PALYNOLOGY IN BIOSTRATIGRAPHY AND PALAEOECOLOGY OF INDIAN LOWER GONDWANA FORMATIONS

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ABSTRACT

A critical synthesis of the new palynological data from sequences out of six boreholes through the Lower Gondwana Formations in India has enabled palynostratigraphic and palaeoclimatic conclusions of significance viz.,

(1) The Lower Gondwana sedimentation commenced with a glaciation followed by another glacial phase, interpolated with a short interglacial. The older glacial phase constitutes the Talchir Stage, the interglacial represents older Karharbari and the younger glacial phase occurred during deposition of younger Karharbari Fm followed by a long interglacial encompassing the Barakar, Ironstone Shale and Raniganj Fms. It has been found that homotaxial deposits of the later glacial phase differed in their lithological, palaeobotanical and to some extent palynological characteristics due to differences in their proximity to centres of glaciation.

(2) In the younger part of the sequence, the Panchet Fm appears to have commenced with another cooler phase presumably due to another minor glaciation.

(3) Immediately following the glacial phases, the interglacials commenced with humid climate which gradually or quickly declined.

INTRODUCTION

PALAEOPALYNOLOGY is a young science as compared to Palaeontology or Palaeobotany. Lately it has acquired a place of distinction among the dependable parameters in biostratigraphy through the efforts of geologists working for the elucidation of basin structure in coal or oil fields. At present palynology has much wider domain than earlier and it is being utilized for the determination of stratigraphy, palaeogeography, vegetational history or evolution.

Among the significant results pertaining to palynological elucidation of Lower Gondwana stratigraphy in different basins of India, an important conclusion has been the recognition of a secondg lacial phase occurring within the Karharbari Stage. This conclusion originally suggested upon geophytological evidence (Bharadwaj, 1969, 1971) is now based convincingly and more precisely upon a synthesis of palynological findings with the known palaeobotanical and lithological data (Bharadwaj, 1974a). The second glaciation was not so intense as the first i.e. the Talchir glacial phase. Thus, during the former, the homotaxial depositions nearer the regions of glaciation developed into glacial or fluvioglacial, non-carbonaceous facies and those farther away from the glaciers resulted into fluvial, carbonaceous facies. The occurrence of the second glacial phase and its concommitant, yet varying, effect on the lithology and phytology of its homotaxial sediments tends to explain satisfactorily the inconsistent relationship of Karharbari Fm. with the underlying and the overlying Formations viz., the Talchir Fm. and the Barakar Fm. respectively. It is explicit now that the older part of Karharbari Formation is the interglacial phase of the first glacial, i.e. the Talchir Formation, and the younger part of Karharbari Fm. is the second glacial phase itself. The Barakar Fm. which directly overlies the second glacial phase is a part of latter's interglacial. Consequently it has been suggested (Bharadwaj, 1974a) that Lower Gondwana sequence of India may be more rationally divided biostratigraphically into the basal Talchir Series and the overlying Damuda Series corresponding to the two glacial cycles, whereby the older part of Karharbari Formation could be included in the Talchir Series as Karharbari Fm. *s. str.* and the younger part be considered as the basal horizon of Damuda Series, or the oldest part of Barakar Fm.

USE OF PALYNOLOGY IN STRATIGRAPHY AND PALAEOECOLOGY

The use of Palynology for stratigraphy is very much recent. During the last two decades whence palynology received increasing attention, more than a decade was spent primarily in the taxonomic study of the dispersed spores and other palynofossils. As these qualitative studies produced understandible data, floristic aspects based upon

quantitative representation of the morphographic entities in spore assemblages began to be used for distinction between those coming from different horizons. The quantitative or the statistical analysis of palynological assemblages based upon standardized samples and uniform preparation procedure and study, proved helpful in correlating strata within the basins which usually had similar depositional conditions over their extent. This approach was successfully utilized for the correlation of coal seams in different basins of India. However, for the interbasinal stratigraphic correlations, as the palynological information from different basins accumulated, it was realized that to mitigate the regional variations due to microclimatic and edaphic differences, suprageneric groups of morphographic units, based upon their presumed affinities, are needed, and with reference to their quantitative representation, only the epibole in their total time range or the biozone (cf. Alpern, 1968) is diagnostic for stratigraphic purposes. Thus, in the synthesis of stratigraphic data attempted here and the conclusions there of (Histograms 1 and 2), the morphographically closer spore genera have been grouped into suprageneric categories and the biozones of these have been ascertained to provide the basis for interbasinal homotaxy and also the biostratigraphical zonation. Considering the differential floristic value of the gymnospermous, woody or the tree component of the vegetation *vis-a-vis* the pteridophytic, nonwoody or the herbaceous component, the former, presumably having been regionally, equitably distributed in contrast with the local nature of the latter, the epiboles of gymnospermous pollen groups have been considered here to be more suited for regional palynostratigraphy.

For the elucidation of palaeoclimate during Lower Gondwana sedimentation, palynology has little direct evidence to offer. However, indirectly the preponderence of pteridophytic spores has been interpreted to suggest humid climate. This is inferred from the normally high humidity requirements of pteridophytes today as well as during the geological ages substantiated by other evidences.

Regarding temperature indicators no plant from Lower Gondwana flora has been known to be thermophilous as we know some from modern vegetation. However, among the Lower Gondwana gymnospermous pollen grains, the thick-walled, spherical trilete spores such as *Callumispora* and the trilete bearing, circular monosaccates such as *Parasaccites, Plicatipollenites* and the like, have been found high in incidence in the glacigene sediments of Australia (Evans, 1969). In India the glacial sediments show high incidence of trilete bearing circular monosaccates with some *Callumispora* and both are equally represented in the interglacial between the first and the second glacials (Bharadwaj, 1774a). In view of these data it has come to be realized that *Parasaccites* complex and *Callumispora* complex indicate proportionately colder environment as their representation increases in an assemblage.

MORPHOLOGICAL GROUPING OF PALYNOFOSSILS

From the rocks of Lower Gondwana deposits in India a large number of miospore genera have been reported so far. Morphographically these genera can be grouped into a number of suprageneric categories on the basis of their organizational similarity purporting to be indicative of affinities.

Zonate Triletes — Such genera as *Indotriradites, Dentatispora, Gondisporites, Potonieitriradites, Decisporis* and the like have basically a subequatorial cingulum or zona with the trilete rays ending upon them. These miospores usually contain an inner body. This organization is restricted to spores of lycopsid affinities.

Azonate Triletes or Monolete — Such genera as *Microbaculispora, Horriditriletes, Indospora, Thymospora* and the like are normally azonate, triangular or bilateral miospores with laevigate or sculptured exine. These spores are usually considered to be of filicinean affinities.

Callumispora Complex — Such miospores from L. Gondwanas as are described under *Callumispora, Divaripunctites or Punctatisporites* are included here. These miospores are circular triletes with a structured exine. The affinities of *Callumispora* complex are presumed to be gymnospermous.

Parasaccites Complex — Spore genera such as *Parasaccites, Virkkipollenites, Plicatipollenites* and the like, with a circular body bearing a trilete or monolete mark and subtending an equatorially girdling saccus, are grouped here. These genera are presumed

sumed to be of gymnospermous affinities.

Densipollenites — It is an alete monosaccate miospore. Its affinities are obviously gymnospermous.

Scheuringipollenites — Normally disaccate spore genera such as *Scheuringipollenites* (*Sulcatisporites*) *Platysaccus, Illinites, Vesicaspora, Cuneatisporites* and the like with a central body lacking any striations, are grouped here. These spores are evidently of gymnospermous affinities.

Striatites Complex — Such spore genera as *Striatites, Faunipollenites, Vittatina* and the like, which are saccate with incipient to well developed sacci and bear striations on the central body, are included here. These spores are obviously of gymnospermous affinities.

Monocolpates — A number of non-striate and striate, monocolpate pollen grains such as described under *Ginkgocycadophytus, Boutakoffites, Striasulcites* and others are grouped here. These spores are obviously cycadalean and ginkgoalean or the like, in affinities.

INVESTIGATED SEDIMENTARY SEQUENCES

The cores from several bore holes as detailed below and the authors who investigated them palynologically, have provided the data for the present synthesis.

NCKB 19 — Bharadwaj and Srivastava 1973.

A deep bore hole down to 689·51 metres from the surface, traversing through the coaliferous Barakar Fm near the top to the glacigene Talchir Fm at the bottom in the Korba Coalfield, Madhya Pradesh.

K. B. 21 — Kar 1973.

A deep bore hole down to 508·2 metres from the surface extending from Ironstone shales through Barakar and Karharbari Fms into the Talchir Fm with typically glacigene sediments deposited over a Precambrian basement in the North Karanpura Coalfield, Bihar.

K 5 — Kar 1969a

A bore hole extending to 326 metres depth and passing through Raniganj Fm and whole of Ironstone shales in North Karanpura Coalfield.

K 2 — Kar 1969b

A bore hole traversing 352 metres of strata in Raniganj and Ironstone Fms in North Karanpura Coalfield.

RE 9 — Kar 1970a, b

A shallow bore hole up to 89·35 metres depth passing through Pleistocene sediments Panchet Fm (84·05-30·90 m) and Raniganj Fm at the base in Raniganj Coalfield (Ondal area), W. Bengal.

NCRD 6 — Bharadwaj and Tiwari MS.

A deep bore hole passing through Panchet Fm nearer the top and Raniganj Fm below in Raniganj Coalfield, (Asansol area) W. Bengal.

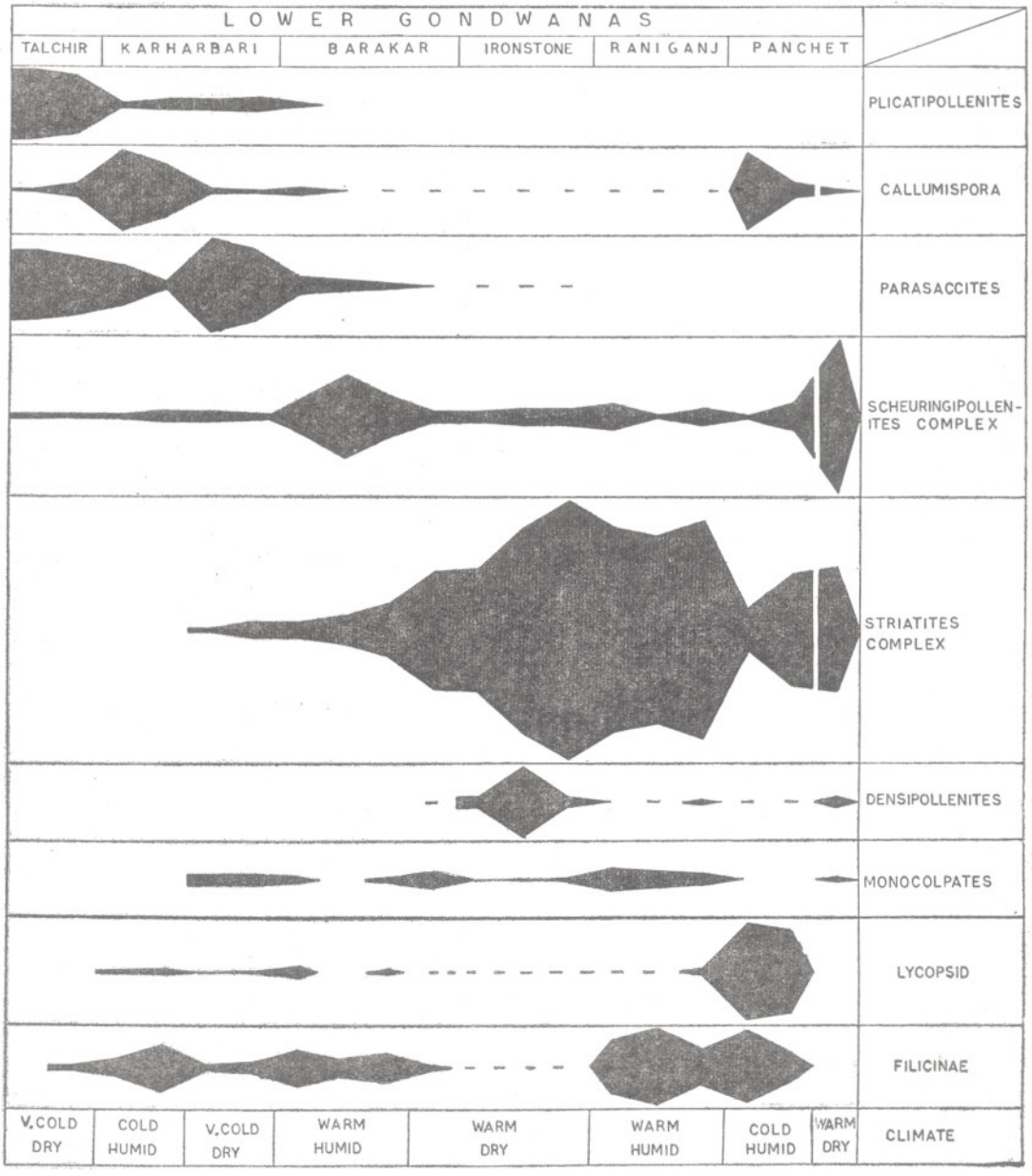
The palynological sequences from the various borehole cores were compounded through careful sliderule matching into one complete sequence representing Lower Gondwana Formations extending from Talchirs at the base to Lower Panchets at the top.

DISTRIBUTION OF PALYNOFOSSILS IN LOWER GONDWANAS (HISTOGRAM 1)

Talchir Formation — Talchir Fm is lithologically characterized by glacial and fluvioglacial sediments recognizable as tillite, sandstone-conglomerate, shale, rhythemite and turbidite facies (Ghosh & Mitra, 1972). It is mostly in shale facies that spores and pollen grains have been found preserved. The most abundant genus is *Parasaccites* with *Virkkipollenites* and *Callumispora* characteristically associated as occurring in the sediments of Talchir Fm, from Korba, and N. Karanpura Coalfields.

Karharbari Formation — Palynologically, Karharbari Fm is divisible into two parts. The older part has a *Callumispora* dominant and *Parasaccites* subdominant assemblage as discovered in the carbonaceous strata overlying the Talchir sediments in the subsurface of Korba (Bharadwaj & Srivastava, 1973) and N. Karanpura (Kar, 1973) coalfields and the younger part contains a *Parasaccites vis-a-vis Parasaccites* complex dominated assemblage. Overlying these, has been recovered a *Scheuringipollenites* complex dominant and *Parasaccites* complex

subdominant assemblage. However, this sequence of the last two assemblages is not comparable to the assemblages of the Upper Karharbari seam — Barakar coal seams sequence in the type area of the former formation (Srivastava, 1973) because only the younger assemblage is represented. It seems that when the *Parasaccites* complex dominated sediments were deposited in Korba, N. Karanpura and Raniganj Coalfields, at the same time the 70 m thick sandstone which lies below the Upper Karhar-

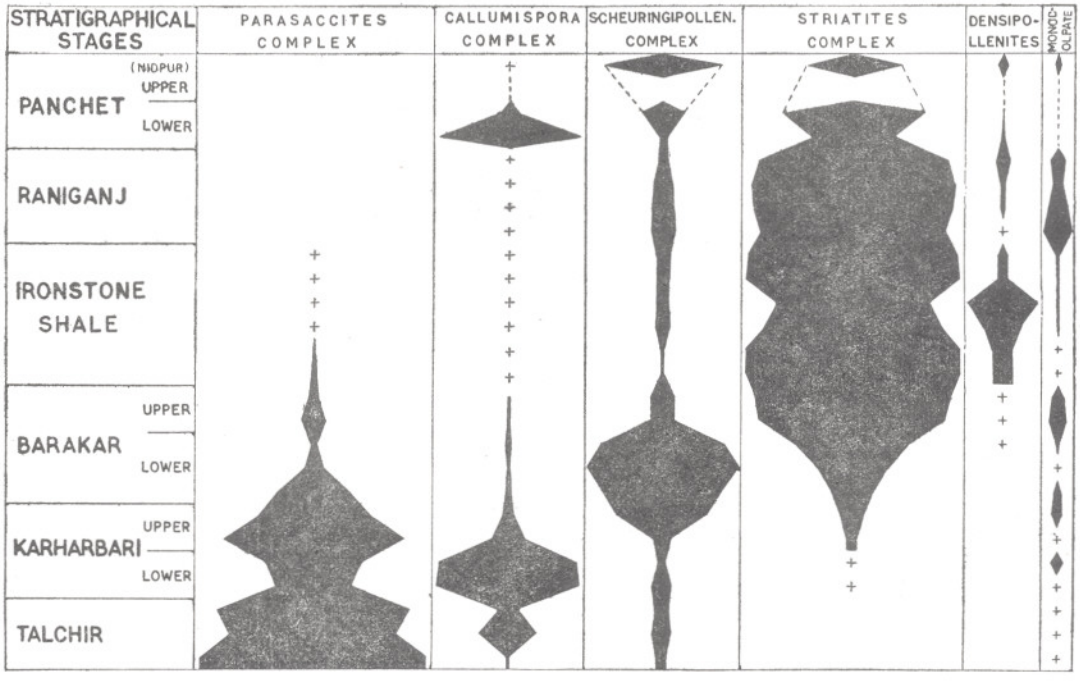


HISTOGRAM 1 — Quantitative distribution of miospore groups and the postulated climatic characteristics through Lower Gondwana sequence of India.

bari seam in Giridih Coalfield was laid. However, in Mohpani Coalfield where too, a similar palynological succession has been reported from a conformable sequence (Bharadwaj & Anand-Prakash, 1972), the sediments homotaxial to the younger Karharbari are glacigene. In view of these correspondences, the *Parasaccites* complex dominated assemblage which initiated the younger Karharbari has been interpreted by Bharadwaj (1974a) to be the phase of a second glaciation in the Lower Gondwana Formations of India, which seems highly probable also because *Parasaccites* complex has been found to be associated always with glacigene sediments in India and other Gondwana countries. Thus, the occurrence of these miospores in appreciable percentage even in sediments laid beyond the extent of glaciers in nonglacigene facies, has helped in the determination of their homotaxy with glacial facies elsewhere.

Barakar Formation — In the subsurface of Korba Coalfield (Bharadwaj & Srivastava, 1973) and in the subsurface of N. Karanpura Coalfield (Kar, 1973-KB 21) the *Parasaccites* complex dominated Upper Karharbari assemblage is succeeded by a *Scheuringipollenites* dominated mioflora. In the latter at 405·6 m level, well within the Barakar Fm beginning at 444 m, the assemblage contains 35% *Scheuringipollenites* complex, 37% *Striatites* complex and 17% *Parasaccites* complex. Closely above this, at 393 m level, the mioflora further distinctly changes containing 82% *Striatites* complex, 6% *Scheuringipollenites* complex and 7% *Parasaccites* complex and continues likewise more or less unchanged up to 178·5 m level wherefrom, the Ironstone shale Formation commences.

Evidently, Barakar Fm is palynologically divisible into the older *Scheuringipollenites* complex dominated and with *Striatites* complex prominently associated assemblage while the younger has exclusively *Striatites* complex dominated spore assemblage. Barakar Formation is a prominently coal rich horizon in India. Its coals have also been widely studied palynologically in different coalfields for determining the correlation of coal seams. These studies have revealed that in the coal facies of older Barakar Fm, zonate and azonate triletes



HISTOGRAM 2 — Relative quantitative incidence of gymnospermous miospores through Lower Gondwana sequence of India.

are often numerically highly represented especially in the basal horizons (Mohpani cf.; North Korba cf., Sohagpur cf.; Bisrampur cf., and Singrauli cf., (Bharadwaj, 1971). In the coals from upper reaches of older Barakar Fm, only the azonate triletes are significantly associated with the dominant *Scheuringipollenites*.

Ironstone Shale Formation — A palynological study of the coals and shales from the type area in Jharia Coalfield (Bharadwaj, Sah & Tiwari, 1965) has been supplemented by the study in detail of the subsurface from N. Karanpura Coalfield (Kar, 1969a, b, 1973). It has established this formation to contain the epibolic biozone of *Densipollenites*. As finally concluded (Bharadwaj, 1974b) Ironstone shale Fm, is divisible into three parts, the basal having 1-11% *Densipollenites*, the middle having 12-40% *Densipollenites* and the top part having 2-7% *Densipollenites*. Besides the diagnostic incidence of *Densipollenites*, this Formation is also characterized by low triletes and dominant *Striatites* complex.

Raniganj Formation — The transition from Ironstone Shales into overlying Raniganj Fm has been palynologically studied by Kar (1969a, b) from the subsurface of N. Karanpura coalfield and as interpreted by Bharadwaj (1974b), Raniganj Fm commences where the epibole of *Densipollenites* ends and triletes and monoletes suddenly increase (over 10%) as against the virtually trileteless Ironstone Shale Fm. *Striatites* complex continues to be dominant through out Raniganj Fm. In the coaly facies, the assemblages contain higher percentages of apiculate triletes and monoletes (Kar, 1969b). Raniganj Fm is best developed in Raniganj Coalfield containing thick coal deposits. The top levels in Raniganj Fm as studied by Bharadwaj and Tiwari (MS) are, as usual dominated by *Striatites* complex and the cryptogamic spores are quite low.

Panchet Formation — The end of Raniganj Fm and the beginning of Panchet Fm has been palynologically studied by Shrivastava and Pawde (1962), Kar (1970a, b) and Bharadwaj and Tiwari (MS). These studies have revealed that the lithological change from carbonaceous shale in Raniganj Fm into green-grey shale of Panchet Fm in a ± conformable sequence, is accompanied with corresponding miofloral change from *Striatites* complex domination to that of *Callumispora* complex. However, this change is rather short lived and *Striatites* complex again assumes a dominating representation. But *Scheuringipollenites* complex appears to have gained over them in ? Upper Panchets (Nidpur) finally.

DISCUSSION

The palynological sequence considered here includes the Lower Gondwana Formations and the Lower Panchet Formation in view of the opinions by some that Lower Panchet is a part of the Lower Gondwanas as it represents the top-most Permian.

Histogram 1 presents the synthesized quantitative distribution of the gymnospermous and pteridophytic miospores through the sequence. It exhibits the position of epiboles of the various spore groups in relation to the different lithological Formations. The epiboles provide diagnostic means in general for the parts or whole of the different Formations.

The sequence commences at the base with epiboles of *Parasaccites* and *Plicatipollenites* in the glacigene Talchir Fm. In the older part of Karharbari Fm, *Parasaccites* reduces, *Plicatipollenites* is almost replaced by the epibole of *Callumispora* and filicinian triletes increase significantly. In the younger part of Karharbari Fm, *Parsaccites* reaches a second maximum at the cost of all other kinds. On the basis of a critical appraisal of the palynological, lithological and palaeobotanical data, I (Bharadwaj, 1974a) have been able to interpret the second maximum of *Parasaccites* as indicative of the second glacial in the Lower Gondwanas of India. The epibole of *Callumispora* with high *Parasaccites* and high triletes which is sandwitched between the 1st and the 2nd glacial, seems to be a cold interglacial. It is presumed to be cold because a combination of high *Callumispora* (= *Punctatisporites*) and *Parasaccites* is found in the glacigene deposits of Australia (Evars, 1969) and to be an interglacial because of high triletes and occurrence of carbonaceous matter in the sediments.

The second glacial is followed by the epibole of *Scheuringipollenites* (= *Sulcatisporites*) complex together with rich striated disaccates and triletes in the older part of the Barakar Fm. However, in its younger part and thereafter till the Lower Panchet

Fm, the epibole of striated disaccates is characteristic. But this epibole shows three constrictions due to interposing of high *Densipollenites* in the Ironstone Shale Fm, high triletes, monocolpates and nonstriate disaccates in Raniganj Fm, and high *Callumispora* and triletes at the commencement of Lower Panchet Fm.

The high incidence of *Callumispora* at the commencement of Lower Panchet is very significant. This genus is known to have been associated with glacial or cold climate in the basal Gondwanas of India and Australia. Hence, presuming that the physiology of the plants which produced these spores did not change during the period intervening between its two maxima, the commencement of Lower Panchet seems to have had a cold climate simulating a glacial environment. Lithologically the greenish colour of the shales containing the *Callumispora* rich mioflora and the presence of pink felspars in homotaxial sandstones support this contention. However, the presence of a tillite at the junction of the Raniganj and Panchet Formations or their equivalents would provide final confirmation about the occurrence of the third glaciation in Indian Gondwanas.

It is apparent that the various gymnospermous pollen groups in the Lower Gondwana mioflora are stratigraphically diagnostic and that palaeoclimatologically some are indicators of cold environment. On the other hand the pteridophytic spores, in view of their generally accepted moisture loving physiology supported by their high incidence in carbonaceous facies, tend to indicate humidity in the environment of their growth directly proportional to their incidence. Hence, a sequence of palaeoclimatic evolution through the Lower Gondwanas as indicated regarding cold temperature by *Plicatipollenites-Parasaccites-Callumispora* and humidity by the pteridophytic spores has been concluded in Histogram 1. It may also be noted that closely following a glacial phase, the pteridophytic spores are often seen to have significantly increased.

Considering that the pteridophytic spores are of little consequence for stratigraphy, Histogram 2 has been prepared based upon relative representation percentages between the gymnospermous pollen grains only, i.e. excluding the pteridophytic spores in computation. This has evidently highlighted some of the epiboles which were not as marked in Histogram 1 due to inclusion of the pteridophytic spores while calculating percentages. Thus, one of the constrictions in the epibole of *Striatites*, complex due to pteridophytic spores has been reduced and the second maximum of *Callumispora* has acquired its dominant relationship. Evidently, while trying to interpret palynostratigraphy it is worth while to determine the class or classes of plants of which the spores seem to be significant for stratigraphic subdivision of the sequence and then to redraw the histogram containing such significant spore groups only, to the exclusion of the rest.

CONCLUDING REMARKS

Considering the distribution of palynofossils in the various facies of Lower Gondwana Fms, it is reasonable to conclude now that the gymnospermous pollen grains exhibit time related and spatially similar distribution. Hence, biostratigraphic division of Lower Gondwanas has been attempted here on the basis of epiboles for the gymnospermous pollen groups only.

There is palynological evidence for three glacial phases, one each commencing the Talchir Series, Damuda Series and the Panchet Series. This is supported by the lithological characteristics of the sediments found in these levels.

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