PALYNOLOGICAL INTERPRETATIONS OF PALAEOENVIRONMENTS WITH REFERENCE TO INDIA[1]

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ABSTRACT

The recent growth and development of Palynology have clearly demonstrated that palynological fossils can be successfully used in determining palaeoenvironments. The present day distribution of plants shows that certain environments are characterized by particular plant communities peculiar to them. This is also broadly reflected in the general correspondance between the vegetational units and the climatic zones of the world. The environmental conditions under which the fossil plants lived are interpreted from the habitats under which their modern equivalents live.

Some of the palaeoenvironments indicated by palynological fossils are — (1) basin of deposition; (2) sea-land level changes; (3) ancient shore lines; (4) distance from land; (5) source or direction of plants; (6) climatic changes and seasonal variations; (7) orogeny; (8) migration of plants; (9) minor changes in topography, stream patterns; (10) biotic factors etc. Palynological evidences indicating palaeoenvironments during Quaternary, Tertiary, Mesozoic and Palaeozoic Eras of India have been brought forth.

INTRODUCTION

THE science of Palynology relates to the study of spores, pollen and other microorganisms — both living as well as fossil. The study of fossil spores and pollen grains originally began as an investigation into their taxonomy and for a number of years remained confined as a subject of plant taxonomy, till the applicability of pollen morphological data to geologic problems was fully understood. In recent years the success achieved by Palynology in age determination of critical horizons, and stratigraphic correlations, has greatly augmented the intimate relation between Geology and Palynology.

Extensive palyno-stratigraphical studies of various geological horizons have demonstrated that lateral changes in biofacies is a common occurrence. These changes are the consequence of differing environmental conditions. Modern phyto-ecological (neo-ecological) studies have shown that ecological conditions determine the occurrence and abundance of certain elements, both floral and faunal, in the assemblage. Since differing ecological environments, e.g. continental, transitional, or marine, are characterized by differing floral or faunal elements, the abundance of these elements in turn indicate the prevalence of that particular environment. As the contemporaneous occurrence of different fossil assemblages are directly related to the difference in ecological conditions, the similarity of assemblages in different time line can be taken as indicative of similarity in ecological conditions. Such similarities of fossil floras in different geological time scale may be as a consequence of the migration of floras due to the onset of inhospitable environmental conditions. The simultaneous termination of a large number of species in a horizon and their replacement in subsequent strata by newer forms is indicative of catastrophic extinction. Such replacements normally occur when major environmental shifts take place.

Environment is necessarily the surrounding conditions, influences or forces by which living things are influenced or modified in their growth and subsequent development. It is the effect of external and internal conditions which singly or jointly act upon an individual or community and imperceptibly guide its nature of development. Climate has perhaps played the most significant role in regulating the environment of a particular region. Sedimentary environment may be classified into the following divisions by means of biologic factors:

I. CONTINENTAL (Fresh water)	Fluviatile
	Lacustrinal
	Swampy
	Desertic

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II. TRANSITIONAL (Brackish water)	Deltaic Lagoonal Near-Shore
III. Marine	Neritic Deep Sea

Palaeoenvironment, as the name implies, deals with the environment of the geologic past. To reconstruct the palaeoenvironment of a basin, during certain period of time, the distribution of land and sea, topography, glacial deposits, character of the sedimentary rocks, geochemistry, palaeomagnetism, fossil flora and fauna of that particular time and place have to be evaluated separately or collectively.

To reconstruct the palaeoenvironment by means of plant fossils two assumptions form the basic guiding principles.

The first principle which advocates the "Theory of Uniformitarianism" was postulated by Hutton as early as 1795. The dictum is based on the well known theme that "the present is the key to the past". It is assumed that the past vegetation also reacted in the same way, as their nearest living relatives do today, to the changing environment such as, scanty or plentiful sunshine, heavy rainfall or drought, excessive humidity or aridity. Plants are stationary and with the advent of unfavourable environment they cannot easily migrate elsewhere like animals, to their preferred habitats. In order to cope up with the changed conditions they develop special characters.

The second guiding assumption holds that the geological history of the earth passed through several climatic and other environmental changes and that these had discernible effect on the past vegetation. Ecological studies of both living and fossil plants indicate three possible effects of changing environmental conditions on plant population:

(1) *Adaptation* — This means that plants or plant parts had the necessary energy to withstand the changed conditions to enable them to adjust themselves to the changed conditions through evolutionary processes. This ultimately resulted in the formation of new taxa.

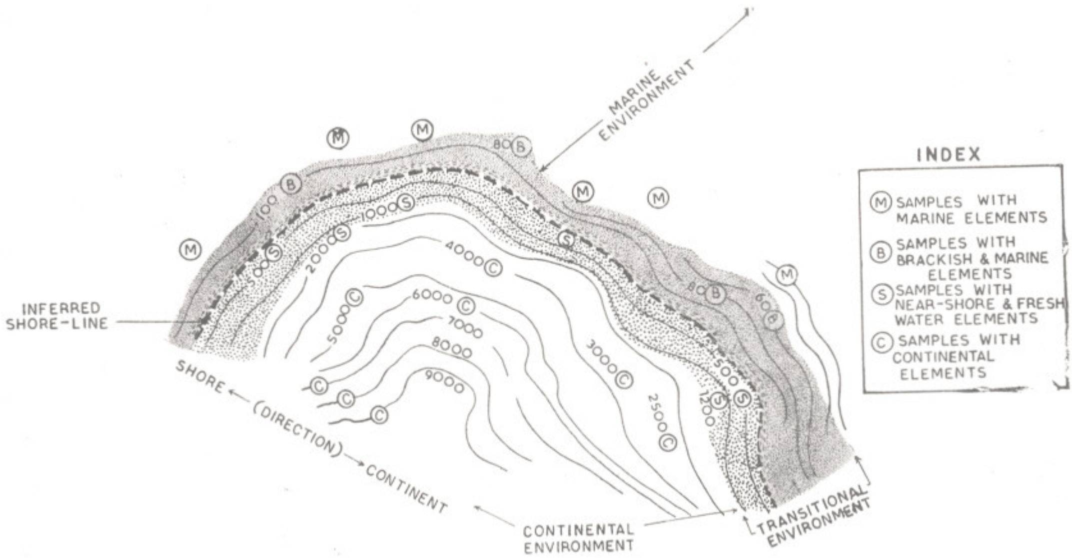
(2) *Migration* — Under certain conditions when plants or plant communities could not adjust themselves to the changed conditions they shifted or migrated to places having their preferred habitat. The prevalence of Indo-Malayan element like *Nipa* in the London clay flora during Eocene times provides a good example of floral migration in relation to environment. The Shola forest in the Nilgiris was a dominant community of South India (Champion, 1936) and it is found now only in solitary patches and the whole community of this closed evergreen forest is dying. The degeneration of this community is partly due to climatic and partly because of biotic factors (Vishnu-Mittre and Gupta, 1968).

(3) *Extermination* — If the plants are unable either to evolve or migrate to their preferred climatic and other ecological environments, extermination is the inevitable result. Devonian to Triassic rocks of India contain enough plant megafossil and palynological fossil evidences indicating that the Devonian-Carboniferous flora became extinct with the advent of the Permo-Carboniferous glaciation. Towards the close of the glaciation a completely new flora known as the *Glossopteris* flora emerged, attained its maximum development during Permian, started dwindling during the Lower Triassic and finally became almost extinct during Middle Triassic.

Palynology, besides spores-pollen, also includes additional microfossil forms such as acritarchs, dinoflagellates-hystrichosphaerids, diatoms, colonial algae like *Pediastrum*, fungal spores, its hyphae and fruiting bodies, chitinozoas, tintinids, nannoconites and a host of other minute bodies. They are generally less than 200 μ in size but in some cases they may attain a bigger size. The presence of algae alone indicates shallow-water condition. Some algae like *Pediastrum* indicate fresh-water (continental) environment while dinoflagellates-hystrichosphaerids characterize brackish-water (transitional) environment. Diatoms indicate *in situ* deposition of the sediments in which they are found. The chitinozoas, tintinids, nannoconites, etc., indicate transitional to shallow-marine environment.

The fungal fossils are rather scanty up to Cretaceous. From the Lower Tertiary onwards they are found in abundance particularly in association with lignites (Sahni *et al.*, 1947; Venkatachala and Kar, 1969b). The presence of epiphyllous fungi in high frequencies indicate warm-humid climate.

The importance of Palynology in tracing palaeoenvironment lies in the fact that palynological fossils are found in almost all



Text-fig. 1 — ISOBOTANICAL CONTOUR MAP INDICATING CONTINENTAL – TRANSITIONAL – MARINE ENVIRONMENTS

sedimentary lithologies ranging right from the Pre-Cambrian to Recent deposits. The other advantage is that a small amount of material may yield a rich assemblage of microfossils The third important fact is that the minute size and the morphological characters of the microfossils are generally distinctive enough to enable a palynologist to imagine the kind of parent plant which produced them. The palynological assemblage from one geological horizon to another varies in quality as well as quantity and indicates specific environment at the time of deposition. With the help of density counts of spores and pollen-grains Hoffmeister (1960) traced the continental, coastal and marine facies of the Morrow formation (Pennsylvanian), Oklahoma, U.S.A. (Text-Fig. 1). The study also helps in the recognition of geological time units, distance of ancient shore lines, correlation of marine and continental deposits, transgression and regression of the seas, orogeny, subsidence of the sediments and other tectonic movements.

A number of palaeoenvironmental interpretations have been given for sediments ranging from Palaeozoic to Quaternary. A comparative analysis of palaeoenvironmental evaluations reveal that rather close and precise palaeoclimatic and palaeoecological interpretations are feasible in almost all deposits of Quaternary time. This is because nearly all the fossil spore-pollen of Quaternary deposits belong to plants which are living today and so it is practical to make direct use of modern phytoecological knowledge. Palaeoenvironmental interpretations by fossil spores and pollen grains after the Quaternary becomes more and more difficult and arbitrary with increasing geologic age. This is because our knowledge of the affinities of the plants which bore the fossil spores and pollen grains becomes more and more indefinite while dealing with the older strata. Palaeocene or Middle Cretaceous times might in all possibility contain a few elements whose relatives are found amongst modern plant community. In sediments older than Middle Cretaceous only a few elements can claim to have a living equivalent. Besides, there are also certain unknown factors of which we know practically nothing. Thus, inferences based on the principles of modern phytoecology alone of Pre-Cretaceous plant communities may in all probability lead to erroneous conclusions.

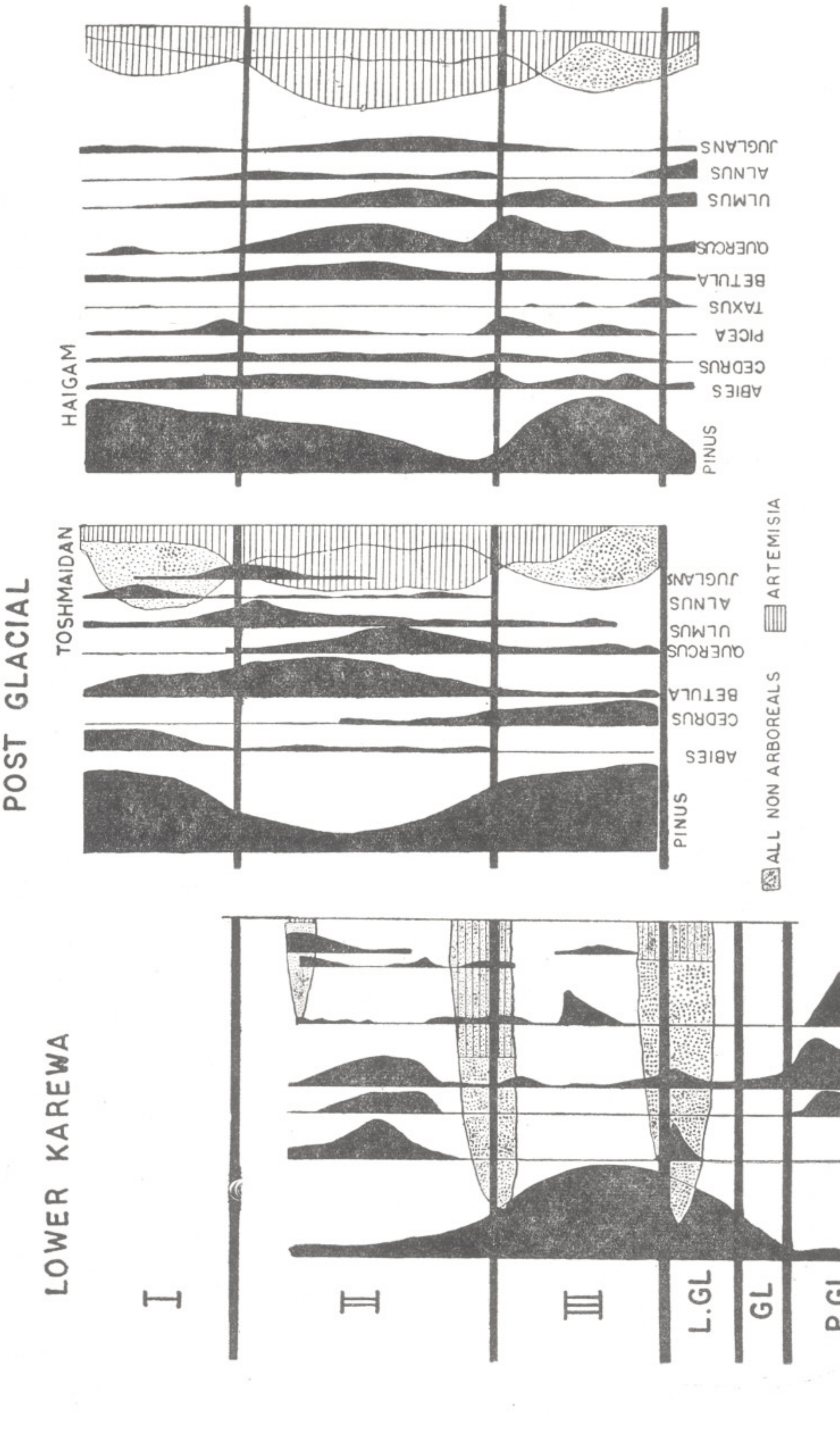
In addition to geological age there are some other limiting factors for inferring palaeoenvironments by palynological fossils alone. The wind pollinated pollen grains are generally over represented than the insect pollinated ones because they are produced in larger numbers and as they are provided with some mechanism (wing, etc.) for flight and they are also transported to longer distances. As a result the air pollinated pollen overshadow the others and if not taken into account may depict a wrong pollen diagram (Wilson, 1964; Chaloner, 1968). The delay in quick burial and the presence of toxic substratum at the place of deposition may also tend to make the mioflora ill-represented. It has also been observed that some bacteria and fungicide mostly favour the unornamented spores and pollen grains, causing a lot of damage. This may lead to a lower representation of these elements (Goldstein, 1960; Elsik, 1966a, 1966b; Kar, 1970) resulting in erroneous inferences. Despite these limiting factors, Palynology has now been accepted as an important tool for interpreting palaeoenvironment because of its other attributes. Palynological fossils have been of much help in the reconstruction of palaeoenvironment and vegetational history of the Sub-Recent and Quaternary deposits of India and elsewhere. The study of Calcutta peat has revealed that about *ca.* 5000 years ago Calcutta and its suburbs might have been a marshy place full of mangrove vegetation which in the present day is restricted only to Sunderban and the estuarine part of the Ganges (Chanda and Mukherjee, 1969).

Palynological studies on the Quaternary sediments in the Sambhar lake, Rajasthan, carried out by Singh (1968) reveal the prevalence of a comparatively cool and wet phase during the last Pluvial (*ca.* 10,000 years). This environment is indicated by the high frequencies of pollen grains belonging to *Mimosa rubicaulis* and Cyperaceae. The profile, in the upper parts (Holocene), shows a progressive decline of Cyperaceae and *Mimosa rubicaulis* while pollen of arid habitats show considerable increase, clearly indicating a change from cool-wet climate to warm-arid environment.

The pollen analytical investigation of the post glacial vegetation in the Kashmir valley by Vishnu-Mittre *et al.* (1962); Vishnu-Mittre and Singh (1963); Vishnu-Mittre and Sharma (1963); Singh (1964); and Vishnu-Mittre (1966) reveals that the vegetational elements of this region had been considerably influenced by the changes in climate. Pollen of *Quercus, Alnus, Betula alnoides,* etc., are quite dominant in the histograms of the post glacial peats. These plants are, however, not found in the proper Kashmir valley today. Their dominance in the early Pleistocene and subsequent decline in the later phases, is attributed to the uplift of the Pir Panjal Range towards the end of the first interglacial (Sahni, 1936; de Terra and Paterson, 1939; and Puri, 1945, 1947). This upheaval acted as a formidable barrier to the monsoon winds in this part, ushering in an inhospitable climate for the growth of *Quercus, Alnus* and *Betula alnoides* which ultimately led to their total extermination (Text-fig. 2).

The microfloral analysis of Middle and Lower Siwalik formations from the Bhakra-Nangal area of Punjab by Banerjee (1968) reveals that during Lower Siwaliks the vegetation was dominated by elements like Palmae, Gramineae, Compositae, Polypodiaceae, etc. indicating a near-shore environment of deposition and a moist sub-tropical climate. The upper Siwalik sediments on the other hand are dominated by pollen grains of *Pinus* and other bisaccate gymnospermous pollen while those referrable to palms and other subtropical elements are totally missing. Grass pollen show considerable decrease in their frequency. The assemblage, thus, points towards a temperate, cool-dry climate. This distinct change of climate, from a sub-tropical to temperate environment is an evidence indicating the Himalayan orogeny. Palynostratigraphical studies of the Tertiary sedimentary formations of Assam (Sah and Dutta, 1966; 1968) reveals that the older Tertiary sediments (Palaeocene-Oligocene) were partly deposited under fresh-water, lagoonal environment and partly under marine environment, in humid, tropical climate. The near-shore aspect is indicated by the high frequencies of pollen belonging to Palmae, Rhizophoraceae, etc. The fresh-water aspect on the other hand is borne out by the presence of pollen of Potamogetonaceae, Nymphaeaceae, etc. and the total absence of brackish-water elements, e.g. dinoflagellates-hystrichosphaerids, etc. The high frequencies of pteridophytic spores point towards a moist-humid environment. (Pl. 1, Figs. 1-5).

Coming to the younger strata (Miocene-Pliocene) of Assam it has been noticed that the pollen elements of Palmae,



PARALLELISM IN VEGETATIONAL DEVELOPMENT DURING EARLY & LATE QUATERNARY PERIOD IN KASHMIR VALLEY

Text-fig. 2-(AFTER VISHNU-MITTRE, 1966)

Rhizophoraceae, Leguminosae, Onagraceae, etc. are completely missing. On the other hand, Podocarpaceous and other elements indicating upland habitat have started coming up along with *Ceratopteris*, *Cicatricosisporites* and *Corrugatisporites* indicating a major change in climatic environment. The present day distribution of Podocarpaceae is mostly restricted above 6,000 feet. The presence of Podocarpaceous elements in younger Tertiary strata points to the prevalence of a subtemperate flora indicating the upheaval of the surroundings. This could therefore be related with the orogeny of the eastern Himalayas.

Palynological assemblage comprising spores, pollen grains and dinoflagellates-hystrichosphaerids recovered from the Subathu Formation (Lower Eocene) of Simla Hills led Salujha *et al.* (1969) to infer that the place of deposition was a near-shore environment and the climate was tropical-subtropical. Earlier, Mathur (1964) had already reported the occurrence of *Botryococcus*, *Pediastrum*, dinoflagellates, and hystrichosphaerids from the Subathu Formation and had also inferred a near-shore environment of deposition (Pl. 2, Figs. 19-34).

Palynological study of the Laki sediments of western India (Mathur 1963, 1966; Venkatachala and Kar, 1968c, 1969; Sah and Kar, 1969) shows that the presence of elements like Palmae, *Barringtonia*, *Rhizophora*, *Sonneratia* and *Pelliceria* indicates a warm-humid, coastal vegetation. The presence of dinoflagellates-hystrichospherids also supports a near-shore, brackish-water envirorment of deposition. The presence of pteridophytic spores in relatively low frequencies points towards the prevalence of comparatively low atmospheric humidity in western India, as compared to that of Assam, during approximately the same time.

Palynological investigation of the Neyvelli lignites by Ramanujam (1966, 1967) indicates a moist, humid, tropical-subtropical climate. The assemblage is characterized by high frequencies of pollen grains of Palmae, *Potamogeton*, *Nymphaea*, *Myriophyllum*, *Urticularia*, *Botryococcus*, etc. indicating a near-shore probably fresh-water environment. Moreover, the complete absence of brackish-water elements also points towards a possible fresh-water deposition.

A critical appraisal of the Mesozoic and Palaeozoic palaeoenvironmental interpretations brings to light a certain sense of unsurity in the deductions because in most cases a number of unknown factors seem to be involved. During the ice age of the past it is quite probable that plants evolved some special characters both external and internal to cope up with the environment. In most cases external characters can be explained by a comprehensive study of the present day behaviour and distribution of plants. But the internal characters like physiological adaptation cannot be determined merely by studying their morphological characters. We are obviously helpless in this matter and so our observations and interpretations in most cases may be speculative rather than elucidative.

Although the application of modern phytoecologic methods in the reconstruction of palaeoenvironment of Pre-Cretaceous horizons becomes considerably difficult, some inferences can however be made by plotting the dominance of certain groups of plants like pteridophytic spores, gymnospermous pollen, dinoflagellates-hystrichosphaerids etc. Lower Cretaceous sediments of western India have yielded a rich palynological assemblage comprising pteridophytic spores and gymnospermous pollen grains (Singh *et al.*, 1964; Venkatachala, 1969). The assemblage is dominated by pteridophytic spores and gymnospermous pollen indicating a warm-humid climate. The absence of any brackish-water element in the Bhuj series is indicative of deposition under fresh-water environment.

During the Upper Jurassic in western India the gymnospermous pollen grains are dominant pointing towards a warmer environment with less rain and humidity in the atmosphere. The presence of dinoflagellates-hystrichosphaerids indicates a near-shore environment of deposition (Venkatachala & Kar, 1968a; Venkatachala *et al.* 1969). The palynological assemblage of Rajmahal hills (Middle-Upper Jurassic) is also dominated by gymnosperomous pollen indicating a warm-humid environment (Sah and Jain, 1965). The environment of deposition was most probably fresh-water. This is borne out by the presence of plant megafossils and the absence of near-shore or marine elements. Palynological fossils from the Panchet and Mahadeva formations (Triassic) of India are meagrely known. The Triassic in India was supposed to have an arid climate. This condition could also be inferred from the microfloral evidence of Nidhpur shale, Madhya Pradesh studied by Bharadwaj and Srivastava (1969). In this assemblage, the pteridophytic spores are virtually absent and the bisaccate elements dominate. The Permian-Triassic palynological boundary in the Raniganj coalfield, on the other hand, contains abundance of pteridophytic spores (Kar, 1970) which indicates a short period of moist-humid climate.

During the Lower Gondwana time, the Raniganj and the Barakar stages seem to have enjoyed a climate favourable for the luxuriant growth of the vegetation. The vegetation comprising ferns, fern allies and gymnosperms might have resulted in the formation of the huge coal deposits (Bharadwaj, 1962; Bharadwaj and Salujha 1964, 1965a, 1965b; Bharadwaj and Tiwari, 1964; Tiwari 1965; Venkatachala and Kar 1968b). The environment seems to have been warm and humid which is in keeping with the growth of such luxuriant subtropical vegetation. The Raniganj stage probably had a comparatively warmer climate than the Barakar stage. During the deposition of the Barren-Measures Succession, the environment might have been comparatively drier and arid. This is evident from the absence of coal in this period. The palynological assemblage is also characterized by low frequencies of pteridophytic elements and dominance of bisaccate pollen grains (Bharadwaj *et al.* 1965; Kar, 1966, 1968a, 1968b, 1969a, 1969b). Palynological assemblages of the Karharbari stage show an almost equal dominance of pteridophytic spores, monosaccate and bisaccate pollen grains. The trilete and monolete spores are found in good percentages in the Lower Karharbari stage of the North Karanpura coalfield, while their percentage dwindles down during the deposition of the Upper Karharbari in the same coalfield. It seems, therefore, reasonable to infer that soon after the melting of the ice, humidity increased in the environment which enabled the pteridophytes to invade the open land. In the Upper Karharbari stage the woody elements seem to have dominated over the pteridophytes. During Talchir times the vegetation was scanty, the assemblage being mostly dominated by monosaccates with very few pteridophytes (Potonié and Lele, 1961). This seems to point towards the prevalence of a comparatively drier phase where the pteridophytes were not able to flourish together with cold conditions envisaged from the evidence of glaciation. Lele and Chandra (1969) have observed a good number of acritarchs in the Umaria Marine beds, Madhya Pradesh, providing palynological evidence of a marine transgression in that area during the early part of the Lower Gondwanas.

Pre-Gondwana sediments in India are not rich in palynological fossils. The pteridophytic spores and gymnospermous pollen are very rare and mostly a few marine algal fossils are found. This indicates the prevalence of shallow-water deposition (Salujha *et al.*, 1967; Sastri & Venkatachala, 1968; Maithy, 1969).

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EXPLANATION OF PLATES

PLATE 1

FIGS. 1-5 *Moist-Humid Environment*

1. *Polypodium* type (Polypodiaceae).
2. Bryophyte spore.
3. *Cyathea* type (Cyatheaceae).
4. *Pteris* type (Pteridaceae).
5. *Lycopodium* type (Lycopodiaceae).

FIGS. 6-10. *Upland Environment*

6. *Rhododendron* (Ericaceae type).
7. *Callialasporites* type.
8. *Alnus* pollen type.
9. *Primula rosea* type.
10. *Pinus wallichiana* type.

FIGS. 11-15. *Fresh-water Environment*

11. *Potamogeton* type (Potamogetonaceae).
12. *Nymphaea* type (Nymphaeaceae).
13. *Botryococcus* type.
14. *Typha* type.
15. *Pediastrum* type.

FIGS. 16-18. *Coastal Environment*

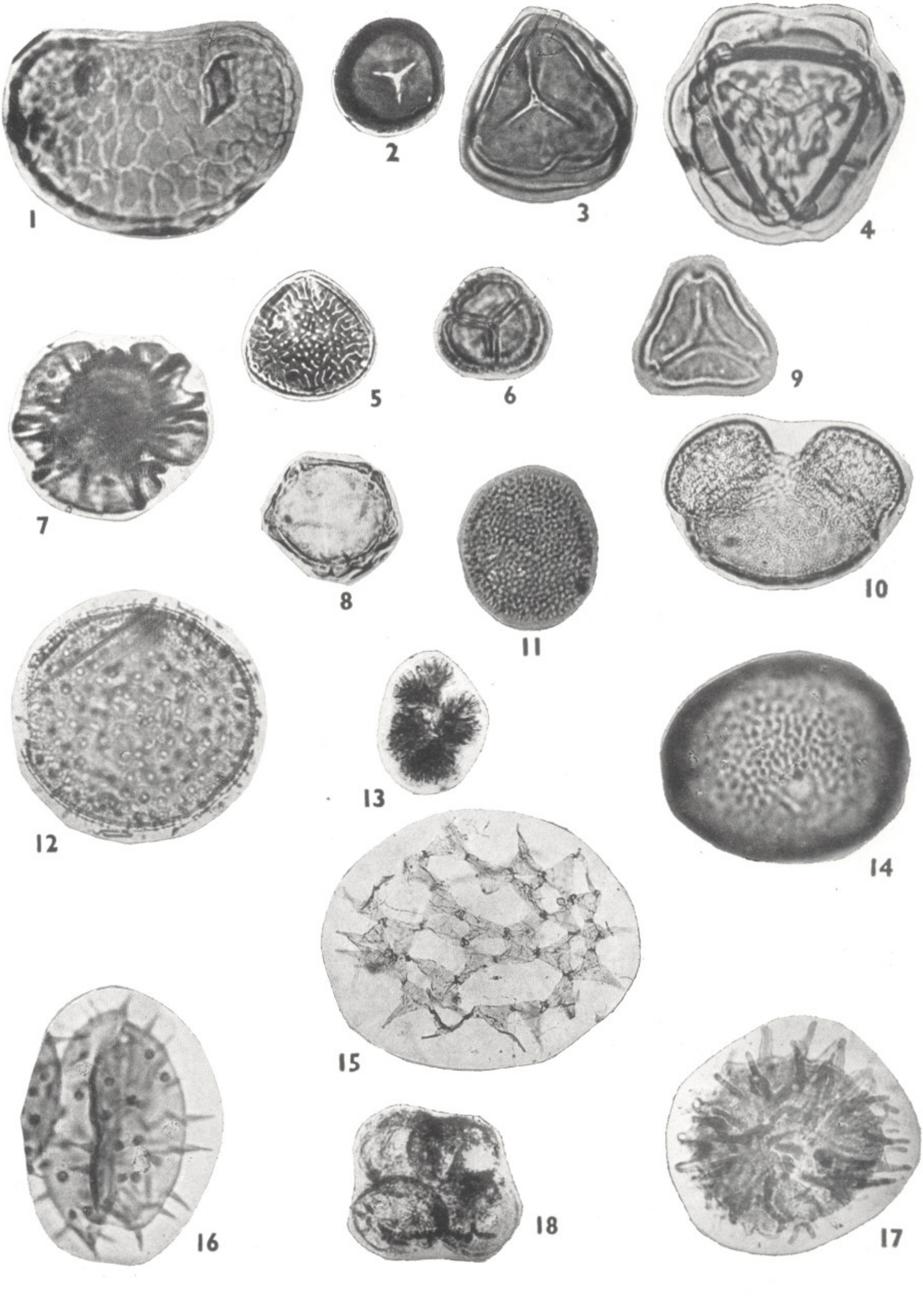
16. *Nuphar luteum* (Palmae).
17. *Monosulcites wodehousei* (Palmae).
18. *Classopollis* type.

PLATE 2

FIGS. 19-34. *Transitional Environment*

19. *Rhizophora* type (Rhizophoraceae).
20. *Barringtonia* type (Lecythidiaceae).
21. *Sonneratia* type (Sonneratiaceae).
22. *Pelliceria* type (Pellicereaceae).
23. *Fromea* type.
24. *Hystrichosphaeridium assamicum* Sah *et al.*
25. *Hystrichosphaeridium transculentum* Sah *et al.*
26. *Canningia* type.
27. *Apteodinium* type.
28. *Leptodinium ovum* type.
29. *Baltisphaeridium* type.
30. *Ascodinium* type.
31. *Oligosphaeridium cephalum* Sah *et al.*
32. Marine diatom (shallow-marine type).

33-34. Chitinizoas (shallow-marine type).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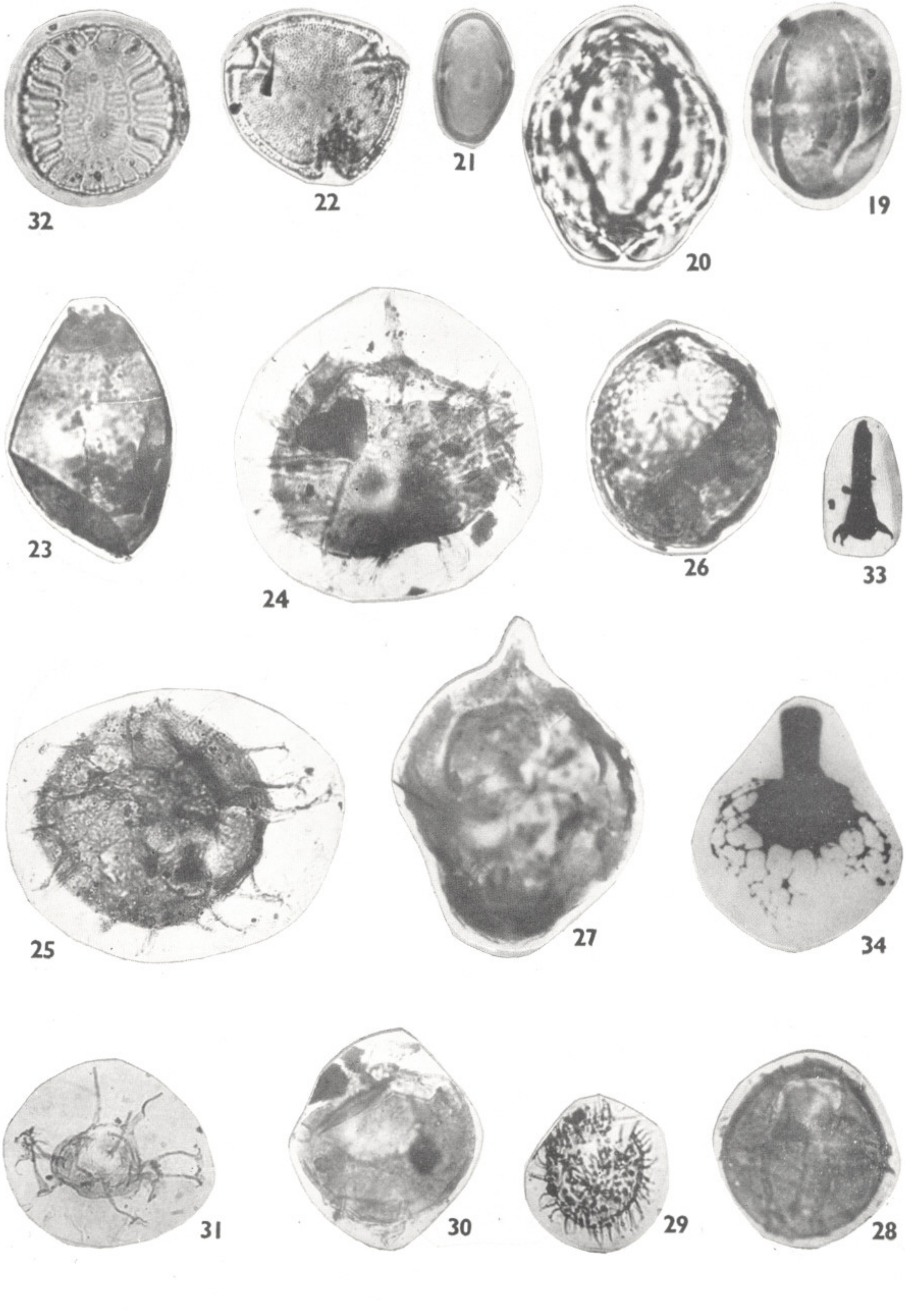
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