SIXTEENTH
SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE
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ROLE OF PALAEOBOTANY IN INDIAN GEOLOGY

BY

G. C. CHATERJI
Geological Survey of India

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ABSTRACT

Palaeobotanical studies in India date back to the third decade of the nineteenth century. Since then there have been significant contributions of critical importance to Indian stratigraphy, of which, of course, the studies on Gondwana flora far outshine others. Sir Albert Charles Seward and Professor Birbal Sahni were the first to modernize the studies on Gondwana flora, and tributes are offered to both of them.

Plant fossils from the earliest Cambrian to the Pleistocene have been recorded from various stratigraphic horizons in India, and studies on the same are to be intensified. Such studies have already helped in palaeoecological interpretations regarding the Gondwana Era and parts of the Tertiary period. Further studies are urgently needed to fill in the blanks in the reconstructed geological history.

Application of palaeobotanical studies in the scientific exploration and development of coal, petroleum and diatomaceous earth has already attained much success in India and abroad. The scope of research in this domain is ever expanding, and the extension of such studies to the problems of exploration of phosphorites and gypsum may prove to be fruitful.

Future studies in palaeobotany in India could pay some more attention to the problems pertaining to the remnants of earliest psilophyton flora, microflora of the Gondwana formations, floral evidence on Permo-Triassic boundary and the search of micro-flora in the so-called unfossiliferous formations of the Himalaya. A greater emphasis on the study of microflora of the Tertiary formations is due, and activities have accelerated in this direction. Simultaneously with these the history of evolution of plant life through the ages need to be reviewed with greater precision This may have important implications in regard to planetary evolution.

Modern researches in palaeobotany tend to be more botanically oriented. The geologists, in their search for evidences to reconstruct the history of the earth, are looking forward to ever increasing contributions from the palaeobotanists who may, therefore, devote some more time to the geological aspects of the fossil plants.

Introduction

I EXPRESS my sincere thanks to the authorities of the Birbal Sahni Institute of Palaeobotany for inviting me to deliver the Sixteenth Sir Albert Charles Seward Memorial Lecture.

Sir Albert Charles Seward, Master of Downing College and Professor of Botany, Cambridge, shone like the most dominant star in the domain of palaeobotany for over two decades. His classical treatise on fossil plants perhaps laid the foundation of this science in the sense that he had systematized the observations of decades. He followed up this grand endeavour with a general review of the flora of the past. He wanted this review to be an immensely enjoyable work, as he had always felt that the earlier masterpiece of his was tainted with touches of unintelligible pedantic intricacies. You would, I am sure, agree with me that he had succeeded with consummate ease. He had looked upon the earth as a live canvas of fascinating changes, a nursery of nature's experiments, as also did Robert Bridges in a different form. Though he delved deep into the traces left by remnants of past events, his mind had travelled ever and ever wider into the future of human imagination. Perhaps he had the same philosophy to believe that one is blessed over all mortals who loses no moment of the passing life in remembering the past.

I feel compelled to project these resplendent leaves out of Sir Albert's life just to resuscitate our own selves with the spirit of devotion, stimulating comradeship and exalted philosophical orientation of mind, which characterized the actions and life of Sir Albert Charles Seward.

It is a tradition to devote this talk to a subject pertaining to palaeobotany As I am not a palaeobotanist by profession, but, one whose profession kept him very close to this science, I would take this opportunity of tracing the role of palaeobotany in Indian geology, and concurrently try to indicate some of the avenues where assistance from palaeobotanists is uregently needed.

Palaeobotany has acquired a place of distinction in the geology of our country from the very early days. The history of palaeobotanical research dates back to 1828 when Brongniart described some fossil plants from the Lower Gondwanas of India. Thereafter an accont of studies on Indian Gondwanas in the form of a memoir was initiated by Oldham and Morris (1863) This was elaborated to a great extent by Feistmantel (1876-86) who described the fossils from most of the horizons of Lower as well as Upper Gondwanas. Then Zeiller (1902) and Arber (1905) elaborated this study, and revised the account on Gondwana fossil flora. The most notable contribution since then came from Seward and Sahni (1920), who reanalysed the information on Gondwana flora on modern lines. Sahni persistently explored newer and newer fields in palaeobotany; and it was he who gave the modern shape to it. One of the fruits of endless efforts of Sahni, the father of palaeobotany in India, is the Institute which is advancing the cause of palaeobotany further.

Palaeobotany has not only enriched geology in India, but it has also distinguished Indian stratigraphy in the realm of world stratigraphy, especially in the domain of Gondwana stratigraphy. There has, therefore, been a superb start and thrilling impetus which palaeobotanical studies have enjoyed in India. In a retrospective vein I would now recount some of the outstanding contributions of this science to geology of India to indicate the future possibilities and the gaps which remain to be bridged.

Palaeobotany and Indian Stratigraphy

Plant fossils are known to occur from Pre-Cambrian to Sub-Recent formations (Table 1). Though they are recorded from so many formations, their application to biostratigraphic classification in India has so far been done in respect of the Gondwanas and some Tertiary formations only. For the Gondwanas this is mainly due to the abundance of fossil plants and comparative paucity of other organic remains. In the oilfields correlations of Tertiary horizons demanded a superior precision, and palaeogeography was also an important objective. Palynological studies provided the answers, though much of this information is still confined to unpublished records.

The Gondwana Era embraces a long range in geological time scale, i.e. from the Upper Carboniferous to Lower or Middle Cretaceous in India. The formidable thickness of nearly 6,600 metres of Gondwana strata could be successfully classified only on the evidences afforded by fossil plants. The salient points of this study which made the classification feasible are shown in Table 2.

Study of fossil plants from several other formations has not so far helped biostratigraphically, but has at least provided some basis for fixation of their ages. I would like to refer to a few examples.

Vindhyan formations contain spores of fungi and fragments of vascular plants. Recent studies on this microfloral assemblage indicate a Cambrian rather than the hitherto supposed Proterozoic age for them (Howell, 1956).

The plant assemblage of Thabo Stage (Po Series) in Spiti studied by Gothan and

TABLE 1 — MAJOR GEOLOGICAL PLANT-BEARING FORMATIONS OF INDIA

Standard scale			Peninsular India	Extra-Peninsular India
Pleistocene, Pliocene			Cave deposits and river terraces	Karewas of Kashmir
Miocene			Cuddalore Sandstone, Rajamahendri Sandstone, Warkalli Bed and Durgapur Beds, etc.	Siwaliks, Dupitila, Dihing
Oligocene				
Eocene			Intertrappean beds	Kasauli
Cretaceous			Himmatnagar Sst., Wadhwan Sst., Barmer Sst., Lameta beds, Cretaceous of Trichinopoly	
Jurassic	GONDWANAS	*Upper*	Nimmar Sst., Bhuj, Jabalpur, Kota, Rajmahal, Mahadevas, Parsora	Jurassic of Salt Range
Triassic	GONDWANAS	*Lower*	Panchet	Triassic of Salt Range
Permian	GONDWANAS	*Lower*	Raniganj, Barren Measures, Barakar, Karharbari, Talchir	Undifferentiated Damudas of Himalayas
Carboniferous Silurian-Devonian				Po Series (Thabo State) Silurian-Devonian of Salt Range
Cambrian		*Puranas*	Vindhyans	Cambrian of Salt Range
Pre-Cambrian		*Puranas*	Cuddapahs	Buxa Series

TABLE 2 — PLANT ASSEMBLAGES AS USED IN CLASSIFICATION OF GONDWANAS

Gondwana Division		Characteristic Plant Assemblages
Jabalpur Series	Bhuj beds, Jabalpur	Abundance of Conifers followed by Pteridophytes and Cycads
Rajmahal Series	Kota, Rajmahal	Abundance of Cycadophytes followed by Preridophytes and Conifers
Mahadeva Series	Maleri, Panchmarhi	No evidence of plant remains available
Panchet Series	Deoli Stage Maitur stage	Glossopteris flora continues, in addition some forms like *Cyclopteris*, *Pachyrachis*, *Pecopteris concinna* and *Dicroidium* appear
Damuda Series	Raniganj, Barren Mea-Measures, Barakar, Karharbari	Abundance of Pteridosperms (*Glossopteris*) along with Palaeozoic ferns, Equisetales with a few Cycads and Conifers
Talchir Series	Talchir shales, Boulder bed	Abundance of *Gangamopteris* and *Noeggerathiopsis* along with other Filicales

Sahni (1937) indicates a Middle Carboniferous age for this stage.

The discovery of Ptilophyllum flora in the lower part of the Nimar Sandstones in Madhya Pradesh, according to the recent unpublished work of Das Sarma and Sinha of Geological Survey of India, reveals closer time-relations of the Lower Nimars with members of the Upper Gondwanas rather than with the marine Bagh Beds.

Himmatnagar Sandstone, Dhrangadhra Beds, Wadhwan Sandstone and Barmer Sandstone of Western India have all been assigned to the Cretaceous only on the basis of floral evidences (Sahni, 1936a).

Several scattered patches of Middle to Upper Tertiary deposits are developed along the east and west coasts of India which are designated as Cuddalore Sandstone, Rajamahendri Sandstone, Warkalli Beds, etc. All these contain plant fossils which have helped in determining their position in the stratigraphic column. Of late fossil fruits and seeds namely *Nyassa* (Pl. 1, Fig. 1) and *Terminalia* (Pl. 1, Fig. 2) have been identified from the Miocenes of Ratnagiri Coast. The stratigraphic position of the Cherra Sandstones has also been largely determined by the plant fossils of the same.

The geology of Bengal Basin had remained practically obscure because of the thick alluvial cover. Palynological studies on the cores recovered during deep drilling under Indo-Stanvac Project helped the establishment of Jurassic-Pleistocene succession in Bengal Basin. Geological Survey of India have also done a good deal of drilling in different parts of West Bengal and the adjacent east coast under the All-India Groundwater Exploration Project and for other explorations. The cores and cuttings have been palynologically studied. The existence of Cretaceous — Lower Tertiary sequences in Burdwan and Birbhum and other parts of the State has also been substantiated; and the Plio-Pleistocene sequences have been outlined.

The presence of Lower Gondwanas was suspected in the Chingleput district of Madras State, which naturally evoked considerable interest because of the usual fossil-fuel content in them. The fossil plants of the cores and cuttings recovered during drilling tend, however, to place them in the Upper Gondwana age.

Palaeobotany and Palaeoecology

It is well known that plants are good indicators of climate and environments. Plant fossils have greatly helped in interpretations regarding palaeoclimate and other aspects of palaeogeography like existence of intercontinental landbridges in the geological past.

The Spiti area remained under the sea for most of the geological time. But portions of Silurian-Devonian formations of this area yielded fossil plants which incidentally happen to be the earliest record of definite land plants in India. This indicates that land conditions existed there, though temporarily, during those periods. Evidences on the existence of variable land conditions in the Himalayan region in the succeeding geological periods are also provided by the results of the studies on the plant fossils of Thabo Stage (base of the Po Series) of Carboniferous age which has yielded the cosmopolitan Rhacopteris flora (Gothan & Sahni, 1937).

Palaeogeographically, the presence of Lower Gondwana flora in the Himalayan region is of great significance, as it demonstrates the northward extension of the Gondwanaland. During the Lower Gondwana period the existence of four major botanical provinces is envisaged. These are Euro-American flora, Angaraland flora, Cathaysian flora and Gondwanaland flora. Studies of the Gangamopteris-Beds of Kashmir have indicated an admixture of Angaraland floral elements and Gondwanaland flora. Recently Kapoor of Geological Survey of India has recorded additional evidences of admixture of *Lepidodendron*, *Lepidostrobus*, *Kawizozamites*, etc., in the Mamal area of Kashmir. These imply the presence of land connections between these two continents of that period through Kashmir. Similarly the admixture of Glossopteris floral elements like *Schizoneura*, *Rhipidopsis*, *Glossopteris* and *Palaeovittaria* with Cathaysian flora has been reported by Kon'no (1966). This suggests the eastward migration of Glossopteris floral elements across the Tethys, possibly through the northeastern part of India. An intensive search of the Permian horizons in this part of the Himalaya may also show similar admixture of elements of different affinities. This eventually may throw light on the configuration of the land connections which might have been responsible for this intermingling of flora.

The Gondwana Era in peninsular India began in the Upper Carboniferous-Permian and lasted up to the Lower to Middle Cretaceous times. Studies on fossil flora have indicated the climatic conditions which prevailed at different times during this era. In several areas like Kashmir, where unrefutable glacial deposits could not be found associated with the Talchirs, widespread cold conditions were inferred from the evidences furnished by the relative abundances of *Gangamopteris*. The climate later became warm and humid as is suggested by the luxuriant development of Barakar and Raniganj flora. Thereafter, semiarid conditions prevailed throughout the Triassic period as is evidenced by the paucity of plant remains in the sediments of that period. Again during Jurassic-Cretaceous times the climate remained warm but with a rise in humidity. This is indicated by the rich flora of the Rajmahal, Jabalpur and Bhuj Series. Thus palaeobotanical studies have helped the reconstruction of palaeoclimatic variations through such a vast period as the Gondwana Era which embraced nearly 150 million years !

In the Himalayan region temporary land conditions came into existence from time to time during the Upper Gondwana period. This is testified by the presence of Triassic and Jurassic plants in Upper Gondwana beds in the Salt Range area (now in Pakistan).

During the Late Cretaceous Early Tertiary period, India witnessed large scale volcanic activities with intervals marked by lacustrine and fluviatile conditions which deposited the Intertrappean beds. This environment is revealed by rich floral contents of the Intertrappean beds which, incidentally, provide the best petrifactions known in this country. The older Mesozoic flora of Pteridosperms, Cycads, and Conifers had dwindled; and the newly appearing flowering plants dominated the scene during the Tertiary period.

Prevalent land conditions in late Tertiary and Pleistocene periods are confirmed by the presence of land plants in the Tertiaries of the coastal area, as well as in the Siwaliks and Karewas.

The Karewas which were deposited during the Inter-glacial periods contain abundant plant remains. They suggest that during these periods, the climate prevailing in Kashmir was tropical to temperate. Further a few of the plants like *Trapa* do not thrive above an altitude of 1600 metres now. However, their fossils are found at altitude of above 3,200 metres. This proved, according to Sahni (1936b), an uplift of these deposits in the Pir Panjal range at least by 1600 metres during the Pleistocene itself.

Economic Aspects of Palaeobotany

Palaeobotanical studies have an important role to play in economic geology, particularly in the scientific development and rational exploitation of coal, petroleum, diatomaceous earth, etc. I would like to elaborate this point in the Indian context.

Coal — Palaeobotany has great significance in coal exploration. Correlation of coal seams of different areas, exploration of extensions of coal-bearing strata and even discovery of new coal fields can be achieved with the aid of palaeobotany In order to search for coal one should know beforehand where to go for it. An unplanned search may prove too expensive and abortive. In India, commercial coal is mostly confined to Permian and Eocene-Oligocene formations. Stratigraphic and palaeoecological information provided by plant fossils have been instrumental in the understanding of the extension of the coal horizons.

The construction of the stratigraphical column in coal-bearing areas is mainly based on the study of plant fossils. The study of spores and pollen in core samples helps in subsurface correlation. This aspect should receive much more attention in India, though in the correlation of certain coal seams this method has already been utilised. Ghosh and Sen (1948) correlated some of the productive coal seams of Raniganj Coalfield.

Similarly De (1960) attempted correlation of Argada coal seam of South Karanpura Coalfield. Bharadwaj and Salujha (1965) made the sporological studies of the eighth coal seam of Raniganj Coalfield, and correlated the same in several collieries. It may be mentioned here that palynological study of core samples for the purpose of exploration of coal has become a standard procedure in Geological Survey of India. Spore and pollen assemblages of the Karharbari, Barakar, Raniganj and Panchet Stages are given in plate 2. The utility of spores and pollen in coal seam correlation has been depicted in text-figures 1-2. A consolidated report incorporating the findings will be published shortly.

Petroleum — As petroleum is usually associated with marine sediments, plant mega-fossils which are restricted to fresh water deposits are of little use in oil exploration. Spores and pollen, on the other hand, occur frequently in petroliferous strata and are of great value to this industry. Study of spores and pollen from drill cores is resorted to in correlating oil-bearing strata and in understanding subsurface geology. Because of their microscopic size, abundant spores and pollen may be available even from a small piece of rock. Thus palynological observations on fragments of cores would supplement the other drill data in dating and correlating the horizons.

This aspect of palynology has been widely utilized by the Assam Oil Company and the Oil and Natural Gas Commission.

Diatomaceous Earth — I need not mention the diverse uses of diatomaceous

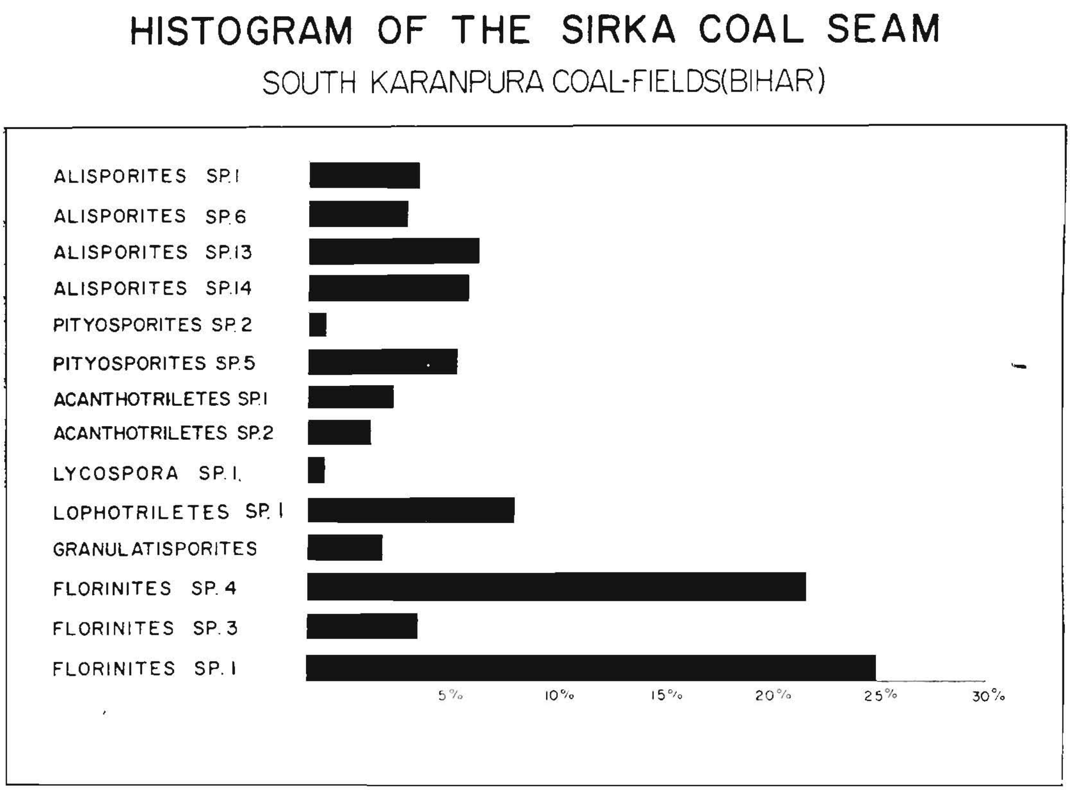

FIG. 1

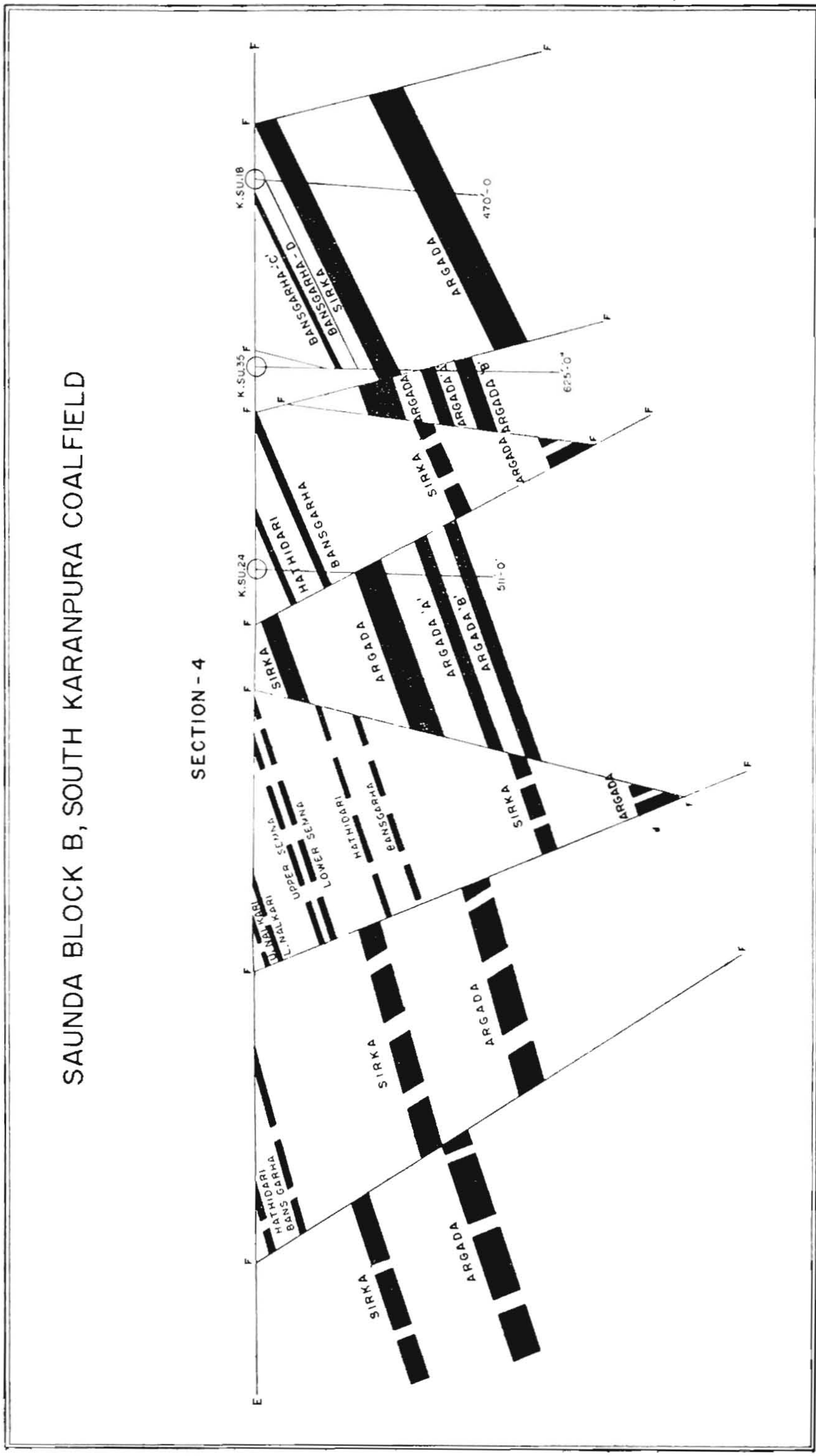
SAUNDA BLOCK B, SOUTH KARANPURA COALFIELD
SECTION-4
E
F
K.SU.18
K.SU.35
K.SU.24
470'-0
625'-0"
511-0'
BANSGARHA 'C'
BANSGARHA - D
SIRKA
ARGADA
HATHIDARI
BANSGARHA
ARGADA 'A'
ARGADA 'B'
U. NALKARI
L. NALKARI
UPPER SEMNA
LOWER SEMNA

FIG. 2

earth which results from accumulation of silica skeletons or frustules secreted by certain algae, called diatoms, together with certain elastics. Study of these diatoms leads to economic finds of diatomaceous earth in virgin areas, and throws valuable light on its quality. Diatoms have been recently reported from the Karewas of Ka hmir by Durga Kanta Roy of Geological Survey of India (Pl. 1, Figs. 3-4).

Others — In our country many projects concerning engineering geology and geohydrology are being undertaken. Most samples of strata recovered in cores obtained during drilling in such projects are amenable to palynological study. And this is done to assist the geologist to interpret the results more meaningfully.

Palaeobotanical and especially palynological studies, may go a long way in the detailed exploration of many economic minerals, such as fireclay, phosphorites and evaporites like gypsum which are known to be found primarily by stratigraphic controls.

Suggestions

From the above account it is evident that palaeobotany holds an important place in Indian geology. A number of geological problems still remain unsolved where palaeobotany can help. Here I would like to enumerate some of these problems.

1. *Psilophyton flora and related problems* — Our acquaintance of early vascular plants which existed during the early Palaeozoic times is very meagre. So far as our present knowledge goes occurrence of these plants is restricted to a very small area in the Himalaya. The Puranas, that is Cuddapahs and Vindhyans of Peninsular India, may yield remains of these early land plants. To enrich the knowledge on this very little known flora, an extensive search of the Puranas should be carried out. This will also help in deciphering the ages of these rocks, which are now matters of conjecture in Indian geology. In this connection, I would like to point out that the study of doubtful microfossils from the Cuddapahs and Vindhyans by Jacob *et al.* (1953 a & b), and Sahni, M. R. and Shrivastava (1962) has indicated them to be probable remnants of vascular plants.

In recent years *Stromatolites* have been recorded from different parts of the country. They deserve a detailed study from the stratigraphic point of view.

2. *Gondwana flora and related problems* — The existing knowledge on the Gondwana flora is fairly advanced. Recently it has been further enriched by palynological information. The accepted classification of the Gondwanas, while having a palaeobotanical basis, was adopted long before these recent developments took place. This classification may now need to be revised in the light of the recent advances in palaeobotany including palynology.

Triassic flora as a whole and Panchet flora in particular are poorly known in India. The study of Panchet flora has got a direct bearing on Permo-Triassic boundary problem which is of international significance. This is receiving some attention in the Geological Survey of India (Satsangi *et al.*, 1968).

The upper and lower limits of the Gondwanas should be more precisely defined. The fossils, particularly those in association with marine intercalations, should be studied in greater detail.

In the Himalayan region there is a vast thickness of doubtful Palaeozoic-Mesozoic sediments, namely the Krols and Tals, which are practically unfossiliferous. Consequently, their exact ages have been controversial. Study of microfossils, which are likely to be discovered from these strata, may solve this problem of Indian stratigraphy. Encouraging results have already been obtained in the search of spores and

PLATE 1

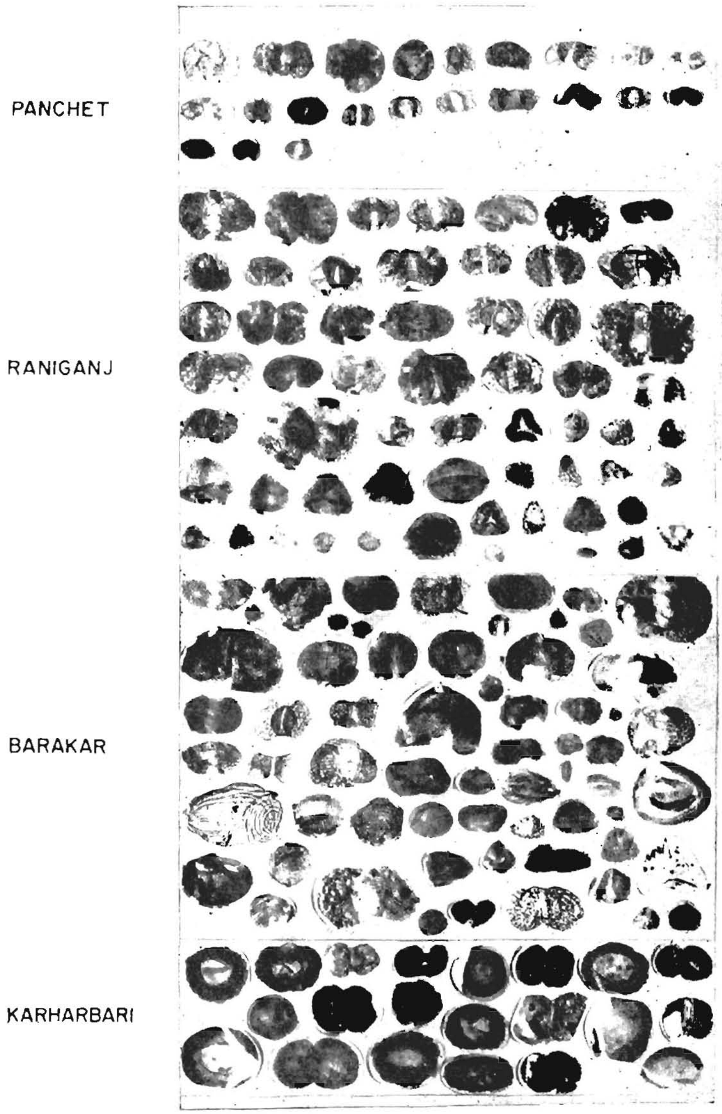

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PLATE 2

pollen from the Krols of Nainital area by Lakhanpal *et al.* (1956), and Ghosh and Srivastava (1963).

3. *Tertiary flora and related problems* — Palaeobotanical studies have helped a lot in solving the controversial problem of age of the Intertrappean beds, but there is still scope of detailed work in this field. Further, Intertrappeans provide the richest assemblage of petrified flora known in the country. Their study will bring to light more information on the internal structure of the plants. This will be of much use in tracing the stages of plant evolution.

Tertiary palaeobotany in general and that of Himalayan region in particular has not attracted the attention which it deserves. This is perhaps partially due to the inaccessibility of the Himalayan region. With acceleration of activity in the Himalaya, this lacuna in palaeobotanical studies will perhaps be bridged shortly.

Siwalik formations do contain plant fossils, but they have been classified mainly on the basis of the evidences f.rn'shed by vertebrate fossils. Rarity and localised distribution of the latter impair their value in detailed correlation. The plants, on the other hand, appear to be more uniform in distribution. Hence a detailed study of the flora should be made wherever they are available. In this context, I would like to include the Karewas as well in view of my earlier statements.

The Miocene of the Andaman Islands and the Pleistocene of Kashmir have been found to contain diatomace.us flora. Widespread occurrence, wonderful preservation and presence in otherwise unfossiliferous rocks give diatoms a status well above other fossils in dealing with the Tertiary and post-Tertiary sediments. Diatomace.us flora, therefore, deserves special attention.

4. *Evolution of plant life through the ages and the implications* — From the geological point of view studies on plant fossils essentially furnish information on the time-relations between strata in which they occur and the environments in which these plants thrived. Historical geology, perhaps the most important sub-discipline of geology, has been the main beneficiary from the contributions of the palaeobotanists. However, the advancing frontiers of physics and chemistry today have reduced other sciences to insignificant dimensions. The suspense which marks the peaks of the curve of development of a science seems to have deserted these so-called minor sciences. The plant world is a major component of the biosphere which is perhaps in geochemical continuity with lithosphere-hydrosphere and the atmosphere; and the studies on the evolution of plant life through the ages could perhaps reveal features of exciting possibilities. Historical geology could receive no more invigorating a suspense than such a contribution promises to bring. Modern researches have registered spectacular discoveries in the domains of quantum physics and molecular biology. The intricacies of biological evolution in time presumably hold clues to events which could have, on the history of planets, far more important implications than known so far. This is a new dimension of palaeobotany, though relatively abstract, which I would like to add to the suggestions made earlier. In his magnificient treatise on plant life through the ages Prof. Seward had perhaps more in mind than what actually appears in print. While remembering him today we would perhaps resolve to advance the horizons of this fascinating science of palaeobotany to the realms where scientific imagination always expected the unexpected missing links.

These days a number of palaeobotanical research projects are being undertaken in India; but I may be allowed to state that these are mainly botanically oriented. I would request this distinguished gathering of palaeobotanists to appreciate the expectations of the geologists, and devote some more time to aspects of geological significance while contributing to the strictly palaeobotanical cause.

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