TWENTYSIXTH
SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE

GROWTH OF PALAEOBOTANY IN RELATION TO BIOSTRATIGRAPHY OF INDIA

BY

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INTRODUCTION

ALBERT Charles Seward was such a distinguished palaeobotanist-cum-geologist that it is a privilege to be asked to deliver a lecture associated with his name. Judging from the galaxy of scholars who have preceded me for this lecture ever since its inception in 1953, I am fully conscious of the onerous responsibility imposed on me, and of my limitations in discharging the same.

Sir Albert Seward was born in 1863, and joined the Cambridge University in 1890 as a Lecturer and rose steadily to be its Vice-Chancellor in 1925. For some times he rendered double service to the University and also as a Master of Downing College. A dominating personality in the world of science for nearly half a century, Seward was elected President of the Geological Society of London in 1922, President of the 5th International Botanical Congress held at Amsterdam in 1935 and President of the British Association for the Advancement of Science.

Noteworthy, however, is his part in furthering progress of palaeobotany by helping young men to become active workers on the subject and among those who under his guidance later became internationally famous plant morphologists and biogeochronologists, mention may be made of Birbal Sahni, Hamshaw Thomas, John Walton, Harry Godwin and Tom Harris (the latter two of whom are still with us), and it is through them that the present day palaeobotanists and biostratigraphers of India and other countries, realize and recognize the deep debt of gratitude that they owe to Seward.

When I was an undergraduate student in Geology at the Presidency College, Calcutta in the mid-twenties, I was for the first time introduced to Sir Albert through his monumental work '*Fossil Plants*' in four volumes (1898-1919) by my teacher, the late Professor Hem Chandra Das Gupta. Seward was a histriographer *par excellence* of palaeobotany and although his " Fossil Plants " is in part out of date, it is still an essential book of reference in any palaeobotanical library, as is testified by a reprint of the four volumes in 1963 by Hafner of New York.

As Seward was specially interested in palaeobotanical studies in general, and India in particular, both in time and space, I feel that I may outline the " Growth of palaeobotany in relation to biostratigraphy of India" and choose this topic as the subject of my talk today.

EARLY HISTORY OF PALAEOBOTANICAL STUDIES IN INDIA

Palaeobotanical studies in India was started in right earnest with the formation of the Geological Survey of India in 1851, and its first Superintendent Thomas Oldham initiated the *Memoirs* of the survey in 1856 to which, he in collaboration with Prof. J. Morris of London University, made valuable contributions in regard to the Jurassic flora of Rajmahal Hills in the series " Fossil flora of the Gondwana System " in 1863, being the volume 1, Part I of *Palaeontologia indica*.

It was, however, left to the Austrian Palaeobotanist, Ottokar Feistmantel, who joined the survey as palaeontologist in 1875, to lay the foundation of Indian Palaeobotany. His monumental works in the subsequent volumes of *Palaeontologia indica*, published between 1877-1886, are well known. These volumes contain detailed enumeration of the plant fossils discovered till then with accurate illustrations drawn by artists from Bengal. It was Feistmantel, who for the first time applied palaeobotany to biostratigraphic classification in India with respect to the Gondwanas and the classification of the Gondwana System as proposed by him, has stood the test of time, as evidences adduced by the scholars of this Institute have amply demonstrated

After the retirement of Feistmantel in 1885 and till the return of Birbal Sahni from Cambridge in 1919, there was an ebb in activity in palaeobotanical researches in India, with only sporadic contributions by R. D. Oldham, H. H. Hayden, E. W. Vredenburg and G. de P. Cotter of the GeologicalSurvey of India.

A redeeming feature, however, was that within this period palaeobotany as a subject of study was introduced perhaps for the first time in India, in the curricula for the M.A. degree in Botany and Geology of the Calcutta University in 1895. 'Fossil Botany' by H. Graf Zu Solms Laubach, Professor in the University of Göttingen, published in 1887 and a revised and english translation of this book by Sir Isaac Bayley Balfour of Edinburgh issued in 1891, was recommended by the Calcutta University as a text book. Feistmantel's researches and other works on Indian flora available till then were duly incorporated in this book.

During the first quarter of the present century specimens of plant fossils from India found their way abroad for study by Arber, Seward and Walton in U.K., Zeiller in France and others.

Seward's investigations on the flora of Afghanistan, Afghan-Turkestan, Assam and Kashmir appeared in several issues of the *Memoirs and Records* of the Geological Survey of India.

At the request of Prof. Seward, the geological Survey of India loaned some of the specimens described and figured by Feistmantel for a restudy. Seward in the early stages of this work was only assisted by Miss Ruth Holden, a graduate of Harvard University and a resident at Newnham College, Cambridge who got herself interested in the study of cuticles of Indian conifers, and Palaeozoic stems of India, published in the *Annals of Botany*. Strong sense of duty led her to join a British Medical Unit in Russia in December 1916 during World War I where she died in April 1917.

Birbal Sahni in the course of his association with Seward took up along with him the revision of the Indian Gondwana Plants and this work was completed by April, 1919 and was published in *Palaeontologia indica* in 1921. Prof. Sahni meanwhile returned to India to join the Banaras Hindu University as a Professor of Botany, in 1920.

It was thus not till after World War I, that the study of fossil plants was revived in India by Prof. Sahni, inspired by that doyen of Palaeobotanist, Sir Albert Seward.

INITIATION OF THE APPLICATION OF PALYNOLOGY IN BIOSTRATIGRAPHY

In 1937, I joined the teaching staff of the Botany Department of the Calcutta University and inspired by Prof. Sahni to take up palaeobotany as my subject. Sahni's review on India's fossil flora in his presidential address to the Botany Section of the Indian Science Congress in 1938, formed the basis of our teaching work on Indian fossil flora both in its botanical and geological aspects.

At about this time, Miss Chenna Virkki (Mrs Jacob) was studying the Gondwana Permian miospore complexes under Birbal Sahni at Lucknow University. She extended her work in a monograph on spores from the Lower Gondwana of India and Australia that formed an important landmark in the history of Permian palynology.

She instituted the genus *Pityosporites sewardi* Virkki in 1937 from the Lower Gondwana rocks above the Talchir Boulder bed.

It may be recalled, Seward instituted the genus *Pityosporites* in 1914, based on his studies on the Antarctic fossil plants, of the British Antarctic (Terra Nova) expedition 1910 and referred to as *Pityosporites antarcticus* Seward.

In 1940, Sahni emphasized " urgent need in India for a thorough study on a large scale of the spores and cuticles of Indian fossil plants, particularly of those from the Lower Gondwana which contain such a vast proportion of our most valuable coals." His call for such study was widely welcomed and resulted in attracting attention in India to their importance in stratigraphy, and the late Dr J. Sen, while yet a post-graduate student in the Calcutta University, working on palynology of Raniganj Coalfield, showed perhaps for the first time in India the application of palynology in stratigraphical geology while correlating the Satpukhuriya, Ghusick and associated seams in 1944.

Further studies lead to a long controversy about the age of the Salt Range Saline Series, in which Sahni played the leading role. Although the Saline Series is now in Pakistan, our interest therein can not flag. The latest work on this problem is that of the German geologists O. H. Schindewolf and A. Seilecher (1955), who favour a Cambrian age purely on sedimentological evidence. The microbotanical evidence put forward in the two Symposia in 1944 and 1946, sponsored by Sahni raised a host of geological and palaeobotanical problems of a more fundamental character envisaging a new line of approach.

Plant fossils are known to occur from Pre-Cambrian to Sub-recent formations. Though they are recorded from so many formations, their application to biostratigraphic classification in India in early years had been mostly confined in respect of the Gondwanas and the Tertiary formations. For the Gondwanas, this is mainly due to the abundance of fossil plants and comparative paucity of other organic remains. In the oil fields, correlation of Tertiary horizons demanded a superior precision and palaeogeography was an important objective. Palynological studies provided the answer.

The Burmah Oil Company Limited sponsored a project under Prof. Birbal Sahni, with a view to find out whether the study of microfossils could assist in the correlation of the Tertiary succession of Assam — Arakan basin, in quest for oil.

Recognizing the importance of geochronological studies, and at the invitation of the Committee on Measurement of Geological Time in India of the Council of Scientific and Industrial Research, for a scheme to organize, systematize and finance research on the subject Professor Birbal Sahni drew out a plan in 1946 for research on the determination of the age of Indian sedimentary rocks containing microfossils but not megafossils.

A palaeobotanical research scheme was initiated by Prof. Sahni in the Department of Botany of the Lucknow University and later in the Birbal Sahni Institute of Palaeobotany.

I may now proceed to review chronologically the progress made since then on palaeobotanical studies in relation to biostratigraphy in India.

PRE-CAMBRIAN SHIELD

The absence of fossil occurrences in the first few million years of earth's history encompassing the Pre-Cambrian Era was until recently an accepted fact.

The Pre-Cambrian includes the earliest seven-eight of the geologic time during which period primitive life originated and organized itself into multicellular life and it is here that vigorous search has been made in recent years of their biologic activity. A large period of geologic time covering the so-called Azoic is now conclusively proved to contain undisputed imprints of life which necessitates a detailed palynostratigraphic studies on the Azoic-Proterozoic sediments.

The Pre-Cambrian shield in peninsular India is widely distributed in Rajasthan, Orissa, Andhra Pradesh, Mysore and adjoining regions. The rocks ranging in age from Dharwars, Cuddapahs, Vindhyans, Cambrians have been palynologically investigated by various workers, since I had reported the occurrence of microfossils from Vindhyans in 1950

Palaeobotanical and palynological works have evolved around the acritarchal and algal remains from the Pre-Cambrian of India. Gowda and Sreenivasa (1969) reported an assemblage of microfossils from the G.R. Formation of Dharwar, consisting of the group *Acritarcha* Evitt, Denuffie & Downie. The organic fossils discovered come from an age group of 2,000-1,400 million years based on the homotaxial relationship.

Gowda (1970) discovered similar algal remains in the Chert members of Dodguni Series in *Chitaldrug* Schist belt of 2,450 million years which are the oldest fossils recorded from India.

In the variety of material seen and in the excellent mode of preservation, the flora discovered in this Archean complex of Mysore has become the most interesting of the undoubted algal flora known from the late Pre-Cambrian deposits of the world.

Subsequently, Venkatachala and Rawat (1974) described a diversified biota from Dharwar-Shimoga Schist belt containing acritarchs, and Cyanophyceae (Chroococalean) algae, spores, algal filaments, etc. In search of microfossils from Dharwar, Ghosh and Bose as early as 1954 examined rock specimens belonging to the Kumarmunda Stage of the Gangpur Series and the Kolhan Series. The microfossils recovered include scalariform and apparently simple pitted wood elements together with four types of spores amongst which monolete ones are noteworthy.

The conclusions drawn by me that had not met with unanimous agreement had always aroused interest and formed valuable contributions to the discussions of important problems of phylogeny and stratigraphy.

Sahni and Srivastava (1962) recovered microspores of primitive vascular and non-vascular plants from the Cuddapah rocks of Madhya Pradesh which indicates that lycopsids and sphenopsids were evolved as early as the Pre-Cambrian These studies have a great bearing and prospects of palynological studies in solving the stratigraphic problems of these ancient sediments.

The Vindhyan sediments covering a large area in Central India remain to a great extent unfossiliferous. Search for remains of life in these sediments centred around the nature of the discoidal remains discovered by Jones (1909). M. R. Sahni (1936) reported *Fermoria minima* and several investigators reported microfossils from different localities. Maithy (1968) recorded *Tasmanites* from the Kaimur Series of Madhya Pradesh. *Tasmanites* previously referred to acritarchs are now attributed to a group of unicellular marine alga, Parsinophyceae. This class was proposed as a result of discovery of using electron microscopy.

Salujha *et al.* (1969-71) recorded acritarchs and algal remains and conclude that Vindhyan sequence ranges in age from Pre-Cambrian — Early Silurian. The fossil contents of Bhimas and Kurnools are similar to those recorded from the Lower Vindhyan (Early — Late Cambrian).

A recent tool in hand in biogeochronological studies is the stromatolite abounding in Pre-Cambrian shield.

Dating as indicated by microfossils for the Vindhyans is at variance with the radiometric dating by Crawford and others.

Extensive studies on the dating of Vindhyans and the Pre-Cambrian sediments on the basis of potassium-argon method carried out in Cambridge by Prof. S. N. Sarkar indicate the age of Vindhyans, somewhere between 1,100 and 900 million years. In the light of this, the plant fossils recorded in the Vindhyans needs re-interpretation.

Normally we should expect geochronology and palaeontology to give concordant results. Any large disagreement suggests a more critical examination of the evidences from both sides and the apparent discrepancies, by different methods need to be reconciled by the Co-ordination Committee on geochronology under the Central Geological Programming Board.

It is indeed encouraging to see the establishment of a C-14 laboratory in this institute as a prelude to other similar methods needed at this time.

On the available radiometric dating and contained protistids, a tripartite division of the Proterozoic of India is attempted.

1. The oldest member, the G.R. Formation of Dharwar Systems (2.5×10^9) contain primitive unicellular material, notably cysts, spores and protistan resting stages called acritarchs of unknown affinities.

2. The Cuddapah (1.0×10^9-2.0×10^9) exhibiting sharply advanced biota is equated to middle Proterozoic.

3. Vindhyan (0.5×10^9-1.0×10^9) indicates the diversification of Thallophyte and development of multicellular organisms.

This tentative division is based on study of unicellular organisms, discoidal bodies of fungal origin, spores, various algae and stromatolites.

There is little doubt that absolute age determination with the help of various radioactive methods, represents a major breakthrough in the earth sciences although doubts have been expressed on its infallibility by Curtes and others while studying the Koobi Fora Formation of Kenya (1975).

The first indications of recorded life are thus about 2,000 million years old (blue-green algae, acritarchs) and around 1,500 million years ago colonies of algae (stromatolites) appear to have made their debut in the geological record.

EARLY PALAEOZOIC FLORAS

The existence of land plants in the Spiti Valley, Punjab Himalayas was alluded to by Sahni for the first time in 1938, based on the collections made by Hayden and Von Krafts of the Geological Survey of India. A posthumous paper by Sahni (1953) gave the details of the possible existence of Psilophytales in India.

Gupta (1967) reported the existence of *Psilophyton princeps* occurring in arenaceous shales lying between fossiliferous Upper Silurian shales and Middle Devonian quartzites of the Spiti Valley of Punjab Himalayas.

In recent years, A. K. Pal of the Geological Survey of India has been working on the Palaeozoic biostratigraphy of Kashmir Himalaya. He discovered a series of plant beds in Devonian and Carboniferous of Kashmir and the results suggest that Devonian-Carboniferous of Kashmir represent a dominantly continental facies with several marine transgressions (as opposed to the prevalent view of their being entirely marine). I had an opportunity to see some of his materials and photographs which are very convincing. The plant fossils are clearly of Northern Continent affinity and the possibility of these horizons being in continuity with the Northern Continent may not be very easy to rule out. These beds are followed by plant bearing horizon of the well known Lower Carboniferous *Rhaeopteris ovata* flora.

The northern record is rich and varied as compared to the southern. If the continents had already occupied in the Lower Carboniferous the position postulated by the drift theory, it is difficult to imagine that these delicate plants were able to survive the physical barriers and different climatic belts in migrating from the north to the south or it is that the plants at this time had reached more or less the same stage of evolution in different parts of the world and as Plumstead suggested they were derived from similar ancestral stocks of algal origin and developed independently.

Kapoor (1969) of the Geological Survey of India has recorded additional evidences of admixture of *Lepidodendron*, *Lepidostrobus*, etc. in the Mammal area of Kashmir.

Earlier Tiwari (1965) reported *Lepidostrobus* from the same horizon in Kashmir.

These studies reveal the existence of early Palaeozoic flora in India and its relationship with the contemporaneous flora of Europe.

Although Pre-Gondwana rocks of India consists of thick sedimentary deposits, the records of land plants are very few. The paucity of fossils calls for more extensive search for the plant remains in these rock formations.

PALYNOSTRATIGRAPHY OF THE BLAINIS AND KROLS

Up to 1974, when a symposium on Blainis and related formations was held at Chandigarh under the auspices of the Indian Geologists Association, no fossil had been reported from the Blainis themselves. A rich assemblage of palynomorphs and acritarchs has been reported by Shrivastava and Venkataraman (1975) from shale samples of Blaini Formation. The occurrence of such short ranging sporomorphs as *Densosporites* sp., *Tripartites* sp., *Triquitrites* sp. and *Latosporites* sp. confirms a Lower to Upper Carboniferous age for the Blaini Formation.

Forms belonging to the Northern flora have not been reported so far from the southern hemisphere. The presence of northern floral elements in the Blaini shales indicate that the basin of deposition was not very far from the northern continent, postulating a major change from south to north and supporting the theory of continental drift.

Prasad and Bhatia (1975) reported tracheids, foraminifera, dinoflagellate algae, ostracode and radiolaria from Blaini tillite horizon of Simla Hills suggestive of a Permo-Carboniferous age for the Blainis.

Palaeontological evidence from the Infra-Blaini sediments by Powar and Phansalkar (1971), viz., remains of gymnosperm wood from the phyllites of undifferentiated Chandpur-Nagthat Formation of Kumaon of Post-Devonian confirms Auden's views about Jaunsars being of Devonian age.

Various attempts had been made since long to fit in the stratigraphical position of Krol Series which is a thick group of massive blue limestone and shales, uncertain by partly consolidated coarse sandstones and are exposed in the foot hill of Himalayas over the Blaini conglomerates and under the Tal Formation. Ghosh and Srivastava (1962) studied Infra-Krols, Krols and Tals of the Mussorie Syncline. They could get polospore which were quite helpful in setting the stratigraphical problem of this series.

On the evidence of Schizeaceous spores Tals are considered as of Jurassic age. The Krol with a preponderance of leptosporangiate fern spores and coniferous pollen are indicative of Triassic age. On a reappraisal of the data subsequently, Sah, Venkatachala and Lakhanpal (1968) on the dominance of nonstriate-bisaccate pollen confirmed the Krols to be of lowermost Triassic, substantiated by such marker types as the abundance of *Voltriacaesporites* and *Triadispora*.

Gundu Rao (1970) on the other hand reported the occurrence of oolites of algal origin and identified: *Volvatella vadosa*, *V. zonales*, *Ambigomellatus horridus*, *Vermiculites irregularis* and *Vesicularis bothrydioformis* from Krol C member of the Krol Formation. The oolites are believed to be of

Pre-Cambrian affinities and may be of Upper Pre-Cambrian in age.

Nannofossils of Jurassic affinity have been discovered from limestone and shales at the contact of B and C stages of Krols in the type area. The age of the Krols is thus a matter of long controversy.

GONDWANA

Palaeobotany has great significance in coal exploration. Correlation of coal seams of different areas, exploration of extensive of coal-bearing strata and even discovery of new coalfields have been achieved with the aid of palaeobotany.

Microfloristic study on the Lower Gondwana deposits has been made extensively in Lucknow and other centres. Bharadwaj and others attempted correlation of coal seams in the Raniganj, Korba, North Karanpura, South Karanpura, Singrauli, Chirimiri, Talchir, Bisrampur, Mohpani, Sohagpur and Baraboni coalfields.

From the exhaustive analyses of the microspores in six coal seams of South Karanpura Coalfield, two distinct biofacies could be evaluated. Miospore genera *Microfoveolatispora*, *Verrucosisporites*, *Indospora* and *Lahirites* constitute upper facies showing close resemblance to the Raniganj Stage. Miospore genera *Punctatisporites*, *Apiculatisporites*, *Didecitriletes* and *Deuletispora*, *Plicatipollenites*, *Cuneatipollenites*, *Gnetaceaepollenites* and *Welwetschiapites* representing lower facies show resemblance to miospore of definite Barakar Stage.

Although a beginning has been made, the finer sophisticated and dependable palynostratigraphic subdivisions of the entire Gondwana sequence is yet to be achieved. Efforts should be made with support from biometric study to establish phylogenetic trends of certain significant taxa, which would obviously be the most dependable time-lineages for widespread correlation.

A possible relationship is noticed among the striate-saccate grains of Lower Gondwana, with the contemporaneous Eu-American flora, though there is evidences of a more serious obstruction to plant migration from northern to the southern hemispheres in the Upper Carboniferous times. In Oklahoma (U.S.A.) the striate-saccate grains first occur in the Des Moines Series (Middle Pennsylvanian) and become abundant in the Missouri Series. In Gearyan Series, they are almost as abundant as in the Lower Permian. There exists an intimate genetic relationship between the microfossils and the petrographic components of coal. Palynopetrographic study is helpful to resolve the complex nature of coal. An integrated approach involving palynological, petrographical and chemical methods is envisaged.

A re-appraisal of the fossil flora of the Gondwanas in recent times and since the classical work of Feistmantel indicating its tripartite division, biostratigraphically the Gondwanas are divisible into five assemblage zones, that could be divided into further subzones. The assemblage zones are:

Gangamopteris Assemblage Zone	*Noeggerathiopsis-Paranocladus* subzone *Gondwanidium-Buriadia* subzone
Glossopteris Assemblage Zone	*Barakaria dichotoma-Walkomiella indica* subzone *Cyclodendron* subzone & *Glossopteris retifera-G conspicua* subzone
Labyrinthodont Assemblage Zone	
Dicroidium Assemblage Zone	
Ptilophyllum Assemblage Zone	*Dictyozamites-Pterophyllum* subzone *Pagiophyllum-Brachyphyllum* subzone *Weichselia-Onychiopsis* subzone

Surange and his school on *Glossopteris* flora have critically investigated and surveyed the vertical range and horizontal distribution of species in the Lower Gondwanas. The investigations carried out by K. R. Surange and D. C. Bharadwaj and their school during the last one or two decades have resolved the various aspects of historical geology, stratigraphy, palaeoclimate and palaeoecology of the Gondwana sequence. Palynological evidence has been adduced to confirm the occurrence of two glacial phases in the older horizons of the Lower Gondwana System of India and are within the Karharbari Stage. Although fossils have not yet been obtained directly from the boulder bed, there is some evidence to show that the flora almost co-existed with the Permo-Carboniferous glaciation in India.

MESOZOIC

A significant contribution in the Mesozoic stratigraphic palynology is the recognition of three palynological zones, viz., *Callialasporites segmentatus* zone of Upper Jurassic, *Microcachrydites antarcticus* zone of Neocomian, and *Coptospora cauveriana* zone of Aptian — Lower Albian ages in the subcrop sediments of Cauvery basin. These are quite extensive assemblage zones of Mesozoics of India which might be recorded in various basins, such as subcrop Godavari Mesozoic or Rajmahal outcrop.

Srivastava (1963) studied the flora of Lathi Formation of Rajasthan and compared with Rajmahal, Jabalpur, Salt Range, Ceylon, Australia, South Africa, Western Siberia and Canada and showed great similarity with the microflora of Australia, South Africa and Western Siberia, differing from that of the Rajmahal and Jabalpur floras.

It has been indicated that the lack of Palaeobotanical data from the Mesozoic of India and South Eastern China does not permit the establishment of the probable migration of the floral elements from some intermediate tropical region in order to explain the existence of common elements in the flora of Western Siberia and Australo-New Zealandian regions.

GANGA VALLEY

On the basis of palynological studies, it was suspected that the upper part of pre-Siwalik sequence in the Ujhani Well of Ganga Valley in Uttar Pradesh belongs to Mesozoic. A re-study of the microflora from rocks below the unconformity resulted in the discovery of primitive trace fossil of the genus *Diplocraterian* along with spores and pollen.

While the trace fossil in the pre-unconformity Pre-Siwalik rocks are indicative of Palaeozoic age, no satisfactory evidence is forthcoming on the invalidity of spores and pollen of post-Palaeozoic age in these beds. Like the Vindhyans and the Krols, the Ganga Valley data needs reinvestigation.

BAGH BEDS

The fresh-water and marine sediments of Upper Jurassic to Tertiary assigned to the so-called Bagh beds of the Narbada Valley in West Central India are well known in Indian stratigraphy for their rich faunal and floral contents. Of the fossil flora, algae are the most conspicuous in the Bagh beds. These contribute considerably to the limestone and percentage of algae by volume ranges from a low 2-3 per cent to high about 30 per cent. The genera recorded are *Parnocalculus*, *Arabicodium*, *Archaeolithothamnium*, *Distichoplax*, *Cayeuxia*, *Halimedia*, *Boueinia*, *Disocladelia*, *Oriporelia*, etc. *Cayeuxia fructilose*, a Codiacean algae belong to Maestrichtian age, while *Distichoplax*, an index fossil for Palaeocene calls for a revised biostratigraphy of the beds indicating seven biostratigraphic zonation with extension into the Palaeocene.

It is noted that several south Indian Cretaceous forms are common in the Bagh Group. It is suggested that the intermingling of the Bagh groups of the Narbada Valley and the Lower Cretaceous forms of South India took place along the passage which opened between India and Madagascar along the coasts of Cape Comorin and Ceylon with the commencement of the Aptian-Senonian transgression. The occurrence of several South Indian Cretaceous forms in the Bagh Group suggests that the latter is homataxial with the former.

A huge thickness of limestones having a profusion of calcareous algae have a direct bearing on the nature of the lime secreting algae in relation to the genesis of the algal limestones.

Kutch

Mathur and others (1970) established five distinct palynological assemblages ranging in age from Neocomian to late Senonian at various localities in Kutch in environments ranging from terrestrial to marine conditions. Presence or absence of *Weichselia* has been suggested as a criterion for the demarcation of Jurassic-Lower Cretaceous biostratigraphy by Bose (1966).

TERTIARY

Neyveli Lignite

The age of Neyveli Lignite, which occurs as a lenticular deposit within the Cuddalore Sandstone, has been so far held as Miocene along with the Cuddalore Sandstone. Not much work has been done to arrive at the age of this deposit. A critical comparison of the palynomorphs based on published materials as well as on those recovered from the lignite with those from the well-dated Eocene formations of different parts of India has been made. The result thereof reveals very close similarity of the bulk palynological assemblage of the two. This similarity obviously leads to surmise a broadly Eocene age of the Neyveli Lignite (Deb, Baksi & Ghosh, 1973). Venkatachala (1973) also supported this age independently. The characteristic elements of the Miocene palynoflora known to date from other parts of India are hardly represented in Neyveli Lignite. On analysis of the stratigraphic set up of this coastal basin, it is thought that Cuddalore Sandstone is a time transgressive unit covering a wide age-interval, in which Neyveli Lignite may be palynologically identified as Eocene. Numerous fossil logs that are known to be of post-Miocene age are thought to have occurred in the topmost part of the Cuddalore Sandstone.

Palynostratigraphic zonations of the subcrop of Cauvery Tertiaries have been established by Venkatachala *et al.* (1971). Lakhanpal (1974) attempted a broad palaeogeographical reconstruction of India during the Paleogene and Neogene times based on his study of the Tertiary flora.

Subathu

The Eocenes of the Himalayan foot-hills have assumed a great significance of intensive oil exploration since similar rocks of same age are producing oil in the Potwar plateau. The sediments known as Subathu extend as a narrow zone along the inner margin from Jammu in the north-west to as far south east as central Nepal.

While based on foraminifera the Subathus could be divided into zones extending from Upper Palaeocene to Upper Eocene, occurrence of *Proxapertites* sp. similar to that obtained from Jalangi in West Bengal is indicative of Lower Eocene. Besides, recovery of hystrichosphaerids in the Bilaspur-Dadahu region indicated shallow marine environment.

From further studies it is clear that Eocene sea did not extend in the present day plains of Uttar Pradesh and Nepal and in the outer foot-hills of Punjab.

Cambay and Bengal Basin

The geology of Bengal basin had remained practically obscure because of the thick alluvial cover. Palynographic studies on the cores recovered during deep drilling under Indo-Stanvac Project helped the establishment of Jurassic — Pleistocene succession in Bengal basin. The existence of Cretaceous-Lower Tertiary successions in Burdwan and Birbhum have also been substantiated by the Geological Survey of India under All-India Ground Water Exploration Project.

Palynology has helped remarkably in recent years in our biostratigraphic study, specially the groups nannoplanktons, dinoflagellates, acritarchs, diatoms, silicoflagellates, etc. It is now evident that spores and pollen are not lagging much behind the other long-reputed traditional animal microfossil, like foraminifera. Recognition of seven distinct palynological assemblage zones characterizing late Cretaceous, Palaeocene, Early Eocene, Oligocene, Miocene, Mio-Pliocene and Plio-Pleistocene in the subcrop-Cretaceous-Tertiary sediments of Bengal basin and their correlation with the rock units of the area seem to be a valuable contribution.

With the establishment of the Oil and Natural Gas Commission at Dehra Dun in 1956, my interest switched on mostly with Tertiary palynology in age determination, correlation and other biostratigraphic problems connected with oil exploration in Punjab, Himachal Pradesh, Saurashtra and Assam. By palynological studies, it was possible to determine the age and correlate the producing wells at Ankleshwar and Rudrasagar in Assam. Cambay basin is a long alluvium covered by semi-graben separating the main Indian Shield from the Saurashtra peninsula. The credit of discovery in this area in 1958 goes to Oil and Natural Gas Commission. This was an event of tremendous importance as it led to discover and develop a fairly large area of oil field, the most important of which is the Ankleshwar field (1959) and Bombay High.

In all these works, the field geological methods was backed up by petrological, palaeontological and palynological support.

Plants display remarkable specificities of environment. The flora in the Cambay basin (Kalol Formation) has been grouped into 15 plant communities, namely, montane, inland, freshwater, xerophytes, fern, palm, low salinity, pro-haline tidal mangrove, algal (*Pediastrum — Oudhkusumites* & *Botryococcus*), fungal, shallow marine, polyaperturates and reworked plant complexes.

Fourteen transgressive and regressive pulses have been interpreted. A fluvio-estuarine, littoral and near shore environment are envisaged.

The results of palynological studies on the subsurface Tertiary sediments from the Bodra Well no. 1 of the Port Canning Project indicate that the sediments are divisible into 3 distinct palynological zones with their contained microflora comparable with the Upper Tertiary microflora of Assam and West Bengal. The presence of two-winged conifer pollen and spores of the genus *Ceratopteris* and *Aneimia* in the Bodra Palynological Zone III recalls the microflora of Simsang Palynological Zone IV of Assam and also of the lower zone of Debagram Formation of West Bengal — these comparisons indicate a Miocene age of Zone III. Microflora of Bodra Zone II and Zone I may be compared with that of upper zone of Debagram Formation being represented by the dominant Dicksoniaceae and common Cyperaceae, Graminae and Coniferae. *Dicksonia* spores are restricted to Zone I while Graminae and Cyperaceae pollen occur only in Zone II. Zone II and I may be stated to range in age from Pliocene to Quaternary. The Miocene-Pliocene boundary falls between depths of 3,315 and 3,456 m.

Post-Miocene prospective area — Bodra, Bakultala, Diamond Harbour-silt-clay sand of marginal marine environment of Mio-Pliocene age constitutes about 5,000 m of thick sedimentary sequence of this basin.

Detailed litho-and biostratigraphic breakdown of this thick Mio-Pliocene sequence is yet to be achieved.

Abundant microplankton, rich vegetation, carbonaceous shales, carbonates and evidences of reducing environment of the Pliocene-Miocene sequence of this prospective basin induces to drill more wells for oil.

Correlation of Biostratigraphy of Siwaliks and Assam

Lower Siwalik & Girujan Clay Stage — The microfloral composition of the lower Siwalik and Girujan Clay Stage are closely comparable by their common elements.

Garo Hills

In the southern foothill of Shillong plateau of Garo hills whose prospective sediment of Palaeocene-Pliocene age are exposed, the sequence contains Rewak shales (source rocks) and Boldanguri sandstone (reservoir rocks).

The stratigraphic framework proposed have stood the test of time for the Oligocene — Miocene part of the succession but some revision have been necessary in the rocks below and above this range.

The work done so far has indicated that palynological data have considerable potentialities to a deeper knowledge of the Assam-Arakan Geology. Apart from the existence of large anticlines, most other favourable factors are present for accumulation of oil in the subsurface Eocene rocks in the South Shillong plateau.

A well drilled at Baghmara near the border between India and Bangladesh revealed the presence of algal limestones. Palaeogene rocks are exposed and covered by younger Kopilis.

Discovery of oil at Kharsang of Arunachal Pradesh at 2,850 m which belong to Tipam group of Miocene.

It is of interest that indications of oil have been found in even younger wells (Namsang beds) in a well drilled beyond the Digboi-Jaipur line of folding.

Apart from correlation of wells, palynological data obtained from Cretaceous to Sub-Recent times has thrown new light on the distribution of flora during the Tertiary times and its bearing on the evolution of the present day flora.

QUATERNARY

Within a thickness of over a thousand feet of quaternary deposits, there are three or four glacial horizons, corresponding to those in the Pleistocene of Europe. Vast thickness of sediments indicated as Quaternary in Indian Geology without any fossil evidences, are areas where we may divert our attention. It needs a multidisciplinary approach. A beginning has been made and it would be interesting to know more about our immediate past.

Who knows if the present age is nothing but the phase of an interglacial period ?

I express my sincere thanks to the authorities of the Birbal Sahni Institute of Palaeobotany to have given me this opportunity to pay my respectful homage to the memory of Sir Albert Charles Seward and the founder of this Institute Professor Birbal Sahni.