta sediments. Recently conducted study on palaeomagnetic, Milankovitcht and carbon isotope stratigraphy has suggested that the Lameta sediments deposited in different regions/basins are time-transgressive. The Lameta to the west (Gujarat and lower Narmada Valley) are older (30N) to the Lameta (30N to 29R) in the east and south. The dinosaurs (titanoaurid-abelisaurid) in India are indicated to have perished at the latest 350 kyr earliest than the level corresponding to the marine KTB. Solution to the problems related to their extinction owing to effect of volcanism, their survival strategy *vis-a-vis* response of other fauna and flora to environmental stress induced by volcanism is likely to be offered in the coming days following a presently ongoing multidisciplinary approach to the subject matter.

Recently carried out study of the Lameta and intertrappean beds associated with Deccan Volcanic suite from the N-D basin, has recorded a strong floral response to the increasing Deccan volcanic activity that spanned 69-61 my. First appearance of dinoflagellates (Palaeoperidiniales) in the freshwater ecosystem with the advent of Deccan volcanism is recorded in the 29R magnetochron of Maastrichtian in the inter-trappean beds. Such inter-trappeans are geographically separated but occur at the same stratigraphic levels in the N-D basin. A majority of inter-trappean beds, barring Lalitpur (that is considered as Palaeocene), have been assigned a Maastichtian age. The Maastrichtian stage represents a duration of at least 5 my (70.6-65.4 my). However, a finer resolution stratigraphy of the Maastrichtian non-marine sequence is presently lacking. The Lameta and inter-trappean beds which are developed at different stratigraphic levels in the Deccan volcanic provinces having well established stratigraphy, offer the most potential layers of sediments for the fine palynostratigraphic resolution. These sediments record the history of faunal and floral changes in response to the physical and chemical changes induced by volcanism.

The Indian non-marine Maastrichtian biota if Gondwanan, Eurasian or endemic and the palaeogeographic connections of the Indian subcontinent, is a matter of debate. Various palaeogeographic models (the southern connection, the African connection, Early India/ Asia collision, endemic evolution/out of India dispersals) and hypotheses based on the lineages of different vertebrate groups including dinosaurs, lizards and mammals and even some based on ostracoda and charophyta, have been suggested. But the validity of such models and the hypothesis postulated remains to be tested. The related problems are further compounded for the lack of report of associated/ articulate skeletons. Most of the fauna from the inter-traps is known by the fragmentary remains and implicitly any taxonomic identification of the specimens represents a part taxonomic identification having its limitations. The utility of such fossils for any palaeogeographic interpretation is to be cautiously applied.

PALYNOLOGICAL INVESTIGATION OF BAPUNG, MOOKHEP AND THANGSKAY, JAINTIA HILLS, MEGHALAYA

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Spores and pollen grains recovered from Bapung, Mookhep and Thangskay in Jaintia Hills, Meghalaya are described. The assemblage consists of 41 genera and 64 species. The pteridophytic spores are more common than the angiospermic pollen whereas the gymnospermic pollen are absent. The common species are *Dandotiaspora dilata, D. telonata, Lycopodiumsporites speciosus, Lygodiumsporites lakiensis, Matanomadhiasulcites maximus, Lakiapollis ovatus, Retitribrevicolporites matanomadhensis* and *Pellicieroipollis langenheimii*. Palynological data suggest a humid and sub-tropical climate during the deposition of these sediments. The environment of deposition has been inferred as coastal swamps. The assemblage confirms a late Palaeocene age for the sediments and is compared with other known Palaeocene assemblages of that region and other parts of India. The similarity in palynoflora suggests prevalence of more or less similar climate during Late Palaeocene in both eastern and western India.

Theme–Popularization of Palaeobiology and Role of Academic Societies

ROLE OF ACADEMIC SOCIETIES IN POPULARIZING PALAOBIOLOGY

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The story of evolution is not complete without palaeobiology, which has an important role in natural sciences. With the application of palaeopalynology in oil and gas studies, palaeobiology also has economic and applied aspects. Its application in deducing palaeoclimate and therefore, role in predicting the future climate, has great societal significance. With the emerging hints at ancient life on Mars and evidence of life in extreme conditions, the subject has been getting into lime light. But in India, particularly, the subject of palaeobiology is craving for attention.

In this case, the goal is to go beyond mere popularization or just spreading awareness. The idea is also to sell it, and to make it a fruitful and attractive career. The lure of more materially rewarding career in professional courses, instead of science, which is less attractive, is a problem common to all the sciences. One difficulty faced by palaeobiology is that exposure to this subject is rather late in the career of students than other basic subjects of science and literature. As students are exposed to other subjects early, they may be making up their mind in favour of those subjects. Even much of the limited mention of palaeobiological matters in books may be a case of missing woods for the trees. Anatomical details without significance in wider picture would do little to attract students to palaeobiology. The continental drift, dinosaurs, atmospheric evolution cannot be talked about without involving fossils. Societies can take up preparing suggestions for revision of textbooks.

In India, some academic societies deal with all science subjects while others are concerned exclusively with biological/ earth sciences. Geological Society of India, Indian Academy of Sciences, Indian National Science Academy, National Academy of Sciences and Palaeobotanical Society, to name a few, do promote palaeobiolgy in some ways but it needs impetus. These and several others, spread all over the country, are related as they deal with the various life-forms. They can play a pivotal role in making palaeobiology a more popular choice.

The historical perspective is that the trend towards any profession is governed by its job potential and role models of the society. However, it would be wrong to surmise that it is material return alone that puts value on a career. Sometimes, even not so materially lucrative fields have been popular because they are considered noble and respectable, for instance teaching. But today when administrative careers and management jobs have been luring the engineers from top grade engineering institutions, do we see hope for palaeobiology? Does palaeobiology offer something in return either in material, social or intellectual terms? The societies must make a realistic evaluation and offer concrete advice and show or induce action. But there is no need to emphasize that the palaeobiologists and their institutions should come forward with initiatives.

It is also necessary to expand the scope of the subject. There are some basic differences between the approaches in different disciplines, e.g. approach of a physicist or mathematician and that of a biologist. The kind of clear-cut distinctions and reductionist methods applicable in the former two subjects are not to be seen in palaeobiology at present. But in an age where walls between disciplines are thinning, it does not help to remain aloof and one should be aiming for a much better interaction. Societies can hold programmes for such interfacing, not only among scientists but also between them and the common people as well as media. Half a century ago, Prof. Birbal Sahni bridged the gap between botany and geology in India. Planetary science has bridged astro-sciences and geology, now we have exobiology. It is time to come out of self- made cocoon. Who is not fascinated by journey to or possibility of present or past life on Mars or Europa? Societies should involve people with charisma from different related disciplines to make palaeobiology look as charming as it is.

Societies may also induce link between research institutions dealing in palaeobiology and teaching institutions by providing fellowships for scientists to go and teach palaeobiology for short periods.

It is not that fellowship of societies need be conferred only for research work (Royal Society does have a category for service to science). In India we have researchers who have been great science popularizer in addition to illustrious careers in science and/ or its management. There are others who made a mark at international level through writing or organizing science popularization. They all did it but without a role of academic societies. However, the societies may promote efforts by opening the fellowship of societies to science popularizers of high calibre. Now there are awards given for science popularization but societies dealing with palaeobiology can consider instituting awards exclusively for palaeobiology popularization.

A large number of academies, who may have earned little money but tremendous respect in community, may help in the form of ideas, time, manuscripts and precious contacts. Many societies publish research journals. Why do they not publish articles on palaeobiology? Some may remember letters from Current Science over a decade ago soliciting articles on classical botany. Similar efforts should help.

We have a large number of senior scientist who can be supported to take up this type of work may be in association with the younger lot. This is where societies can play a pivotal role. Societies should approach institutions like Vigyan Prasar and NISCAIR rather than waiting for them to take initiative. The intellectual bank of subject matter is with the societies. We also need a change from metro-centric path that results in hurriedly cooked material from busy people.

But the societies must help people in getting out of mindset that it is something low to write for the young. No doubt that a lot is being written in the name of popular science that is not worth the paper it is printed on but to produce or present good material for the young is not easy and demands more clarity in basics and command over the current knowledge than writing for the others. Properly graded books and articles need to be produced in palaeobiology. There is a strong need for societies to help crystallizing ideas on commercial application of palaeobiology and also present palaeobiology in an intellectually stimulating form. These will definitely cause a swing in the trend and make palaeobiology a hot destination.

Theme–Teaching and Research in Palaeobiology

THE ESSENTIAL DIMENSION OF MICROPALAEONTOLOGY MISSING FROM THE INDIAN CURRICULA

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Palaeontology or the study of fossils is a course work commonly included in the syllabi of geologists so as to: (i) demonstrate how life has evolved over the geological past; and (ii) prove that yes, the composition of the air, land and water had been varying from time to time.

Consequently, the modern day geologists land up studying biological classification and description of ancient organisms depicted in time. Obviously they feel that an obsolete subject has been wrongly placed in geology, which is meant to deal with the earth-ocean-atmosphere dynamics and interaction. Palaeontology or palaeobiology has taken a backseat in the Indian academic scenario because the curriculum comprises traditional theoretical knowledge, whereas the need of the hour is social and industrial applicability to sustain mankind. The recent trends demand applicability in fields of Petroleum, Resource and Disaster Management, Climate and Global Change prediction and modeling. In such a scenario macro-palaeontology has restricted use and applicability whereas micropalaeontology gains primary status.

Professionals realize the need of the working knowledge of microfossils only after stepping into the market, wishing they had been exposed to the subject earlier. Agreed is the fact that vertebrate and macro-palaeontology is essential to be taught at the under graduate level, to introduce the subject and establish its importance as a constituent of earth science studies. But at the postgraduate level when students are mastering a subject and being moulded into professionals to compete in market, it has become a must that students are imparted full-fledged knowledge in micropalaeontology. Due to its diverse applicability especially in understanding climatic changes, today the subject has emerged as an independent discipline of R&D and industry globally. With independent institutes being run and degrees being offered in the developed countries, bells are ringing in our country to at least begin recognizing the potential and the need of micropalaeontology. The subject needs to rise beyond diagrammatic sketches in journals, by hearting biological names / classifications and temporal and spatial distribution of ancient organisms. It is time that the students are exposed to understanding the significance and applications of micropalaeontology, assuring them that the subject has a potential to give them a living. Many recent studies showed that in addition to climate related research like palaeomonsoons, sealevel fluctuations and palaeostorms/tsunamis, micropalaeontology can be used as effective tool to decipher pollution and pay a role in planning preventive measures like environmental impact assessment [EIA] and identification of effluent disposal sites including pipeline surveys. Therefore, it is suggested that all such applications may be included in teaching and research material for postgraduate classes.

DEVELOPMENT OF PROXIES AND RECONSTRUCTION OF HIGH RESOLUTION RECORDS FOR PALAEOMONSOONS: FORAMINIFERAL STUDIES FROM THE ARABIAN SEA

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In view of the increasing evidences of global warming due to increasing concentration of green house gases, it is more necessary to assess the impact of possible warming on monsoonal rainfall as Indian economy largely depends on rainfall. To assess the net impact of green house effect, record of palaeomonsoonal fluctuations for the last few thousand years are required and on much finer resolution of time. Such information is prerequisite to understand the climatic systems and the development/ testing of reliable long-term predictive models. Due to absence of written records of climatic variations older than ~150 yr, various proxies have been used to study the past climate. Out of whole array of proxies applied to reconstruct past climatic variations, foraminifers have been used most extensively, mainly due to their widespread abundance and sensitivity towards environmental changes.

In recent years, attempts are being made to study marine sediments to generate high-resolution proxy records for rainfall fluctuations. First, some of the existing techniques using various parameters of foraminifera like distribution, abundance, coiling direction, mean size, oxygen isotope, etc were evaluated. During these studies, certain new techniques were also developed for determining palaeomonsoons. The original idea of using dimorphic ratios or mean proloculus size (MPS) in palaeoclimatic reconstruction was based on sediments from the North Sea. Further, significance of correspondence between river (Kali in Karwar) discharge and mean proloculus size of benthic foraminifera exhibited the use of MPS in palaeomonsoonal studies. Similarly, while studying surface and subsurface sediments off central west coast of India, it was noticed that morphological (coarser morphogroups) variations of benthic foraminifer's response to salinity can be used as additional tool in palaeomonsoonal studies. These techniques are simple, less expensive, time saving in sorting out samples and adaptable to computer image processing. Development of these techniques helped to generate high-resolution records of palaeomonsoons. Since reliability of any new technique can be best supported through culture experiments, a foraminifera culture programme is established at the National Institute of Oceonography, Goa and detailed work in this direction is in progress.

In order to establish the late Quaternary geologic history of the equatorial Indian Ocean on millennial scales, foraminiferal studies were carried out on a core (CC1 GC2) collected from 4.57° S latitude, 82.58° E longitude and a water depth of 3700 m. Down-core variation in the characteristics (abundance, mean diameter) of planktic foraminiferal species *Orbulina universa* was studied. Based on the down-core variation of mean diameter of O. universa, that has been reported to be inversely proportional to salinity and directly proportional to temperature, it can be concluded that, high temperature and low salinity conditions prevailed at around 14000 yr, 39000 yr., 65000 yr. and 83000 yr. B.P. By applying the same criteria in another core from 3869 m water depth near the Carlsberg Ridge, low salinity conditions were noticed ~8800, 5500 and 2200 BP.

In quest for high resolution records (decadal to century), core samples off Karwar, west coast of India were analysed. The results showed the clear signals of marked high rainfall around 4000 and 3500 years BP and reversal of rainfall condition since 3500 years B.P. with a marked low at 2000 years BP. These findings gathered support from palynological investigations of the same core. It was also inferred that monsoonal precipitations were rather high at 280, 840, 1610 & 2030 years B.P. A cyclicity of approximately 77 years in concentrations of drought years was also deciphered and possibilities of correlation between inferred cycle and Gleissberg cycle in variation of radius of the sun were pointed out.

WHY IS STUDY OF PALAEOBOTANY ESSENTIAL?

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On a multimillion-year time-scale, plants were the pioneer organisms to develop on Earth. The role of these micro-organisms is profoundly important in ameliorating the initially hostile environment paving the way for colonization by other organisms. It took millions of years to convert the reducing atmosphere into oxidizing state. Rhizoid and root activity reduced substrate instability, promoted chemical weathering and increased nutrient availability and opened up niches for exploitation by other organisms. It has resulted in a gigantic and thick forest in Silurian-Devonian period. These huge forests contributed to the building of fossil fuel in the earth crust even the oil and natural gas deposits, so essential for the welfare of human being, resulted from the geochemical processes on plants and their parts.

The subsequent co-evolution of animals contributed further in the diversification of flora and fauna. Thus fossil evidences are the only authentic and direct source of information for unraveling evolutionary mysteries of the past. Even the process of extinction due to over-exploitation and encroachment by animal population, owes its explanation in the study of palaeobotanical evidences. The human civilization centered around its own self, later on resulted into depletion of vegetation, overpowering Nature's balance, causing threat to survival of plant communities that are only organisms using CO_2 and releasing O_2 in the atmosphere. The human beings have been so selfish, that they have utilized the coal and oil for their own benefit but forgot about their sources.

Even in education system, this approach is being followed under the pretext of developing applied science. The scientists and educationists are overlooking the importance of those branches which have a tremendous impact on evolutionary science. The different branches of applied botany can only be fostered if the basic roots are understood by studying plaeobotanical evidences. It has been observed that in the palaeontological science, due importance is being given to animal fossils overlooking plant components, though the plants provided them food materials of equal significance. This can be attributed to lack of proper knowledge in the subject.

The teaching of palaeobotany should also be looked after in the new perspectives and approaches of the subject. The continued researches in the palaeobotany have generated ample data describing numerous parataxa, without establishing their relationships and importance in phylogeny. The time has come to think over on these aspects. It is not sufficient to describe and name of the new species but its place in linking with the present day vegetation has also to be undertaken. The present approach to proliferate genera and species on personal bias should be avoided.

Similarly, the applied aspects of palaeobotanical science have to be included in the curriculum, so that process of coal and oil formation can be aptly studied involving importance of plant contribution.

It is essential for all the researchers to come out of the exploration phase of plant assemblages and concentrate on meaningful interpretation. At the same time it is necessary to popularize palaeobotany by introducing new approaches, involving vegetation scenarios, building up database, finding evolutionary changes at chemical level, etc.

There has been a tendency in the present days that important topics are neglected from the curriculum to accommodate the so called modern and applied topics. This approach also has to be curbed because all branches of science are equally important. (There is no introduction of group Pentoxylales even in the UGC model curriculum). These tendencies have reduced the due importance of the subject, consequently resulting into reluctant attitude among the students and teachers and both for teaching and research in palaeobotany. The curriculum for teaching in botany should be so arranged from B.Sc. to M.Sc. that the fossil taxa from various groups of plants and ages giving their strutural, evolutionary significance and contribution to the vegetation existing at that time be emphasized for overall importance towards welfare of the human being. Such an approach will implicate its importance towards research in the field of Palaeobotany. As far as job opportunities are concerned, various national institutes and teaching organizations should be asked to collaborate and carry out interinstitutional projects for mutual benefit.

IMPORTANCE OF PALAEOBIOLOGY IN NATURAL HISTORY MUSEUMS AND MODERN METHODS OF EXHIBITING FOSSILS

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Natural history museums exhibit remains of both present and past organisms and natural objects so that we can understand their origin, evolution and interrelationship. These institutions are in the service of the society and are open to both general public and scientific researchers. Palaeobiology is an integral part of any natural history museum. Palaeobiology puts ancient life in its perspective, by studying how long term physical changes of worldwide geography and climate have affected the progress of life; how ecosystems have responded to these changes and have altered the earthly environment; and how these common responses have affected the present day biodiversity. Therefore, in order to understand the present day biodiversity it is important to appreciate the biota of the past. One cannot visualize a natural history museum without exhibits of fossil plants or animals. And what can be a better place than a natural history museum to exhibit the fossilized remains of past organisms, including those of our ancestors? All over the world, people throng the museums to see dinosaur fossils. Fossils of apes and humans are regarded as equally interesting.

The present paper discusses the various modern ways in order to make the best use of the available display area in a natural history museum, so as to create interest among the general public.

(i) Like any other display, fossil exhibits have to be **theme** based and should attract the attention of a wide range of viewers.

(ii) Usually displayed fossils are thoroughly cleaned and glued wherever needed. At least at one place in the museum one should **recreate the sedimentary sequence** and show where and how fossils occur in the field, before they are excavated.

(iii) Reconstructions of two dimensional and three dimensional **palaeohabitats** of important fauna and flora are essential to help the general public to visualize the past environment.

(iv) A gallery should have **moveable** display boxes and **adjustable** lighting system.

(v) An **interactive computer** with a **floor plan** is of immense help to the visitors.

(vi) A children corner, with **toys** and zigzag **puzzles** and **video films** of various fossil plants and animals, create a lot of interest among the visitors.

(vii) A natural history museum has to be **dynamic**, its collections and exhibits have to be upgraded and updated regularly.

(viii) In order to **maintain** a museum some funds can be collected by selling replicas of important fossils, postcards and models.

Theme–Integrated approaches to Palaeobiology and Sedimentology

FEASIBILITY OF MINERAL MAGNETIC STUDIES IN THE QUATERNARY SEDIMENTS

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Magnetic particles are ubiquitous. The oxides of iron are sensitive to climate with a short response time but once formed they can have stable records over longer geological times. Mineral magnetic studies (both natural remanence and laboratory) induce magnetic properties that lead us to identify sediment sources, quantify source mixing and estimate duration of erosive processes on time scales ranging from months to millennia. Environmental/climatic parameters (temperature, wind velocity, circulation pattern, etc.) are imprinted in the concentration, grain size and mineralogy of magnetic minerals and reflect the weathering, pedogenic and denudational regimes prevailing through the major climatic shifts of the Quaternary Period. This provides rapid insight into the nature of these shifts and their effects on weathering, soil development and erosion rates and reconstruction of palaeoenviornments and palaeoclimates.

Mineral magnetism of relatively young sediments has become an extremely popular tool to infer the palaeoclimatic changes, soil characteristics, sediment mixing, provenance and magnetic pollution screening. Extensive work has been carried out on the loess sections of the world to understand their origin and deduce multi-proxy climatic records. Links between climatic change and the magnetic properties of sea sediments have been studied in many parts of the world. Some current researches are exploiting this technique to establish quantitative link between moisture regime and pedogenic enhancement of susceptibility. Natural remanence magnetism and laboratory induced magnetic properties, such as susceptibility and isothermal remanence, help in reconstruction of past climatic conditions and sheds light on the pattern and impact of former monsoon regimes within the region.

The principle of environmental magnetic technique is based on the amplification of inherent magnetic mineral characteristics using a variety of magnetic fields of known direction and intensity more commonly at room temperatures and in special cases in elevated temperatures. As a result the weakly magnetic sediment samples and mixtures can also be analyzed and characterized quite successfully by using mineral magnetic techniques. These techniques require little sample preparation, are rapid, often grain size indicative and non destructive. Measurements include field and temperature dependence of various types of induced and remanent magnetizations. Thus, this non-destructive and simple technique is one of the most feasible techniques to study the Quaternary sediments for palaeoclimate, provenance studies and pollution studies.

EARLY AGRICULTURAL ECONOMY IN NORTH-EASTERN VINDHYAS: AN ARCHAEOLOGICAL PERSPECTIVE

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The present article highlights a synthesis of information on the pre- and proto-historic agriculture-based subsistence economy of early rural communities, in north-eastern Vindhyas. The vast area, stretching over the plateau region and alluvial tract in adjacent plain, envelopes a large number of early settlements, which reveal the gradually evolving sequences of farming communities from primitive metal-free stages of Neolithic cultures up to the considerably advanced Iron using cultures. So far, excavations at Koldihwa, Mahagara and Malhar have revealed the beginning of agriculture evidenced by a domesticated form of rice (*Oryza sativa*) during 6th-7th millennia B.C. The sign of economic change in agriculture and the dietary of Neolithic people, similar to modern practices, are noticeable by the incidental appearance of Harappan nutritional traits in north-western India. The diverse crop assemblage recorded in this region of north-eastern Vindhyas includes the remains of barley (*Hordeum vulgare*), bread-wheat (*Triticum aestivum*), dwarf-wheat (*Triticum sphaerococcum*), lentil (*Lens culinaris*), field-pea (*Pisum arvense*), chick-pea (*Cicer arietinum*), grass-pea (*Lathyrus sativus*), safflower (*Carthamus tinctorius*), linseed (*Linum usitatissimum*) and onion (*Allium cepa*) of Mediterranean & Central Asian origin; African jowar-millet (*Sorghum bicolor*), ragi-millet (*Eleusine coracana*), cow-pea (*Vigna unguiculata*), til (*Sesamum indicum*), water-melon (*Citrullus lanatus*) and castor (*Ricinus communis*); and Eurasian Italian-millet (*Setaria italica*), in addition to indigenous crops of rice (*Oryza sativa*), kodon-millet (*Paspalum scrobiculatum*), green-gram (*Vigna radiata*), black-gram (*Vigna mungo*), moth-bean (*Vinga aconitifolia*), horse-gram (*Macrotyloma uniflorum*) and Indian mustard (*Brassica juncea*). Collective evidence shows that the double cropping system was followed in the summer and winter seasons. The stable agriculture helped in building up economic prosperity, and the same trend continued from Neolithic to Iron Age cultures. In view of the fully established agricultural system in the region of north-eastern Vindhyas, the cultural relationships of the farming communities has directly or indirectly been established with the altogether diverse cultures in the distant north-western regions. However, the complex process of the dispersal of crops in terms of diffusionary trends is difficult to be established and not fully demonstrable in the present state of archaeological background. Future research in this region is expected to fill up gaps in the time and space.

DIVERSITY IN JURASSIC- CRETACEOUS PTERIDOPHYTES OF INDIA

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Pteridophytes are a group of primitive vascular plants that include lycopods, sphenopods and ferns. These plants have special significance in understanding Mesozoic fossil flora of Gondwana deposits. A number of taxa belonging to lycopsids and sphenopsids occur in Palaeozoic deposits. The terrestrial plant communities of pteridophytes first appeared during Devonian. However, luxuriant growth of horsetails and tree ferns occurred in the Carboniferous Period, commonly known as 'Age of Ferns'. The Mesozoic deposits display a diversified group of pteridophytes in which ferns are quite prominent. They grow as perennial herbs, trees, epiphytes and floating plants. These ferns are megaphyllous in nature whose leaves (fronds) usually emerge as circinate vernation. Their axes vary in complexity with steles of almost all types, viz. protostele, actinostele, plectostele, solenostele, etc. Most of the Mesozoic ferns are eusporangiate while some are leptosporangiate (Salviniaceae).

The flora of Jurassic-Cretaceous deposits is known as 'Ptilophyllum Flora'. Floral assemblage reported from various Gondwana basins of India (Kutch, Kathiawar, Himmatnagar, South Rewa, Satpura, Rajmahal, Mahanadi, Krishna-Godavari, Palar and Cauvery) include fern and fern allies, e.g. pteridosperms, cycads, bennettitales, pentoxylales, ginkgoales, coniferales and a few angiospermous fructifications. Pteridophytic remains documented from these basins are assignable to different families, viz. Lycopodiaceae, Selaginellaceae, Isoetaceae, Equisetaceae, Marattiaceae, Osmundaceae, Gleicheniaceae, Schiziaceae, Matoniaceae, Dennstaediaceae, Dicksoniaceae, Cytheaceae, Dipteridaceae and Salviniaceae. These ferns are seldom preserved due to their delicate nature and low preservation potential of their cellular architectures. The fossil records of the pteridophytes in Indian Gondwana are significant in deciphering phytogeography, age determination and palaeoclimate.

ANGIOSPERMOUS FOSSIL LEAVES FROM THE SIWALIK FORELAND BASINS AND ITS PALAEOCLIMATIC IMPLICATIONS

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The Siwalik sequence attains an average thickness of 6000m and is exposed all along the Himalayan foot hills from the Potwar Plateau in the north-west to Brahmputra in the north –east covering a distance of 2400 km. The Siwalik sediments are made up of rock materials resulting from denudation of slopes of the Himalayan mountains and deposited on the flood plains of the foreland basins over a span of 20 Ma. These are now exposed at several places along the northern boundary of the Indian subcontinent. The Siwalik sediments are characterized by alternate presence of sandstone and mudstone facies, the later very often containing abundant angiospermous fossil leaves belonging to both Monocotyledonous and Dicotyledonous families

The angiospermous fossil leaves so far recovered from the Siwalik foreland basins of India, Nepal and Bhutan have been analysed and an attempt has been made to deduce the palaeoclimate during the Siwalik sedimentation (Mio-Pliocene). The physiognomic characters of the fossil leaves have been studied in relation to climate. The leaf physiognomic features that have used as an aid in determining past climate are mainly drip tip, leaf margin, leaf size and venation density. In the fossil leaf assemblage (about 250 taxa) there are number of leaves having conspicuous drip tips, a characteristic leaf feature of the many plants in excessive wet conditions which serve to drain rain water quickly. The dominance of entire margin of the leaves (about 95%) indicates the presence of tropical climate. The other feature like leaf size, leaf texture, nature of petiole and venation density, etc. collectively suggest tropical climate with heavy rainfall during the deposition of sediments.

As almost all the fossil leaves recovered from the different localities of Himalayan foreland basins have been identified with the modern taxa of the angiosperms up to the specific level, it would be easy to infer the palaeoclimate of the region on the basis of their present day distribution. It is evident that most of the comparable taxa in this assemblage are not found at present in the foot hills and became extinct due to prevalence of unfavorable climatic conditions. Further, on the basis of nearest living relatives of the angiospermous fossil leaves, it has been concluded that there are three major types of elements: (i) evergreen; (ii) evergreen and moist deciduous; and (iii) mixed deciduous. The evergreen elements dominated the flora of the Himalayan foreland basins during Mio- Pliocene times in contrast to mixed deciduous elements that dominate today.

Theme–Biodiversity: Past and Present

LIGHT MICROSCOPIC STUDIES ON POLLEN GRAINS OF SELECTED CYPERACEAE SPECIES FROM SOUTHERN TAMIL NADU: RELEVANCE IN PALAEOVEGETATION STUDIES

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Seven species of Cyperaceae have been selected for quantitative studies on their respective pollen morphology through light microscopy. The species chosen are *Bulbostylis barbata*, *Cyperus compressus*, *C. rotundus*, *Fimbristylis argentea*, *F. ovata*, *Kyllinga triceps* and *Scirpus articulatus*. The background or basis for this selection is as follows: In most of the fossil and modern pollen studies, Cyperaceae has been classified as a single pollen taxon as it has often not been possible to go beyond this. Thus the use of these pollen markers as habitat and climate indicators is better served by a finer identification because members of this family, though found mainly in wetlands (Bush 2002), also occur in upland forests and drier regions, making the interpretation of their occurrence more difficult.

In a recent ongoing study (Anupama *et al.* 2005), while studying sections from a tank in Madurai District, Tamil Nadu, we found that it is possible to distinguish the pollen of Cyperaceae preserved in the sediments into at least two broad categories. As the studied section represents the sediment run-off harvested within a rain fed catchment, gathering inputs from the surrounding hills, a finer interpretation is possible if one of the main markers, such as Cyperaceae could be further distinguished morphologically. This would aid in better interpretation of the fossil pollen data, when coupled with detailed studies on the habitats of the respective taxa.

With this in mind, detailed checklists of the vegetation in the catchment and quantitative studies on the herbaceous strata were undertaken from which the species of Cyperaceae occurring in the tank bed and the surrounding areas were identified. Fresh herbarium and pollen collections have been made for each of the species. The floral materials from these specimens were used to prepare pollen slides by acetolysis using Erdtman's Acetolysis Mixture (Erdtman 1966) at a temperature of 90° C for 7 to 10 minutes and later mounted with glycerine jelly.

The pollen are usually pear-shaped and punctitegillate/ scabrate with lacunae and the number of apertures varied from zero to four (Huang 1972; Mandal & Chanda 1981, Faegri & Iversen 1989, Moore *et al.* 1991). The apertures were in the form of depressions. At least 30 grains of each species were measured in a light microscope under 1000x to arrive at the quantitative descriptions.

In our paper, we present a detailed description of the pollen morphology of each species based on LM observations of each species, along with digital photographs. Quantitative characters for distinguishing Cyperaceae pollen have been provided. We also envisage carrying out similar studies on members of Amaranthaceae mainly because they have been very often clubbed with Chenopodiaceae and found that members of at least two genera, *Aerva* and *Gomphrena* show distinctive features.

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Theme–Emerging Trends in Palaeobiology, Session D–Proxies and parameters in Palaeoclimate assessments

PHYTOLITHS: A NEW TOOL IN QUATERNARY PALAEOCLIMATIC STUDIES

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Phytoliths are microscopic opal particles that are deposited in or between cells of living plant tissue. They occur in many plant families but are especially abundant and diverse in the family Poaceae. Due to their distinctive morphological characters and taxonomic relevance they have the potential for encoding significant archeological and palaeoenvironmental information. After the decay and decomposition of the plant tissues, phytoliths are liberated into the soil and are easily transported along with the silt size fraction to the depositional site. The main advantage of phytolith as palaeoecological microfossils is their preservability in soils and sediments under oxidizing conditions where pollen and spores and other organic microfossils are scarce. Hence, phytoliths are now considered as the new palaeoecological tools particularly in dry regions. Due to their resistance to weathering processes, fossil phytoliths are very helpful in dealing with palaeoecological studies of palaeosol horizons of the Quaternary successions. Phytoliths are now being increasingly used for the reconstruction of palaeovegetation patterns, especially in deciphering forest/grassland ecotones (Alexandre *et al.* 1997, Barboni *et al.* 1999, Blinnikov *et al.* 2002). They have an advantage over the pollen records as they can be identified to a more precise taxonomic level than grass pollen, relating them to subfamilies with specific environmental preferences, including C_3 and C_4 grass types. A part of organic carbon of the original plant, freed from the contamination, is occluded in phytoliths. Hence, phytoliths are now being considered as the perfect material for stable isotope studies for palaeoenvironmental interpretations in the Quaternary successions.

Phytolith types are based on their geometric shapes, usually in outline. The rondel and trapezoid phytolith morphotypes correspond to subfamilies Pooideae and Festucoideae (C_3) that are adapted for cool and moist environmental conditions. The saddle phytolith morphotype occurs chiefly in subfamily Chloridoideae (C_4) that consists of grasses adapted for warm summer conditions. Dumbel and cross phytolith morphotypes are characteristic of grasses belonging to subfamily Panicoideae (C_4) that proliferates in the tropical region during warm and humid summers. Rods, circular, bulliform and pointed morphotypes are phytolith of grass epidermal tissue without any taxonomic significance. The multiplicity and redundancy of many phytolith morphotypes prevent the attribution of phytolith to species and genus (Rovener 1971, Mulholland & Rapp Jr. 1992). Hence, morphological attributes of phytolith assemblages are now being used to decipher fluctuations in the past grass vegetation.

The subhumid and semi-arid zone that borders the arid zones of India is very sensitive to monsoonal fluctuations and can provide good evidence of past monsoonal variability in this region. Phytolith studies of Late mid Holocene succession of mainland Gujarat that borders the southern fringe of Thar Desert, have established their potentiality to understand the monsoonal fluctuation in this region. The semidry-subhumid climatic conditions of Gujarat also favour domination of shrubs and grasses over woodland type of vegetation. The grass cover fluctuates rapidly depending upon the rainfall pattern in these areas. Phytolith study is, therefore, viewed as a more promising new palaeoecological tool for continental past climate in this region. Phytolith studies were performed on mid Holocene succession of Kothiakhad (Mahi basin) and Itola (Dhadhar basin) sections. The

Kothiakad (2.5 m) and Itola (8 m) sections consist of alternating sand, silts, silty-sand and organic rich clays. For phytolith extraction, sediment samples were processed according to the techniques of Kelley (1990). The extracted phytoliths were counted and classified according to the classification of Mulholland and Rapp Jr. (1992). Ratio of characteristic cool and arid to warm and humid phytolith associations was found to be a potential parameter to reconstruct the monsoonal variability in this region. Our findings indicate that SW monsoon gradually weakened during the Late mid Holocene while winter monsoon which is known to have commenced during Early mid Holocene, was still persistent around 3620 yr BP leading to cool climatic conditions. The microscopic charcoal fragments present in the lowest horizons in Itola section, contain abundant phytoliths of chiefly wheat and barley along with cool season grasses, indicating strengthened winter rainfall and a considerably weak summer monsoon. Phytolith studies show extremely weak SW monsoon and frequent winter precipitation in the sand dominated horizon in the later phase of this interval that could have resulted in a climatic deterioration and development of dry and arid climatic conditions in this region. The dry and arid phase of few hundred years of Late mid Holocene is followed by a period of wet and humid pulse of enhanced SW monsoon at 3320 yr BP as evidenced by abundant warm season grass phytoliths and cultivated rice phytoliths, along with paddy field indicator diatoms in Itola section. After 3320 yr BP SW monsoonal activity fluctuated greatly with considerable increase in warm and dry conditions during summer months. The study also provides clues to the possible link between rise and fall of Harappan phase of the Indus valley civilization and the monsoonal variability during Mid-Late Holocene in this area.

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ASPECTS OF BIODIVERSITY OF KONKAN AND NORTH WESTERN GHATS OF INDIA WITH SPECIAL REFERENCE TO PRESENT AND PAST ENDEMICS

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India is a megabiodiversity country with high level of endemism of its flora and fauna. It harbours two hotspots, viz. Eastern Himalaya and Western Ghats amongst the 25 hotspots identified throughout the world. In the present inventory we have undertaken North Western Ghats and Konkan regions of India. North Western Ghats is the region between Dangs forest, south of Tapi river in Gujarat, and Goa near Kalinadi in North Kanara district of Karnataka, stretching ca. 700 km. Konkan is the coastal tract of Maharashtra facing the Arabian Sea towards the west and the Sahyadri hills (North Western Ghats) on the east which stretches ca. 530 km. North Western Ghats is a chain of mountains running parallel to west coast of Maharashtra, Goa and some parts of Karnataka. This mountain chain is a part of the Indian plate of the Gondwana origin with basaltic lava flows of Deccan trap and some part with Dharwar system. Konkan is ca. 50 km broader in north and ca. 30 km in width southwards and is characterized by hills and plains, forests, bare rocks and lateritic plateaux. Geologically Konkan belt exhibits the entire geological sequences from the oldest Pre-Cambrian to the youngest/recent Quarternaries.

One of the main and easily identifiable components of biodiversity is endemism. Endemic is ascribed to any taxonomic unit or taxon which occurs in a restricted area, usually isolated by geographical or temporal barriers. The studies of these endemic elements of a country or geographical region throw light on the biogeography of the area, centers of speciation, areas of extinction, vicariance and adaptive evolution of the flora occurring in the area. The Western Ghats comprises ca. 1600 endemic plant species of which North Western Ghats together with Konkan harbours ca. 600 species. Further within the endemics, herbaceous taxa dominate over the arborescent ones. These endemics have their own strategies for their survival and adaptation to the various kinds of habitats. The area is exposed to a much longer dry period, except for the months of SW monsoon (Jun—Aug) leading to a stressful environment for plants resulting into occurrence of succulent (*Frerea indica* a palaeoendemic species, *Sarcostemma intermedium*, both restricted to cliffs), pubescent (most of the Acanthaceae and Fabaceae members), ephemerals (Acanthaceae, Balsaminaceae, Commelinaceae, Eriocaulaceae, Fabaceae, Poaceae) and geophytic plants. The geophyte is a typical group of plants that are confined to the lateritic plateaux (lowland and highland), cliffs and well exposed hill slopes where conditions are relatively very harsh. The area under study is a centre of diversification and speciation for geophytes especially for monocots and certain dicocots like bulbous (*Crinum brachynema*, *C. elenorae*, *C. woodrowii*, *Dipcadi concanense*, *D. minor*, *D. saxorum*, *Drimia polyantha*, *D. polyphylla*, *D. razii*, *D. wightii*, *Scilla viridis*), rhizomatous (*Curcuma inodora*, *C. neilgherrensis*, *C. pseudomontana*, *C. purpurea*, *Hitchenia caulina*), cormous (*Camptorrhiza indica*, *Iphigenia magnifica*, *I. pallida*, *I. stellata*) and tuberous plants (*Amorphophallus commutatus*, *A. konkanensis*, *A. sylvaticus*, *Aponogeton satarensis*, *A. bruggenii*, *Arisaema caudatum*, *A. murrayi*, *A. sahyadricum*, *Brachystelma kolarensis*, *Ceropegia attenuata*, *C. fantastica*, *C. huberi*, *C. jainii*, *C. lawii*, *C.*

maccannii, *C. mahabalei*, *C. noorjahaniae*, *C. panchganiensis*, *C. rollae*, *C. sahyadrica*, C. *santapaui Chlorophytum bharuchae*, *C. borivilianum*, *C. glaucoides*, *C. glacum*, *Habenaria crassifolia*, *H. heyneana*, *Merremia rhynchorhiza*, *Theriophonum dalzellii*, *Typhonium bulbiferum*, *Vigna khadalensis*, *V. vexillata*). Poikilohydry is another important component of North Western Ghats. Here specialized adaptation is shown by plants growing in condition of periodic water stress called as desiccation tolerant or resurrection plant species owing to their unique adaptation for sustaining during dry periods e.g. rocky cliffs (*Arthraxon jubatus*, *Tripogon capillatus*, *T. jacquemontii*), seasonal streams (*Cladopus hookerianus*, *Polypleurum dichotomum*). Another peculiar observation is a monotonous chain/strand of Acanthaceae members (*Neuracanthus shaerostachyus*, *Strobilanthes callosa*, *S. integrifolia*, *S. ixiocephala*, *S. reticulata*, *S. sessilis*), the understorey of this particular strand forms a peculiar niche for endemics (*Abutilon ranadei*, *Ceropegia evansii*, *C. media*, *Habenaria crassifolia*, *Nervillea aragoana*, *Peristylus aristatus*). Pollination and dispersal strategy is another aspect that worth to be illustrated. Plants that grow on cliffs and slopes are adapted to anaemochory/anaemophilly (*Arthraxon jubatus*, *Tripogon lisboae*, *T. jacquemontii*) and atelophilly/atelechory mechanism (rain splash/wash) (*Begonia concanense*, *B. crenata*, *Crinum brachynema, C. woodrowii*, *Eria reticosa*, *Habenaria rariflora*, *Hubbardia heptaneuron, Sonerella scapigera*) while those grow on lateritic plateaux prefers entomochory/entomophilly (*Eriocaulon konkanense*, *E. sedgewickii*, *E. tuberiferum*, *Euphorbia panchganiensis*, *Impatiens lawii*, *Rhampicarpa longiflora*, *Utricularia purpurescence*) and anaemochory/anaemophilly (*Dimeria woodrowii*, *Glyphochloa forficulata*, *G. mysorensis*, *Indopoa paupercula*, *Schizachyrium paranjpyeanum*). In general the ephemerals (herbaceous) dominate over the perennials within the endemics of Northern Western Ghats and Konkan. The biodiversity of Konkan and North Western Ghats is also interesting in light of evidence accrued from the fossil records derived from this region.

The Konkan coast and North Western Ghats had also been habitat of many taxa whose records were found in the sediments. Some of these taxa had already been displaced from the west coast since the Neogene. These include, to mention a few (*Cullenia exarillata*, *Gluta ?travancorica*, *Shorea ?roxburghii*). Though these plants do not occur at present and as such their absence has implications in palaeoclimate study. The fossil evidences of some of the endemic species for e.g. presence of pollen of *Cullenia* (can be compared with the extant *Cullenia exarillata*) and megafossils like *Anacardioxylon ratnagiriense* (can be comparable to the wood of *Gluta travancorica* (Anacardiaceae) an endemic plant species which at present limits to southern Western Ghats of Kerala and Tamil Nadu) from Ratnagiri district and *Shoreoxylon vayganiensis* (the wood of *Shorea* (Dipterocarpaceae) which can probably compare with the southern peninsular endemic *Shorea roxburghii*) from Sindhudurg district of Konkan in the lignite samples and their conspicuous absence (local extinction) in the present day vegetation along Konkan coast and North Western Ghats is attributed to climatic shift as a result of latitudinal shift and decline in rainfall since Late Neogene. Both *Cullenia* and *Gluta* require excessive humid conditions, with annual rainfall over 3500 mm. Infact, such climatic shift is more pronounced from Karwar to further north and relatively less towards South (Kerala coast) where wet evergreen forests are still surviving due to more or less a uniform tropical climate right from Neogene period. Along with the above mentioned climatic markers we are trying to identify the present day climatic markers of both Konkan and North Western Ghats, some of them are being considered as potential records for climatic consideration.

Theme–Emerging Trends in Palaeobiology, Session D–Proxies and parameters in Palaeoclimate assessments

ROLE OF NANNOFOSSILS IN ASSESSING PALAEOCLIMATE

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Coccolithophores are possible modern counterparts of calcareous nannofossils (nanno = dwarf). Coccolithophores are tiny (2-20 ìm), marine golden brown algae, which are unicellular, flagellate phytoplankton belonging to phylum Haptophyta and division Prymnesiophyceae. They are characterized by a cell wall covering a coccosphere containing coccoliths. These are made up of calcite mineral (calcium carbonate), which are preserved as fossils. Coccoliths are phenomenally abundant in sea-floor sediments above the calcite compensation depth or CCD and preserve the composition of the overlying photic zone communities. Their fossil record is continuous from their first occurrence in Late Triassic to the present day. Nannofossils are exceptionally useful for biostsratigraphy since they are abundant, planktonic, rapidly evolving and largely cosmopolitan. Their minute size, exceptional abundance and acid free techniques are helpful in quick study of a small rock chip, which is of particular value in hydrocarbon exploration and scientific drilling. Considering their biostratigraphic value, they are used as primary reference fossils on most DSDP (1968 - 1983) and ODP (1985 - present) cruises.

Recently, coccolithophores are also utilized for palaeoclimatic interpretations. Palaeoclimatic reconstructions from the study of calcareous tests of nannoplanktons have resulted from basically three types of analyses: (i) The oxygen isotope composition of calcium carbonate; (ii) The relative abundance of warm and cold water species; and (iii) The morphological variations in particular species resulted from environmental factors.

Oxygen has three isotopes with mass 16, 17 and 18, usually the more abundant 16 (lighter) and 18 (heavier) are used for interpreting palaeotemperature in a mass spectrometer. The abundance of isotope O^{16} is very large compared to O^{18}. Oxygen isotopes are utilized as a palaeothermometer on principle that the temperature affects the relative abundance of the heavy and light molecules of oxygen in the water escaping the sea surface. If calcium carbonate (of a nannoplankton) is crystallized slowly in water, O^{18} is slightly concentrated in the precipitate relative to that remaining in water. This fractionation process is temperature dependent, while the concentrating effect diminishes as temperature increases. When the organism dies the tests sink to the sea bed entrapped in fecal pellets of copepod crustaceans and is laid down, with millions of other tests, as sea floor sediment (calcareous ooze), thus preserving a temperature signal (in the form of an oxygen- isotopic ratio) from a time when the organisms lived. If a record of oxygen isotope ratios is built up from cores of ocean sediment, and the cores can be accurately dated, this will provide a method of palaeoclimatic reconstruction.

EMERGENCE OF BIOTA AND THEIR FOOTPRINTS ON THE SANDS OF TIME: ICHNOLOGY OF THE PRECAMBRIAN – EARLY CAMBRIAN SUCCESSIONS OF INDIA

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The Precambrian encompasses about ninety percent of the duration of the earth's history (4.570 Ga to 0.543 Ga) with gradual increase in atmospheric oxygen, a necessary component in the biosphere's evolution.

While evaluating the evolutionary tempo and trends in the biosphere, it is convincingly becoming clear that one of the giant leaps of evolution remains the emergence of the eukaryotes. Eukaryotes, being a complex configuration of organic molecules, was much easily modifiable under changing physical and chemical conditions and the process of mutation gave them the advantage to generate new forms of life. In this process, the metazoans evolved as one of the major inhabitants of the earth. Another major evolutionary leap in the biosphere is the appearance of animals with a varied body plan, ecological selectivity and flexibility to shift to changing environmental conditions (mobility).

Tracing these biological events in deep time has never been simpler, although broad framework of early evolution is better understood now than what it was about a decade ago. In the evolutionary scheme of things, record of these various bio-events on a chronological scale, makes them much relevant as it provides them the much required time lines for tagging them with other physical, chemical and geological events associated with evolution of the earth as a whole. Lately, the blurred evolutionary scheme of the late Precambrian to early Cambrian has turned into sharp focus and well constrained geochronometric scheme marking significant biological events at this juncture provide a much reliable authenticated picture of this important time interval of the geological past.

In the initial palaeontological records dealing with macroscopic metazoans, it is quite tricky to draw a sharp boundary between body and trace-fossils as preservation of both the biotic entities are in siliciclastic sediments.

Much before the emergence of first animals, there are definite evidences to suggest that metazoans (which may or may not be synonymous with animals) made their appearance in shallow seas. This can be verified by way of their impressions recorded in sedimentary profiles. As a matter of fact and logical understanding, the appearance of the metazoans would not have been sudden but gradual as is well seen in sedimentary records by way of occurrence of metazoan traces much earlier than the metazoans themselves. I would now discuss this particular aspect which is the main focus of this article.

Amongst the first evidences of a community which had the capacity to shift from one place to another through a process of biologically controlled mechanism (locomotion) are the minute trails suggesting bilaterian activity on the low energy floors of the ocean in a shallow depth domain. These records are from the Neoproterzoic sequences having an age of about 600 million years before present. In a bit younger strata, evidences of variation in these wriggle marks are present suggesting the novel body-plans emerging as a natural consequence to evolution.

Globally, four major evolutionary stages seem to represent tempo of the trace-fossil development which may not necessarily be directly tagged with the occurrences of invertebrate fossils near the Precambrian-Cambrian Boundary. These stages are as follows:

D. Very complex, well diversified and well distributed Phanerozoic types of traces including those made by trilobites.

C. Scanty but complex traces, including those made by ? arthropods (in the pre-trilobite level); traces also occurring across the bedding planes.

B. Meandering trails on bedding planes with definitive organized structures.

A. Simple straight to curved surfacial trails or rain-print like circular impressions.

A list of some of the trace-fossil forms (Table-1) which have been recorded from well constrained late Proterozoic successions of the world is provided.

The Indian Scene: Amongst the Indian successions, the Lesser Himalayan Krol Belt represents one of the best developed trace-fossil repositories in which typical Ediacaran to Atdabanian type of traces are developed. Although, a few of the most controversial occurrences of Precambrian traces are known from Vindhyan successions, a thorough study in Kurnool, Kaladgi, Cuddapah, Marwar Supergroup of Peninsular India and Inner sedimentary Belt of Lesser Himalaya needs to be carried out to understand the true scenario in this part of the world. The paper discusses some of the trace-fossil occurrences from the above mentioned basins in the light of modern evolutionary theory near the Precambrian-Cambrian Boundary.

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Table 1. List of Precambrian Ichno-taxa

S.No.	Name of Ichno-taxa	Age Range
1.	*Cochlichnus*	Ediacaran/ Vendian/ Sinian/ Terminal Proterozoic / Neoproterozoic III to Phanerozoic
2.	*Gordia arcuata*	
3.	*Gordia marina*	
4.	*Harlaniella podolica*	
5.	*Helminthopsis*	
6.	*Helminthoida*	
7.	*Helminthoidichnites*	
8.	*Monocraterion*	
9.	*Nenoxites curvus*	
10.	*Neonereites biserialis*	
11.	*Neonereites uniserialis*	
12.	*Planistiralichnus*	
13.	*Planolites beverlyensis*	
14.	*Protospiralichnus*	
15.	*Torrowangea*	
1.	*Bilinichnus simplex*	Ediacaran/ Vendian/ Sinian/ Terminal Proterozoic / Neoproterozoic III
2.	*Intrites*	
3.	*Palaeopascichnus delicatus*	
4.	*Palaeopascichnus sinuosus*	
5.	*Shaanxilithes ningquiangenesis*	
6.	*Vendichnus vendicus*	
7.	*Vimenites*	
1.	*Planolites*	Riphean/ Cryogenian

TERRESTRIAL PHYTODIVERSITY OF INDIAN MESOZOIC-AN EVOLUTIONARY PERSPECTIVE

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Nature has immense potentiality to nurture and sustain life forms. Fauna and flora on earth, which constitute the biosphere, are essential for maintaining congenial physical environment. Total array of plants, animals, insects and microorganisms, occupying a particular geographical region, make the biodiversity. These organisms variously occupy different ecological niches, such as land, water, air, sea and associated habitats. Earth's land surface is mostly covered by a great variety of plants. Present phytodiversity is result of long periods of evolutionary change. History of plants that existed during Mesozoic era provides clue to evolution of modern vegetation panorama. Mesozoic era witnessed extinctions, innovations and geological events. Moreover, Mesozoic plants were fodder for herbivorous dinosaurs and advent of flowering plants completely transformed earth's phytoscenario. Mesozoic diversity was influenced by taphonomic bias and climatic factors.

Plant fossils embodied in Indian Mesozoic sequences (Triassic, Jurassic, Cretaceous) are systematically categorized into various taxonomic groups. Depending on the plant part preservation-leaf, stem, root, wood, pollen, spore, fruit, seed, etc. and their character assessment, taxonomic affinities have been determined. Mesozoic continental sequences, spread over eastern, western, central and southern regions of India, encompass plant parts in the form of impressions, compressions, petrifactions and associated preservation types. Plant groups belonging to bryophytes, pteridophytes, gymnosperms and angiosperms are variously represented in different sedimentary sequences. During the Mesozoic, major groups of vascular plants made their appearance, flourished and got extinct though some survive even today. The present synthesis highlights Indian Mesozoic terrestrial phytodiversity as evidenced by fossil records. Growth of luxuriant vegetation with rich diversity characterizes Mesozoic terrestrial ecosystem.

Triassic: The landscape of Triassic was sculptured by deglaciation. The Indian Triassic represented by Panchet, Nidpur, Parsora and Tiki lithounits, differentially reflects Glossopteris and Dicroidium floras, together with floral components of pteridophytes, cycadophytes, Ginkgoales, conifers, etc. Fossils records from the Damodar, Auranga, Son-Mahanadi and Pranhita-Godavari basins indicate prevalence of plants bearing *Glossopteris, Dicroidium* and *Lepidopteris* types of leaves. Early Triassic land plants were dominated by pteridophytes and cycadoferns. During the Late Triassic, they were replaced by conifer-cycadeoid flora, along with pteridophytes. Seed fern groups, viz. Glossopteridaceae, Peltospermaceae and Corystospermaceae, became extinct at or near the end of Triassic. Extensive land conditions and widespread erosion during the Triassic do not allow complete preservation of plant records. Adverse conditions probably resulted in floristic impoverishment. Floral records known from distant horizons suggest dry environmental conditions.

Jurassic: Plants of Indian continental Jurassic are relatively less known. Land plant fossils known from the Kota (Pranhita- Godavari), Lathi (Rajasthan), Dubrajpur (Rajmahal) and Hartala (Madhya Pradesh) suggest gymnosperm dominant phytosphere. Araucariaceae, Podocarpaceae, Taxaceae, Cheirolepidiaceae (extinct), Ginkgoales, Cycadeoidales (extinct), ferns, sphenopsids and lycopsids chiefly constitute Jurassic flora. Plants were preserved in the form of leaf, wood, spore/pollen which continued to occur in Early Cretaceous sequences. Low phytodiversity during Jurassic was attributed to extensive erosion and non-deposition of continental deposits on the Indian subcontinent.

Cretaceous: A mixed flora comprising many cosmopolitan taxa preserved along with endemic forms which are collectively known as the Ptilophyllum flora distributed in various sedimentary realms, characterizes Indian Early Cretaceous sequences. Plant fossils belonging to bryophytes (Spherocarpaceae, Riellaceae and Anthocerataceae), pteridopytes (Lycopodiaceae, Selaginellaceae, Isoetaceae, Sphenophyllaceae, Equisetaceae, Marattiaceae, Osmundaceae, Gleicheniaceae, Schizaeaceae, Matoniaceae, Dennstaediaceae, Dicksoniaceae, Cyatheaceae, Dryopteridaceae, Polypodiaceae, Dipteridaceae, Weichseliaceae and Salviniaceae) and gymnosperms (Pteridospermales, Cycadales, Pentoxylales, Bennettitales, Ginkgoales, Taxales and Coniferales) exhibit rich phytodiversity. Few angiospermous fossils (Aquifoliaceae, Loranthaceae and Liliaceae) are also recorded from the Indian Early Cretaceous sequences. Rhizomes, roots, wood, petioles, leaves/sporophylls, isolated sporangia, spores, pollen and seeds, etc. belonging to different plant groups constituted chief phytomass of Early Cretaceous. Bulk of floral constituents, with intermingling Gondwanan and European representatives due to northward movement of India, contributed to relatively abundant diversity. Numerical differences of plant taxa were a result of taphonomic bias. The Early Cretaceous landscape supported various habitats of plant growth, like coastal areas, river valleys, open low lands and even uplands.

Late Cretaceous witnessed explosion of flowering plants on Indian continent. Pollen data suggest predominance of angiospermic pollen as evidenced by their records in the Cauvery, Krishna-Godavari, Bengal and Assam-Arakan basins and Deccan Intertrappeans. Plant megafossils got preserved in the Late Cretaceous semi-arid deposits of Lameta and volcano sedimentary units of Deccan Intertrappeans. Pteridophytes and gymnosperms were sidelined by tremendous adaptability of flowering plants. Most of the modern families of angiosperms dominated vegetational scenario of Late Cretaceous sequences.

During the Cretaceous, India broke free of Gondwanaland and became an island continent. The continents began to take on their modern shapes. Marked regional differences in floras between the northern and southern continents were developed. Although the Jurassic floras of ferns, cycads and conifers continued, the most dramatic occurrence during the Cretaceous was the first appearance of angiosperms. Evolution of structural innovations by the flowering plants gave them an evolutionary advantage. At the end of the Cretaceous, a number of modern plant forms had evolved. The Cretaceous was brought to an end by one of the greatest mass extinctions of all time, the K-T event or terminal Mesozoic extinction. Most of the plants survived due to their tenacity. Abrupt changes hardly occurred in plants since new taxa were always added. Plant evolution being gradational, new forms appeared from time to time and got better adapted to changing selective pressures. Plants respond to major environmental stresses with long delays, pointing less influence of extrinsic factors. Survival of living fossils, such as *Selaginella, Lycopodium, Equisetum, Gleichenia, Matonia, Osmunda, Weltrichia, Ginkgo biloba* (maiden hair tree), *Ephedra, Araucaria* and others testifies endurance of plants. Since terrestrial plants are the most sensitive organisms to changes on continental scale, distribution of major plant groups provides the best assessment of global climate change. Revolutionary challenges in deciphering Mesozoic climates, utilizing plant fossil evidences, are being attended world over and phytodiversity studies enhance utility of palaeogeographic and palaeoclimatic interpretations.

SYNERGISTIC TOOLS TO POPULARIZE FRAGMENTARY SCIENCE

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Coevolution of environment and organism has been a centre of debate amongst the scientists. Life, as known today, in the recent past and in deep past has undergone dramatic change. The food chain was repeatedly subjected to alterations. Causes of such changes and their impact can be studied through palaeobiological inputs. Palaeobiolgy is a fragmentary science dealing with incomplete fossil evidences. Biofossil evidences help to chronologically decipher past changes. Both traditional and integrative approaches have been employed to examine life history. Recent developments in various disciplines and analytical techniques transformed study patterns. This led to synergistic models to propose local, regional and global models of the earth. Plants are relatively resistant to cataclysms. Asteroid impact that eliminated the dinosaurs 65 million years ago, did not adversely affect plants because of ability of their seeds and spores to lie dormant during unfavorable conditions. Fossil plants have helped to demonstrate that the global environment has changed radically through time. Determining the reaction of past plant communities to more gradual changes in climate is now helping to predict the future effects on vegetation of global warming. The whole plant reconstructions are compared with co-occurring fossil species to reconstruct ecological communities of the past. These interesting palaeobiological inferences should be popularized in the society.

Science is a method of knowing cause and impact. It is a way of life more than religion. It is a tool to understand micro- and macro-cosmos and creates new knowledge. It is a way to perceive complex things in a comprehensive mode and is a logical and rational means of unraveling causality of phenomena. It builds up facts that are repetitive as well as reproducible and results are subject to modification. It is imperative for the scientist to be a part of argument that needs to be proved and ought to be as true for each individual mind as for his own. Partnerships are advocated to reach the benefits of science to less privileged. Science adventure knows no boundaries and there has been a fusion of thoughts; different disciplines advocating same fact in different connotations. It has become true even for science popularization efforts.

Knowledge accrued on various palaeobiological aspects is being disseminated through various tools. These include scientific meets, museums, electronic media, print media, advertisement, governmental and non-governmental agencies, involvement of children/people through science popularization, organizing exhibitions, building up databases and exchanging subdata sets etc. Using computer software, science material is produced combining text, numerical data, photographs, charts and other visual graphic elements. Other conversions, like photographs and drawings into digital images, manipulation of those images and design, developing presentations and advertising campaigns, typeset and color separation and translation of electronic information on to film or other traditional forms, etc. have been employed in science communication. Internet has emerged as a strong medium of mass communication. Publication specialists, journalists, scientists, electronic prepress technicians, electronic publication specialists, image designers, typographers, compositors, layout artists and web publication designers all are contributing to palaeobiological science awareness. Information in the form of books, business cards, calendars, magazines, newsletters, newspapers, packaging, slides and tickets is being disseminated. Even media, like press, radio and televisions cover palaeobilogical reports, but the impact seems to be insignificant. Improvement of the situation is a strategic issue but it means not only the increase of frequency but also of quality. Development of awareness and attitude is indispensable for all citizens. Science professionals have important role to reach grass levels of society. Modern technological tools should be utilized to disseminate knowledge. Scientific temper at all levels of knowledge should be enhanced. It is imperative to have a positive action by science managers with deep insight in coexistence and co-determinism norms.

It is not enough for palaeobiologists to remain stable in size for very long since there is significant increase in palaeobiological collections. Hence there is more and more valuable information available for extraction from existing data. It is high time and palaeobiologists should try to stimulate new growth while avoiding inflation or fragmentation. Emphasis on vertical integration across disciplinary boundaries and collaborations with in palaeobiology is on rise. Since palaeobiology is a combination of biological and historical sciences, it has added advantage to work out mechanisms involved to know how the natural archives of the earth got preserved.

A new global verve is required to improve science dissemination approaches, as follows: (i) Shared vision for future is advocated; (ii) Advanced skills, learning, reasoning, creative thinking, making decisions and solving problems to be updated; (iii) Skilled persons, teachers, mentors and scientists needed to motivate young aspirants; (iv) Professionally valuable and globally available scientific data should be utilized; (v) Sharing of data related to science via the worldwide web should be encouraged; (vi) A student friendly approach should be preferred; (vii) Synthesis of knowledge in understandable publications and reports/projects should be stimulated; (viii) Complimentary and unique roles by individual pursuers needed; (ix) Depending on ability, context and understanding science reports should be made simpler; (x) Irrespective of gender, age, disabilities, cultural and ethnic background, aspirations and interests, science should be disseminated; and (xi) Challenge lies in synergy of approaches adhered.

PALI FORMATION - A PALYNOLOGICAL OVERVIEW

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The sediments, younger to the coal bearing Barakar Formation were placed together under the informal name "Supra-Barakar" by Hughes (1885), in the western part of the South Rewa Basin, Madhya Pradesh. The Supra-Barakar sediments encompass Pali, Tiki and Parsora formations, ranging in age from Late Permian to Late Triassic/ Early Jurassic. The stratigraphic dispute arose due to the uncertain relationship among these sediments with their fossil contents recovered by various workers in the past.

Pali Formation is divisible into three members i.e. Lower, Middle and Upper Pali respectively. The Lower Member consists of alternate band of red and green clays and medium to coarse-grained feldspathic sandstone, buff and white coloured sandstone and mottled clays. The Middle Member consists of whitish to grey, medium to coarse-grained sandstone, grey shale, carbonaceous shale and thin coal seams. The Upper Member characterized by the predominance of chocolate coloured shale, alternating with fine to medium-grained, feldspathic sandstones in association with violet green and brownish shale.

The palynological investigation of Pali sediments, Son Graben have led to the recognition of the following five palynoassemblages based on their qualitative and quantitative representation.

1. Faunipollenites various
2. Faunipollenites+Striatopodocarpites
3. Striatopodocarpites+Crescentipollenites
4. Arcuatipollenites+Densipollenites
5. Falcisporites+Densoisporites

These assemblages can be classified into two major groups. One group (Assemblage1-4) belongs to Late Permain due to the preponderance of striate bisaccate chiefly *Faunipollenites, Striatopodocarpites* and *Crescentipollenites*. A number of genera though show sporadic distribution, yet are stratigraphically significant, viz. *Distriatites, Guttulapollenites, Playfordiaspora*, *Alisporites* and *Goubinispora*. The other group (Assemblage-5) belongs to Triassic and shows dominance of non-striate bisaccate, cavate and cingulate spores. Some of the significant taxa recorded in the assemblage are: *Falcisporites, Satsangisaccites, Krempipollenites, Densoisporites, Brachysaccus, Lundbladispora, Tikisporites* and *Staurosaccites*.

The Lower Member of the Pali Formation is non- coaliferous horizon which correlates with Barren Measures of Damodar Valley. The Middle Member is coal bearing strata and corroborates with the Upper part of the Raniganj Formation (Damodar Valley); Bijori Formation (Satpura Basin) and Kamthi Formation of Godavari and Mahanadi basins of Indian peninsula. The lower part of the Upper Pali Member resembles the Panchet Formation of Damodar Valley and shows the Permian/ Triassic boundary. An attempt has also been made to compare these assemblages with other Gondwana basins of India

PROBLEMS AND PROSPECTS OF STABLE ISOTOPE APPLICATIONS TO MARINE MICROFOSSILS

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Stable isotopes of carbon and oxygen have found wide applications in various branches of earth sciences, including palaeoclimate and palaeoceanography using marine microfossils. In this paper we discuss various problems that arise during the measurement and interpretation of stable isotope ratios, especially of foraminifera. The stable oxygen isotope ratio (ä^{18}O) of planktonic foraminifers is governed by both the Sea Surface Temperature (SST) and the global ice volume (i.e. sea level) effects. Recently, the effect of bicarbonate ion concentration in sea water on ä^{18}O has also been discovered. In some foraminiferas (e.g. *G. sacculifer*), it has been suggested that the last chamber must be removed before isotopic analysis, as that is secreted at deeper regions in the water column, where the temperature is lower (each Celsius degree decrease in temperature leads to to ~0.2‰ increase in the ä^{18}O. We present new data to characterize the variability of the relationship between the surface ocean water ä^{18}O with its salinity, and investigate decadal variations in the same. We also discuss other "vital effects". The carbon isotope composition of planktonic foraminifera can indicate surface productivity. This is because during photosynthesis by marine phytoplankton, ^{12}C is preferentially taken up leaving the remaining bicarbonate reservoir enriched in the ^{13}C. Thus enhance ä^{13}C of planktonic foraminifera, in many instances, can relate to the surface productivity. However, we cite examples, where this straight forward interpretation may mot be valid. We also discuss precision and accuracy of measurements and cite examples where conclusions unwarranted by data are drawn. We also propose different methods to extract the palaeoclimatic/ palaeoceanographic information from the stable isotope data and give examples.

PALYNOSTRATIGRAPHY OF THE NEOGENE SEDIMENTS OF INDIA- CURRENT STATUS AND FUTURE DIRECTIONS

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The Neogene includes the Miocene and Pliocene epochs and spans about 22 million years during which the world became much drier and cooler, culminating into hard conditions and biotic disaster of the Pleistocene ice ages.

The Neogene sediments of India are exposed in four distinct areas namely north eastern India (Meghalaya, Assam, Tripura, Mizoram, Arunachal Pradesh and West Bengal); northern India (Uttaranchal, Himachal Pradesh, Haryana, Punjab and Jammu & Kashmir); western India (Gujarat) and southern India (Tamil Nadu, Kerala, Maharashtra and Karnataka). A considerable amount of palynological information has been recorded from Neogene sediments and various palynozones have been established by using significant palynofossils. A brief account of Neogene palynofloral assemblages and their utility in palynostratigraphy have been discussed in the present paper.

The Neogene sediments of north-eastern India are represented by Surma, Tipam, Dupitila, Namsang and Dihing groups and are exposed in the southern fringes of Shillong Plateau, Surma Valley and Assam. A variety of palynofloras have been documented from different sections by many palynologists. On the basis of palynofossils, Baksi (1962) divided the Simsang River Section, Meghalaya into four zones, of these, Zone IV represents Surma. The first and detailed palynostratigraphic zonation of the Bhuban formation exposed in Jaintia Hills, Meghalaya has been proposed by Saxena *et al.* (1987). The palynostratigraphic zonation was also attempted in Girujan Clay, Namsang Group (sub-surface) and Jorajan well, Upper Assam (Sah *et al.* 1980, Nandi 1981). But the palynological information from Bokabil, Tipam Sandstone, Dupitila and Dihing are very scanty.

The Neogene sediments of western India (Kutch Basin) are represented by Khari Nadi, Vinjhan Shale and Sandhan formations. Kar (1985) recorded palynoflora from Khari Nadi Formation and divided the sequence into three cenozones. Palynological information is also available from Vinjhan Shale but attempts have not been made to propose the palynostratigraphic zonation in Vinjan Shale and Sandhan formations.

The Neogene sediments in north–western India are represented by Kasauli Formation (Shimla Hills), Upper Dharmsala (Kangra valley), Upper Murree (Jammu area), Indus Group (Ladakh area) and Siwalik Group. Very scanty palynological information is known from the above areas except Siwalik sediments. The Siwalik sediments are continental deposits which were laid down in the foredeep on the southern side of the rising Himalaya in India (Himachal Pradesh, Uttaranchal, Haryana, Punjab and Jammu & Kashmir), Nepal and Pakistan. Extensive palynological studies have been made on Siwalik sediments from Himachal Pradesh, Punjab and Haryana and generated good amount of palynological data. The first palynostratigraphic zonation has been done by Nandi (1975) from Jwalamukhi area and later by Saxena and Singh (1982) in Upper Siwalik of Hoshiarpur-Una, Punjab and more recently by Rao and Patnaik (2001) in Late Pliocene sediments of Pinjor Formation, Haryana.

Palynological records are known from the Neogene sediments of Cauvery Basin from bore-holes at Karaikal, Mannargudi and Madanam and the sequence has been divided into two cenozones (Venkatachala & Rawat 1973). Rich palynological data have also been recorded from Neyveli Lignite Mine I, II and III, but no palynostratigraphic zonation has been made. A well preserved spore-pollen assemblage has been recorded from Tertiary sediments of Quilon and Warkalli formations. Rao (1990) proposed palynostratigraphic zonation of the Arthungal Bore-hole, Alleppey District, Kerala and divided bore-hole sequence into three cenozones, of these third one represents Lower Miocene. Attempts have also been made to correlate Arthungal and Kalarakod bore holes of Alleppey District, Kerala with surface sediments (Rao 1995, 2001). A variety of palynoflora is also recorded from Sindhudurg Formation, Maharashtra and Mangalore area, Karnataka.

A critical review of the published palynological information known from Neogene sediments of India reveals that limited efforts have been made to utilize the palynofloral data in making biostratigraphic zonation. In some areas, studies are confined to the documentation of the palynofossils. Palynological information is known from a number of Siwalik sequences of India but is still insufficient for precise palynostratigraphic zonation and correlation. The palynological records of Neogene sediments of Uttaranchal are very poor for palynostratigraphic zonation.

A good amount of palynoflora has been recorded from Neogene sediments, still there are plenty of gaps in our knowledge regarding palynostratigraphy and correlation. Some gaps have been identified and future directions proposed. An effort has also been made to synthesize and collate the published information to understand the present status of the Neogene palynostratigraphy and correlation in different basins of India. It is suggested that a multidisciplinary approach is necessary for establishing high resolution palynostratigraphy and developing ecological models.

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BIODIVERSITRY IN WESTERN GHATS: CONCERNS, STRATEGIES AND PRIORITIES

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Western Ghats, being one of the global hotspots of biodiversity supports an enormous vegetal wealth, which over the years is undergoing great stress due to anthropogenic disturbances. This region, which forms the "Malabar Botanical Province", according to phytogeographers is a narrow stretch running from the hills south of Tapti River in the north to Kanyakumari in the south along the west coast of India covering the states of Goa, Maharashtra, Karnataka, Tamil Nadu and Kerala. The narrow stretch of Western Ghats running approximately 1500 km encompasses a considerable gradient of climatic conditions, which have resulted in the development of diverse forest types ranging from the dry scrub types to the semi-evergreen and evergreen forests. Details of these forest types and their floristic composition are discussed. The development of the tropical rain forests in the southern Western Ghats and the 'sholas' in the Nilgiris region are the most outstanding features of Western Ghats. The entire Western Ghats biogeographic region is a major genetic estate with an enormous biodiversity of ancient lineage. Nearly 4300 species of flowering plants occur here of which 56 genera and 2100 species are endemic. Karnataka alone harbours 3900 species belonging to 1323 genera and 199 families while Nilgiris have 2611 species of flowering plants. Some dominant families are Poaceae, Leguminosae, Orchidaceae, Acanthaceae, Euphorbiaceae, Asteraceae, Lamiaceae and Rubiaceae. Analysis of endemic species reveals that Western Ghats, being much older in age than Himalayas, supports a large majority of relict or palaeoendemics. Another unique feature of the endemic flora of Western Ghats is the prevalence of monotypic genera such as *Adenon*, *Calacanthus, Polyzygus, Erinocarpus*, *Frerea*, *Griffithella*, *Haplothismia*, *Jerdonia*, *Lamprochaenium*, *Nanothamnus*, *Wagatea* and *Willisia*. Some of the arborescent genera having maximum endemic taxa are *Memecylon* (16 spp.), *Litsea* (15 spp.), *Symplocos* (14 spp.), *Cinnamomum* (12 spp.), *Syzygium* (11 spp.), *Actinodaphne* (9 spp.), *Glochidion* (9 spp.), *Grewia* (9 spp.), *Diospyros* (8 spp.), *Dalbergia* (7 spp.), *Hopea* (6 spp.), *Drypetes* (6 spp.), *Poeciloneuron* (2 spp.), *Blepharistemma*, *Erinocarpus*, *Meteoromyrtus*, *Otonephelium* and *Pseudoglachidion*. The latter five genera are again monotypic. The flora of Western Ghats, particularly southern W. Ghats shows close affinity with the flora of Sri Lanka, supporting the view that Sri Lanka was connected to South India during the geologic past. Some important species common to both regions are listed. Agasthyamalai hills, Anamalai ranges, Nilgiris and the Palni hills are the hyperdiversity areas in Western Ghats, which are also the hotspots pockets. The Western Ghats region is also a rich germplasm centre of number of wild relatives of our crop plants such as the cereals & millets, legumes, tropical & sub-tropical fruits, vegetables, spices & condiments and a few others. Species of *Piper*, *Oryza*, *Myristica*, *Elettaria*, *Amomum*, *Zingiber*, *Phaseolus*, *Vigna*, *Atylosia*, *Cinnamomum* and *Curcuma* show great variability in southern Western Ghats. The alarming rate of loss of biodiversity in Western Ghats is a major concern today. Shifting cultivation, grazing, indiscriminate lopping, extraction of timber and fuel wood, spread of alien weeds, recurrent forest fires and selective removal of certain species such as the medicinal plants have all resulted in total destruction of the virgin forests which now survive only as pockets in the mountains summit areas. The accelerated

population growth followed by expansion of agriculture, introduction of plantation crops like tea, coffee, rubber have resulted in the extermination of many taxa, endangering a number of economically important timber and other species. Discussing the major strategies for conservation, the author prioritizes certain issues for urgent action. Inventory of base line data and development of computerized databases, assessment of genetic diversity at least in wide spread taxa, identifying and conserving and monitoring the hotspot pockets of biodiversity (19 such sites are identified by the author), protection of sacred forests and special habitats, establishment of gene bank/seed bank, conservation of critically endangered species are some issues suggested for action. Finally, the author calls for urgent attention for generating the trained manpower in taxonomy for shouldering this big responsibility of inventorization and conservation of the rich biodiversity of Western Ghats.

Theme–Interface of Palaeobiology with other disciplines

PALAEOBIOLOGY: DISINTEGRATION OF AN INTEGRATED SCIENCE

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Palaeobiology is an integral part of all evolutionary studies as it provides (or should provide) complete information of the fossil organism at various scales of observation, ranging from global distribution in space and time, its place in modern ecosystem analogs down to that of the individual cell (and intra-cellular) structure at the micro- or nano-meter level. This projected goal however is rarely achieved. Firstly, most fossils are incompletely preserved and secondly, the present day earth is but a poor representation of all the dynamic atmospheric, lithospheric and biospheric processes that have been in operation for the last 4 giga years. Nonetheless, in spite of the stated drawbacks, palaeobiology seeks to integrate data from several major sister disciplines some of which are: geology and field data, comparative and functional morpho-structural anatomy, DNA-based molecular phylogenies and cladistics, ecology and sedimentary environments, palaeobiogeochemistry and stable isotopes, biomechanics and computer-simulated modelling of life processes. A few case studies are presented here to illustrate some of the problems in interfacing palaeobiological studies with those of other disciplines. It is time now to lessen our dependence of using "Form Genera" no matter how useful they may be in the short term and try to concentrate on a more holistic approach to reconstruct the entire organism as a living entity interacting with the biotic and abotic components of its environment, specially in terms of Richter's *Aktuopalaeontologie*.

OBSERVATIONS ON ETHNO-BOTANICAL STUDIES IN INDIA

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Ethnobotany is defined as the study of total natural and traditional interrelationship between man and plant (wild and domesticated) and domesticated animals. The culture and economies of various tribal communities and forest-dwellers scattered in forest of various geographic zones in India, vary with the ecosystems. Some depend entirely on hunted and gathered food for their subsistence and some are largely dependent on agriculture. Utilizing the plant resources in forest, the tribal people developed their own cultures, customs, taboos, folk-tales, food, medicines, etc. and discovered a large number of plants for multifarious uses. Many plants used today were originally identified and developed through indigenous knowledge. Ethnobotanical research in India enriched our knowledge of numerous plant species and a large number of ethnobotanical literature appeared over the last hundred years.

It appears from recent literature that there are certain aspects of ethnobotanical research, which have not received due attention. At present, most of the ethnobotanical studies have largely been pursued from academic point of view rather than from utilitarian viewpoint. Presently, the major focus of ethnobotanical study has involved the identification and inventorisation of plant used by tribal and rural population. These have been concerned mainly with the cataloguing the plants used by Indigenous people. If the present and future attempts continue in the same direction then the recording of the useful plants would remain preserved in scientific literature rather than their wider use. The chief objective of ethnobotanical research would never be realized. If these trends continue, someone may question "what worth is ethnobotanical research?" It is all the more important now that the purely academic research should be channelized to meet the growing requirements and developmental projects for the betterment of the society. The ethnobotanical research is privileged to meet this requirement and its channelization into applied aspects is strongly needed. People have forgotten the data published in earlier literature like Books on Regional Floristics, Forest Working Plans, Survey of Tribals by Anthropologists, reports of tribal development projects, ethnotraphies, archaeological accounts, travelogue, district gazetteers, herbals, materia-medica, etc. have much useful information on ethnobotany of India. The oldest record about herbal medicines written on palm leaves about 1710 A.D. was discovered from South Bastar in Madhya Pradesh. This document record 93 types of herbal medicines used in the district. These earlier literature have not only dealt with the records of plants and their uses but also in many cases with the process of preparation of useful products. Besides recording the useful plants along with their uses from academic, economic and conservational viewpoint it is equally important that the process of the preparations of the useful products from the wild plant along with combinations and proportions of other plants must also be recorded. Without knowing the method of preparation of the useful producrs, information of names and uses of the plant would not be of any worth for the future generations. With all the efforts of the Government towards the socioeconomic development of the tribals, it is most likely that the methods of preparation of useful products and techniques for many articles from wild plant life would eventually be lost to posterity. Howsoever crude the tribal methods of preparation of the useful products are, they have distinct advantages and they could be improved upon with the present day technical knowhow.

END CRETACEOUS FLORAL CHANGE INDUCED BY DECCAN VOLCANISM- PALYNOLOGICAL EVIDENCE: IMPLICATIONS FOR MAASTRICHTIAN STRATIGRAPHY AND ENVIRONMENT

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Is Deccan volcanism responsible for the global extinction of biota towards the Cretaceous-Tertiary Boundary? It is a matter of active debate for over the last 3 decades. It is difficult to perceive that the Deccan volcanism which erupted episodically over an extended period of 8 m.y. (Sheth *et al.* 2001) outpouring at least 10^6 km^3 of lava that spread over an area of more than 500, 000 km^2 on the Indian subcontinent, has no role to play in the extinction towards the KTB. If the volcanism is responsible for bringing effective changes in the biota towards the end Cretaceous on global scale, its effects is expected to be more pronounced in the regions proximal to the volcanic sources in the Indian subcontinent. The eruption of Deccan volcanism has caused both the physical and chemical changes affecting the then existing physiography and prevailing atmosphere and climate. The response of flora to the changing scenario is expected to be recorded in associated sediments, represented by the Lameta and intertrappean beds.

It is critical to record the history of gradual floral changes in the sediments induced by the Deccan volcanism. It is in this context that the palynofloral study of the Lameta and intertrappean beds occurring at different stratigraphic levels within the Deccan volcanic suite of the Nand -Dongargaon (N-D) basin and adjoining area having a well established stratigraphy, was taken-up to observe the trend of floral change. The palynofloral study was supplemented with the litho- and biofacies analysis. Our study has suggested a strong floral response to the initiation of the Deccan volcanic activity in the region, which can be summarized as follows:

(i) The Lameta Formation, which is capped by the lower most flow in the area, is characterized by the presence of fairly good concentration of pollen grains of gymnosperms (*Araucariacites, Classopollis, Podocarpidites, Callialasporites, Cycadopites* and *Belmiopsis*) and angiosperms (*Palmaepollenites, Longapertites* and other dicot pollen grains). Pteridophytes (*Azolla* and *Biretisporites*) and fungal spores are however poorly represented in the sediments. Apart from the palynomorphs the magafloral record from the basin comprises charophytes, *Araucaria* seeds and leaves, *Brachyphyllum*, impressions of monocot and dicot leaves and fossil woods of palms, Lecythidaceae and Sapindaceae. Event of first appearance of diatoms (*Aulacoseira*) in the Maastrichtian fresh water ecosystem within 30N chron has been recorded. The diversified diatoms assemblage is associated with the varved clays developed within the lake sequence bearing gypsiferous clays. The lake sediments show cyclicity induced by climatic changes.

(ii) The lower most intertrappean bed having a distinct freshwater fossil assemblage occurring between the first and second basaltic flow (Anandvan, Daiwal and Khandala-Ashta localities) is characterized by the presence of marker Maastrichtian palynomorphs, viz. *Aquilapollenites bengalensis, Azolla cretacea, Gabonisporis vigourouxii*, *Triporoletes reticulatus* and *Turonipollis helmigii* associated with dinoflagellate cysts (*Palaeoperidinium* and *Selenopemphix*). The level of first appearance of dinoflagellates with the advent of Deccan volcanic activity has been recorded within the 29R chron of the Maastrichtian. The appearance of dinoflagellates is marked by the remarkable decrease in the concentration of diatoms (Samant & Mohabey 2005). Overall, the assemblage shows presence of good concentration of angiosperms and pteridophytes and distinct decrease in the concentration of gymnosperm pollen grains. An increase in the concentration of fungal spores and epiphyllous fungi relative to the assemblage of the underlying Lameta Formation is observable.

(iii) The second intertrappean bed bearing freshwater bivalves and gastropods, did not yield any palynomorphs. The third intertrappean bed occurring at a higher stratigraphic level between the third and fourth flows (Sindhi and Mahalgaon localities) has all the marker Maastrichtian palynomorphs of the lower most intertrappean. However, the assemblage is marked by the distinct appearance of diversified primitive polyaperturate (stephanocolpate and colporate) pollen grains with disappearance of dinoflagellates and diatoms. Fossil woods fragments are present in this higher intertrappean bed.

Based on lithofacies and biofacies analysis supplemented with the stable carbon and oxygen isotope studies of the Lameta sediments of the different basin, it is now well established that the Lameta sediments are deposited in alluvial-limnic environments under semiarid climatic condition with a strong seasonality. The initiation of Deccan volcanic activity during the Lameta time brought drastic physiographic, atmospheric and climatic changes induced by degassing of CO_2, SO_2 and other associated gases. The effect of the changes induced by the volcanism is reflected in the intertrappean sediments and its floral content. The intertrappean sediments are dominated by cherts that could be precipitated in the local basin owing to increase in acidic conditions following the volcanism. The calcrete profiles, which are characteristic of the Lameta sediments, are totally absent in the intertrappean beds. The change in the climate from the semiarid during the Lameta to the sub-humid and humid during the intertrappean sedimentation is envisaged with the advent of Deccan volcanic activity.

Locally in the N-D basin it has been observed that the initiation of Deccan volcanic activity with enormous outpouring of lava terminated a majority of the existing flora. Following the first phase of volcanism the ecosystem was struggling to re-establish during the period of repose, however, initially it could succeed only to the extent of supporting the aquatic and herbaceous plant dominated community. The lake sediments of the first intertappean bed at Daiwal, in the study area, appear to be deposited over a period 4 k.y. (Hansen *et al.* 2005). No evidence of any megaflora as found in the Lameta could be recorded at any level in this section. The megaflora makes appearance only at the higher stratigraphic levels, viz. intertrappeans of Sindhi and Mahalgaon.

In our opinion the initiation of volcanism created more hostility in the depositional environment that proved more fatal to the plant community. The flora struggled to gradually get established in the new ecosystems and was striving to attain the stability. The effect of volcanism on the contemporary sediments and flora at local, regional and global levels is still under assessed and the future study should focus on this vital aspect.

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CHARACTERIZATION OF THE INDIAN COAL DEPOSITS

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The coal is a prerequisite for running the thermal power stations and is also utilized for various industrial purposes. Therefore, there is an urgent need to take up a critical assessment regarding characterization of this precious fossil fuel. A series of biological, biochemical, geochemical and thermal changes are involved in transformation of the vegetal matter/peat in to coal. Rank and the constitution of the coal is taken in to account to decide the best utilization of this coal wealth, therefore, emphasis on research work to generate a systematic coalfield wise database is required. India has 20107 billion tonnes of coal reserves, which are mainly classified under cocking and non-cocking types. Despite of this, we are not self sufficient to meet out our own requirements, therefore serious efforts are needed to enhance the coal exploration. Coal Bed Methane reserves have been recently identified in several blocks, which approximately covers an area of 1942.42 sq km from Raniganj, East Bokaro, West Bokaro, North Karanpura and Sohagpur coalfields. Details regarding depth of occurrence of such coals, their rank variability and material composition would be of immense help in ascertaining the coal bed methane potential of the virgin tracts, being investigated for coal exploration through subsurface studies in several Indian coalfields.

TERTIARY VEGETATIONAL CHANGES AND PALAEOCLIMATE OF NORTH- WESTERN HIMALAYA: EVIDENCE FROM SPORES AND POLLEN

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The present paper deals with the vegetational change and palaeoclimate during Tertiary period in the North-western Himalaya based on evidences from fossil spore and pollen records. Qualitative and quantitative changes in the palynofloral composition of spore- pollen assemblages recorded from different localities of this region elucidate the general trends in the vegetational change. The composition of assemblages is mainly controlled by the changing patterns of climate, moisture flow and altitudinal disposition. The Palaeocene vegetation from the Dras volcanics of Ladakh Himalaya is of semi-evergreen type. It seems to have been supported by a tropical to subtropical climate. However, the composition of the Late Eocene to Miocene palynofossils from the Tarumsa Formation of Ladakh depicts a gradual shift towards colder climate, which also marks the appearance of moist deciduous forests. Available data provide cogent evidence that during the Middle Miocene several cold loving plant taxa migrated to this region from the mainland of Asia in response to the onset of colder climatic conditions brought in by the orogeny of Himalaya. The Palaeocene -Eocene palynological assemblages from the Kalakot area of Jammu and Kashmir and Kalka- Shimla areas of Himachal Pradesh are generally conspicuous by the dominance of dinoflagellate cysts. Palynofossils comparable to the members of the following families are present: Lycopodiaceae, Schizaeaceae, Matoniaceae, Polypodiaceae, Parkeriaceae Liliaceae, Nymphaeaceae, Poaceae, Arecaceae, Oleaceae, Anacardiaceae, Alangiaceae, etc. Palynoflora largely belong to the semi-evergreen coastal vegetation having a tropical climate. Late Eocene-Oligocene palynofloral assemblages show high incidence of palms and *Podocarpus* pollen. It is comparable to coastal transitional type of vegetation. The Oligocene palynoflora of Himachal Pradesh is mainly represented by herbaceous elements and tree ferns. Angiosperm pollen comparable to *Castanea*, *Gallium*, *Amaranthus*, and members of Arecaceae, Fabaceae, Sapotaceae, etc. constitute an important part of the Oligocene palynoflora. The assemblage also includes pollen of Bombacaceae and several other angiosperm families indicative of a subtropical climate. It is clear from the distribution of palynofosssils that the composition of Palaeocene-Eocene palynological assemblages exhibits the characteristics of tropical vegetation, particularly reflecting semi- evergreen type to mixed coastal type of vegetation, depending upon the prevailing environmental conditions, though they have been recovered from widely different latitudes of Himalaya. Therefore, it seems possible to generalize that these floras had not till then adapted themselves to altitudinal tiering. This region was uplifted continuously in the Neogene period as a result of the Himalayan movement. Further changes in the climate and rate of precipitation are well reflected by the composition and distribution of subsequent palynofloras. Early Miocene palynofloral assemblage of Himachal Pradesh is inferred to be subtropical and humid type of vegetation. The Siwalik palynofloras (Middle Miocene -Pliocene) are generally poorly preserved because of the wide prevalence of oxidizing environment of deposition. A significant increase in temperate pollen and mesothermic taxa contemporaneous with the decrease in tropical families confirms a climatic amelioration in this region.

The prevalence of Abietineae over the Podocarpaceae gives the forest its Neogene affiliation. Palynofloral evidence also confirms that the Himalayan altitude was much less in the Miocene period. Three types of forest communities were identified, viz. tropical wet semi-evergreen, wet subtropical and humid temperate. The distinctive features of the Miocene floras in Himalaya seem to be their adaptation to different altitudinal belts. Some important constituents of floras in the North-west Himalaya are *Albizia, Anisoptera, Cassia, Dalbergia, Diospyros, Dipterocarpus, Ficus, Cyanometra* and *Ziziphus* along with the members of Moraceae, Euphorbiaceae, Myrtaceae, Fabaceae, etc. The Middle Miocene orogeny of Himalaya elevated the range sufficiently high, which accelerated the rate of migration of plant taxa from the Mediterranean and Sino-Japanese regions. Further rise in Himalaya during the Late Miocene-Pliocene-Middle Pleistocene resulted in colder climate, lesser precipitation and increased aridity. These conditions proved harsh for moisture loving plants, viz. *Dipterocarpus* and others. They either perished or moved away to peninsular areas in south where equitable climate proved conducive for their growth. During Pliocene, a major palynofloral change has been observed in North-western Himalaya: wet tropical forest gradually disappeared from the low altitude areas whereas the wet subtropical and temperate forests were transformed into dry or moist forest. Cold loving plants established themselves well on the elevated slopes of western Himalaya. Enrichment and diversification of the Neogene Himalayan flora took place due to several factors some of which are: the development of physical barriers brought in by orogenic movements, change in climatic patterns as controlled by the rise of Himalaya and sustained migration/immigration of several plant species from adjoining areas. History of vegetation and variations in climate by and large match with the periodic phases of the Himalayan uplift. The continued rise of Himalaya acted as a barrier for the flow of moisture from the Indian Ocean resulting in lesser precipitation, higher snow cover and increased aridity. The progressive change in vegetation during the last 60 Ma particularly corresponding to the altitudes and latitudes of the Himalaya is clearly reflected by rapid diversity in the composition of taxa evolving from evergreen, semi-evergreen, moist deciduous, dry deciduous, warm temperate and temperate in alpine types. However, low lands and plains of India continued to remain warm and wet /dry even after the uplift of the Himalaya. Immigration and extinction of plant taxa have played a major role from the Miocene onwards when land connections among circum-Mediterranean areas had mostly been established. Besides climatic factors, it seems possible that the immigrating plant taxa might have caused extinction of several endemic forms through tough competition and vigorous colonization of the newly acquired lands. All these factors are likely to have contributed in developing the modern flora of North-western Himalaya.

Theme–Integrated approaches to Palaeobiology and Sedimentology

MICROBIAL MAT-MEDIATED STRUCTURES IN PROTEROZOIC SANDSTONE AND THEIR IMPLICATIONS

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Non-uniformitarian microbial mats influence on physics of Proterozoic sedimentation is explored in different Proterozoic sandstones. A wide variety of microbial mat-related structures on sandstone bed surfaces support unusual cohesiveness within the granular sand deposited in a high-energy marine environment. The cohesiveness is manifested in abundant preservation of several delicate primary structures and also in their replication, even being subjected to high energy currents. SEM studies reveal some filamentous microbial remnants. Low rate of sedimentation and severely restricted sediment reworking as implicated in prolific mat growth, could also have influenced Proterozoic sequence building pattern in siliciclastic depositional system.

ROLE OF PALAEOBOTANICAL SOCIETY IN POPULARIZATION OF PALAEOBIOLOGY

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The role of professional scientific societies in dissemination and popularization of scientific knowledge can never be overemphasized. Most of the societies have their own journal that publishes articles in its specified field. Some of the well established societies organize national and international conferences, seminars or workshops, either on specialized or on general topics.

The Palaeobotanical Society (hereinafter called Society) was initiated and organized by Late Professor Birbal Sahni F.R.S., and registered under the Societies Registration Act XXI of 1860 on 3rd June 1946. Since its very inception the objective of the Society has been to promote palaeobotany and allied sciences. For achieving this objective, the Society publishes a journal - Geophytology, books, monographs and other literature on palaeobotany and related fields; holds scientific meetings and organizes lectures, seminars etc.; and does all such other acts as may generally be considered necessary for achieving the above objective. The role played by the Palaeobotanical Society in this direction is summarized below:

1. On 10th September 1946 the Society established an Institute for research in palaeobotany and Professor Birbal Sahni was appointed as its first Director in an honorary capacity. After the demise of Professor Sahni, the Institute of Palaeobotany was renamed as "Birbal Sahni Institute of Palaeobotany" in honour of its illustrious founder. The Society continued to develop the Institute till 1969.

2. The Society started publication of its journal Geophytology in 1971. Geophytology publishes research papers on all aspects of palaeobotany and palynology and such branches of botany and geology which have bearing on palaeobotany, e.g. plant morphology and taxonomy, ecology, plant geography, phylogeny, archaeobotany, stratigraphy, sedimentology, palaeontology, biopetrology, etc. So far, 34 volumes have been published.

3. The Society has so far organized nine scientific conferences, viz. 1st Indian Geophytological Conference (December 1975), 2nd Indian Geophytological Conference (March 1978), 3rd Indian Geophytological Conference (December 1979), 4th Indian Geophytological Conference (November 1981), 5th Indian Geophytological Conference (November 1983), Special Indian Geophytological Conference held at Pune (November 1986), 7th Indian Geophytological Conference (November 1987), Golden Jubilee Conference-Vegetational Dynamics of the Past and Present (November 1995) and National Conference on Biodiversity-Past and Present (November 2002).

4. The Society resolved in the year 1978 to award The Palaebotanical Society International Medal to all palaeobotanists irrespective of their nationality, religion or creed for their outstanding and internationally acclaimed contribution to the study of fossil plants in its widest sense. The Medal is awarded every alternate year. The recipient of the medal delivers a lecture on the subject of his work at the Medal Award function. So far, 14 internationally recognized palaeobotanists have received this Medal.

5. The Society recognizes the scientific achievements of its members by awarding them the Fellowship of the Society. As on date, there are 45 fellows.

6. The Society awards one of its members every year partial financial assistance for attending international conferences/ seminars abroad.

FOSSIL FUNGAL SPORES

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Fungi are a group of achlorophyllous, nonvascular thallophytic plants. They are either parasitic or saprophytic and reproduce by spores. Fossil fungal remains are found in almost all sedimentary formations ranging from Precambrian to Recent. However, only a few records are published from pre-Tertiary sediments. Fungal debris is often found associated with spores-pollen and includes spores, fragments of hyphae, sclerotia, conidiophores, setae, germlings and fructifications. The fungal remains are extremely resistant to chemical and biological degradation and hence, are easily recoverable from the sediments. The present paper, however, deals with fungal spores only.

Fossil fungal spores exhibit a variety of morphological variations. The morphological features considered for the identification of these spores are shape, size, symmetry, nature and number of apertures, septa and septal thickenings and stratification and ornamentation of spore wall. The fossil fungal spores from pre-Quaternary sediments are mostly described under artificial taxa. Nature and number of cells and pores are generally considered as criteria for generic differentiation, whereas shape, size and spore wall features are considered for specific differentiation. The fungal spores may be monocellate (amerospores), dicellate (didymospores), tricellate, tetracellate or multicellate (phragmospores), muriform (dictyospores), filiform (scolecospores), spirally coiled (helicospores) or star-like (staurospores). Similarly, they may be inaperturate, monoporate, diporate, triporate, etc. A brief account of fungal spores recorded from the Indian sediments, is given below:

Amerospores (monocellate): *Basidiosporites* Elsik (elongate, psilate, monoporate, pore offset from one apex), *Diporisporites* van der Hammen (generally elongate, diporate, pores on opposite ends), *Exesisporites* Elsik (monoporate, psilate, circular outline, pore minute, oriented in the centre with a thickened polar area around the pore), *Hypoxylonites* Elsik (oval to elongate, bilateral, psilate, bearing an elongate scar, slit or furrow), *Inapertisporites* van der Hammen (inaperturate, shape and size variable, psilate to variously ornamented), *Lacrimasporonites* Clarke (spatulate to elliptical, psilate, monoporate, pore apical), *Monoporisporites* van der Hammen (spherical to subspherical, monoporate, psilate-finely punctate), *Palaeoamphisphaerella* Ramanujam & Srisailam (psilate-scabrate, elliptical, oblong or rhomboidal with rounded ends, equatorial pore placed equidistantly); **Didymospores (dicellate):** *Dicellaesporites* Elsik (inaperturate, psilate, shape variable), *Didymoporisporonites* Sheffy & Dilcher (monoporate, pore apical, spore wall psilate to punctuate), *Diploneurospora* Jain & Gupta (elliptical, upper cell prominent, thick walled, sculptured with longitudinal ribs, lower cell small, hyaline with faint rib sculpture), *Dyadosporites* van der Hammen ex Clarke (diporate, with a single pore at each end of the spore, psilate to variously sculptured), *Fusiformisporites* Rouse (inaperturate, bearing characteristic elongate striae, ribs, ridges or costae oriented parallel to the longer axis); **Phragmospores (with three or more cells):** *Brachysporisporites* Lange & Smith (obovate, cells much broader than long in a sharply graded series of diminishing size from a large domed apical cell to a small hyaline attachment cell), *Cannanorosporonites* Ramanujam & Rao (tetracellate, barrel shaped, basal and terminal cells smaller than central cells), *Diporicellaesporites* Elsik (elongate, diporate, one pore at each end of the spore), *Foveoletisporonites* Ramanujam & Rao (elongated, four or more cells, foveolate, foveolae irregularly aligned), *Multicellaesporites* Elsik (inaperturate, psilate to scabrate, three or more cells, shape variable around a single axis), *Ornasporonites* Ramanujam & Rao (tetracellate, fusiform, rugulate-reticuloid, diporate, one pore at each end, apical cells much smaller than two central cells, central septum straight, other two septa curved), *Pluricellaesporites* van der Hammen (monoporate, psilate to scabrate, cells linear along longer axis), *Polycellaesporonites* Chandra *et al.* (multicellate, inaperturate, elongate, psilate, one end rounded, other end giving rise to a tube-like projection, cells arranged in clusters); **Dictyospores (muriform):** *Spinosporonites* Saxena & Khare (circular to subcircular; inaperturate, multicellate, each cell giving rise to a robustly built spine), *Staflosporonites* Sheffy & Dilcher (inaperturate, psilate to punctate, four or more irregular cells arranged in clusters along more than one axis, shape variable), *Tricellaesporonites* Sheffy & Dilcher (tricellate, inaperturate, cells along more than one axis, shape variable, spore wall psilate to punctate); **Helicospores (coiled):** *Elsikisporonites* Kumar (monoporate, nonseptate, tubular and coiled, pore at outer end, spore wall smooth and hyaline), *Involutisporites* Clarke (monoporate, psilate, transversely septate, coiled, psilate to variously ornamented); **Staurospores (star shaped):** *Frasnacritetrus* Taugourdeau (=*Tetraploa,* main body rectangular, spherical or oval, psilate to variously ornamented, with four unicellular processes); and **Others:** *Alleppeysporonites* Ramanujam & Rao (inaperturate, multicellate, branched, basal and terminal cells each with a conspicuous appendage), *Appendicisporonites* Saxena & Khare (subcircular, inaperturate, psilate, multicellate, each cell possesses a long process), *Rhizophagites* Rosendhal (nonseptate, thick walled hyphae with terminal subspherical vesicles of varying size).

It is noticed that a number of fossil fungal spore genera recorded from the Indian sediments need taxonomic revision, as these are either invalidly published or their diagnosis and status are not properly understood and therefore their species are required to be recombined with some other suitable genera.

The importance of fungal spores in biostratigraphy has been explored from time to time. However, the available data indicates that fungal spores are only of limited value in stratigraphy. On the other hand, fungal spores, particularly those that can be related to modern taxa, are very useful in the evaluation of the palaeoenvironment.

BIODIAGENETIC CHARACTERIZATION OF COAL/ORGANIC SEDIMENTS-A FUTURISTIC TRENDS

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Present day energy crisis has necessitated a need to understand the characterization, assessment and behavior of organic matter in time and space so for as their hydrocarbon potential in any basin is concerned. The delineation of the biodiagenetic level, i.e. the level attained by organic sediments in response to the differing depositional environments and basinal characteristics, is the most important aspect to decipher the prospects of hydrocarbon potential in the basin.

The quantification of the biodiagenetic level can be achieved by different methods, viz. petrographic and chemical. The multidisciplinary approach is the need of the hour to unravel the history of the hydrocarbon progenitors and their hydrocarbon potential in the basin. In view of this, varied methods to ascertain the diagenetic level have been reviewed.

Fluorescence, which is the luminance of the substance excited by radiations, is the most important property, which has been used by coal petrologist/ petroleum geologist to characterize the biodiagenetic level. Similarly, vitrinite reflectance has also been used to characterize the diagenetic level attained by the coal/organic sediments.

The varied parameters of geochemical methods have been reviewed in order to be more precise as for as their genetic level characterization is concerned for the exploration and exploitation of hydrocarbon in the basin.

Further, varied merits/demerits of these parameters have been elucidated for the emerging futuristic trends in biodiagenetic level characterization in the hydrocarbon exploration activities.

Theme–Interface of Palaeobiology with other disciplines

SIGNIFICANCE OF GEOCHEMICAL APPLICATIONS IN PALAEOBOTANICAL STUDIES

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The major objective of the palaeobotanical studies is to understand the vegetation pattern of the entire geological time-scale. Since vegetation of a particular time and space is directly governed by the climate and local environmental conditions, a better understanding of the subject can provide important information on palaeoclimate and depositional environmental conditions of the associated rock and sediments. Similarly, the ever increasing demand for energy requirements could also be addressed more scientifically if we have a comprehensive understanding of our fossil fuel resources which is nothing but the product of past floral assemblages.

With the advancement in the fundamental and applied science disciplines and also in technological know-how, it is essential to shift our attention from the monotypic palaeobotanical approach (mere understanding of plant mega- and micro-fossils and their palaeoclimatic/palaeoenvironmental implications) to a multidimensional one, which would add new vistas in palaeobotanical researches.

The geochemical approach (both inorganic and organic) using sophisticated techniques (spectroscopy, mass spectrometry, chromatography, etc.) towards various palaeobotanical problems have made significant contributions and considered to be a very good tool in understanding and resolving many issues such as palaeoclimate and monsoonal trends, biological marker trends, productivity and nutrient dynamics, Hydocarbon maturation trends and byproduct recovery, nature of K/T boundary and associated fire phenomenon, extinction of varied flora and fauna, etc. Therefore, it is quite clear that geochemical approach has great potential in palaeobotanical researches both academically as well as industrially.

LOOKING BACK AND INTO THE FUTURE OF STROMATOLITE STUDIES: INDIAN PERSPECTIVE

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The present paper summarizes the global advancements made in the stromatolite studies, including the significant Indian contributions and traces the Indian efforts, strengths and gaps in their studies. It also brings out the future line of investigation for stromatolite studies in the country. The study of stromatolites is almost a century old. Kalkowsky (1908) coined two terms "stromatoid" and "stromatolith" (words originated from Greek, *stromat* means to spread out; Latin *stroma* means bed covering; and Greek *lithos* means stone), along with ooid and oolith but without comprehensive definition of stromatolites. Since 1908, stromatolites have been recorded in almost every Precambrian sedimentary terrain on all the continents except Antarctica. Besides Precambrian (Archaean and Proterozoic), these structures are also reported from a few Phanerozoic sedimentary deposits. At present, the Shark Bay in Australia, Yellowstone National Park in USA, Baha California in Mexico, Solar Lake and Ras Muhammed Pool (Sinai), Dead Sea and Lake Hoare in Antarctica (Parker & Simmons 1981) are such spots where stromatolites very similar to ancient ones, grow even today. Demonstrably, one can divide the entire span of stromatolite studies in the last century in three distinct periods: firstly, the investigative phase of studies (1900-1950 A.D.), secondly stabilizing phase (1951-1975 A.D.) and lastly swinging phase of disinterest/interest (1976-2000 A.D.). Last five years (2000-2005) have once again seen resurgence of interest in stromatolite studies.

In India, structures similar to stromatolites were recorded as ring like features by McClelland (1834). Subsequently, King (1872, p. 189) reported them as laminated and segregated limestone in peculiar way, whereas Auden (1933, pl. 1, fig. 2) photo-documented and recorded such structures in different Indian Precambrian basins as spheroidal Fawn Limestone, yet no systematic studies were undertaken until sixties of last century. Investigations of late sixties not only brought forward the extensive stromatolite occurrences in the Precambrian sediments of India but continued search also recorded them in younger sediments of the Talchir Formation (Pandya 1987), which has been considered to be of fresh water origin (Ghosh *et al.* 2001). In spite of the extensive exposures of stromatolites on global scale, no efforts were made on their systematic studies in the first half of the twentieth century. In India, a few concerted attempts of taxonomical descriptions were made by Valdiya (1969, 1989), Kumar (1976), Chandrasekhar *et al.* (1980), Tiwari (1989), Sharma (1996) and Moitra (1999). The other frontiers of investigation, as attempted in different parts of the world, were not addressed with same vigour in India.

Issues and opportunities - In spite of the multifaceted aspects of studies in the past, stromatolites, even at present, are as much enigmatic as they were in early part of the last century. Walter (1976, p. 1) in his book 'Stromatolites' commented that Kalkowsky 'coined and defined the word stromatolith, yet there is increasing controversy and confusion as to its use'. On the global scale, the debate concerning their definition (microbial and laminated/ genetic/ descriptive), nature (biogenic/ abiogenic), formation (accretion/ precipitation), causative organisms (bactertia /cyanobacteria; prokaryotes /eukaryotes), status (index fossil /general fossil), biostratigraphic potential (mileposts), classification (binomial Linnaean system/ sedimentary structures /mathematical formulae) and economic importance (primary/ secondary enrichment), depositional environment indicator (dipsticks /real /proxy), etc. is far from resolved. Even the understandings about the ascent and decline of stromatolites in the earth history are shrouded in the hypotheses, assumptions and premises. A few attempts have demonstrated the usage of recent stromatolites in understanding the Sun-Earth-Moon relationship and deciphering the speed of rotation of the Earth as well as number of days in a year (Awramik & Vanyo 1986, Sheldon 1989). Similar attempts can be made on stromatolites of different geological ages. These studies are possible only on undisturbed and extensive exposures and incidentally such exposures are available in India as well where this relationship and hypothesis can be tested (Sharma 2003). In recent years, few researchers have recorded the secular variations in the stable isotopic composition of the stromatolitic carbonates while others have attempted to decipher the age of the stromatolites (direct dating of the carbonates) with the help of isotopes. Researchers have shown the interest in search of extra-terrestrial life and evidences of early life. Report of structures similar to the algal laminites from the Mars is the other line of investigations. These aspects are different dimensions of studies and indicate the interest shown by the stromatophiles (scientists who study the stromatolites).

Indian status—Observations during the nineteenth century made by different workers on peculiar structures in carbonate belts, while preparing the geological maps of our country, can at best be considered as passing reports of stromatolites. Since the issues are wide and open, opportunities of studies are also ample and engrossing. On the Indian scenario, stromatolites are mainly treated in short reports and rarely few of them have been dealt for taxonomic details. Many seminal papers on the definition of the stromatolites are testimony that it is yet not agreed upon to the satisfaction of most of the stromatolite workers (Kalkowsky 1908, Awramik & Margulis 1974, Krumbein 1983, Brune & Moore 1987, Riding 1999). Indian workers have made no contribution on this issue. The genesis of stromatolites has also been debated at several levels and most of the stromatolite researchers agree with Hoffman (1973), who stated "something that haunts geologists working on ancient stromatolites is the thought that they might not be biogenic at all." In many cases, biogenic origin has been argued and established to a satisfactory extent (Grey 1984, Sharma & Shukla 1998, Riding & Sharma 1998, Batchelor *et al.* 2004, 2005), however, in few cases, it is refuted as well (Hofmann & Jackson 1987, Grotzinger & Rothman 1996, Sharma & Sergeev 2004). For satisfactory grouping, different researchers have proposed number of classifications of stromatolites but two of them, proposed by the Indian researchers (Bhattacharya 1980, Raaben & Sinha 1989), are worth mentioning because of their novel approach. Classification scheme of Raaben and Sinha (1989) has been refined by Semikhatov and Raaben (2000), and that is presently *in vogue*. Hofmann (1976) and Zhang and Hofmann (1982) had applied statistics and computer software in morphometric analysis of stromatolites. This technique has been found useful in stromatolite biostratigraphy. Banerjee and Chopra (1986) have successfully used this technique in India.

Direct dating of carbonate rocks is a new tool in geochronology of stromatolites bearing rock strata (Moorbath *et al.* 1987, Jahn & Cuvellier 1994). There is only one stance in our country where this new technique has been attempted, on Cuddapah stromatolites (Zachariah *et al.* 1999). Geochemical analysis of stromatolites for understanding the sea chemistry and environmental aspects is being extensively used. This analyses was initiated in late seventies (Schidlowski *et al.* 1975, 1976). In this regard, a few attempts were made in India as well (Sathyanarayan *et al.* 1987, Kumar 1988, Banerjee & McArthur 1989, Kumar & Tewari 1995, Kumar *et al.* 2002).

Geomicrobiology has opened a new vista in deciphering the role of microbes in enrichment of minerals in the earth's history. A lot of efforts have been made to understand the role of microbes in enrichment of phosphorites, magnesite and uranium. These economic minerals are found in abundance in association with stromatolites in Indian Precambrian sequences. Even in some cases, the enrichment of base-metal deposits has also been attributed to the stromatolites (Verma 1980). Indian researchers have made significant contributions in understanding the phosphorite genesis and role of microbes. The phosphorite occurrence, in association with stromatolites, is comprehensively studied in Udaipur, Rajasthan (Banerjee 1971, Chauhan 1973), Bijawar Group in Lalitpur, Uttar Pradesh (Banerjee 1982), Tal phosphorite in Mussoorie (Patwardhan & Ahluwalia 1973, Patwardhan 1980, Banerjee *et al.* 1986) and Gangolihat Dolomite, Pithoragarh, Uttaranchal (Patwardhan 1973). The magnesite deposites are recorded in the Jammu Limestone in Katra area (Raha 1975) and in Gangolihat Dolomites in Pithroagarh (Valdiya 1968). Strata-bound uranium mineralization in the stromatolite bearing Vempalle Formation of the Cuddapah Supergroup has been reported and its genesis has been discussed (Vasudev Rao *et al.* 1989). Although stromatolites are good indicator of depositional environment, only a few serious efforts have been made to use them in basinal analyses in India (Chandrasekhara *et al.* 1980, Banerjee & Basu 1980, Raha 1980, Sarkar & Bose 1992). If recent publications on stromatolites are any indicator, then it is clear that researchers are interested in understanding the sea chemistry, depositional environment and oxygen evolution in atmosphere through isotopic studies of stromatolites (Melezhik & Predovsky 1989, Melezhik *et al.* 1997 a, b, 1999).

Future Research Direction—Poor radiometric age constraints of the Precambrian basins of India and extensive exposures of stromatolites in these terrains offer opportunities to conduct varied studies particularly related to the biostratigraphy and geochronology. Sudden glaciations in the earth history and change in atmospheric conditions are recorded in carbonate deposits that are deciphered by various isotopic patterns. Studies of the palaeoclimatic fluctuations on the earth in the past are very much required. Rise and fall of stromatolites are also seen in terms of related mass extinction and advent of new groups of plant and animal life. Breakup of Rodinia and floating Indian mass experienced drastic changes that can be studied by the patterns recorded in extensive carbonates deposited in the Precambrian. Undisturbed exposures available in India can be a target of Sun-Earth-Moon system studies. Global interest in search for extraterrestrial life (SETL) has opened a new vista for stromatolite studies. On Earth, stromatolites are repository of primitive benthic microbial remains. In depth knowledge on stromatolites will be useful in Indian efforts of SETL and the global mission on Mars as any primitive life form on other planets is presumed to be similar to early life on the Earth. The scopes of studies are in plenty and universities and institutions together can play an important role in initiating these studies.

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Theme–Emerging Trends in Palaeobiology, Session A–Early life on Earth and signatures of Extra Terrestrial Life

ENIGMATIC PRECAMBRIAN CARBONACEOUS MACROFOSSILS-RETROSPECT AND PROSPECT

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Overall shape of an organism or a group of organisms is often seen on the rock surface as a carbon layer, or carbonaceous compression. Such carbonaceous fossils are found in rocks as old as 2 billion years. They represent a variety of organisms including colonies of prokaryotes, single-celled eukaryotes, and fossil seaweeds. These micrometre-thick and millimetre to centimetre sized carbonized fossils are known from nearly all the continents. They are generally preserved as simple films with or without distinct ornamentation; variably oriented folds are best regarded as compactional artifacts. Their outlines range from ribbon-like to regular and irregular, round and angulate shapes. Rarely they are also found as envelops of three-dimensional structures.

Several assemblages of morphologically distinct remains are now known, although, due to lack of distinct characteristics other than gross shape, the biological affinities of these fossils are, to a large extent, still uncertain.

Several attempts for suprageneric biological classification of the remains have been made, but none is comprehensive or entirely satisfactory. These classifications are purely morphological, referring only to discoidal and/or filamentous remains of which the biological affinities remain obscure. The groups, proposed by various authors, are as follows: Fermoriidae (Sahni 1936), Chuariidae (Wenz 1938), Megasphaeromorphida (Timofeev 1970), Vendotaenides (Gnilovskaya 1971), Chuariamorphida (Sokolov 1976), Chuariaceae (Duan 1982), Huaiyuanellidae (Xing 1984), Longfengshanides (Duan *et al.* 1985), Cyphomegacritarchs (Fu 1986), and Vendophyceae (Gnilovskaya *et al.* 1988). The monograph edited by Gnilovskaya *et al.* (1988) contains the most comprehensive suprageneric classifications to date.

To accommodate all morphologic types of megascopic carbonaceous films, Hofmann (1985, 1987, 1992) used a tentative informal system of categories for generic level taxa named after the dominant genus. The major categories recognized include Chuarid, Tawuid, Ellipsophysid, Grypanid, Longfengshanid, Moranid, Beltinid, Vendotaenid, Eoholynid, Sinosabelliditid and Sabelliditid remains.

Some workers have tried to assess the affinity of these forms. Hofmann and Chen (1981) recognized that Moranids and Beltinids represent whole and fragmented colonies and mats of prokaryotes and amorphous organic matter. They also opined that Chuarids and Vendotaenids recorded from early Proterozoic sediments too might be bacterial or cyanobacterial in origin. However, some Vendotaenid forms with longitudinal striations suggest algal (metaphyte) affinity for them. Zhang (1988) has compared *Longfengshania* to the bryophyta. Walcott (1919) and Taylor (1957) compared *Morania* with modern free-floating globoidal colonies of the cyanobacterium *Nostoc*. Sun (1987) reported numerous obscure, filamentous impressions on the surface of *Tawuia* and opined nostacalean affinity for them. However, morphologically they can also be compared with sausage-shaped colonies of *Wollea*. Metazoan affinity has been suggested for *Tawuia-Sinosaballiditid* association. Beltinids have been variously regarded as structureless biogenic matter, or fragments of prokaryotic mats and colonies, or eukaryotic algae. Sokolov (1976) and Glaessner (1976) attributed Sabelliditid remains to worm affinity, however, ultrastructure investigations by Urbanek and Miezejewska (1983) were inconclusive on worm affinity. It needs to be realized that these categories/genera are based only on external morphology and are not necessarily representing same taxa. Therefore, it is not correct to generalize finding based on the study of fossils from one or two places for the whole group. It will be better that we restrict ourselves in separating out those forms from these groups that can be recognized as independent phylogenetic entities.

The above contention can be best exemplified by taking up the case of *Chuaria*. The *Chuaria* has been variously regarded as a problematicum, brachiopod, gastropod, hyolithid operculum, trilobite, e.g. medusoid, chitinous foraminifer, cyanobacterial colony, green alga, and megascopic acritarch (Jones 1909, Chapman 1935, Sahni 1936, Ford & Breed 1973, Suresh & Sunder Raju 1983, Maithy & Shukla 1984, Sun 1987). *Chuaria* reported from different localities vary in size, thickness, mode of preservation, e.g. if black opaque *Chuaria* and light brown coloured *Chuaria* are found on the same surface, they definitely represent two separate phylogenetic forms. It is now necessary that new methods of investigations, e.g. biostatistics, scanning electron microscopy, transmission electron microscopy, palynological analyses, comparisons to recent cyanobacteria and also organic geochemical analysis of these forms for extracting possible biomarkers, are employed to understand their affinities. Employing similar techniques, Steiner (1997) concluded that *Chuaria circularis* is a form-taxon representing mainly prokaryote colonies of various biological affinities and their outer envelopes and *Tawuia dalensis* possibly represents an ecophene of *Chuaria*. It is also necessary not to look at these forms in isolation. The fossils associated with these forms are important as they may help in recognizing the much needed stages in their life cycle. Kumar (2001) opined that *C. circularis, Tawuia*, and *Tilsoia,* which are found preserved in association of each other**,** are parts of a single plant, which has been named by him *Radhakrishnania*. Such efforts are steps in right direction. However, such conclusions should not be generalized for the whole group. Therefore it is necessary to restrict ourselves to separate out those forms from these groups/form genera that can be recognized as independent phylogenetic entities leaving the original groups/ forms intact to accommodate the remaining forms.

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COAL PETROLOGY — A SHIFTING ROLE FROM COAL UTILIZATION TO FUEL EXPLORATION

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Coal petrology deals with the study of microscopically recognized remains of vegetal source matter (macerals = 'minerals' in rocks). The study has ascertained the origin of coal from pre-historic vegetation existing millions of years ago. The vegetal matter contributing as a source material is observed in various states of preservation (from structured to unstructured). For convenience, the vegetal debris in coal, as recognized under the microscope (transmitted, reflectance and fluorescence modes), are classified and categorized into three main maceral groups - vitrinite, liptinite (or exinite) and inertinite, on the basis of their origin, optical and chemical properties.

Each maceral being specific in its origin, evolution and environmental conditions during genesis has tremendous interpretative value. The studies of coal macerals are utilized to deduce the depositional environment during coal formation. Vitrinite-rich coals are formed in anaerobic (wet-reducing) condition, whereas aerobic (dry-oxidative) condition resulted into the formation of inertinite-rich coals. Further, the petrological investigations are convincingly utilized to interpret the suitability of coal for burning in thermal power plants for electricity generation and for other industrial purposes. Apart from combustion, suitability of coals for gasification (generation of gas), liqufefaction (generation of light hydrocarbons), carbonization (coke making) and upgrading purposes (blending, coal preparation/ beneficiation) is predicted from various petrological investigations made on coal. Optical properties (reflectance and fluorescence) and quantitative estimations of coal micro-constituents overall reflect the chemical properties and thus help in various interpretations. Macerals of the liptinite group are relatively hydrogen-rich, while those of the vitrinite group are oxygen-rich. The macerals of the inertinite group are chemically distinguished from the preceding groups by being relatively rich in carbon.

Evidently, coals with coking property should normally be of medium to low-volatile bituminous stage (rank) having 70-80% carbon content ($R_{o\ max}$ 1.10-1.50%) and reactive components (vitrinite + liptinite) ranging between 45 and 75 %. Coals having high contents of hydrogen-rich macerals (fluorescing vitrinite + liptinites) are amenable for hydrogenation processes. Washing and blending are the two major routes for coal beneficiation. Detailed cleaning tests on different grain size fraction proved fruitful for suitable preparation of non-coking coals for use as blending coals with low ash and high rank coals.

Global demand for energy has necessitated exploring all the possibilities of coal utilization for energy generation. This led to the development of new techniques in scientific and technological fields. Petrological studies, till now conventionally utilized to predict the suitability of various coals for specific industrial purposes, are presently utilized to interpret the potentiality of coal for methane generation. Thus, there is a great shift in the role of coal petrological studies from coal utilization to fuel exploration.

Methane gas occurring in coal beds is called coal bed methane (CBM). It originates during the time and pressure induced diagenetic and catagenetic stages of coal formation. Since, the gas generates during the coal formation, there is no doubt about its existence in all the coals. However, the amount present and gas generating and producing capacities vary from coal to coal. The petrological study of coal is the most reliable and best way to obtain information on various coal bed methane (CBM) related aspects, since macerals, which are the basic unit of coal, vary in their methane generating (liptinite)/ retaining (vitrinite)/ producing (inertinite) capacities. Coal rank is considered to be one of the most significant parameters for CBM generation, which is possible only when coal has reached the threshold of methane generation (thermogenic: $R_{o\ max}$ 0.70-1.40%).

Various studies have identified the important factors influencing methane storage and recovery from coal beds. These include coal type (maceral composition), rank, cleat, natural fracturing and stress, pattern of mineral infilling in fractures, permeability of coal, moisture content, gas in place reserves, as well as geological parameters, like coal reserves– thickness and extent, seam structure, burial history/ depth of coal basin and hydrodynamic regime. Thus for CBM exploration and exploitation, the work should be oriented to problem based researches. CBM related petrological data (rank, maceral composition, permeability, etc.) should be generated in all basins having good prospects of CBM generation. In order to have self reliance in the field of CBM, the coal scientists and coal producing and utilizing organizations in the country should work in close cooperation and coordination.

EARLY LAND PLANT DEVELOPMENTS: GLOBAL PROGRESS AND INDIAN PRIORITIES

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The Earth was formed about 4,600 million years ago by the consolidation of the accretion disc of debris orbiting the Sun. Nitrogen, hydrogen and carbon dioxide dominated the earliest atmosphere. The earliest bacteria relied on hydrogen and some carbon dioxide while extracting energy from inorganic compounds, which had a marked impact in reducing the atmospheric levels particularly of hydrogen. There are no fossils of these early life forms. The oldest known fossils are dated about 3500 million years, with the remains of small filamentous organisms looking like cyanobacteria. In the rocks of almost same age, stromatolites are found, which are carbonaceous mounds formed by cyanobacteria. By the beginning of the Palaeozoic Era (ca. 570 million years ago) the chemical composition of the oceans and atmosphere was broadly similar to that of today. Relatively high levels of atmospheric oxygen were, therefore, already available for life outside the oceans. It was not until about 430 million years ago that life, led by plants slowly started to take hold on the land. The geography of the world at that time was different from today. In the middle Silurian, there were two main land areas separated by the Rheic Ocean, the Laurentia which includes much of Europe and North America; and Gondwana which includes the rest. The best known early land plant fossils come from Laurentia. The fossils have also been recorded from other parts of the world, including Australia, central and east Asia, Africa and South America.

Four phases of colonization on the land, by the plants, are recognized:

Phase 1 (?Precambrian - Early Phanerozoic): During this phase, there existed a terrestrial ground cover in the Precambrian perhaps as early as 2200 Ma ago (Edwards & Selden 1993), but the direct fossil evidence for such a covering of presumably prokaryotes has not yet been documented (Wright 1985, Retallack 1990). The widespread occurrence of cyanobacteria in the Precambrian could be a circumstancial evidence favouring the existence of such early land cover. Thus it seams reasonable that the land surfaces were initially coated by photosynthesizing mats of cyanobacteria and other prokaryotes and then by photosynthesizing protists (algae). Retallack (1990) cited the 3000 Ma Jerico Dam and the 2200 Ma Waterval Onder palaeosoils as probable Precambrian examples of soils produced by interaction between organisms and sediments, based on the detection of wispy trace fossils and some fabric and structures in these palaeosoils, which can be related to sediment binding. Such surface mats would have had limited binding capacities but could have encrusted wide range of substrates.

Phase 2 [(Mid-Ordovician (Llanvirn) - Early Devonian)]: The evidences for this phase are based not on megafossils but on the sporomorphs (cryptospores) and the cuticles recovered from bulk maceration of fine grained clastic sediments belonging to a variety of Ordovician and Early Silurian environments, both continental and marine. These earliest dispersed spores are called cryptospores that comprise monads, dyads and tetrads lacking any trilete mark on their surface. The cryptospores are either naked or enclosed within thin, laevigate or variously ornamented envelopes and also impregnated with sporopollenin or sporopollenin type macromolecules as suggested by their preservations in the ancient deposits. Cryptospores are neither algal (having sporopollenin) nor belonging to a higher plant group (trilete mark absent). Gray (1985, 1991) was of the opinion that the cryptospore tetrads were derived most probably from the hepatic group of bryophytes. She noted that among free sporing embryophytes, only hepatics regularly produce permanent tetrads, some of which are contained within an envelope, similar to certain enclosed cryptospore tetrads. Cryptospores thus present an indirect evidence for a land vegetation for which there is a little or no megafossil record. This suggests that the vast majority of plants during Ordovician and until Late Silurian lacked the appropriate recalcitrant biopolymers (such as lignin) in the tissues that enhance fossilization potential (Gray 1985, Edwards *et al.* 1999).

The earliest dyads and tetrads are described as 'Permanent' because they do not readily separate into discrete units and a resilient membranous sac frequently surrounds them, which may be smooth or ornamented. The beginning of second phase of colonization is based on tetrads reported from mid-Ordovician (Llanvirn) of Saudi Arabia (Gray 1991), while low diversity assemblages of tetrads and dyads are recorded from Caradoc sediments in Welsh Border land (Richardson 1988) and in Murzuk Basin, Libya. In the Ashgill, they are found in central Bohemia, the Appalachian region, Kentucky and Quebec in North America and possibly also in South Africa. Records of somewhat more diverse sporomorphs of greater size occur in the Early Silurian of South America (Parana Basin, Brazil; Gray *et al.* 1985), Ghana, North Africa (Tunisia, Morocco) as well as North America and Britain. Thus by the end of the Ordovician, land surfaces over a wide geographic area were affected by this second phase of colonization. In the Late Silurian (Pridoli), although spore diversity is low compared with trilete spores, in absolute abundance cryptospores outnumber trilete spores and remain numerous in Gedinnian, suggesting that the parent plants were still an important component of land vegetation (Fanning *et al.* 1991).

In the Libyan Caradocian record, Gray *et al.* (1982) illustrated a fragment of cuticle with cellular imprints similar to examples described in the Silurian (Lang 1937, Edwards 1982), which are attributed to *Nematothallus* Lang. Such cuticles are unequivocally derived from land plants, although the nature of underlying tissues and indeed the affinities of plant remain obscure. Lang (1937) considered that the cuticles covered a plant of predominantly tubular constructions including internally ornamented tubes (Burgess & Edwards 1991). Smooth tubes are recorded in the Ordovician, but the earliest ornamented forms occur in the late Llandovery (Pratt *et al.* 1978), long after the first appearance of cuticles. The absence of any perforations in these cuticles resembling stomata or liverwort pores suggests that their primary function may not have been to reduce evaporation, achieved in extant plants by a waxy layer within the cuticle. A superficial resilient covering could have acted as a UV light absorbing screen, facilitated run off or deterred pathogens in the pioneering land plants (Edwards & Selden 1993). Lack of information, because of non-preservation of the vegetative parts of the spore producers, suggests that these plants had not evolved the homoiohydric characters of vascular plants (Raven 1984). Gray (1985) argued persuasively for a primary adaptive radiation on land of poikilohydric plants (algal plants, which have little or no capacity to restrict water loss) with a nonvascular grade of organization comparable with that of bryophytes.

Phase 3 [Early Silurian (Llandovery, Upper Aeronian) - Lower Devonian (Gedinnian)]: This phase is characterized by the appearance of miospores, monads with well defined discrete trilete marks. The age of the oldest recorded miospores is probably Aeronian (Llandovery type area, Burgess 1991; Tuscarora Formation, Pennsylvania, Strother & Traverse 1979). There are convincing records in the Rhuddanian of Libya, North America and possibly Ireland. The existence of *Ambitisporites* *vavrdovii* and *A. avitus* may be evidence of evolutionary progression from a separating 'Permanent' tetrad to trilete spore with discrete trilete mark (Richardson 1988). The advent of sculptured spores in the late Wenlock (Homerian) heralded a major diversification in sporomorph sculpture and structure, which continued into the Lower Devonian.

The Wenlock event is recorded in Southern Britain, Libya and Spain and was more or less synchronous with the appearance of fertile megafossils of pteridophyte-like plants. Earlier Llandovery age axes are sterile (Schopf *et al.* 1966). The Irish fossils resemble *Cooksonia* which occurs in Late Silurian and Early Devonian, but they are devoid of any anatomical detail. *Cooksonia* itself, found in the Ludlow and Pridoli (Late Silurian) of North America, Britain, Bohemia, Libya and Podolia (Richardson & Edwards 1989, Edwards 1990), is characterized by smooth isotomously branching axes terminated by globular or discoidal sporangia. Although no complete plants have been found, the small diameter and lengths of Silurian axes are suggestive of plants of short stature, probably rarely more than a few centimetres tall. The limited evidence (Edwards 1990) indicates that vegetation in Late Silurian Laurentia was dominated by plants of this aspect (Rhyniophytoids) with variation produced by differences in sporangial shape and nature of sporangial appendages (Edwards & Davies 1990) and it persisted into the Early Devonian.

The recent demonstration of tracheids in Lower Devonian *Cooksonia pertoni* confirms its vascular status (Edwards *et al.* 1992), but tracheids have been seen neither in other Devonian rhyniophytoids nor in Silurian fertile axes (Edwards & Rogerson 1976). A growing body of evidence from Late Silurian sporangia has revealed that some of the spores in the dispersed record, particularly the oldest ones (*Ambitisporites*) were indeed produced by rhyniophytoids (Fanning *et al.* 1991). Although Richardson and MacGreger (1986) were able to distinguish five assemblage zones in the intervals between Aeronian and the end of Silurian, there is no evidence for major change in vegetation in the present northern hemisphere. Based mainly on life cycles of modern pteridophytes and on the preservation of the rhyniophytoids in marine and fluvial sediments, it has been postulated that these simple land plants colonized moist habitats in coastal areas (Edwards 1990).

Phase 4 [(Late Ludlow (Australia)/ Early Gedinnian (Laurentia) - Late Devonian (Frasnian)]: The advent of forth and final phase is marked by a major change in higher plant architecture. Innovations in growth patterns brought out change in vegetation structure as plants grew taller. There was an increase in sporing potential, because of the development of strobili and trusses. The recent demonstration of tracheids in Early Devonian *Cooksonia pertoni* strengthens the possibility that at least some of the rhyniophytoids were indeed vascular plants. Two major tracheophyte groups, viz. Zosterophyllophytina and Drepanophycopsida (Lycophytina), appear. Throughout the Early Devonian, there were major diversifications in vascular plants (zosterophylls and trimerophytes). At the end of the phase, Zosterophyllophytina and Drepanophycopsida became extinct in the Frasnian, although herbaceous lycophytes persist to the present day (Edwards & Berry 1991). However, there were major changes around the Emsian-Eifelian boundary, where the trimerophytes disappeared, involving major evolutionary innovation with profound effects on vegetation structure and reproductive strategies. The advent of progymnosperm in the Eifelian marked the beginning of a new era with the acquisition of the vascular cambium. The evolution of heterospory occurred in a number of groups with the earliest ovules recorded in the Famennian.

In the present southern hemisphere, the beginning of the phase is marked by records of *Baragwanathia* and in the present northern hemisphere by the genus *Zosterophyllum*. These two taxa exemplify the two major kinds of gross morphology in early land plants, viz. axial systems and the leafy stems typical of herbaceous lycophytes today. The erect system of *Zosterophyllum* was relatively simple. Gensel and Andrews (1984) reported that Emsian *Pertica* and *Trimerophyton* might have reached 2 metre in height. This increase in size was achieved only by primary growth, the first record of secondary xylem being in Eifelian progymnosperms, e.g. *Rellimia* and *Aneurophyton*. Evidence for stratification in phytocommunities is seen in the Emsian of north-eastern America, where Gensel and Andrews (1984) suggested that many Zosterophyllophytes, *Drepanophycus* and *Kaulangiophyton*, all with rhizomes and aerial shoots, grew in dense, low mats, while trimerophytes, such as *Pertica* and *Trimerophyton* formed a second taller layer. The advent of secondary thickening in Eifelian progymnosperms and the probable fore runners of the arboresent lycophytes (*Lepidosigillaria* and *Lepidodendropsis*) in the Givetian further increased capacity for upward growth.

The earliest progymnosperms (*Aneurophyton*) were bushes, but by the end of Devonian, *Archaeopteris* had a well developed, at least one meter wide, trunk (*Callixylon*) and branching crown with a profusion of small, laminar leaves. At the same time the arborescent lycophyte *Cyclostigma* was approaching the dimension of Carboniferous swamp forest forms. Indeed, the presence of thin coals in both Middle and Upper Devonian points to the existence of well-developed swamp communities.

The best known early plant fossils come from Laurentia, which includes much of Europe (Bohemia, Germany, Turkey, Bulgaria, Ireland, Wales, England, Scotland, Belgium, Spain and Czechoslovakia), North America (U.S.A., Canada and Arctic Canada) and Greenland (Spitsbergen). The rest of the records are from South America (Brazil, Paraguay, Bolivia and Argentina); Africa (Libya, Ghana, Tunisia, Morocco and South Africa); Asia (China, Kazakhstan, Russia, western Siberia, Saudi Arabia and Viet Nam) and Australia. There are only two doubtful records of early plants in India, i.e. ?*Taeniocrada* and *Psilophyton princeps* from the Silurian and Lower Devonian of Spiti Valley. Besides being the presence of Silurian and Devonian sediments at various places in Kashmir, Ladakh, Lahaul, Spiti and Kumoun Himalayas, no serious efforts were made to search the early plant life in these rocks. Now it is a high time that such researches relating early plant life be started in the early Palaeozoic rocks.

COAL AND ORGANIC PETROLOGY: RECENT DEVELOPMENTS, FUTURE CHALLENGES, AND APPLICATION IN EXPLORATION AND UTILIZATION OF FOSSIL FUEL RESOURCES

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The science of coal petrology evolved in 1913 when White and Theissen published a report on the microscopic examination of coal. Since then this subject has been progressing in leaps and bounds. Moreover, there has been periodic refinement in the terminology and classification of microscopic constituents of coal (macerals) by the International Committee for Coal & Organic Petrology (ICCP) - a non-profit organization looking after the development and international exchange of scientific information related to organic petrology. For the last couple of years this committee, in association with the Society of Organic Petrology, is trying to bring uniformity in nomenclature for the sedimentary organic matter at large. Since the approaches and techniques of coal petrography are being used for the characterization of petroleum source rocks and oil shales, the scope of this subject has been broadened and the very science is being renamed as 'Organic Petrology'. In recent years, new terms have evolved for the macerals of vitrinite, inertinite and huminite groups, and terms for the macerals of liptinite group are under process. Further, the ICCP has constituted sub-committees to device nomenclatures for the microscopic characterization of dispersed organic matter (DOM), coke textures, pulverized fuel chars, fly ash and matrix porosity of coals.

The ICCP has constituted a working group in August, 2000 to focus on 'New Methodologies in Organic Petrology' with a task to review new methods and techniques that could advance the horizon of organic petrology in relation to chemistry of coal macerals, maturation studies, coal combustion problems and environmental issues. Further, this would strengthen the subject to face the future challenges, particularly the growing demand for clean fuel. The new methods and techniques under examination are: (i) application of Laser Microscopy - FAMM (Fluorescence Alteration of Multiple Macerals) in organic petrology; (ii) application of Confocal Laser Scanning Fluorescence Microscopy in organic petrology; (iii) investigation on the organic-mineral matter association and distribution in coal using Colour Image Analysis; (iv) transmission Electron Microscopy (TEM), as a tool in characterizing organic matter further to organic petrology; (v) quantitative mineralogical analysis of coal using Advanced X-ray Diffraction technique; and (vi) application of Reflectance Micro-Fourier Transform Infrared (FTIR) analysis to the study of coal macerals.

The organic petrology is one of the most powerful tools which provide remarkable ability to the human eye to recognize systematic patterns in complex and heterogeneous material like sedimentary organic matter. The organic petrographic techniques crucial for industries are maceral and microlithotype analysis, vitrinite reflectance and liptinite fluorescence intensity/alteration measurements, porosity (particularly matrix and phyteral) assessment and coke and char texture analysis. These organic petrographic techniques have applications in fundamental and applied research, such as, maceral / microlithotype analysis used in coal and petroleum source rock characterization, blending of coal for coke making, interpretation of palaeodepositional environments, coal bed methane exploration and characterization of coals for combustion, hydrogenation, gasification and underground coal gasification. Vitrinite reflectance measurement is applied in coal rank determination, oil and gas exploration (maturation assessment), basin modeling and coalbed methane exploration. Fluorescence microscopy is another method for characterizing the compositional evolution of sedimentary organic matter, particularly in relation to oil and gas generation. Thus, organic petrography has become a major tool and often an integral part of the tests during the exploration, mining, beneficiation, marketing and utilization phases in the coal industry and is an indispensable tool in exploration for oil and gas.

ORIGIN OF ANGIOSPERMS: IMPLICATIONS OF PALAEOENVIRONMENTAL CONDITIONS AT ITS CRADLE IN INDIA

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Early Cretaceous provided conducive environmental conditions for the primary radiations of the flowering plants called the angiosperms, which during the middle Cretaceous underwent a major diversification. Since then they diversified and evolved rapidly and by the onset of the Tertiary, they were a major group of the land plants. Today the land vegetation cover is dominated by the angiosperms, having more than 250, 000 species whereas, the earlier most-dominant plant group, the gymnosperms has only about 750 species. Success of the flowering plants is due to their form and functional adaptation in varied ecological conditions. The beautiful scenario of our land is primarily due to the wide varieties of flowers and leaves of this group. The origin of the angiosperms remains a subject matter of investigation and is often considered a puzzle in botany, what Charles Darwin called an "*abominable mystery*". The answers to the fundamental questions regarding the center and timing of origin, their progenitors, evolutionary trends and phylogenic relations within the group are mainly sought to deduce their origin and evolution. Various theories for the origin of this group are proposed which can be referred in the classical works of Axelrod (1952), Cronquist (1968), Takhtajan (1969), Stebbins (1974), Hughes (1976), Dilcher (1986), Doyle and Donoghue (1987) and Stuessy (2004), but none of the theories are equivocally accepted.

The question, when and where did the angiosperm evolved, can be best solved by the palaeobotanical studies. For such studies, India provides an important site, because this part of Gondwanaland includes the most accepted regions of the angiosperms evolution and diversification. Takhtajan (1969) suggested that the "*cradle of the angiosperms*" occurs somewhere between Assam and Fiji in the south-east Asia including Burma, Thailand, Indo-China, and Malaysia. The above centre of origin was proposed on the basis of high abundance of extant "primitive angiosperms" (e.g. Magnoliaceae and Winteraceae) and not based on the fossil evidences. Takhtajan (1969) himself acknowledged the above flaw (lack of the fossil evidences) in the theory of south-east Asian origin of the angiosperms. Khasi and Jaintia Hills (earlier a part of the state of the Assam and now in the state of the Meghalaya) comprising the part of the region of the proposed sites of the origin has considerable significance for the fossil studies. At present these Hills harbour a rich flora with many primitive families of angiosperms and is the richest tropical flora of Asia, if not the world. Since Palaeozoic, these Hills remained above the sea level to harbour the flora. However, the conditions of fossilization were possibly not suitable there, but on its southern part (a coastline during Mesozoic when India was an island drifting northwards) coastal sediments got deposited and they can provide the signatures of angiosperms.

The sedimentary rocks exposed in the southern part of the Khasi and Jaintia Hills area are the Sylhet Traps (Albian), Jadukata and Mahadek formations (both of Upper Cretaceous) and a complete sequence of Tertiary deposits. The Sylhet Trap is exposed at some places but is mostly subsurface and has not been attended for plant fossils, although its equivalent Rajmahal Traps in the Indian peninsula is rich in plant fossils, but rare in angiosperms. The extent of volcanic sediments during the Albian time indicates a major disturbance to the ecosystem and consequently biosphere was subjected to the stress and it is known that under such conditions evolutionary shift do occur, which may have favoured the angiosperms. Therefore, a serious search for fossil angiosperms in the Traps (particularly the chert beds) is of utmost importance. The next successive sediments are the Upper Cretaceous sediments of Jadukata and Mahadek formations which have been extensively studied but yet no megafossils are recovered but do contain a rich representation of pollen of the angiosperms belonging to both monocots and dicots (Kar and Singh 1987). From the pollen assemblage of Upper Cretaceous of this area as well as from other parts of India, a high diversification of the flowering plants is inferred.

"Iridium layer" at the top of the Mahadek Formation indicates the well-known extraterrestrial impact attributed for the Cretaceous-Tertiary (K/T) "mass extinction" (Alvarez, *et al.* 1980). But when this global impact was felt, India was simultaneously subjected to one of the largest volcanic episodes of the world, the remnants of which is exposed in the most part of the Peninsula, known as the Deccan Traps. Whether the mass extinction at K/T was due to the volcanism or the extraterrestrial impact is a subject matter of discussion. Whatever may be the cause of extinction, the Indian Plate was more severely affected by the volcanism than by the meteoritic impact. During quiescent period of the Deccan volcanism, thin sediments between two successive lava flows known as Deccan intertrappean contain angiosperm fossils indicating that they were capable of adapting to such stressful ecological conditions. The flora developed after the K/T events was dominantly of the angiosperms and seems to be the manifestation of the new ecological conditions created after the catastrophe. The fossil flora recorded from the top of the Deccan volcanic sediments (mostly described as "intertrappeans") is the richest contemporary flora of the world. Angiosperm fossils, both megafossils and pollen, dominantly represent rest of the Tertiary floras of India.

The climatic shift in the past is mainly due to the changes in the concentration of carbon dioxide, when CO_2 increases global warming occurs bringing the "Greenhouse effect" and when it decreases a global cooling occurs causing an "Icehouse effect". Early Cretaceous atmospheric warming in India was principally due to the volcanism (Rajmahal and Sylhat traps), which favoured establishment and diversification of angiosperms. During the Late Cretaceous due to the Deccan volcanism and the meteoritic bombardment, warmer conditions reappeared, eliminating some plants including a few angiosperm groups and introducing new and more diverse angiosperms. This period also witnessed diversification and evolution of insects and mammals and established co-association with the angiosperms for the process of pollination. Many of the angiosperms modified their floral structures to facilitate pollination by specific insect and thus a co- evolution of insects and the angiosperms was facilitated. During the Eocene, the Indian Plate touched the Asian Plate closing the Tethys Sea thereby allowing exchange of plants. The rise of Himalayas in the later period and periodicity of rain greatly influenced the climate and an endemic flora was established. During Pleistocene when "Icehouse effect" appeared prominence of monocots was established in India.

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PROBLEMS IN TEACHING AND RESEARCH IN PALAEOBIOLOGY

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Palaeobiology is a rare branch of geology/ biology which deals with the study of ancient life on the earth. Expertise in the field is rare and only available at major research institutes or a few national universities in India. The study of palaeobiology needs sophisticated microscope, along with well equipped laboratories and machinery for preparation of thin sections. Main problem encountered in Precambrian palaeobiology is the complete absence of body fossils. Recovery of fossils is scarce in metamorphosed sedimentary terrain. Specific information about early organismal history is relatively scant and based on inference from determinations of later developments. Various major groups of organisms are considered in relation to their supposed origin but sharp line of definition and distinction are notably lacking. It is too difficult to identify many of these in terms of available fossils. In Precambrian nearly all the forms are recovered from cherty and siliceous sediments and hence, options are restricted and discovery of organic remains depends on search of cherty rocks.

POSSIBLE SOLAR FORCING OF LATE HOLOCENE INDIAN MONSOON RAINFALL

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Nearly one-quarter of the world's population is affected by the seasonal rainfall brought by the Southwest Indian Summer Monsoon. Meteorological records and historical accounts document repeated episodes of drought on inter-annual to decadal time scales. Recent climate model simulations indicate that multi-decadal monsoon failures may be possible. Our work investigates this longer-term variability of the Indian Monsoon using the oxygen isotope composition of stalagmites collected from caves throughout India. We have generated a high-resolution (~1-10 yr), absolute dated, oxygen isotope record covering the last 1400 yr from a stalagmite collected from Dandak Cave located in central-eastern India. The record reveals multi-decadal to century-scale intervals of anomalously heavy oxygen isotope values that we interpret as periods of reduced monsoon rainfall. During the Medieval Warm Period the monsoon was generally stronger (fewer shorter intervals of reduced rainfall) while during the Little Ice Age it was generally weaker (more frequent and longer intervals of reduced rainfall). We also note a striking resemblance between our monsoon rainfall record and the residual $\delta^{14}C$ record. If the variations in the $\delta^{14}C$ record are related to changes in solar luminosity, our record suggests a possible causal link between reduced (enhanced) monsoon precipitation and lower (higher) solar luminosity. Our results from a core monsoon region of India appear to corroborate studies from other regions suggesting solar forcing of Indian/Asian Monsoon variability on decadal to centennial time scales.

APPLICATION OF PLANKTIC FORAMINIFERA IN INFERRING PAST OCEAN CIRCULATION AND CLIMATE

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Planktic foraminifera are passive surface ocean dwellers and their spatial distribution in the world ocean to a large extent is controlled by surface circulation pattern and water temperature. The modern distribution of planktic foraminifera in the surface water column to a large extent is similar to their distribution as thanatocoenose in the ocean sediments. This very fact makes planktic foraminifera important as an indicator for the past ocean surface circulation. In addition, the planktic foraminifera respond to the climatic fluctuations experienced by the surface layer of the ocean and thus their shell attributes have been widely utilized for inferring palaeoclimates. Further, the temperature, salinity, nutrients and food supply in the surface layers of the oceans affect the planktic foraminifera making them more useful for inferring palaeotemperature, palaeosalinity, palaeoproductivity of the oceans. In this abstract, we restrict ourselves more to the utility of planktic foraminifera in inferring past ocean circulation changes which is very much linked to the palaeoclimatic oscillations.

The ocean circulation greatly affects the heat transport from one part of the ocean to another part and to a great extent controls the climate of the world. The role played by Gulf Stream in transferring vast amount of heat from tropics to the polar areas in north Atlantic is well known. This transport is a part of the great oceanic conveyor belt mainly driven by sinking of immense quantity of high salinity waters in the North Atlantic. This North Atlantic Deep Water (NADW) mixed with Mediterranean outflow travels throughout Atlantic towards Indian Ocean and then to Pacific through Antarctic Circum Polar Circulation. The NADW upwells within the world ocean returning water to the upper layer within Antarctic region and into the Themocline (Gordon 1986). Antarctic thermocline upwelling results in the formation of Antarctic Intermediate Waters (AAIW), which after spreading below thermocline upwells into the thermocline. There are two routes by which the upper layer water returns back to the Atlantic Ocean: the cold water route within the Drake Passage in which AAIW and Subantarctic Mode Water (SAMW) pass into South Atlantic (Georgi 1979, Piola & Giorgi 1982 & McCartney 1977); and warm water route in which the Indian Ocean thermocline water is introduced to the south Atlantic south of Africa (Gordon 1985). Gordon (1986) gave convincing arguments about the importance of the warm water route. An important segment of the warm water route is through Indonesian Seaway where the Pacific thermocline water enters into Indian Ocean (Srinivasan & Sinha 1998, 2000). A small part of the Indonesian throughflow turns south along the western margin of Australia in the form of Leeuwin Current (Sinha & Singh 2003). Here in this paper we try to show in what way planktic foraminifera have helped in (1) variable strength of Leeuwin current in the southeast Indian Ocean and (2) inferring past intensity of Indonesian throughflow and impact of these circulation changes on the regional climate during Plio-Pleistocene. The importance of the return flow has already been discussed above and it can be appreciated that the variable strength of Indonesian throughflow and Leeuwin Current are related not only to the North Atlantic palaeoceanography but to a great extent on the El Nino and Southern Oscillation (ENSO).

In the Western Pacific there is a piling up of warm waters known as the Western Pacific Warm

Pool (WPWP). Past changes in the WPWP have been linked to the El Nino conditions in the Eastern Pacific. In general, during El Nino like conditions there is a decrease in the WPWP resulting into weakening of the Leeuwin Current and reduced Indonesian throughflow. This is well reflected in the changing assemblage of planktic foraminifera off Western Australia at ODP site 763A (Exmouth Plateau). The change is very much pronounced. During weak Leeuwin Current, there is a dominance of the northward flowing Cold West Australian Current resulting into increase in the abundance of typical temperate water planktic foraminifera, *Globorotalia inflat* at site 763A. During Pleistocene, we could identify three such distinct episodes. These are also the intervals of intense upwelling at the western margin of Australia which at present is the only eastern boundary region undergoing no upwelling due to modern dominance of Leeuwin Current. Thus, with the help of planktic foraminifera we show that atleast during Pleistocene three times Leeuwin Current was almost shut down or became very weak and during these times the northward winds dominated causing offshore Ekman transport and resultant upwelling. Also these were the intervals of intensified West Australian Current.

Studies by Srinivasan and Sinha (1998, 2000) showed that during 5.6 to 4.2 Ma, there was a difference in planktic foraminiferal biogeography between tropical Pacific and Indian Ocean. This was inferred by the absence of *Pulleniatina spectabilis* from the Indian Ocean while this species is frequent in the tropical Pacific. Stable isotopic studies of *Pulleniatina spectabilis* showed it to be a deep dwelling planktic foraminiferal species (within thermocline) and thus Srinivasan and Sinha (2000) inferred that during 5.6 to 4.2 Ma, the Indonesian Seaway acted as an effective biogeographic barrier to the deep dwelling planktics while the shallow surface connections continued.

Since our understanding of Cenozoic palaeocirculation and palaeoclimate depends upon the relative abundance and stable isotope chemistry of planktic foraminifera species sampled from deep sea cores, we are continuing our research efforts on studying the biogeographic pattern of planktic foraminifera from different part of the world and in different time slices during last 5 million years. In addition, data from the JGOFS (Joint Global Ocean Flux Studies) with regard to physical, biochemical factors that control the vertical distribution, vertical and lateral migration and flux of planktic foraminifera from surface to sea floor is also taken into consideration.

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LANDSCAPE EVOLUTION AND CLIMATIC INTERPRETATIONS IN THE GANGA VALLEY: EXPLORING FACIES AND MAGNETIC SIGNATURES

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The Ganga basin in the Himalayan foreland is a part of the world's largest area of modern alluvial sedimentation and supports a population of over 200 million people. The Ganga plain deposits not only provide a modern analogue for the ancient fluvial sequences of the Himalayan foreland basin but they also provide one of the most significant continental records for understanding the interplay of climate, tectonics and eustatic changes in generating thick sedimentary fills in a monsoon-dominated foreland system. Given the large dimensions of the Ganga basin and the lack of an integrated approach, the available data are fragmentary, and several important questions regarding the sedimentary architecture and the process-form relationships of the parent rivers remain unanswered. This presentation reviews the available information on the near-surface Late Quaternary stratigraphy of the Ganga plains, and reports new results based on studies of river cliff sections and shallow boreholes down to ~50 m depth.

The major rivers of the southern Ganga Plains are characterized by narrow incised valleys, bordered by cliffs, with active floodplains a few kilometers wide. The intervening interfluves, up to 100 km wide, are more elevated floodplains out of range of big-river flooding and traversed by smaller plains-fed channels. There is a strong contrast in elevation and style between valley and interfluve floodplains. We have investigated the history of channels and floodplains over the past 100 ka in the Kanpur region of Uttar Pradesh using two drill cores in the Ganga Valley (Jagdishpur and Firozpur), cliff sections for 70 km along the valley margin between Bithur and Kannauj, and a drill core in the interfluve (lIT Kanpur). The stratigraphic framework is supported by OSL and radiocarbon dates, as well as magnetic susceptibility profiles and clay-mineral analysis.

The valley cores contain channel belts attributed to the palaeo-Ganga, which yield dates of 26 ka and 6 ka. The Ganga was close to its present position at 26 ka and probably accumulated channel and floodplain sediment until precipitation and discharge were greatly reduced during the Last Glacial Maximum (LGM). Stratigraphic sections in the valley margins (proximal interfluves) such as Bithur document a motif of repeated alluviationlincision reflecting floodplain attachment/detachment in response to monsoonal fluctuations and this has importance for broader models of alluvial basin filling. At Bithur, floodplain deposits dated at 27 ka are overlain by eolian and lake deposits, suggesting that wide areas of the valley were converted to swamps and dunes during the LGM as the floodplains "detached" from the parent river. The river probably began to incise as the monsoon intensified and discharge increased after 15 ka, and the channel appears to have shifted to its present position prior to 6 ka, when additional incision created the high cliffs at Bithur and Kannauj. Valley fill cores such as from Jagdishpur and Firozpur also show manifestation of monsoonal dynamics in terms of hydrological adjustment of channels. The floodplain deposits in the valley fill cores show only modest evidence for pedogenesis, in accord with their position proximal to a large, sediment-charged river.

Despite its location only 10 km from the Ganga Valley, the 50 m interfluve core consists entirely of floodplain fines that date back to about 86 ka. The interfluve appears to have been a site of floodplain accumulation from small plains-fed channels over this period, during which Himalayan and plains-fed channels appear to have occupied separate floodplain tracts, with large parts of the plains detached from the direct effects of the big rivers. The interfluve floodplains were sites of more intense pedogenesis, and accumulated through cycles of aggradation and soil formation, possibly in response to monsoonal fluctuations on a timescale of 10^3 to 10^4 years.

Facies distribution and transitions at all sites are well-picked up by magnetic signatures. Magnetic mineralogy of the alluvial sediments in this region is dominated by ferrimagnetic minerals, like magnetite, mainly in SD-PSD domain size with few SP particles. Antiferromagnetic minerals, like hematite/goethite are also recorded but in lesser abundance. It is inferred that the magnetic minerals in the sediments may have been derived from the breakdown of heavy minerals such as hornblende and garnet which are present in the unaltered horizons of the section and profiles. Magnetic enhancement in channel facies (SD-MD domain) indicates detrital flux whereas that in floodplain facies :SP domain) indicate pedogenic events.

PALAEOCLIMATIC RECONSTRUCTION FROM THAR DESERT PLAYAS: RESULTS TO DATE AND FURTUE DIRECTIONS

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Some of the first works on the playas were initiated at the Birbal Sahni Institute of Palaeobotany, Lucknow by Late Dr. Gurdeep Singh and his coworkers in early seventies of the 20th century. It is therefore quite appropriate to talk on the current status of research in this area and highlight the future directions. A number of playas occur in the Thar Desert in western Rajasthan, India; most of them are filled with sediment and are usually dry at present. Palaeoclimatic records from playas in the Thar Desert are rather scarce but the available studies have recorded definite climatic oscillations based on pollen records and limited sedimentological investigations. Earlier work at BSIP and some later research on Sambhar, Didwana and Lunkaransar playas showed that these playas had fluctuating hydrological conditions between ca. 12-6 ka and a high stand between ca. 6-4 ka. A sustained high lake stand between ca. 7.2-5.6 ka was recorded at Lunkaransar followed by drying which coincides with a period of intense dune destabilization. Studies on the Bap-Malar and Kanod playas in the arid core of the Thar Desert indicate that these playas remained saline throughout their existence from > ca. 18 ka to mid Holocene and finally dried up at least 1000 years earlier than the playas in the eastern Thar Desert.

This paper reviews the current status of research on the Thar Desert playas and presents our latest work on the Sambhar, the largest playa of the Thar Desert. Our recent investigations are based on a ~23 metres deep core from the centre of the playa and we have used an integrated mineralogical and geochemical approach to derive information regarding palaeohydrological and palaeoclimatic fluctuations in the Thar Desert for the last ~30000 years. Seven evaporite facies, identified from the mineralogical data, reflect variable brine chemistry throughout the history of the playa. The complete absence of gypsum-rich facies in the upper 5 metres and dominance of carbonate- and gypsum-rich facies in the lower parts of the core reflect fluctuations in salinity level induced by climate change. Stable isotope data on carbonates ($d^{18}O$ values) correlate with the [MgO/(MgO+CaO)] ratio, geochemical ratios (Na/Al, Na/Ti, Na/K) and the evaporite mineralogy. These data, coupled with AMS chronology of the organic fraction of the core sediments, have been integrated to interpret evaporation/inflow ratios which reflect humid and arid climatic conditions. Our data reconstruct the palaeoclimatic fluctuations in the Thar Desert margin for the last 30 ka and show significant spatial variation from the available lacustrine records from the Thar Desert. The Sambhar playa does not show any evidence of complete desiccation throughout its history although we record arid phases during the LGM and between ca. 7500 and 6800 years.

Despite a very comprehensive data set on evaporite and geochemistry, the climatic reconstructions and vegetation history from this region remain inadequate due to the lack of systematic palynological investigations. Given the fact that the available core from Sambhar records the longest climatic reconstructions from any of the playas in the region, it may be extremely rewarding to initiate detailed palynological investigation of this core and tie up the data with other mineralogical and geochemical proxies.

UPPER PALAEOZOIC FLORA OF INDIA: RANGE, SUCCESSION AND DEVELOPMENT

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Silurian-Devonian plant fossil assemblages from extra-peninsular region are rare and ill-preserved but well known lycopsid flora is recorded from Lower Carboniferous. Upper Carboniferous flora is not known due to lack of fossiliferous horizons.

The Upper Palaeozoic sequences belonging to different formations of Permian Period, e.g. Talchir, Karharbari, Barakar, Barren Measures and Raniganj are well exposed in different Gondwana basins of Peninsular India i.e. Damodar-Koel, Rajmahal, Son-Mahanadi, Satpura and Wardha-Godavari. Gondwana equivalent sediments are also recorded from Darjeeling, Sikkim and Arunachal Pradesh in northeast Himalayan region.

The distribution of plant fossils suggests three fold division, Lower, Middle and Upper Gondwana floristic zones, characterized by Glossopteris flora of Permian Period, Dicroidium flora of Triassic and Ptilophyllum flora of Jurassic-Cretaceous. Similar floras are also recorded from other Gondwana countries, e.g. South America, Africa, Australia and Antarctica.

It is difficult to find out the origin of Glossopteris flora in Indian Gondwana sequence because the elements of the flora start appearing abruptly in earliest sequence of Permian, i.e. in Talchir Formation, immediately after the end of glacialal phase. It has been discussed that the NBG flora (*Nothorhacopteris-Botrychiopsis-Ginkgophyllum*) discovered in the Late Carboniferous of Argentina represents the ancestral stock of Glossopteris flora. As the name of flora indicates, the glossopterid plant remains are the dominant constituent and represent about 80-85% of this flora. Other plant remains are represented by bryophytes, lycophytes, arthrophytes, pteriodophytes, conifers, cycads and ginkgopsids alongwith some elements of uncertain affinity.

The floral succession in different formations of Permian Gondwana shows the presence of *Gangamopteris, Noeggerathiopsis, Glossopteris* and limited records of conifers in Talchir Formation. In Karharbari, the flora indicates diversification trend with variety of new forms like *Euryphyllum, Rubidgea, Botrychiopsis, Buriadia, Phyllotheca, Psygmophyllum,* etc. Quantitatively and qualitatively, the species of *Gangamopteris* and *Noeggerathiopsi*s dominate the scene. The association continues to flourish during Lower Barakar phase but in Upper Barakar assemblage increasing tendency of *Glossopteris* leaves and vanishing of earlier forms are visible. In some of the basins variety of ginkopsid leaves are discovered. The specimens showing upright *Glossopteris* bearing stem axis in attachment with *Vertebraria* root and *Diphyllopteris* and *Deogharia,* likely seedlings of glossopterid, are discovered from this formation. Interestingly typical element of Euramerian flora, i.e. *Annularia* foliage shoots and fertile shoots of *Sharmastachys, Rajmahaliastachys* and *Tulsidabaria* having affinity with northern flora are described from Barakar Formation. Barren Measures Formation is devoid of workable coal seam and the plant fossils recorded from this formation characteristically show the presence of lycopsid genus *Cyclodendron* alongwith the leaves of *Glossopteris.* The flora is not much diversified. During Late Permian, in Raniganj Formation, the Glossopteris flora developed to its maximum strength and many new types of sterile, fertile foliage shoots of ferns *Asansolia, Dizeugotheca, Dichotomopteris, Damudopteris, Damudosorus*, *Trithecopteris, Cuticulatopteris, Leleopteris;* new species of *Glossopteris* instituted on the basis of external as well as on cuticular features, new types of glossopterid leaves *Belemnopteris, Pteronilssonia, Rhabdotaenia*, *Sagittophyllum, Laceyphyllum;* number of male and female fructifications *Plumsteadiostrobus, Jambadostrobus, Venustostrobus*, *Kendostrobus;* equisetalean genus *Raniganjia; Searsolia*-type conifer and number of structurally preserved seeds, sporangia and fossil woods are recorded. The Raniganj equivalent Kamthi flora also demonstrates the similar composition but presence of *Partha, Lidgettonia, Denkania* types of glossopterid fructifications, seed bearing *Khania, Utkalia* and *Surangephyllum, Handapaphyllum* leaf forms in Mahanadi basin makes the flora distinct. The Glossopteris flora shows extinction towards the end of Permian and a new flora having pteridospermous plant *Dicroidium* replaces the scene, however, narrow forms of *Glossopteris* tatter in Lower Triassic plant fossil assemblage.

Barring glossopterid and ferns the fossils of other groups of plant in Glossopteris flora are commonly known by their sterile part and they are assigned to different plant groups mainly on the basis of their similarity in external morphological features. The morphological and evolutionary features of different types of glossopterid leaves and fructifications suggest that the plant group developed in successive horizons through reticulate and non-reticulate leaf forms and multiovulate and branched types of fructifications. On the basis of direct and indirect evidences different types of reconstruction model for the plant of *Glossopteris* are proposed.

Theme–Emerging Trends in Palaeobiology, Session E–History of Human Impact on Plant world

ANCIENT AGRICULTURAL HISTORY: A PALAEOETHNOBOTANICAL CONTEMPLATION IN NORTHWESTERN REGION OF INDIAN SUBCONTINENT

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The review embodies the physical nature of the botanical evidences, which survived preservation for millennia of years in archaeological sites. It also includes reconstruction of regional models of subsistence, strategies and ecology of ancient settlements. Emphasis is laid on the fundamental aspects of man and plant relationship during the onset of arid conditions in the beginning of Holocene. This interaction ultimately led to the mode of origin of agriculture by the development of annual ancestors of our crop plants under the state of physical stress during the changing environmental conditions as a result of rise in temperature and melting of glaciers.

Theoretical models have been discussed on the possible ways in which the biotic factors and the role of man in food-gathering stage must have inadvertently resulted. This was probably due to selection and domestication of palatable plants, the oldest of initial cultivation, during the Neo-thermal Age (ca.15000-10000 B.P.) when majority of modern annuals are regarded to have evolved (Boureill 1972).

Study of plant remains of human workmanship, survived in pre- and proto-historic settlements, helps to reconstruct the history of man and plant relationship in the Dark Ages. The archaeological contexts for the earliest signs of domestication have been termed 'Mesolithic' in some areas (Gupta 1979). Mesolithic folk were hunters and food-gatherers. Settled farming economy of Neolithic communities and subsequent development in the technology and dispersal of crops (diffusion) during the following Copper and Iron Age cultures in time and space have also been discussed.

The palaeoethnobotanical material survives from the period of the beginning of agriculture in three different forms (Renfrew 1969). The carbonized material in the form of seed/fruit remains and wood charcoals, impressions of straw and chaff in mud-daub used in the construction of walls and roofs of houses and coarse potsherds and as small fragments of silica skeletons (phytoliths) of the epidermis and glumes. They can be identified through microscopic investigations particularly in grasses, in ash and cotton detritus. The bulk of the material considered here was preserved by carbonization as a result of overheating near a hearth, or in a parching oven or by a house fire in the area in which they were stored. They did not become carbonized by spontaneous combustion. Impressions too form the chief source of evidence for the pre-Neolithic husbandry.

Wheat and barley, before the important excavations in Baluchistan, were regarded as introduced from west Asia. The evidence of the centre of origin in Baluchistan has become more impressive in view of the plant evidence integrated with the archaeological evidence, from earliest times (around 7000 B.C.) to the Harappan times at Mehrgarh, Nausharo and several other sites in the region. The earliest record of emmer-wheat (*Triticum dicoccum*) - a tetraploid wheat in the north-western region of the subcontinent, also comes from the evolutionary sequences of Neolithic-Chalcolithic cultures at Mehrgarh in Baluchistan (ca. 7000-4300 B.C.), in association of wild and cultivated forms of primitive as well as advanced wheat and barley. Unconventional occurrence of emmer-wheat is also recorded from Harappan sites in Punjab and Haryana. Essentially, the cultivation of emmer-wheat is adapted under severely adverse conditions and to the soil having low fertility with high percentage of salts, as seen in Baluchistan and Afghanistan.

Rice is primarily a crop of Ganga Valley region. Ancient Malhar in district Chandauli and Lahuradewa in district Sant Kabir Nagar in the Middle Ganga Plain have pushed back the antiquity of rice cultivation during fifth and sixth millenia B.C. respectively and its early diffusion towards the Sarasvati Valley in the north-western direction, is evident in the economy of Harappan communities of Haryana and Punjab during 2850-2500 B.C.

Pulse crops of lentil, field-pea, chick-pea, grass-pea, linseeds, etc., are western and central Asian domesticates and are included in the early agriculture in north-western Indian subcontinent, in consequence of their occurrence along with other cultural traits.

Cotton (*Gossypium arboreum/herbaceum*) occupied the foremost place among commercial crops of the Harappans. Cotton textile in the Indus Valley was the product of sophisticated textile craft. Apart from actual fibre, numerous woven textile impressions were found at Harappa and Mohenjo-daro and other sites in northwestern part of Indian subcontinent.

Advanced agricultural practices, as seen at Early Harappan sites in Punjab and Haryana, clearly indicate their transition from the self-contented agricultural communities to urban phase of Indus-Sarasvati (or Harappan) civilization. This could not be attributed to sudden innovation in agricultural technology. There are notable developments from the data generated in recent past at the Birbal Sahni Institute of Palaeobotany, Lucknow, like cultivation of garden plants by the Harappans in Punjab, plants of religious significance (including aromatic essential oil yielding plants) used in fire offerings during Kushana Period (100-300 A.D.) in Haryana. Remains of some condiments in Harappan context from Punjab and Haryana and meaningful perspective of medicinal history in the Indian archaeological context in the northwestern parts of India from Harappan to Iron Age cultures, have also been deciphered (Saraswat 1992). There are evidences of plant remains, such as *Datura stramonium* and *Cannabis,* in the Harappan context, which are used to worship Lord Shiva. Stone objects from excavations at Mohenjo-Daro resembling 'Shivlinga' and terracota specimens of 'linga-cum-yoni' at Kalibangan as seen commonly in temples are other supporting evidences (Marshall 1931, Lal 2002).

In northern zone, at Neolithic Kanishpur, Baramulla district, Kashmir considerable advancement in crop husbandry and the forest economy, add further to the Neolithic cultures of Kashmir Valley during 2800-2000 B.C., thereby revealing presence of crop remains originally of Mediterranean regions and fruits of central Asian zone along with local weeds and wild taxa. Earlier investigated sites in Kashmir Valley include Burzahom, Gufkral and Karewas.

In western zone, there are records of ancient agricultural economy from Harappan sites in Gujarat, viz. Surkotada and Shikarpur, millet growing zone in Rann of Kutch and from Rajasthan, particularly at Kalibangan with ploughed fields, one of the most important site on the bank of extinct Sarasvati or Ghaggar.

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TRADITIONAL PALAEOBIOLOGY-CURRENT STATUS AND RECENT DEVELOPMENTS

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Traditional palaeobiology is basic and fundamental discipline. It is the base, on which the entire edifice of palaeobiology is erected. If any harm is done to it, its future is in danger. But the traditional palaeobiology cannot survive in the present form. It has to change and incorporate in its canvas the new disciplines and emerging thoughts. One has to make a fossil more dynamic and live. It is not only a stone with plant or animal imprint but it tells the story of its origin, diversification and evolution. It is the work of palaeobiologists to give it a meaning and name. If we neglect the studies of palaeobiology we will be deprived of the past knowledge of the biological world.

Truely we can say, palaeobiology has lost its prime position and has gone to its lowest ebb. To some extent, we palaeobotanists are responsible for its decline. The number of scientists pursuing this discipline has declined sharply, because majority of scientists are attracted towards more fashionable disciplines like biotechnology, bioinformatics etc., with more promises and expectations. If this decline is not checked it will be suicidal for the growth of the palaeobiolgy.

The past record of palaeobotany (palaeobiology) is very good. A number of new fossils have been discovered. That resulted in the knowledge of the vegetation of the Glossopteris Flora (Gondwana floristics); vegetational patterns of Satpura-Wardha-Godavari, Gujarat and Rajasthan; floral diversification and evolution of Rajmahal Basin; flora of Damodar and Son-Mahanadi basins; and others. A number of new concepts have been given. Birbal Sahni Institute of Palaeobotany, Lucknow and other academic institutions became the international centres of the palaeobotanical research. It is reflected by a number of papers published in the international journals. But the current status is not that bright, as it was in the past. Except Birbal Sahni Institute of Palaeobotany, Lucknow, palaeobotanical research is continuing only in a few academic institutions like universities of Allahabad, Calcutta, and Burdwan and Agharkar Research Institute, Pune and others.

Palaeobotany like other discipline is also changing. There is a shift from the morphological and floristic studies to the determination of the palaeoenvironment, palaeogeography and biostratigraphy.

The future of palaeobotany may not be as bleak as it appears. It is no more a discipline of biologists only but is pursued more vigorously by geologists, earth scientists, chemists, physicists and others. It has become multidisciplinary in approach. As a result, the centres of palaeobiology have shifted from the biology departments to others like, earth science, environmental science, ecology, etc.

The world scenario of the palaeobiology is promising. Palaeobotanists worked out the basic problems of evolution, e.g. the origin of land plants, the origin of first vascular plants (*Cooksonia*), gametophytes of Rhynie Chert, discovery of the first angiosperm, ancient DNA, palaeomolecular phylogeny, swimming sperms in extinct Gondwana plants and others. These are the areas of the traditional palaeobiology. They have thrown fresh light on different unknown aspects of the evolution.

India is full of potentiality. The structural details have been worked out with the latest techniques and electron microscopy. There are many areas which are still virgin and need to be worked out. It requires the repeated collections of the fossil plants from different fossil localities of the country. There is a change in the scientists' views and the study is not only confined to the investigation of structural details but other aspects like environment, stratigraphy and comparison with living counterparts to have a holistic view of the fossils of that age.

How the coming generation would know about the great events that had occurred in different geological ages, without the knowledge of traditional biology? The importance of the traditional biology will never be minimized. It is important and it will ever remain important.

SOME ASPECTS OF PALAEOZOIC PTERIDOPHYTES OF INDIA

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A retrospection of Indian Palaeozoic pteridophytes reveals that despite their poor representation in the Silurian and Devonian strata, there is a rich diversity of such plants in Lower Carboniferous and Lower Gondwana strata.

From the Silurian strata of Po Series of Spiti in Himachal Pradesh, impressions of only two elements, viz. *Psilophyton* and *Hostimella*-like axes assignable to Psilophytales were reported by Sahni (1953). Similarly two elements are also reported from Devonian strata of Kotsu Hill and Diuth Spur of Aishmuqam Formation in Kashmir Himalaya, viz. *Taeniocrada* and *Protolepidodendron* by Singh *et al.* (1982).

Rich assemblages of Lower Carboniferous pteridophylls and lycopods have been reported from Thabo Plant Bed, Spiti (Himachal Pradesh), Gund Formation in Pir Panjal Range and Wallarama spur of Liddar Valley in Kashmir Himalayas. Gothan and Sahni (1937) reported pteridophylls like *Sphenopteridium*? *furcillatum*, *Sphenopteris* sp. and *Rhacopteris ovata* from Thabo Plant Bed. Later, HØeg *et al.* (1955) described ?*Rhodea* sp., *Rhacopteris ovata*, *R. inqeuilatera*, *Rhacopteris* spp. a and b., *Asterophyllites* sp., ?*Adiantites* spp. a and b. Pal (1978) and Pal and Chaloner (1979) described from a fresh water lithostratigraphic unit lying between Fenestella Shale and Syringothyris Limestone of Gund Formation near Jawahar Tunnel in Pir Panjal Range. These forms include *Archaeosigillaria* sp., *Lepidosigillaria quadrata*, *Lepidodendropsis fenestrata*, *Cyclostigma indica*, *Arachaeocalamites radiatus*, *Rhacopteris* cf. *circularis* and *Rhodea tenuis*. Singh *et al.* (1982) reported *Archaeosigillaria minuta*, *Lepidodendropsis peruviana*, *Cyclostigma* cf. *pacifica* and *Rhacopteris ovata* from the same locality.

From the Visean strata of Kotsu Hill, Kumar *et al.* (1980, 1987) reported the occurrence of *Sublepidodendron* while Singh *et al.* (1982) described *Palmatopteris* cf. *furcata*. Singh *et al.* (1982) described from C stage exposed at Wallarama spur and some exposures of A stage of Middle Visean to Bashkirian age *Archaeosigillaria minuta*, *Lepidosigillaria* cf. *quadrata*, *Lepidodendropsis* cf. *peruviana*, *L. fenestrata*, *Cyclostigma* cf. *pacifica*, *Rhacopteris ovata*, *Triphyllopteris lescuriana* and *Rhodea* cf. *subpetiolata*. Later, Pant and Srivastava (1995) reinvestigated Wallarama bed and reported two new genera *Pseudobumbudendron* and *Spondylodendron. Pseudobumbudendron is* represented by two species *P. chaloneri* and *P. meyenii* while monotypic *Spondylodendron* is represented by *S. wallaramensis*. They also reported a new species of *Lepidodendropsis*, viz. *L. liddarensis*. *Archaeosigillaria quadrata and Nothorhacopteris argentinica* were the new reports from this locality. Some forms of decorticated axis called *Knooria* and *Aspidiaria* were also reported from this bed.

In various stages of Lower Gondwana strata of peninsular India, extremely rich assemblage of pteridophytes has been reported as a result of the contribution of early workers like, Royle and Feistmantel, investigations of scientists from Birbal Sahni Institute of Palaeobotany, Lucknow and Pant School of Palaeobotany at Botany Department, University of Allahabad and also by exploration of workers in Palaeobotany at Botany Department of Calcutta University. These include various species of sphenopsids, like *Lelstotheca* (4 spp.), *Paracalamites* sp., *Phyllotheca* (7 spp.), *Raniganjia* (2 spp.) *Schizoneura* (3 spp.), *Sphenophyllum* (7 spp.), *Giridia indica, Sharmastachys pendulata, Rajmahaliastachys elongata* and *Tulsidabaria indica;* lycopods, like *Cyclodendron* (2 spp); and fertile and sterile pteridophylls, viz. *Alethopteris* (2 spp.) *Botrychiopsis* (2 spp), *Damudopteris* (2 spp) *Damudosorus* (2 spp), *Dichotomopteris* (6 spp.), *Leleopteris* (2 spp.), *Merianopteris major*, *Neomariopteris* (6 spp.), *Pantopteris gracilis*, *Pecopteris* (4 spp.), *Sphenopteris* (4 spp.), *Trithecopteris gondwanensis, Asansolia phegopteroides, Santhalia bansloensis, Liknopetalon rajmahalensis* etc.. Lower Gondwana strata of extra-peninsular India have yielded *Sphenophyllum* (2 spp.), *Lobatannularia* (3 spp.), *Pecopteris* (4 spp.), *Dizeugotheca*? *falcata,* etc.

The Indian palaeobotanists have very seriously concentrated on various aspects of Palaeozoic pteridophytes from India. These include: (a) study of diversity of pteridophytic assemblages and creation of a number of new genera and species; (b) understanding of their structural details from the available impression and compression fossils using LM and SEM; (c) study of taxonomic riddles like acceptance of generic name *Asansolia* vs. *Dizeugotheca*, validation of name *Damudopteris*, use of name *Sphenophyllum* instead of *Trizygia, Paratrizygia* and *Parasphenophyllum;* (d) implication of our knowledge in solving phylogenetic riddles, e.g. phyletic slide of annulus in fern sporangia on basis of structure of sporangia in *Damudopteris polymorpha* and evolution of sporangiophore of *Equisetum* using structure of *Tulsidabaria;* (e) discovery of fertile parts of various pteridophytes like sphenopsids and ferns; (f) understanding of the architecture of pteridophytic plants like *Neomariopteris hughesii;* and (g) analysis of floristic composition from various stages of peninsular Lower Gondwana and admixture of floras on basis of exotic looking elements in the extra-peninsular Lower Gondwana flora, e.g. flora of Mamal bed in Kashmir Himalayas.

I feel our weakness involves natural injustice as well as anthropogenic slackness. In India we do not get petrified Palaeozoic remains to work out structural details like *Acitheca, Scaphidopteris, Sturiella* and *Lagenopteris* and *Grandeuryella renaulti* studied by Lesnikowaska and Galtier (1991, 1992) from France. We are not able to work out the foliar and cauline anatomy of pteridophytes as worked out by Wang and Li (2001) in case of *Rastropteris pingquanensis*. We are unable to understand evolutionary trends in stellar morphology, xylem maturation pattern, trace formation, petiole anatomy and ontogeny of Indian and Gondwana pteridophytes as described by Galtier and Phillips (1996). An impartial self analysis reveals that our approach to the study of fossil pteridophytes is rather descriptive and has certain drawbacks specified here, viz. (a) lack of qualitative and quantitative palaeoecological studies of Indian Palaeozoic pteridophytes like the work of DiMichele and Phillips (2002) and Röâler (2000); (b) lack of computer simulation for reconstruction of architecture of plants on the basis of small fragments like Daviero and Locoustre (2000); and (c) Lack of computer application for cladistic approach like Bateman (1994) and Retallack (1997) in case of heterosporous lycopods. Röâler (2000) visualized the Late Palaeozoic tree fern *Psaronius* as an ecosystem in itself as *Psaronius* tree ferns showed several interactions like *Psaronius –Psaronius, Psaronius-Ankyropteris, Psaronius- Tubicaulis, Psaronius-Anachoropteris, Psaronius-?Grammtopteris, Psaronius-Dadoxylon, Psaronius–Callistophyton, Psaronius* and evidence of animal life. Due to limitation of available preservational types as impressions and compressions only in India, there are meagre chances of such work

If we intend to increase our knowledge about Indian pteridophytes, we should repeatedly make efforts for fossil hunting so that better-preserved plant fossils are collected. We should work hard in having quantitative analysis of our data and develop computer simulations for making the reconstruction of the past pteridophytes. We should try to develop computer based phylogenetic models.

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STATUS OF MICROBIAL LIFE IN PRECAMBRIAN SEDIMENTS OF INDIA: AN OVERVIEW

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Life on earth has a long and rich history and extensive data on early life is available. But the picture is still in a flux, as new theories along with new discoveries are emerging day by day and each new finding pushes the life's evolution further back in time. The oldest record of microscopic life was considered from Apex Chert, Pilbara Supergroup, Western Australia (3.5 Ga), but recently it is considered to be controversial. The earliest organisms were prokaryotic mainly cyanobacteria; possible eukaryotes appeared at 2000- 1750 Ma and diversified at about 1100 Ma, followed by inexplicable decline in abundance and diversity between 900-675 Ma. Eukaryotes included fungi, chlorophytes and rhodophytes. A coincident rise in acritarch diversity sometimes refered as big-bang of eukaryotic evolution, has also been noticed.

In India despite extensively developed sedimentary sequences in both peninsular and extra-peninsular regions (Archaean to Proterozoic), authentic data on early life is too meagre. Biogenicity and syngenicity of most of the reported microfossils have invited skepticism. Abiogenic structures or artificial artifacts have been described as biogenic. During last two decades, need for caution in distinction between biogenic and abiogenic contaminants has been recognized world-wide. An integrated approach is thus essential for the verification of any artifact purported as a microfossil. The study of early life on earth must be supplemented by geochemical fingerprints, contextual evidences from palaeogeographic environment, geological history, biological evidences, along with morphological data supporting biogenic origin. On the contrary, in India these aspects have been taken casually and inadequate data on early life is available. Microfossil reports from Archaean are very few. The oldest microfossils are from the 3.1 billion years old rocks of Iron Ore Supergroup. Other reports from the Sandur Schist Belt (Archaean), Chhattisgarh Basin and Cuddapah Supergroup (Proterozoic age) are also available, which need critical evaluation.

Vindhyan Supergroup is internationally acknowledged as one of the best repository and potential sedimentary basin of India to explore the evidences of early life. Data available from this Supergroup revealed a highly diversified and complex ecosystem prevailing at the time of its sedimentation. Attempts have also been made to evaluate the available data on microfossils in terms of biogenicity and syngenicity. Inconsistency in age data (based on isotope study and other parameters) has changed the traditional age of its sedimentation further back (now suggested ~1700 Ma). Controversial reports on small shelly fauna and triploblastic animal traces (Lower Vindhyans) have drawn the global attention. The upper age limit is suggested as Pre Vendian on the basis of carbonaceous fossils reported from the upper most litho-unit of the Supergroup. Report on Vindhyan akinites, which are considered as an indicator of atmospheric evolution, is a step ahead in the direction of Vindhyan palaeobiology. Microfossils have been reported from Semri, Rewa and Bhander groups. Efforts should be made either to explore the sequence for evidences of life or to find out the reasons for their absence. In Extra-peninsular India, authentic record of microfossils is available from the Deoban Formation (Meso-Neoproterozoic age), Gangolihat Dolomite, Jhiroli Magnesite (pre-Vendian -Vendian age), Infra Krol Formation (Late Proterozoic- early Vendian), Chert-Phosphorite Member of Tal Formation

(Precambrian- Cambrian boundary), Chambaghat Formation (Terminal Neoproterozoic). In all these reports microfossils have been reported from the petrographic thin sections of chert, with convincing syngenicity as well as biogenicity.

In most of the reports, following significant aspects of Precambrian palaeobiology are untouched:

(i) Taphonomy: Taphonomic window can give a better picture of earliest biosphere and can provide an insight into preservational biases of Precambrian fossil records.

(ii) Biodiversity: It will support the understanding of interactions between climatic changes and biological evolution.

(iii) Ion microprobe study of individual microfossil. It can give the atmospheric CO_2 levels of that time. The nature of early atmosphere is of paramount importance in our understanding of the origin of life.

(iv) Isotope ratios of residual biosignatures: light carbon, sulphur and nitrogen isotopes can prove the authenticity of early life evidences.

Analyzing the present scenario of Indian Precambrian microbial life, future direction of study should be: (i) re-evaluation the available fossil records; (ii) study of proxies of Precambrian environmental changes through time; (iii) search and identification of prokaryotes and eukaryotes and analysis of their genomic sequences; (iv) construction of biogeochemical models for ecosystems and testing them with isotopic analyses; and (v) recognition of biologically produced structures and artificial artifacts and identification of chemical and mineralogical bio-signatures.

Detailed field work and search for more convincing biosignatures and tests based on stable isotopes directly on suspected fossils can answer the nagging issues of unending debates, regarding the authenticity of fossils.

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EARLY ANGIOSPERMOUS DICOTYLEDONOUS WOODS FROM INDIA

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The discovery of angiospermous remains from the Lower Cretaceous of Russia (Samylina 1968), Japan (Kimura 1980, Suzuki *et al.* 1996), North America (Friis *et al.* 1994) and Portugal (Fris *et al.* 2000) and from Late Jurassic-Early Cretaceous of China (Sun *et al.* 1998, Sun & Dilcher 2002) clearly indicates that angiosperms were in co-existence with *Williamsonia, Ptilophyllum* and the mighty dinosaurs. Gymnosperms started declining after Early Cretaceous, but angiosperms evolved and occupied diverse habitat all over the world.

In India, Early Cretaceous angiospermous records are meagre. From Rajmahal Intertrappean beds of Bihar few angiospermous pollen (Aptian, ca. 117.5 Ma) were described by Tiwari and Tripathi (1995). Two more angiospermous fructifications were reported from different localities of Rajmahal Hills (Sharma 1997, Banerji 2000). But no definite angiospermous wood has been reported from India or elsewhere. Some vessel-less dicotyledonous woods were reported earlier from Early Cretaceous sediments of India, Japan and other countries were lately found to be representatives of Bennetitales or some extinct gymnosperms.

The oldest known angiospermous wood from India have recently been reported from Infratrappean beds (Maastrichtian) of Lameta Formation (Kar *et al.* 2004). Prior to this, woods reported from Deccan Intertrappean sediments (Maastrichtian-Danian) were believed to be the oldest angiospermous woods from India. In the present communication data from both infratrappean and intertrappean beds has been taken into consideration.

During Cretaceous primitive features are expected to be present in higher percentage. The primitive and advanced xylotomical features and their significance in evolutionary trends were sorted out on the basis of fossil and living woods as suggested by many wood anatomists and lately given the name Baileyan trend (Carlquist 1988). Bande and Prakash (1984), Wheeler and Bass (1991), and Srivastava (1996) statistically showed that woods with primitive structures in Baileyan sense were actually dominant in Cretaceous and advanced characters were more common in gradually younger horizons of Tertiary.

The features related to major trends of xylem evolution, according to I.W. Bailey, are as follows:

1. Porosity: Diffuse porous usually precede ring porous, however it can be modified climatologically.

2. Growth rings: Absence of growth ring is considered as primitive and its presence is a derived feature.

3. Vessels/Pores: (a) Solitary pore precedes multiple pores and clustures; (ii) pores with angular cross section are primitive than rounded ones; (iii0 scalariform intervessel pits are most primitive whereas opposite and alternate ones are most advanced; (iv) longer vessel elements precede shorter elements; and (v) scalariform perforation plates with many bars are most primitives whereae few bars and simple plates are most advanced.

4. Axial parenchyma: Aporacheal distribution (diffuse → diffuse-in-aggregate → apotracheal lines → apotracheal bands) precedes paratracheal distribution (scanty → vasicentric → aliform → aliform confluent → paratracheal banded).

5. Rays: Heterogeneous rays (Kribs type I → type II → type III → type V) precede homogeneous rays (Kribs type IV → type VI).

6. Fibres: Not related to major trends of evolution.

7. Storeying: Storeying of various elements, such as vessel elements, parenchyma strands and rays is considered to be highly specialized features.

In India, from Infratrappean beds of Lameta Formation only two angiospermous woods *Euphorioxylon indicum* and *Barringtonioxylon deccanense* were reported by Kar *et al.* (2004). However many woods are present around Zeerabad, Dhar District, but most of them are in the form of cast and depict no internal structure.

The Deccan Intertrappean flora is richest and most thoroughly studied flora of Maastrichtian-Danian age. Fairly good amount of data is available on the dicotyledonous woods of this flora. So it is desirable to analyse their evolutionary trends indicated by their xylotomical features.

About 72 woods belonging to 25 families were taken into consideration for the study of evolutionary aspect of anatomical features. No vessel-less angiosperm (the so called primitive angiosperm) is known either from Lameta Formation or from Deccan Intertrappean sediments. According to many workers vessel-lessness might be a derived feature in dicotyledons. The study shows that all the woods are diffuse porous. Scalariform perforation plates are present in two genera, *Gomphandra* and *Hydnocarpus,* scalariform to opposite intervessel pits present only in one genus *Leea.* In one genus *Sterculia*, parenchyma cells and vessel elements show storeying tendency while rest of the woods have simple perforation plates and alternate (few opposite) intervessel pits, However, high percentage of apotracheal parenchyma and heterogeneous rays indicate primitiveness.

Some of the anatomical features are influenced by ecological conditions and such characters always do not depict evolutionary trends. Since Indian Cretaceous-Palaeocene flora is distinctly tropical, growth rings and ring porocity are absent due to non-seasonality. Simple perforated elements are adapted for efficient water supply and scalariform perforation plates are eliminated due to high rates of transpiration as evidenced in the modern woods of tropical region (Baas 1982). Likewise, alternate intervessel pits provides strongest wall support than opposite or scalariform pitting because most of the genera are dicotyledonous trees of tropical evergreen to semi evergreen forests (Carlquist 1988).

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MORPHOLOGICAL EVOLUTION OF INDIAN GONDWANA MEGASPORES

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Megaspores or the female reproductive units of heterosporous land plants are the larger spores which, on germination in extant plants, give rise to female gametophyte. Occurrence of megaspores is an important step in evolution of early land plants. Their presence during Gondwana, especially in Permian, is indicative of existence of heterosporous cryptogams which are not adequately represented by megafossil records. Indian Gondwana megaspores are recorded throughout the Permian and Mesozoic periods. They have been basically categorized on the basis of their shape, presence and absence of tri- radiate mark, extension of tri-radiate ridges up to or beyond contact ridges and nature of walls. Mainly two types of wall layers, viz. exosporium-the outer wall layer and mesosporium or the inner wall layer are recognized in dispersed fossil megaspores. Distribution and type of ornamentations on exosporium, presence and absence of cushions on mesosporium and, if present, arrangement of cushions along tri-radiate mark are significant characters for circumscription of megaspore taxa. Besides systematics, different structural patterns are helpful in tracing affinities with different plant groups. Megaspores are circular, triangular or oval in shape throughout the Permian. However, in Mesozoic, oval megaspores are less common. Whereas, trilete megaspores are of common occurrence, alete megaspores are reported only from Barakar and Raniganj formations. Tri-radiate ridges extend beyond contact ridges only in one genus, viz. *Duosporites* which has been reported from both Early and Late Permian. Such megaspores are absent from Mesozoic. On the basis of distribution pattern of ornamental processes the megaspores are categorized as azonate, zonate and gulate. The exosporium is either laevigate, granulate, verrucate or bears a variety of ornamental processes, viz. coni, baculae, setae, mammillae or various kinds of simple, bifurcate, multifurcate spines and variously branched appendages. Similarly, mesosporium is with or without cushions. If present, cushions are either arranged in a single row or trigonally in multiple rows or haphazardly along the tri-radiate mark. The type of ornaments on the exosporium shows a distinct evolutionary trend. The Early Permian megaspores of Talchir and Karharbari are by and large granulate, verrucate, finely verruacate or with small protuberances, rods, baculae and coni. However, the megaspores of Permian (Barakar and Raniganj), Triassic and Cretaceous show a variety of structurally complex ornamentations. In Barren Measures, megaspores are relatively fewer in number and hence structurally less diversified. Mesosporium on the other hand, shows an inconsistent pattern of structural organization through Gondwana. Whereas all kinds of arrangements of cushions along tri-radiate mark, viz. in a single row, multiple rows or haphazard/irregular along with smooth mesosporium are found in Lower Gondwana megaspores, in Upper Gondwana megaspores, the mesosporium is either indistinct or distinct with a few cushions arranged irregularly along the tri-radiate mark. Gondwana megaspore studies in India have gained momentum during last five years (Jana 2004, Jha & Tewari 2003, Jha *et al.* 2005, in press, Srivastava & Tewari 2001, 2002, 2004, Tewari *et al.* 2004). Reports from other Gondwana countries are sporadic (Glasspool 2003). Moreover, parameters adapted for circumscription of Indian megaspore taxa are manifold including shape, extension of tri-radiate ridges, exosporium and mesosporium characters, which appropriately categorise the megaspores in an organized way.

Exosporium based categorization proposed by Glasspool (2003) has little merit in systematically classifying the megaspores. Since different kinds of exosporia and mesosporia reflect development of different structural organizations in evolutionary history of land plants, a proper taxonomic differentiation of these female reproductive units is essential for a better understanding of evolution of various heterosporic groups of cryptogams.

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Theme–Emerging Trends in Palaeobiology, Session A–Early life on Earth and signatures of Extra Terrestrial Life

ASTROBIOLOGY: THE SEARCH FOR EXTRATERRESTRIAL LIFE

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The new science of Astrobiology includes life's origin, evolution and distribution in the universe. Our solar system formed 4.6 billion years ago by the shock wave of a supernova explosion. Asteroids, comets and meteorites were formed as small extraterrestrial bodies. There is evidence for the presence of silicon carbide grains in the Murchison meteorite and the isotopic study supports that they are of supernova origin. The Murchison and other meteorites (Didwana-Rajod) may have played an important role in the origin of life. The basic building blocks of life (amino acids) have been recorded from many meteorites. The biomolecules of life (nucleotides, lipids, amino acids) are unique to meteorites and extraterrestrial in origin. The meteorites and comets may have been a potential source of organic compounds on early Earth. Life must have been originated in some planet of our solar system probably after the final stage of bombardment of the solar system by bolides dated at 3900-3800 million years. Recent discovery of amino acids from a number of meteorites recovered on Earth (most probably from asteroid belt between Mars and Jupiter in our solar system) strongly supports the idea that the biomolecules and nanno bacteria exist in outer space. The microbes are transported to the early earth by meteorites blasted out of the other planets and landed on Earth.

The oldest bacterial microfossils and stromatolites on Earth are recorded from 3465 million years old Apex Chert of Western Australia. Stromatolites or microbialites are biogenic carbonate buildups produced by benthic microbial communities on Earth. Stromatolites represent the earliest megascopic signatures of life on Earth (and possibly on Mars). The biochemical, stable isotopic, GC-MS and Laser Raman spectroscopic techniques have confirmed the presence of organic matter (kerogen/ polycyclic aromatic hydrocarbons and amino acids) of biological origin in the stromatolites and microbiota. The recent highly successful space missions to Mars, Europa and Titan for search of extraterrestrial life (fossil or living microbes, organic compounds, amino acids, methane gas, etc.) is a major scientific breakthrough in space biology or astrobiological research.

The astrobiology has been recognized as science for extraterrestrial search for evidence of microbial life whether fossil or extant in the Cosmos. In the search for life in other planets we have to properly understand the Precambrian life on the Earth as best analogue. Recently, some new techniques have been devised to confirm the biogenicity of the Precambrian microfossils found in black cherts ranging in age from 3500 to 850 million years. Laser Raman imagery and spectroscopy has been used to analyze the molecular compositions of individual cellular microfossils from all over the world including the Indian lesser Himalaya and the peninsular shield. Ion microprobe analysis has been done to analyze the carbon isotopic composition of individual fossils in Precambrian rocks. Atomic force microscopy has been used to study the submicron scale kerogenous matter of the Precambrian microfossils. Mossbauer spectroscopic study of the iron biota and minerals in banded iron formation and stromatolites will be very useful about their origin. These studies have been used in the Martian (ALH) meteorites recovered from Allan Hills, Antarctica, SNC group of meteorites (Martian) from India and Egypt. A detailed study of these meteorites is in progress. A case study of using 3.46

billion years old stromatolitic chert biota from the Pilbara in Australia for searching fossil microbial film on Mars is another important astrobiological experiment. Beagle 2 (the failed landing mission to Mars) was dedicated to the search for past life on Mars. A 3.46 Ga microfossiliferous sedimentary rock was used as a reference sample. Microbial mats were found at the surface of the sediments. This rock formed in an environment and from materials that would have existed on early Mars. Preliminary experiments with the Beagle 2 Camera confirmed that it should be possible to identify sedimentary structures such as ripple marks and wavy laminations in detail. A 2 mm high ministromatolite/ thrombolite layer was also visible. The microscopes and the spectrometers fitted in the Beagle 2 would have provided additional information for chemical, isotopic and gas (GC-MS) analysis. The biogenicity of the organic matter must have been tested on Mars. The recent study of Martian geology has discovered unquestionable astrobiological evidence such as extensive iron oxide deposits at Terra Meridiani. The Tinto River, south-western Spain is being studied as a terrestrial analogue on Earth. The lake Vostok in Antarctica is currently being studied as a possible analogue for life on Europa and other icy planets of the universe. The new concept of snowball earth, microbial life in extreme environments such as Antarctica and Atacama desert have astrobiological significance. A more recent meeting of study of the origin of life held in China discussed these aspects in detail.

Astrobiology is a new field of science bringing together many scientific fields of study. NASA has designed a set of classroom activities and Internet course for teaching astrobiology in collaboration with Center for Educational Resources. The course integrates the NASA Astrobiology Roadmap. All the major universities in USA and Europe have astrobiology institutes and provide information on the central concepts related to the field of astrobiology and also giving inquiry based curriculum material for teaching astrobiology. Astrobiology as a future science is already accepted in the western countries. This is high time that the Indian universities and institutes must realize the importance of this newly emerging field of science and some initiatives must be taken to introduce astrobiology in the curriculum at the undergraduate level in the universities. A small network of Indian astrobiologists has been formed recently and it is proposed to expand its activities.

Theme–Emerging Trends in Palaeobiology, Session A–Early life on Earth and signatures of Extra Terrestrial Life

PRECAMBRIAN-CAMBRIAN BOUNDARY ACRITARCHS IN LESSER HIMALAYAN SEQUENCE

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Acritarchs are phylogenetically heterogeneous organic-walled microfossils known from the Proterozoic and throughout the Phanerozoic. Their high taxonomic diversity, versatility of occurrence in several ecological conditions attracted palaeobiologists worldwide. As acritarchs are proved to be useful for a better perceptive of biostratigraphy, palaeogeography, and palaeoenvironment of all Palaeozoic systems, the significance of acritarch research is appreciated and established to a greater extent in Neoproterozoic- Cambrian sequences also, particularly in sediments where no other fossils occur.

The fossil records of acritarchs show a clear pattern of change in morphology and size with time. An increase in diversity of acritarchs observed during the late Riphean and early Vendian, a decrease during middle to late Vendian, followed by a successive increase throughout the Cambrian. Recent studies dealing with Proterozoic microfossils show that acritarchs of Palaeoproterozoic and Mesoproterozoic can be easily differentiated from their Neoproterozoic counterparts. Acritarch assemblage of Late Riphean age is characterized by distinctive sphaeromorphs and polygonomorphs, whereas Early Vendian acritarchs are large acanthomorphs which disappeared at or near to the time of the main Ediacaran animal radiation. Late Vendian acritarch assemblage is represented by simple leiosphaerids and small acanthomorphic acritarchs. Acanthomorphic acritarchs further diversify during the early Cambrian and these are much smaller in size and are quite distinct from the Neoproterozoic species. This change demonstrates an apparent phase of organic radiation, which may be due to changes in the abiotic as well as biotic factors. Neoproterozoic organic– walled microfossils including large acanthomorphic acritarchs have been reported from China, Australia, Siberia, Svalbard and India in strata that lie above Varanger glaciogenic deposits but below diverse Ediacara faunas. Precambrian-Cambrian boundary assemblages characterized by small acanthomorphic acritarchs are reported from China, Central Asia and East European Platform.

The Neoproterozoic-Cambrian period is a significant part in the Lesser Himalayan geological history. The Inner Krol Belt of the Lesser Himalaya contains mineralized and organic- walled microfossils of Proterozoic-Cambrian boundary interval from different stratigraphic successions. Studies dealing with acritarchs during Neoproterozoic –Cambrian in Lesser Himalaya are relatively in its infant stage compared to other biostratigraphically important microfossils such as small shelly fossils, trilobites and trace fossils etc. From the Lesser Himalaya, Early Vendian microfossils including large acanthomorphic acritarchs are described from the Infrakrol and Lower Krol formations. Acanthomorphs reported from Infrakrol Formation have a size range of 60 to 1100μm, unknown from pre- Varanger rocks and are not even reported from rocks bearing diverse Ediacaran metazoan fossils. These microfossils represent diverse phytoplankton and benthos of shallow Neoproterozoic seas shortly after the Varanger glaciation. This acritarch assemblage is comparable to other Neoproterozoic microbiotic assemblage from China, Australia, Svalbard and east central Siberia. The chert Member of Tal Formation, lying stratigraphically above the Infrakrol and Lower Krol formations, contains sphaeromorphic and small acanthomorphic acritarchs typical of the Precambrian-Cambrian boundary interval. Interestingly, abundant small shelly fossils have been recovered at the same level in the Mussoorie and Garhwal synclines. The assemblage is closely comparable to Precambrian-Cambrian boundary microbiotic assemblages in China, Central Asia and East European Platform. The study of such assemblages, therefore, offers an opportunity to extend studies in other parts of the Himalaya, and review the whole Proterozoic and the Neoproterozoic-Cambrian boundary sequences. The detailed study will be utilized for biostratigraphic zonation, their worldwide correlation and palaeoenvironmental interpretations of the Himalayan sequences.

LOWER GONDWANA SEEDS

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A large number of seeds are described from Lower Gondwana but mostly remained structurally uninvestigated. The seeds are found dispersed and mixed up with other organs after being detached from the plants, which produced them. Like other plant fossils, seeds are also preserved in a variety of ways depending upon their structure and the conditions that were prevailing at the time of deposition of the fossil beds. They may be found petrified *(Cardiocarpus*) or occur as impressions (*Samaropsis, Cardiocarpus*), moulds and casts or as carbonized compressions (*Walkomiellospermum, Platycardia,* etc.). The seeds preserved as impressions are least satisfactory for structural studies. Seeds preserved as mould and casts are also equally unsatisfactory for study of anatomical details although in these the third dimension may be seen. The best preserved fossil seeds for study of structural details are petrified. Seeds, that come next to petrifactions in the preservation of internal structure, are compressions where the original substance of the seed is compressed and squashed between the layers of sediments which themselves become compressed and compacted by the piling up of the sediments during the deposition of the fossiliferous beds. Fibres and the stone of seeds, vascular tissues, starch grains in megaspore and even archegonia are preserved in the female gametophyte (Pant & Srivastava 1963, Pant *et al.* 1985).

A few attached seeds and a far larger number of detached ones have been described from the Lower Gondwana of various parts of the world. The only Lower Gondwana seeds which have been found petrified are those described by Gould and Delevoryas (1977) and these are found attached to a dorsiventral fructification.

The seeds which are preserved as impressions but they are attached to organs called *Arberia* (White 1908, Rigby 1972), *Dolianitia* (Millan 1967), *Cardiocarpus* type of seeds attached with *Australoglossa* (Holmes 1974) and a number of seeds attached with reproductive organs described under name *Denkania* (Surange & Chandra 1973), *Partha* (Surange & Chandra 1973), *Plumsteadia* (Rigby 1963), *Lidgettonia (*Thomas 1958) etc. The structure of these bodies is unknown.

The seeds, which are preserved as compressions and attached, are *Maheshwariella bicornuta* (Pant & Nautiyal 1963), *Platycardia*, *Pterygospermum* (Pant & Nautiyal 1960), *Buriadiospermum* (Pant *et al.* 1985), *Cornuspermum* (Banerjee 1969) *Shivacarpus* (Pant *et al.* 1985), *Otofeistia* (Pant *et al.* 1985) and seeds of *Birsinghia* (Pant *et al.* 1995).

A large number of detached seeds, which are preserved as impressions, are known from Lower Gondwana. These are reported from Talchir, Karharbari, Barakar and Raniganj stages of India and other countries under the name *Carpolithes, Samaropsis, Cardiocarpus*, *Cycadospermum, Cornucarpus, Indocarpus, Nummulospermum* and *Eurocarpum* by different workers. The seeds are mainly differentiated on the basis of wing and horn-like projections at the micropylar side or on the basis of shape. Among these seeds, *Cardiocarpus* and *Samaropsis* are dominant forms in Lower Gondwana but these two genera are rather artificial groups based on morphological differences. Among these seeds, there are only two Lower Gondwana seeds, viz. *Rotundocarpus* (Maithy 1965) and *Sterocarpus* (Surange 1957), which are radiospermic but *Sterocarpus* seems to be a scale and radiospermic nature of *Rotundocarpus* is uncertain. Therefore all the seeds, described from Lower Gondwana, are platyspermic in nature.

The compressed seeds are best preserved and show the structural details because they yield envelopes, which could be regarded as outer, and inner cuticles of integuments, the nucellar cuticle and megaspore membrane. Thet also show chalazal hole and micropylar canal, where pollen grains may be seen.

At present, only 16 compressed seed genera are described from Lower Gondwana, which show the full structural details. These are: *Cornuspermum*, *Maheshwariella, Platycardia, Pterygospermum, Spermatites, Walkomiellospermum*, *Cerviculospermum (Collospermum), Retortistoma, Palispermum, Bulbospermum, Palaeocarpus, Shivacarpus, Otofeistia, Buriadiospermum* and *Birsinghpuria* and seeds of *Birsinghia*. All these seeds are platyspermic and orthotropus except *Buriadiospermum* and *Palaeocarpus*, which are anatropous. Some seeds are definitely stalked. Mostly seeds are longer than broad but *Shivacarpus latus* is broader than long. Some seeds show a wing or a narrow border around the nucule. Few seeds show a prominent median ridge while other show micropylar modifications like funnel, horns, etc.

The outer cuticle of seeds also shows variations, e.g. marks of crystals and presence of stomata. *Retortistoma* show curved micropylar canal. *Shivacarpus johillensis* and *Platycardia bengalensis* show fibrous layer between cuticles of integument with impressions of cells bearing scalariform thickenings like tracheids. Some seeds show elongated fibres but *Palaeocarpus* shows short sclereids.

The nucellar cuticle is also very remarkable and it is prolonged into nucellar beak above the pollen chamber. In *Bulbospermum* the pollen chamber forms a bulbous dome-shaped structure at the base of micropylar canal. The megaspore membrane in some seeds is raised and forms tent pole like structure below which the surrounding depression are seen as 2 or 3 spherical dark bodies (archegonia). The seeds are pollinated by either monosaccate or bisaccate pollen grains but *Buriadiospermum* and *Walkomiellospermum* are pollinated by unwinged monocolpate pollen grains.

The seeds of *Palaeocarpus birsinghpurensis* and *Cerviculospermum (Collospermum) ovalis* have circular archegonia, tent pole and two winged pollen grains inside the pollen chamber may suggest that they belong to plants allied to Cordaitales and have characters both of Glossopteridales and Cordaitales. This may indirectly support the view about cordaitalean affinities of *Glossopteris* held by Schopf (1976).

The structural details and pollination of these seeds suggest that during the Palaeozoic Era, seeds of at least three major groups of gymnosperms existed in Lower Gondwana countries. These were: (i) seeds of *Glossopteris* and allies, which are pollinated by disaccate pollen grains. Their plants may have been related to pteridosperms; (ii) seeds of plants possibly closely or distantly allied to Cordaitales and Ginkgoales; and (iii) seeds belonging to plants of a possible primitive coniferous stock. Such seeds are pollinated by asaccate, monocolpate pollen grains. These seeds can also be used as stratigraphic markers for various Lower Gondwana horizons of India.

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BIODIVERSITY IN WESTERN HIMALAYA, PRESENT SCENARIO, MANAGEMENT EFFORTS AND FUTURE DIRECTION

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The present biodiversity of western Himalayas has evolved concomitantly with its ecosystem and environment in the past. It is currently under pressure for rapid and radical transformation. Effects of global atmospheric and environmental changes on biodiversity are less threatening as compared to anthropogenic local pressures. Local efforts of conservation and management in view of population pressure alone need reorientation for saving biodiversity. This would require change in strategy and conservation methods more than those in a legal framework.

POTENTIAL OF ANGIOSPERMOID CHARACTERS IN POLLEN THROUGH TIME

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To recognize and identify true angiosperm pollen, study of pollen wall morphology is very important. The angiosperm pollen have tectate-columellate exine structure, i.e. the pollen wall is differentiated into two layers separated by columellae. This exine configuration of angiosperm pollen is well documented in the Aptian-Albian palynofloras. The pre-Cretaceous records of pollen, having angiospermoid characters, are described but their angiospermous affinities are not ascertained. Several columellate-tectate, polyplicate (with characteristic auriculae) pollen types are observed from the Jurassic, Triassic, Permian and even Late Carboniferous. These are *Multimarginites, Cornetipollenites, Pentecrinopollis,* cf. *Retisulcites, Daminites* and *Lasiostrobus*.

The variation in the morphological characters is due to the genetic change responsible for evolution, through time, in gametes, which propagate the species. Each morphological structure and sculpture characteristics of pollen wall are probably controlled by one or more genes interacting in concert. The nature has experimented with angiosperm exine pattern several times in the history of plant evolution. The genes controlling the angiosperm characters in pollen became activated at different time plane under stressed climatic conditions. The stressed time levels correspond to the morphological expression of angiosperm characters in pollen and have been reviewed. These are referred as Character Manifestation Steps from Late Carboniferous to Early Cretaceous.

PALAEOBIOLOGY IN NATURAL HISTORY MUSEUMS

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The modern panorama of the Earth's surface exhibits amazing diversity in animal and plant life. It is the result of a complex process termed as Organic Evolution. The theory of evolution claims that present day organisms are descendents of life-forms that existed in the past. A fraction of past life could be preserved in the rock strata as fossils. The study of fossils provides unique insight into patterns of diversification and extinction. It also unfolds relationship of these patterns with the ever changing physical environment of this planet. A natural history museum is interpreted as a documentation centre of living and non-living components of the Earth. Its serves as a source of knowledge and information particularly related to the history of life. Since a limited part of the holdings can be exhibited, the major part of collections is stored and studied by the scientists of Palaeobiology Department of these museums. The knowledge generated through collections and research is displayed in the form of specimens, models, panels and other communicative media. The displays and exhibits incorporating the generated knowledge act as an excellent source of information and help to educate the audience, students and scholars.

Extinction is the rule in the history of life. It is the ultimate fate of all the species and is clearly noticeable in the fossil records. In the history of life this process is of continuous occurrence and, as a matter of fact, it creates opportunities for origin of new species. The fossil record shows a sequence of appearance of different life forms through time. Through the fossil records only, it could be established that unicellular organisms appeared before the multicelled ones, plants inhabited the Earth before animals and invertebrates gave rise to the vertebrates. In addition to these, many facts regarding the phylogeny in different groups of plants and animals have been revealed by the study of fossils. The phylogeny, once established, can reveal the evolutionary trends that are perceptible in a group of organism including the extant ones.

Multifaceted researches in different fields of earth science have reveled that fossils, organosedimentary structures and rocks are the treasures of history of life. Stromatolites provide evidence of widespread photosynthesis by prokaryotes during Precambrian time. The process of photosynthesis increased the level of free oxygen in the oceans and the atmosphere. It triggered the diversification of eukaryotic algae. Presence of molecular oxygen in the sea water and atmosphere during the middle of Precambrian is indicated by the banded iron formation and widespread occurrence of oxidized iron in sedimentary rocks. Fossils of eukaryotes are known from Early Proterozoic but their presence in the Middle Proterozoic is unequivocal. The oldest fossil of multicellular organism is from more than 1.5 billion years old rocks. Reported in the form of carbonaceous impressions, probably they are algal remains. About 600 millions years ago soft bodied forms, grouped under Ediacaran fauna, suddenly appeared. These had enigmatic body and can not be related to any animal or plant group. These organisms did not survive into the Cambrian.

The Cambrian Period is known as the time of explosion of life. Varied shelly forms appeared at the start of this period. Variety of invertebrates and vertebrates existed in Early Cambrian. Primitive fishes were jawless and flourished from Silurian to Devonian. Jawed fishes emerged in Devonian. For a long time, life was restricted to the ocean because terrestrial environment on early Earth was not suited for life due to ultraviolet radiation. But plants, with certain modifications, succeeded in inhabiting the land about 500 million years ago. Land plants rendered a new world to the animals and greatly affected the global environment.

Late Silurian and Early Devonian land plants were simple, dichotomously branched and had few leaves. Some branches bore terminal sporangia. Well differentiated root-shoot systems developed in Late Devonian plants and by this time the earliest forests came into existence. Dense forests were established during Carboniferous, a period which is characterized by occurrence of coal measures all over the world. Most of the terrestrial organisms had already emerged by the Carboniferous and therefore Palaeozoic was the time when well organized terrestrial ecosystems got established. During Late Carboniferous, reptiles diversified rapidly. Flying and aquatic reptiles appeared in Late Triassic. Dinosaurs and mammals, which descended from some other reptile group, appeared in Late Triassic. Dinosaurs diversified and flourished in Jurassic and Cretaceous but by the close of Cretaceous, due to some catastrophic event, era of these animals ended.

At the end of Jurassic, the climate became colder and small dinosaurs began to develop features for insulation. Feathers of some theropods, the small carnivorous dinosaurs, began to perform the function of flight. Some theropods evolved into birds by losing teeth, developing fused fingers to form wings and shortening of tail. Mammals, though appeared in Late Triassic, did not diversify till the Cretaceous Period.

Triassic and Jurassic periods continued to be dominated by seedless plants and gymnosperms. A new group of gymnosperm, the Cycads, evolved during the Triassic. By the Early Cretaceous, these plants started dwindling and were replaced by the most evolved and successful plants- the angiosperms. Commonly also known as flowering plants, they immensely diversified in Cenozoic Era and almost all kinds of habitats were colonized by the plants of this group. Diversification of angiosperms through Cenozoic provided variety of landscapes and habitats to animals which probably also contributed to the radiation of mammals. In the Cenozoic, global climate was the warmest during Early Eocene. During this period, tropical forests, inhabited by the archaic huge herbivores covered most of the continent. Small placental mammals grew larger in Eocene. By the Middle Eocene, time gradually the climate became cooler and drier. In Early Oligocene, thick ice sheets developed in Antarctica and tropical forests were replaced by the deciduous ones and more advanced mammals evolved.

Miocene palaeogeography was more or less similar to that of the present time. Due to the Himalayan uplift, grasslands expanded in the inner continental regions, whereas humid temperate forests developed in the marginal areas. Climatic differentiation became more distinct and new floras and faunas appeared. The Quaternary Period is marked with rapid and strong climatic fluctuations caused by glacial and interglacial cycles. Various large mammals flourished in the ice age and vegetation changed during the period. Many large mammals of Quaternary became extinct by the end of last glacial age, about 10000 years ago. Extinction of these animals might be due to sudden warming of climate and also due to hunting by humans. About 2.4 million years ago early humans appeared in Africa and probably inhabited the forest rather than savanna. Thereafter, other human species evolved there and in due coarse of time some of these became widely spread in other continents.

FOSSIL MICROTHYRIACEOUS FUNGI

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Chiefly tropical to subtropical in distribution, the microthyriaceous fungi are epiphyllous in nature. Members of this family commonly occur on epidermis of leaves, stems and flowers of higher plants. The evolutionary development of microthyriaceous fungi, therefore, might have been related with proliferation and spread of angiosperms. Growth of these fungi is significantly related with precipitation rather than temperature. Profuse occurrence of these fungi is noticed in areas having precipitation more than 100 cm per year. Microthyriaceous fungi have scutate fruit bodies called thyriothecia. In most of the cases thyriothecia possess radiating rows of mycelial cells giving an appearance of tissues arranged in radial fashion. These are the fruiting bodies or ascocarps and contain asci that are surrounded by or enclosed within protective tissues. Ascocarps may be in the form of closed globose structures or flask-shaped bodies with an opening known as ostiole or the saucer shaped open structures.

Amongst all members of the epiphyllous fungi, the microthyriaceous forms are easily identifiable in palynological assemblages. These are quite commonly represented in palynological preparations from all horizons of the Cenozoic Era but the first record of this family is from Late Cretaceous. Fossil species of this fungal group are classified under Fungi Imperfecti. Fossil microthyriaceous fruiting bodies generally lack free mycelia and spores. Due to this reason, in most of the cases, it is extremely difficult to relate these with extant genera. Assignment to the modern counterparts is further hampered due to the fragmentary nature and incomplete margins of the fossil specimens. It is, therefore, not possible to describe these under the natural system of classification which is based on morphology of extant forms. To overcome these problems, fossil fruiting bodies are described under the artificial system of classification based on morphological features only.

Fossil microthyriaceous species have been described under 13 genera. Characteristic features considered for their classification are: shape and margin of the fruiting body, characters associated with the dehiscence mask, presence or absence of pores in individual cells and nature of the central part of the fruiting body. Most of the fruiting bodies reported from Tertiary sequences of India, are spheroid and nonostiolate. Amongst these, *Phragmothyrites, Callimothallus* and *Microthyriacites* are the most common. *Phragmothyrites* is spheroidal, nonostiolate body having nonporate, more or less isodiametric cells. Margin of this fruiting body is smooth. *Callimothallus* resembles *Phagmothyrites* in all morphological features but differs in possessing a pore in each cell in middle and central part of fruit body. Forms described under *Microthyriacites* are rounded, nonostiolate and have two to three tires of thickened central cells. Middle and peripheral tires of cells are radially elongated while the central ones are isodiametric. Other Indian microthyriaccous forms have been described under the genera *Asterothyrites, Euthythyrites,* M*icrothallites, Plochmopeltinites, Trichopeltinites, Paramicrothallites* and *Trichothyrites.*

A critical assessment of palynological literature reveals that, in many cases, forms with diverse morphological features have been ascribed to single genus whereas those with similar morphological features have been assigned to different genera. Such treatment has not only added a long list of un-named species under various genera but also limited their scope to biostratigraphic application. It is, therefore, necessary that taxonomic status of many of these forms is reviewed.

SYLLABUS IN PALAEOBOTANY

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Teaching of palaeobotany in Indian universities is gradually getting neglected because of lack of specialists. There are only a few universities, which are engaged in teaching and research in palaeobotany and one can count them on fingers. There are hundreds of post-graduate colleges in India having a syllabus of palaeobotany, but scanty attention has been paid to teaching mainly due to lack of literature and specialists. Fossil plants belonging to Pteridophyta and Gymnospermae constitute 3/4 of the syllabus, which is taught in the Indian universities. New topics should be introduced in the syllabus, apart from the basic chapters, e.g. (i) kind of plants that have existed in the past for their own sake and thrown light on the origin of modern flora; (ii) different kinds of environmental settings and depositional patterns under which the plant fossils are formed; (iii) appearance and disappearance of major plant groups and their role in the evolution; (iv) past environment and climate including the ecological conditions; (v) geographical distribution of plants and their migration routes; and (vi) evolution of a taxon or group based on plant fossils. For promoting this discipline in teaching and awareness, it is suggested that: (i) arrangements should be made for placement of animal and plant fossils in the national museums in the form of "fossil gallery" for the awareness among the masses; and (ii) from time to time Refresher courses, exclusively on palaeobotany, should be arranged to discuss the current awareness in this discipline among university teachers, researchers and institute scientists.

PALYNO-CHRONOLOGY OF THE MESOZOIC SUCCESSION ON INDIAN PENINSULA

Vijaya

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Palyno-Event stratigraphy of the nonmarine succession spanning from the basal-most Triassic (Permo-Triassic transition) to Lower Cretaceous in the Mesozoic sedimentary basins of Indian peninsula has been subjected to review. The first appearance of an index species in spore-pollen, at any level, plays an effective role in the dating of rocks and contributes in the making of stratigraphy. The so far objectively formulated syntheses of palynological successions provide characterization of each assemblage zone. The bench-mark events identified here in the Mesozoic succession have their significance in the palyno-chronology of these deposits.

The first event-level demarcated in stratigraphy is the Permian-Triassic boundary, which is broadly considered the chronological boundary, and this has also been evidenced from the vertebrate fossils and lithological characteristics. Here is the major evolutionary shift in functional morphology of fauna and flora, however, no indication of mass extinction in landplants is recorded. Above the Permian-Triassic level, coal formation ceases to exist and sedimentary sequence of varied facies, viz. mudstone, clays, siltstones, sandstones, shales, limestones, does occur up to the level of Lower Cretaceous. In the Triassic sequence, several evolutionary shifts occurred in the spore pollen morphology. At the basal-most Triassic, the key taxa, which have made their FADs, get established and represent the Lower Triassic palynoflora. The only notable feature within the Triassic sequence is the changing pattern of the key-taxa in their relative abundance, and the FADs of certain marker species at different levels. These levels are identified as the event-levels.

As such, no scheme of palynozonation in the Gondwana sequence is based exclusively on the last occurrence (LO). The suggested broad-based correlation provides a frame work, though it needs refinement. There is no sequential record of continuous palyno-assemblages in the Triassic deposits from the Mesozoic sedimentary basins. Hence, efforts are made to understand the genetic uniqueness in the palynoflora because here it has been ecologically and microclimatically biased than that of the Permian time.

Recently, the palynological data to evaluate the Triassic-Jurassic transition is added on record, but its limits are not known precisely. The status of continental Jurassic on the Indian peninsula is currently proved and its palynological characterization has added more data from Rajmahal Basin, and Panagarh area in Raniganj Gondwana Basin. A correlation of various palynoassemblages in the Jurassic deposits is still imprecise. The transition in spore-pollen composition from Jurassic to Cretaceous is apparently smooth, rather than drastic, and hence it could be located at the basal-most Rajmahal Formation. This may indicate a stratigraphical vicinity to Jurassic-Cretaceous boundary.

The palynological succession in the Lower Cretaceous could be identified in detail because the data is available from far and wide profiles on Indian peninsula. Here, dominance datums do not play decisive role in shaping stratigraphy, but the FADs of marker species make characteristic differences in zonation schemes.

For this kind of palyno-chronology, pattern based events are identified in the palynoassemblages which have marked provinciality. The Permo-Triassic transition reveals gradational change in terrestrial flora along with precursors of Early Triassic. The FADs of various species for correlating palynozones may not coincide precisely, but broad equations exist in such correlations. Similarly, Triassic-Jurassic transition is marked as substantial extinction horizon. For this boundary level, very meagre palynological data is on record. As such, the history of Triassic and Jurassic palynosequences is not fully documented to explore the sequential events in the palynoflora in shaping the stratigraphy. But apparently, a concept can be evolved broadly in the spore-pollen complex through this time span.

CLIMATE RECORDS FROM TREE RINGS: INDIAN SCENARIO

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Long term, high resolution proxy climate records are useful to understand the natural climate variability and anthropogenic impact superimposed over it. Amongst the known climate proxies, the tree rings are unique in terms of the existence of precise dating control and the calibration of chronologies against the concurrent instrumental weather records. Statistically verifiable robust calibration models are used to develop climate reconstructions for the length of tree ring series.

Climate over the Indian region is characterized by the monsoon system, which is linked with various land-ocean phenomena operating over distant regions. In view of this, long term climate records from the Indian region are expected to provide useful database for global change studies. We present here the recent achievements in tree ring researches and their potential application in climate change studies in India.

Various tree species growing in peninsular and extra-peninsular regions in India are known to produce distinct, precisely datable growth rings. Though many such tree species are known to live longer than millennium years, their current availability is highly constrained due to heavy exploitation of forest resources. From the peninsular region natural teak forests have almost disappeared and are replaced with recent plantations, the oldest being at Nilambur in Kerala which were raised way back around 1840s. The longest chronology of teak (590-2000 A.D.) prepared so far is from Kerala (Shah 2005). This chronology is expected to provide valuable information on early summer monsoon (May-June) variations.

The western Himalayan region has been extensively explored in recent years for tree ring studies. The tree ring chronologies of various species, viz. *Abies pindrow*, *A. spectabilis*, *Cedrus deodara*, *Juniperus macropoda*, *Pinus gerardiana*, *P. roxburghii*, *P. wallichiana* and *Taxus baccata,* have been prepared from different forest stands with distinct environmental conditions. The longest ever prepared tree ring chronology is of Himalayan cedar (747-2003 A.D.) and Himalayan pencil cedar (420-2003 A.D.). There is still fair possibility of extending these chronologies by using tree ring samples from snags, river driftwoods and timbers used in old buildings.

The tree ring chronologies largely developed from the western Himalayan region, irrespective of species, show that the growth of trees are largely favoured by cool and wet conditions during the premonsoon, when growth usually starts in trees even up to their upper sub alpine limits. This offers the potential to develop multicentury to millennia long climatic reconstructions. The climate reconstructions so far developed from the western Himalayan region are for mean premonsoon temperature. Irrespective of their length, the climatic reconstructions from the western Himalayan region, developed by various authors, show strong consistency on decadal to inter-decadal scale, thus cross-verifying each other. The longest ever published mean premonsoon temperature reconstruction, based on tree ring width chronology developed from an ensemble of tree samples longer than 500 years length pooled from network of 16 homogeneous sites in western Himalaya, extends back to 1226 A.D. (Figure 1). This multicentury long mean premonsoon temperature reconstruction (1226-2000 A.D.) shows strong variability during the Little Ice Age (LIA). The temperature records do not show long term century scale cooling during the Little Ice Age (LIA), the term largely used for the period showing large scale glacier expansion in Western Europe. For this, it could also be stated that the LIA might have been a minor event in the western Himalayan region at least for the premonsoon for which the temperature reconstructions are available. Recent data emerged from wide geographic regions show large scale variability in climate during this period. For this reason, many cilmatologists express reservation over the usage of the term LIA.

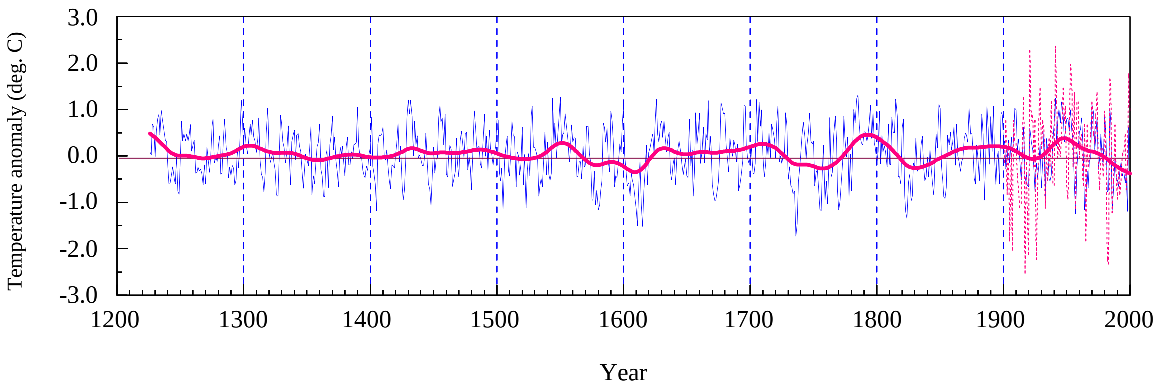

Figure 1. Premonsoon summer temperature reconstruction (1226-2000 A.D.) for western Himalaya. Anomalies are relative to 1961-1990 mean. The dotted curve is instrumental data superimposed over the reconstructed one. The thick smooth line represents the 50-year spline curve with 50% frequency response cut off (after Yadav *et al.* 2004)

The mean 20th century temperature records, both instrumental and proxy, of the western Himalayan region do not show warming as indicated over high latitude regions. The reason for this has been implicated to be the decreasing trend in minimum temperature since 1960s. Contrary to this the minimum temperatures have increased globally even at higher pace as compared to the maximum temperature.

Compared to temperature reconstructions from tree rings, the precipitation reconstructions for the Himalayan region are few. This is largely due to strong topography forced spatial variability in precipitation. The precipitation records of low elevation weather stations usually do not represent the precipitation over high elevation tree ring sites. Due to this, tree ring data from sites far from the weather stations result in poor calibrations.

The chronologies prepared from the eastern Himalayan region are few and not well replicated yet. However, the tree-ring studies of *Larix griffithiana* and *Abies densa* have shown strong potential for reconstructing summer temperature. Robust climatic reconstructions based on network of such tree ring data should be very useful to understand climatic changes in context of the past several centuries.

Though the potential of stable isotopes in dendroclimatology in India has been well recognized, much work remains to be done to get valuable data worthy of interlinking with other proxies.

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LATE ABSTRACT

DIVERSITY IN INDIAN LEGUMES: PRESENT STATUS

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Leguminosae (*nom. alt.* Fabaceae) or the 'Legume family', comprising about 19,000 species in 850 genera, is the third largest family of Angiosperms in the world. The family includes a range of life forms from small herbs, climbers, shrubs, huge lianas to gigantic trees, and is characterized by the presence of pods of various shape and size. They are important components of almost all the terrestrial ecosystems across the world, but show maximum diversity in tropics and subtropics with their principal centers of diversity and distribution being Africa and South America. Legumes are highly important, both economically and ecologically. They not only enrich soil through Nitrogen fixation, provide protein-rich food to man and his domesticates, yield invaluable industrial products like drugs, dyes, resins, tannins, gums, timber, etc., but also render aesthetics and beauty to the landscapes through a wide array of ornamentals. Because of their values to the mankind, the legumes have received much attention from the botanists across the globe.

In India the legumes are represented by about 199 genera and 1250 species (Sanjappa, 2001) distributed mostly in Peninsular India (550 species), Himalaya (500 species and the North-eastern India (400 species). Of these subfamily Caesalpinioideae comprises 32 genera and 175 species, subfamily Mimosoideae 23 genera and 175 species, whereas subfamily Papilionoideae comprises 144 genera and 902 species. Genus *Crotalaria*, with 97 species occurring in India, is the largest genus of legumes in the country followed by *Astragalus* with 85 species. On other end of the spectrum 83 genera of Indian legumes are represented by just a single species in the country. About 263 taxa or *ca* 21 per cent of the total Indian legumes are endemic to the country, including two genera, viz. *Hardwickia* and *Moullava*, both monotypic. Another genus *Humboldtia*, which is represented by six species in world, has five species endemic to South Western Ghats, whereas the sixth species extends to Sri Lanka as well. Occurrence of about 65 species of fossil legumes, referable to over 30 extant genera, like *Albizia, Cassia, Cynometra, Kingiodendron, Milletia,* etc. (Awasthi, 1992), further suggest the indigenous nature of Indian legume flora. Whereas, Indian legume fossils referable to African genera *Baphia, Isoberlinia, Tetrapleura,* and Malaysian *Koompassia* indicate a closer phytogeographical affinity between these regions.

This rich diversity in Indian legumes, notwithstanding, about 77 species of Indian legumes, including critically endangered taxa, like *Cynometra bourdilloni, C. beddomei, C. travancorica, Dialium travancoricum, Gleditsia assamica, Gymnocladus assamicus, Humboldtia bourdilloni, H. decurrens, H. unijuga, Inga cyanometrioides, Kingiodendron pinnatum, Pterocarpus santalinus*, etc. are threatened today (Rao et al., 2003), because of various anthropogenic influences on biodiversity. The Botanical Survey of India, through intensive field surveys, has been able to relocate some such species in wild in recent years and has brought about 40 endangered and endemic legumes under *ex situ* conservation in its various experimental botanic gardens located in different bio-geographic regions across the country.

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