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# Gondwana Palaeozoic and Mesozoic palynology in India

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Palaeopalynology is the study of spores, pollen and other related reproductive units of vegetation dispersed and deposited in the sediments of the geological past. Birbal Sahni envisaged a great future for palaeopalynology in India. He<sup>1</sup> wrote in 1947, 'By comparing the microfossils in a sufficiently close series of rock-samples, taken from different areas and different levels the strata can be more accurately correlated, with results that are often of scientific interest as well as helpful in the exploitation of the mineral wealth of the Earth, e.g. oil and coal.' His keen interest in unfolding the mystery of early traces of *Glossopteris* flora<sup>2,3</sup> prompted Virkki<sup>4,5</sup> to make a beginning in the study of spores and pollen in the Early Permian sediments of India and Australia. Subsequently, this institute initiated intensive investigations to build a broad-based infrastructure in palynology, encompassing all aspects of study of the sediments of various geological ages in India. The Gondwana sequence attracted the attention of Sahni, because of the Talchir glacio-marine sequence and its flora<sup>6</sup>, he then vigorously discussed Wegener's theory of continental drift based on the concept of Gondwanaland<sup>7</sup>, and the enormous coal deposits entombed in the Lower Gondwana sequence<sup>3</sup>.

The spore-pollen coat—the exine—is the toughest organic material nature has ever produced; hence it is most suitable for preservation. Moreover, these are produced in enormous numbers by plants. Palynology is, therefore, an effective tool for dating the sequences of strata and their correlation. The analysis of changing palynofloras in relation to evolution along temporal scale helps in biostratigraphy. Coal is an important fossil fuel and palynology is useful in determining age and relationship of coal seams.

Morphography—the study of form—is the basis of stratigraphic palynology. From morphographic analysis and variation studies of Permian, Triassic, Jurassic and Cretaceous palynomorphs a vast palynological database on morphotaxonomy is available. The recognition of the unique body-sac attachment in the radially-symmetric monosaccate pollen, viz. *Plicatipollenites*, *Parasaccites*, which bear well-organized germinal mark on the proximal face—a prepollen character—was a major breakthrough<sup>8,9</sup>. In addition, several taxa of trilete, monolete spores and striate, non-striate saccate pollen, exclusively typical of the Gondwanaland, were circumscribed, e.g. *Crucisaccites*, *Densipollenites*, *Barakarites*, *Indospora*, *Microbaculispora*, *Corisaccites*, *Goubinisporea*, *Staurosaccites*, *Indotriradites*, *Gondisporites*, etc.

Sahni visualized the significance of distributional columns of spores and pollen based on standard geological sections<sup>10</sup>. Accordingly, several studies were carried out in type-sections of various formations located in Damodar, Satpura, Son–Mahanadi and Godavari graben, Cauvery and East Coast, Rajmahal and Rajasthan and Kachchh basins. This led to the structuring of a working model (Figure 1) for palynological sequences through the strata in the time-frame of Permian to Lower Cretaceous in India<sup>11–13</sup>. The subsurface material procured by extensive drilling in search of coal and oil by the Geological Survey of India and Oil and Natural Gas Commission proved very useful in such studies.

The Talchir palynoassemblages do not contain typical Late Carboniferous mesosporoid or zonate spores. They show six morpho-evolutionary stocks (*Potonieisporites*, *Parasaccites*, *Virkkipollenites*, *Plicatipollenites*, *Pityosporites* and *Crescentipollenites*) which

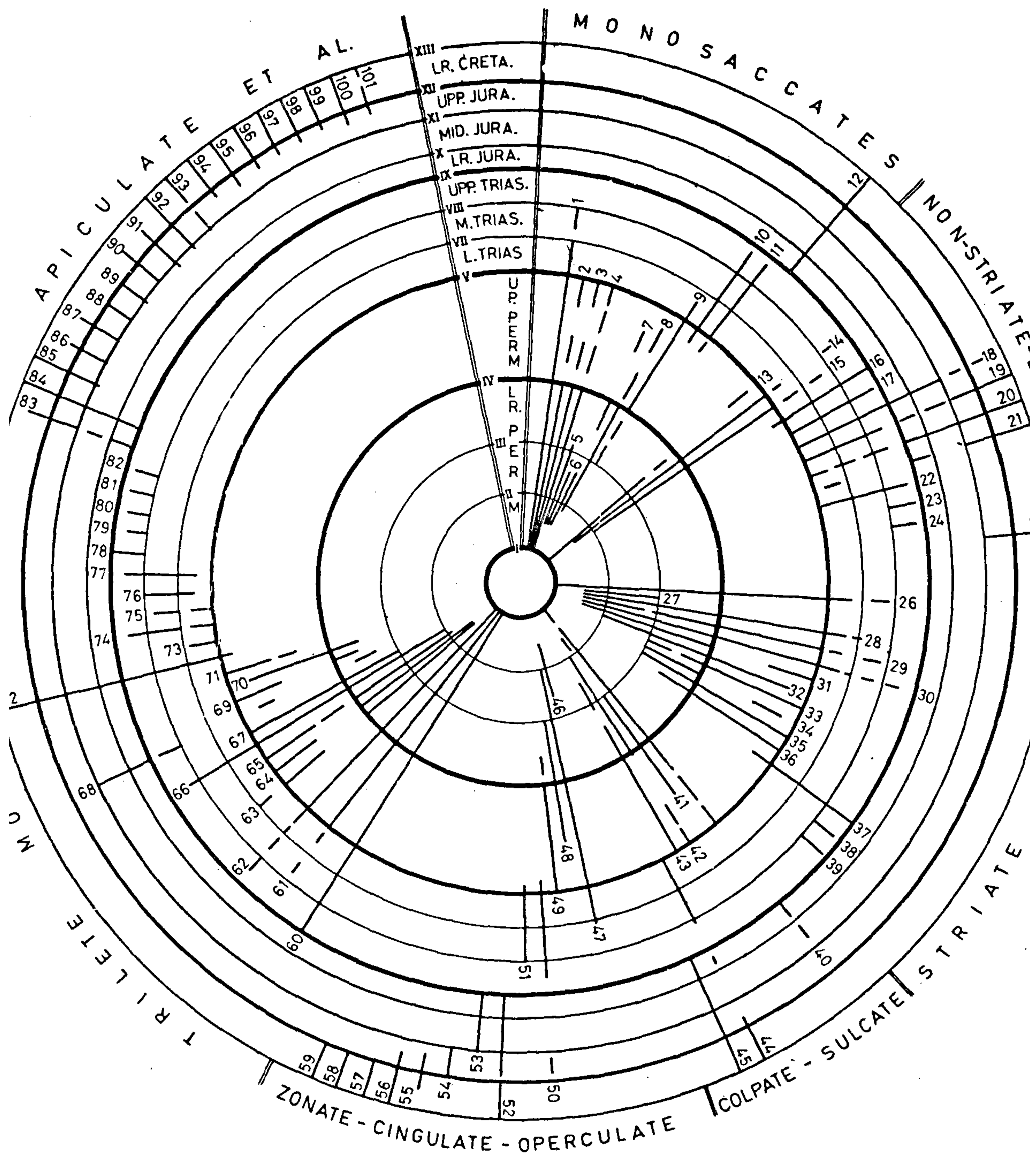


Figure 1. Circle range diagram to show FADs and LADs of important spore-pollen genera from Late Lower Asselian (I) Aptian-Albian (XIII). The tie-points of Sakmarian (II), P/Tr boundary (VI), Carnian (VIII), M. Jurassic (X) and Aptian-Alb (XIII) are also based on fauna or radiometric dates. Extent of epochs not to scale. Taxa depicted as index numbers are listed below for authors of taxa refer Tiwari and Tripathi<sup>37</sup>). 1, *Parasaccites*; 2, *Plicatipollenites*; 3, *Potonicisporites*; 4, *Vestigisporites*; 5, *Crucisaccites*; 6, *Rugasaccites*; 7, *Tuberisaccites*; 8, *Barakarites*; 9, *Densipollenites*; 10, *Playfordiaspora*; 11, *Goubinispora*; 12, *Callialasporites*; 13, *Pityosporites*; 14, *Scheuringipollenites*; 15, *Cuneatisporites*; 16, *Falcisporites*; 17, *Klausipollenites*; 18, *aperturopollenites*; 19, *Alisporites*; 20, *Araucariacites*; 21, *Podocarpidites*; 22, *Satsangisaccites*; 23, *Brachysaccus*; 24, *Minutosaccus*; 25, *Podosporites*; 26, *Crescentipollenites*; 27, *Circumstriatites*; 28, *Faunipollenites*; 29, *Rhizomaspora*; 30, *Striatopodocarpites*; 31, *Tiwariasporis*; 32, *Vittatina*; 33, *Verticipollenites*; 34, *Lueckisporites*; 35, *Corisaccites*; 36, *Guttulapollenites*; 37, *Lumatisporites*; 38, *Infernopollenites*; 39, *Staurosaccites*; 40, *Ginkgocycadophytus*; 41, *Striasulcites*; 42, *Pretricolpispollenites*; 43, *Cycadopites*; 44, *Monosulcites*; 45, *Jayantisporites*; 46, *Indotriletes*; 47, *Dentatispora*; 48, *Gondisporites*; 49, *Densosporites*; 50, *Lundbladispore*; 51, *Cingulatisporites*; 52, *Trilobozonosporites*; 53, *Lycopodiacidites*; 54, *Coptospora*; 55, *Cooksonites*; 56, *Aequitriletes*; 57, *Murphyospora*; 58, *Leptolepidites*; 59, *Verrucosisporites*; 60, *Brevitriletes*; 61, *Callumispore*; 62, *Microfoveolatispora*; 63, *Microbaculispora*; 64, *Horriditriletes*; 65, *Laevigatosporites*; 66, *Lacinitriletes*; 67, *Dictyotriletes*; 68, *Indospora*; 69, *Didictriletes*; 70, *Navalesporites*; 71, *Osmundacidites*; 72, *Ararisporites*; 73, *Guttatisporites*; 74, *Triplexisporites*; 75, *Novitasporites*; 76, *Ringosporites*; 77, *Convolvospora*; 78, *Dubrajisporites*; 79, *Foveosporites*; 80, *Gabonisporis*; 81, *Rajmahalispora*; 82, *Dictyophyllidites*; 83, *Classopollis*; 84, *Bosporites*; 85, *Concavisporites*; 86, *Contignisporites*; 87, *Foveotriletes*; 88, *Impardecispora*; 89, *Klukisporites*; 90, *Matomispore*; 91, *Retitriletes*; 92, *Trilobosporites*; 93, *Cicatricosisporites*; 94, *Baculatisporites*; 95, *Callispora*; 96, *Divisisporites*; 97, *Gleicheniidites*; 98, *Labiipollis*; 99, *Samthalisporites*; 100, *Triporoletes*; 101, *Triporoletes*.

subsequently sprouted and ramified in course of time and flourished up to the end of Permian<sup>14</sup>. Palynological evidences thus strongly support an Early Permian, rather than Carboniferous age for the Talchir sediments. The marine fauna of Manendragarh, taken as a reference point, confirms an Early Late Asselian date for the beginning of Gondwana sequence in India<sup>15,16</sup>.

The palynological data support the initiation of certain radially symmetric monosaccate pollen, comparable to those found in Talchir, at the Viséan–Westphalian level in Australia and South America<sup>17–19</sup>. The cladistically determined ancestral stock found in earliest Talchir sediments could have emerged from a progymnospermous population of earlier time, through Pseudosaccitrileti spore group of Early Carboniferous the radial monosaccates could have evolved<sup>14</sup>. In the Indian Peninsula these events are not preserved because of the non-deposition of the Cambrian to Lower Asselian sediments.

The quantitative frequency patterns of spore-pollen genera support a tripartite division of Permian in India. The Talchir and Karharbari formations are closely related on the basis of dominant monosaccate pollen, the Barakar Formation has a fairly declined monosaccate and diversified bisaccate population, while Kulti and Raniganj formations have a wide spread of striate disaccate pollen. These three segments may represent Lower, Middle and Upper Permian<sup>11</sup>. On the other hand, the qualitative distribution of taxa favours a bipartite system, because of a total decline in monosaccate pollen types at Barakar/Kulti boundary<sup>14</sup>.

In Peninsular India, the P/Tr boundary has been demarcated on the basis of FADs and LADs of spore-pollen species<sup>20</sup>. The event of high turnover reflected in palynomorph occurrences is broadly correlated with lithostratigraphy, estheriid stratigraphy and plant megafossil occurrences. From palynological comparisons with Salt Range and West Australian marine sequence it is concluded that the Raniganj–Panchet formational boundary is the most suited date as P/Tr boundary on the Indian Peninsula<sup>21,22</sup>. Thereafter, the climate becomes relatively drier and warmer with respect to the Raniganj Formation, and coal deposition ceases, but palynology does not support the earlier views that hot arid climate (red beds were taken as evidence) prevailed during Panchet deposition because a rich pteridophytic (including lycopsidean) population existed at that time as reflected by spores. The red beds are obviously the product of oxidation.

In the Son Valley, the question of age and sequential position of the Pali–Parsora–Tiki formations is yet to be resolved, but palynology can help in solving these problems. The P/Tr transition has been located at the basal part of the Upper Pali Formation<sup>23,24</sup>. Similar palynological levels are also recorded from the

Godavari and Mahanadi Valley basins where Permo–Triassic passage has been inferred to lie within the Upper Kamthi bed<sup>25,26</sup>. The Early Triassic age of *Dicroidium*-bearing Nidpur beds in Son Valley has been reassessed by distinctive assemblage having well represented multitaeniate pollen. The lithostratigraphic sequence in this section, having Parsora-type lilac-coloured massive sandstone conformably capping the *Dicroidium*-bearing bed, further corroborates the conclusions based on palynology and plant megafossils, that the Nidpur beds are of Scythian age<sup>27–30</sup>. The total synchronicity of Pali, Kamthi, Raniganj, Motur and Bijori formations is not supported by palynofossils, as some of these formations contain Late Permian and Early Triassic palynofloras. The spores and pollen recovered from Tiki Formation are unique (*Brachysaccus*, *Staurosaccus*, *Infernopollenites*), representing a palynoflora of Carnian–Early Norian age of which there is a control by well-known fauna<sup>31,32</sup>. A similar palynoassemblage has been recovered from Dubrajpur Formation, thus identifying a level for Early Norian in Rajmahal Basin<sup>17</sup>. The Late Norian event of mass extinction has not yet been located palynologically, but the non-continuation of Early Norian elements of typical morphology up into the Lower Jurassic assemblages points to possibility of a major break in the flora at the end of Triassic<sup>14</sup>.

The absence of Jurassic sequence in Indian Peninsular Gondwana (except in the Pranhita–Godavari Graben) has been suggested in recent years, mainly on the basis of radiometric dates ( $115 \pm 10$  Ma) of the trap flows in the Rajmahal Basin<sup>33,34</sup>. Thus, an Aptian–Albian age has been assigned to the package of the Rajmahal traps. The close similarity of Jabalpur and Athgarh formations with Rajmahal Formation suggests a palynofloristic homotaxy, although being homotaxial does not necessarily mean being synchronous. The palynological zonations are still being formulated in this regard. Their delimitation is difficult because palynofloras at the Jurassic–Cretaceous transition are fairly uniform and the taxa earlier thought to be the markers of Lower Cretaceous—e.g. *Cooksonites*, *Coptospora*, *Aequitriradites*, *Appendicisporites*, *Retitriletes*, etc. have been found lately in the Upper Jurassic also<sup>19</sup>. Moreover, the data from continuous sections are still lacking and the radiometric dates of well-defined sequential flows are yet to be obtained. Presently available data indicate that the assemblages of Early Cretaceous Rajmahal Formation significantly change after each trap-activity and hence the chances of missing the earliest Neocomian palynoassemblages are more because of the barren nature of the sediments. The data from Cauvery Basin<sup>35</sup> have been useful but a tagging of FADs, LADs and epiboles of taxa with other basins of India is urgently needed for resolving the

problem of Jurassic-Cretaceous boundary.

The age and the span of Dubrajpur Formation in Rajmahal Basin have been determined by palynology. The successions of palynoassemblages in this formation are now equated with those of Kulti, Raniganj, Panchet and Supra-Panchet formations<sup>36-38</sup>. The record of early angiospermous pollen within the lower Intertrappean bed of Rajmahal Formation marks a Late Neocomian-Aptian date in the terrestrial deposits of Rajmahal Formation<sup>39</sup>.

Palynological studies have been effectively used in the correlation of coal seams in different coalfields of Lower Gondwana sequence. During the last three decades, serious attempts have been made to establish palynological relationships amongst the known coal seams and also those located during exploration in the subsurface. The comparisons were mostly based on percentage frequency of the spore-pollen taxa at generic levels. Nonetheless, the results have not always been satisfactory, particularly for seam-to-seam correlation in Barakar and Raniganj formations. There are two reasons for this anomaly, (i) that the highest and lowest occurrence of taxa generally are mutually inconsistent because the existence of the parent vegetation had been environmentally biased and ecologically controlled, and (ii) the rate of evolution had been very slow during the Barakar and Kulti-Raniganj span and so differences among assemblages are least expressed in the closely spaced coal seams<sup>14</sup>. In view of the above facts, precise correlation can be obtained only by applying well-defined species-based zonation schemes. The steady FADs and LADs of marker species and their application through quantitative stratigraphic methods developed during the last decade<sup>40,41</sup> can provide finer correlation.

The flora of Early Permian had its impact on the Permian palynoflora of Tethyan Himalaya in Malla Johar, Spiti, Salt Range and peripheral Gondwana of the northeastern region<sup>42,43</sup>. The greater Gondwana radiation of floras has been supported by the occurrence of some similar pollen and spores in the now-widely separated regions of Tibet and China<sup>44</sup>. The occurrence of an unusual monosaccate pollen—*Crucisaccites*, with cruciate saccus attachment—in Lower Permian of China and in India suggests that the northerly accreting strips of land and microplates calved off from the greater Gondwanaland, must have taken the gene-pool material of common stock which existed during Carboniferous time when China and north Tibet plates were also a part of this supercontinent<sup>44</sup>.

Professor Sahni's vision of studying botanical affinities of dispersed spores and pollen remains a challenge! The field is difficult, but enormously promising to establish parentage and further under-

standing the evolution and diversification of floric components. The use of modern techniques, such as ultramicroscopy, computers, standard biostratigraphic cladistics, tracing the evolutionary trends and identifying the events of significance, are urgently needed. The scenario of palynology has been constructed but a continuous and complete portrait with finer details of relief are yet to be painted on the vast canvas of Gondwana of India.

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