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TOWARDS A GONDWANA PALYNOCHRONOLOGY

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Since the inception of the human race, the human beings are striving hard to unfold the mystery of nature. The fields of such activities are innumerable, the arrays of search are complex, and the circumferences of knowledge are ever expanding. Yet, we go on and on, in the search and research of the truth. Perhaps, the nature instigates the human being for this thirst of continued activity since the time immemorial. Professor M.R.Sahni was one of the such seekers of the truth with a burning desire to commitment for the knowledge of geo-biosciences. His landmark contributions to the earth system sciences in general, and Palaeontology in particular, are highly commendable. As a knowledgeable teacher, ardent researcher, effective administrator, able organizer and humble gentleman, Professor M.R.Sahni will always be remembered by the community of scientists as well as others who knew him or know his valuable work.

I had an opportunity to meet Professor M.R.Sahni in the early sixties at the Birbal Sahni Institute of Palaeobotany, Lucknow when he was the Chief Guest on 14th November, the Founder's Day Function of the Institute. This being the birthday of his elder brother, the Founder of the BSIP - Professor Birbal Sahni, the Birthday Cake was cut by the Chief Guest. After his short speech – as he was a man of few words, Prof. M.R. Sahni was talking to the people in the hall, particularly to the younger stratum of the gathering. To me — an young research scholar and a new entrant in the institute, this was a very exciting occasion as I thought about the two great brothers who devoted their lives to unfold the mystery of plant and animal fossils and contributed immensely to the knowledge during the twenteeth century. At that time, it was also engraved on my memory that how polite and soft-spoken he was, and at the same time floated subtle and intelligent humour.

I feel highly honoured for having been invited by the Palaeontological Society of India to deliver the lecture today. I express my thanks to the Executive Council of the Society and its Secretary, Prof. M.P. Singh, for giving me this opportunity through which I am paying my respectful tribute to the Founder of the Palaeontological Society of India – Professor M.R.Sahni. I also express my gratitude to Prof. S.Kumar, officiating Head of the Geology Department, Lucknow University and other faculty members of the Geology Department for their kind gesture and the hospitality extended to me.

I am thankful to you all, Ladies and Gentlemen, who have come here to attend this function, and spared some of your precious time to listen to my talk.

The **Gondwana Sequence** on Indian peninsula is basically a nonmarine succession of sediments containing typical plant and animal fossils. Hence, the Standard Global Chronostratigraphic Scale can not be used directly in the conventional way. However, from amongst several parameters, the palynoassemblage zones are best suited for such collation because they can be calibered to identify several benchmarks in relation to marine beds in the Tethys Himalayan sequence and other regions on the Gondwanaland. These tagging-points for the SGCS may be further reinforced by other evidences, and a structural framework thus erected may be effectively utilized to interpolate the intermediate assemblages, basing their correlational affinities on other indices.

The 17th Professor M.R. Sahni Memorial Lecture delivered on 15th March, 1999.

THE INDIAN GONDWANA

For the first time, H.B.Medlicott (1872) initiated the term "Gondwana", in an unpublished report, for a succession of nonmarine sediments on the Indian peninsula having fluviatile, lacustrine or glaciogene attributes with characteristic plant and animal fossils. The name was derived from the ancient kingdom of `Gonds' in Central India. Subsequently, the term was formally adapted and in due course of time became conventional to encompass very wide aspects, including lithostratigraphy, biostratigraphy, palaeogeography and even chronostratigraphy (Blanford *et al.* 1856; Medlicott and Blanford, 1879; Oldham, 1893; Fox, 1931; Du Toit, 1937; King, 1958; Pascoe, 1959; Sastry *et al.*, 1977; Mitra and Raja Rao, 1987). As it is in vogue today, the term *Gondwana Sequence* in stratigraphic sense includes naturally related succession of sandstones, shales, coals, carbonaceous shales, tillites, clays and associated rocks; this package of sediments is also characterized by plant and animal fossils having Gondwana affinity. It is basically a nonmarine sequence but lately, marine signatures have also been recorded at various levels (Tiwari *et al.*, 1995; Chandra, 1996; Mukhopadhyay, 1996; Ravi Shankar *et al.*, 1996). Both litho- and bio-characters have been utilized in determining the temporal limits of the sequence which is defined to range from basal Permian to the end of Early Cretaceous.

The recognition of Jurassic succession in several basins on peninsular India and a correlation of important episodes with Himalayan Mesozoics are supportive of a continuous sedimentation from Triassic to Jurassic; therefore, the views that the upper boundary of Gondwana be drawn at the end of Triassic are not tenable (*see* Sastry *et al.*, 1977; Datta *et al.*, 1983; Venkatachala and Maheshwari, 1991; Venkatachala *et al.*, 1993; Sen Gupta, 1996; Ravi Shanker *et al.*, 1996; Vijaya and Tiwari, 1996; Tiwari, 1999a). So also, the paralic and shallow marine sediments in natural association with Gondwana facies and faunal and floral intercalations are grouped within the Gondwana Sequence. Thus, the contemporary extra-peninsular sequences of the Indian subcontinent showing Gondwanic attributes of plant and animal fossils are qualified for intimate Gondwana relational affinity.

The depositional history of the Gondwana Sequence in different basins (fig. 1) has been typically different from each other because of variable spasmodic uplift and subsidence in the fault-bound grabens, half-grabens or troughs (Datta & Mitra, 1982; Tewari and Casshyap, 1996). Therefore, the sequences do not conform to any unified scheme of inter–basinal lithological correlation; and so the discussion on bipartite or tripartite division of the Gondwana is futile. It has been, thus, derived that biostratigraphical parameters are the only suitable criteria which can classify and give an age-tagging to various groups of formations in a simplified and unitary way. Such an approach also provides a tool for long-range correlation of the late Palaeozoic and Mesozoic sequences amongst the continents of the southern hemisphere which constituted the Gondwanaland. The floras of the Gondwanaland – *Glossopteris*, *Dicroidium* and *Ptilophyllum* floras – were not known from outside of this supercontinent, and hence they provide a unique parameter for studying the inter-relationship as well as biostratigraphy.

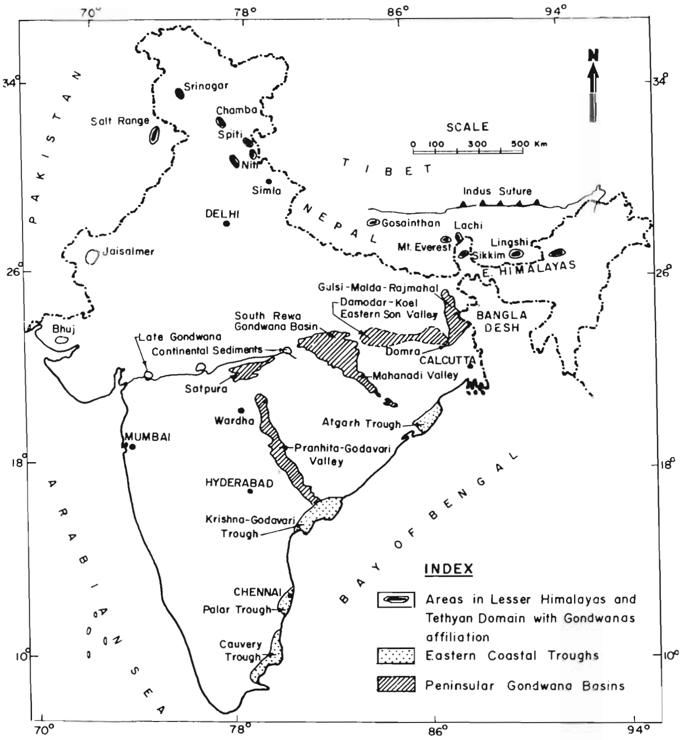


Fig. 1. Indian subcontinent showing Gondwana basins on the peninsula, troughs along east-coast, and areas in western India, Lesser Himalaya, Tethyan realm (including Pakistan) having Gondwana relational affinity.

PALYNOCHRONOLOGY

The Standard Global Chronostratigraphic Scale (SGCS) is developed mainly on the basis of marine fossils, and the Gondwana Sequence on the Indian peninsula is primarily a nonmarine deposition. Obviously, any attempt to tag the SGCS with the Gondwana formations does not conform to the so-far-practiced methods. Such a problem could, however, be tackled by the application of the nonmarine biochronostratigrpahy which has been enriched by the rigorous studies of mega- and microfossils of plant and animal origin. The sequencing of biozones with an aim to develop a scale can also be purposefully reinforced by the data, wherever available, on magnetostratigraphy, radiometric ages and sequence stratigraphy.

In addition to the well-documented floras and the spore-pollen assemblages produced by them, there are evidences which provide independent dating to several levels in the Gondwana Sequence of India. To cite examples—marine invertebrate *Eurydesma-Productus* fauna of the Talchir Formation, *Gondwanosaurus* fauna of the Raniganj Formation, *Lystosaurus* fauna of the Panchet Formation, Conchostracan zonations in Permo-Triassic sequence, Phytosaur assemblage from the Tiki Formation, Sauropod fauna of the Kota Formaion, and ^{40}Ar/^{39}Ar dating of the Rajmahal Traps (Sastry *et al.,* 1977; Datta and Mitra, 1982; Satsangi, 1987; Ghosh *et al.,* 1988; Tiwari and Tripathi, 1995). Notwithstanding such multiple evidences, the spore and pollen biochronology makes a core-system which could be collated with the SGCS because palynomorphs are found in astronomical numbers in the sedimentary rocks, and theoretically all the sedimentary strata must contain them. Also, the palynofossils are complete entities in themselves reflecting the nature of their mother vegetation and indicating the strings of morphographical evolution as well as changing patterns of climate through time. Taphonomically speaking, they are made-up of the wonder material – the sporopollenin, which is least effected during preservation. The spores and pollen are widely distributed through dispersal by animals, water and air, cutting across the barriers of environment. Other types of fossils found in the terrestrial environment generally may not occur widely in spatial and temporal continuity, mostly they are ill-preserved, incomplete or fragmentary and do not transgress the specific limits of climate, ecology or environment. It is important to note that the beds containing characteristic fauna could be cross-correlated, with other strata having no animal fossils, only by the palynoassemblages. All the more, spores and pollen are the only fossils which are abundantly common to both marine and nonmarine regimes and, therefore, can be used effectively for inter-correlation. This property enhances the utility of palynozones in tagging the Gondwana nonmarine formations with the SGCS, giving them an inferential standard bearing. In view of such a potentiality of utilization, the term "Palynochronology" is being coined here to express the spore-pollen biochronology in an assertive and specific meaning.

As regards the terminology and nomenclature of Gondwana-time-intervals, the formal Stage or Series levels may not be used righteously or could not be introduced anew because of the inherent nonmarine nature of the sequence qualified by the natural assembly of both litho- and biostratigraphic attributes. Instead, in case of palynochronological determinations, the time-levels could be defined by delineation of palynoassemblage zones. The identification of rigorously structured palynochronological units, i.e. zones, also help in inter-correlation amongst various basins on the peninsula and widely apart regions on the Gondwanaland (fig. 2) which could be marine or nonmrine; evidently, such tie-points could as well be extrapolated with the marine-based SGCS by way of palynofossils.

For various formations through the Gondwana Sequence, type sections based on lithological characters are well documented (Sastry *et al.,* 1977). However, since 'Stages' based on nonmarine fossils can not be instituted, the 'Stratotypes' or Global Standard Section and Point (GSSP) are not required to be assigned to time-intervals. Instead, 'Reference Section' for designated palynoassemblage-zone could serve the purpose of correlation (Lucas, 1994). Also, the GSSP can not be correlated palynologically, without taking plant evolution and migration into consideration, with widely separated

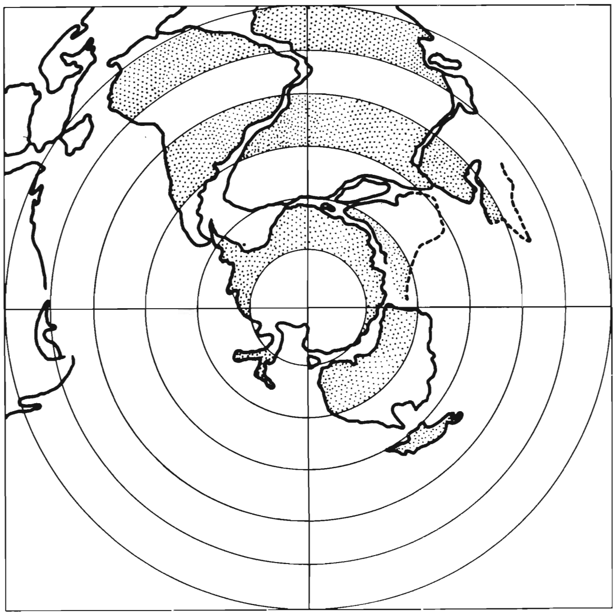


Fig. 2. Position of Indian subcontinent in relation to the Gondwanaland during Early Permian time. The great Permo-Carboniferous glaciation, the relative distance from the South Pole and latitudinal positioning (shown by concentric zones) influence the variability of the palynofloras on the Gondwanaland, although their basic nature is closely related. The northern landmass (Euramerica, Angara and Cathaysia: not shown in the map) having been situated in the tropical, subtropical and temperate belts of relatively warmer regions, experienced different climate and supported floras having least relationship with the *Glossopteris* - *Dicroidium* floras of the southern landmass at that time.

points on northern and southern hemispheres, during Palaeozoic and Mesozoic times, because the floras of these regions basically differed from each other.

The concept of palynochronology evolves around the structuring of palynoassemblage-zone. There are several kinds of zones depending on the parameter applied for stratigraphy (ISSC 1971, 1972 in Hedberg, 1976; Tiwari and Tripathi, 1992). The palynoassemblage-zone is one of the such zones which represents the basic unit of palynostratigraphic classification of a sequence and it encompasses a body of rock defined or characterized by its palynofossil contents. The term 'Palynochron' could as well be used for the time-equivalent unit of a palynozone but since no formal system has been yet evolved for such a time scale, a palynoassemblage-zone with a prefix of taxonomic epithet could be conceptualized in the sense of time. However, the ultimate aim of such a synthesis should be fixed on naturally arranged time units (i.e. 'palynochrons') when the data attains a complete and continuous status.

The most suitable structuring of palynoassemblage-zone is done on the basis of unique groups (i.e. individualistic association) of species with short-range occurrence and easily identifiable characters. The DOD (Dominance Datum), FAD and LAD of selected taxa and their morphographic evolutionary lineages are also useful factors to determine the characterization of a zone but each of these factors has its own limitations, viz., DOD could be eco-biased, and FAD and LAD could be imprecisely determined at times because of reworking, taphonomy or insufficient representation of specimens in a population; so also evolutionary linkage may show wide array of inconsistency because of environmental influence. In spite of these limitations, such analyses aid to the core-constitution of a palynozone in relation to the sequencing of palynoevents and consequently to the palynochronology (Tiwari, 1996, 1999a).

BENCHMARKS AND CROSS-CORRELATION

In recent years, well-structured palynoassemblage-zones through the unified run of the Gondwana Sequence of India have been established which prove to be effective in inter-basinal correlation on the peninsula as well as inter-regional tagging across the Gondwanaland (Tiwari and Tripathi, 1992; Prasad *et al.*, 1995; Prasad, 1997; Lindström, 1996; Warrington, 1996a, b; Vijaya, 1997 a, b; Tiwari, 1999a). The relative positionings of various palynozones in relation to the SGCS, *vis-a-vis* the lithostratigraphic sequence through Triassic, Jurassic and Cretaceous Gondwana are depicted in fig. 3. Although all the strata are not dated independently by evidences other than palynology, yet the ages of several levels are enforced by the animal fossils or by a match with palynofloras which occur in marine strata of established age; examples for Permian Period are given in fig. 4. Such benchmarks provide a strong framework to interpolate, with greater confidence, other packages of the sequence, which are dated only on the basis of palynology, so that a palynochronological order emerges. This scale could be employed in correlating Gondwana succession in various basins of India (*see* Tiwari, 1999 a).

Streching further, the palynozonation scheme tagged with SGCS could as well be closely compared with those in other regions of the Gondwanaland. However, the latitudinal disparity, the distance from the south pole, and the land-sea distribution influence the compositions of palynofloras in the distantly located continental sections on the Gondwanaland (fig. 2). Nevertheless, the basic Gondwanic nature of the assemblages does not change and hence a pattern-based comparison is striking. This further enhances the bondage between palynosequences and the SGCS because several of the horizons in the regions of the Gondwanaland, outside of the Indian peninsula, are marine in origin and dated independently on the basis of other parameters also. A Gondwanan correlation with SGCS and time-intervals suggested by palyno-succession is given by Tiwari (1999 a).

The palynological characterization and chronostratigraphy of some of the benchmarks in the Gondwana Sequence of India are discussed below:

Early Permian

1. The advent of Gondwana Sequence is recognised with the Talchir Formation in almost all the basins on the Indian peninsula and equivalent formations in the extra-peninsular India, coastal regions and the Tethyan Himalaya. The palynoassemblage zones are qualified mainly by the prominence of radial and bilateral monosaccate pollen species (of the genera *Potonieisporites, Plicatipollenites, Parasaccites*). These zones are structurally related to the Permian rather than the Carboniferous palynofloras (Vijaya, 1996). The qualifying spore species of the Carboniferous age, such as of — *Reinchospora, Lycospora, Cristatisporites* and other lycopsid elements with small zonate-cingulate species are also absent from the basal Gondwana of India, and hence the Late Carboniferous, or even Carbono-Permian connotation can not be given to the Talchir palynofloras. The abundance of *Glossopteris-Noeggerathiopsis -Gangamopteris* having no Rhacopterid elements in the Talchir Formation also supports a Permian affinity, and not of the Carbono-Permian. The conclusion is further enforced by *Eurydesma-Deltopecten-Stepanoviella* fossils of invertebrate marine animals which decipher Late Asselian to Sakmarian age for the Talchir Formation. In Manendragarh and Umaria marine beds of Madhya Pradesh, the episodes correspond to two transgressive phases of the same age in the Tethys sea in Himalayan region (Ravi Shanker *et al.*, 1996).

The basic three palynological Assemblage-zones identified in the Talchir Formation could further be correlated with *Parasaccites* zone of the Victoria Group of Trans-Antarctic Mountain (Boulder Bed and above), Antarctica (Truswell, 1980; Playford, 1990), younger part of Stage 2 of Eastern Australia (Allandale Fauna); *Pseudoreticulatisporites confluence* zone of Western Australia (Evans, 1969; Kemp *et al.*, 1977; Foster, 1979; Backhouse, 1991, 1993) and the Assemblage in 'Upper Shale' (which overlies the Dwyka Tillite) in South Africa (Tiwari, 1974). All of these palynofloras have an Asselian-Sakmarian affinity.

2. The palynoflora continues to diversify with FAD of several species as well as emergence of many new types of organizations in pollen (e.g. *Crucisaccites, Stellapollenites*), in the time subsequent to the Talchir deposition. The overlying Karharbari Formation is closely related with the Talchir Formation by way of palynological contents; hence a Sakmarian to Artinskian age-relationship could be suggested for the Karharbari palynozones (Tiwari, 1999a).

From Antarctica, palynofloras of the Beacon Super Group of the Dronning Maud Land and the Mount Glossopteris Formation in Trans-Antarctica are correlated with the palynozones of the Karharbari Formation (Playford, 1990; Lindström, 1995; 1996). Similar affiliation may be noticed with Stage 3 in eastern province of Australia (Evans, 1969). The spore-pollen assemblages of the lower portion of the Coal Measures in Sakoa Group of Madagascar and the Karoo Zone 3 of the Middle Ecca Series in South Africa are closely related with palynozones of the Karharbari Formation (Rakotoarivelo, 1972; Anderson, 1977).

Late Permian

The DODs of striate bisaccate pollen, along with *Densipollenites, Gondisporites, Crescenti-*

pollenites and *Verticipollenites* species characterize the palynoflora of the Raniganj Formation. The Late Permian tagging of this palynoflora is enforced by the nonmarine animal fossils — *Gondwanosaurus bijoriensis, Rhinosuchus wadiai, Dicynodonts* and *Detocephalus* fauna in the equatable horizons. The conchostracan biozone — *Cyzicus-Monoleaia* zone, (Ghosh *et al.*, 1988) also supports the age of the palynozones described as *Gondisporites raniganjensis* and *Densipollenites magnicorpus* Assemblage-zone (Tiwari and Tripathi, 1992; Tiwari, 1999a).

The Late Permian palynofloras known from the Amery Group of East Antarctica, Buckley Formation from Mount Archernar and Fossilryggen Vestfjella Dronning Maud Land, Antarctica resemble the Raniganj palynoflora (Balme and Playford, 1967; Truswell, 1980; Playford, 1990; Lindström, 1995, 1996). Similarly, palynologically defined Stage 5a to Stage 5 — *Playfordiaspora velata* and *Protohaploxypinus microcorpus* zones of Australia (Faunal zones III & IV), Lower Sakamena Group of Madagascar, Karoo Zone 4 and 5 of South Africa, and Zone 5 of South America have impressive correlativity with the palynozones identified in the Raniganj and its equivalent formations (Evans, 1969; Anderson, 1977; Foster, 1979, 1982; Azcuy, 1979; Marques-Toigo, 1991).

In the structure of palynoassemblage, the Chhidru Formation in the Salt Range, Gungri Formation in the Spiti Valley, and the Kuling Shale Formation in the Niti Region of the Tethyan Himalaya have a significant cross-correlation value when compared with the palynofloras of the Raniganj Formation and its coeval strata on the peninsula. The basic elements in the above cited comparisons are the abundant striate pollen, *Densipollenites*, *Marsupipollenites*, *Indospora*, *Gondisporites*, and so also the subtle FAD of Triassic precursors, such as — *Lundbladispora*, *Densoisporites*, *Playfordiaspora*, etc. The characteristic pattern of occurrence and relational affinity in totality gives the palynozones of the Raniganj and those of its equivalent strata a Kazanian-Tatarian aspect (Balme, 1970; Tiwari *et al.*, 1996; Singh *et al.*, 1995).

Early Triassic

The sequence of spore-pollen species zones recognized so far in the Panchet Formation, or its coeval strata on the peninsula, depicts an Early Triassic relationship. The '*Klausipollenites schaubergeri*' and *Playfordiaspora cancellosa* zones have been identified from several other regions on the Gondwanaland, including the marine beds. The Induan-Olenekian age affiliation of these horizons could as well be determined by the *Lystosaurus, Chasmatosaurus, Brachyops leticeps* and *Amblypteris* faunas which have long-range correlation potential. The record of *Cyzicus*, *Palaeolimnadia* and *Cornia* biozones of the conchostracans in ascending order in the succession parallelly equated with palynozonations supports an Early Triassic age for Panchet palynofloras (Ghosh and Dutta, 1996; Tiwari, 1999 a).

The Tethyan sequence in the Kathwai Member of the Early Triassic Mianwali Formation in the Salt Range, the Basal part of Lilang Group in the Lingti Hill Section of the Spiti Valley, and the Rambakot Member of the Early Triassic Shal Shal Formation of Niti Area exhibit palynoassemblage structure which is intimately related with that of the Panchet Formation and its coeval strata on the peninsula (Balme, 1970; Singh *et al.*, 1995; Tiwari. *et al.*, 1996).

Broadly, the Raniganj-Panchet Boundary represents the Permian-Triassic Boundary although the litho- and palynological levels of the change do not coincide precisely because of the intermixing of the lithologies at the interval (Tiwari, 1999 b, c). The palynochronology for the PTB interval is correlated with those in most of the regions on the Gondwanaland, including the Tethyan Himalaya. Although in finer details, or in representation of minor hiatuses, there could be some degree of discordance in correlation but a well-projected, pattern-based palynological shift, without an extinction is depicted at this benchmark (Tiwari and Vijaya, 1992; Tiwari, 1999 c).

Late Triassic

The Late Triassic sequence on the peninsula is represented by partial sectors of the Dubrajpur

Formation in the Rajmahal Basin, Tiki-Parsora formations in the South Rewa Basin, Denwa Formation in the Satpura Basin, Maleri Formation in the Godavari Basin and certain subsurface strata in the Kachchh Basin. The three unified palynozones — 1. *Rajmahalispora rugulata*, 2. *Brachysaccus ovalis*, and 3. *Dubrajisporites triassicus* — have been dated as Carnian to Norian (Tiwari and Tripathi, 1992). This age is independently controlled by reptilian remains — *Mataposaurus maleriensis, Pachygonia incurvata, Paradapedon huxleyi* and *Phytosaurus maleriensis* from Tiki beds in South Rewa Basin (Chatterjee and Roy Chowdhury, 1974). In addition to these fossils, the uppermost horizon of the Maleri Formation contains condontosaurid Prosauropod and teeth of *Archosaurus*. On the basis of *Plateosaurus,* the top bed of the Maleri Formation is consisdered to be Late Norian to Rhaetian in age (Kutty and Roy Chowdhury, 1970; Kutty *et al.*, 1988).

In the subsurface of Kachchh, a lavel has been identified in the lower reaches of the 'Jurassic sequence' which yielded a *Rhaetipollis germanicus* Assemblage-zone indicating a Rhaetian - Hettangian age (Koshal, 1975).

The Upper Triassic palynoassemblages of India have an affinity with eastern Australian assemblages (Onslow Microflora : De Jersey & Raine, 1990; Foster *et al.*, 1994). Relational pattern of Late Triassic palynofloras of Indian Gondwana with those in other continents of the Gondwanaland depicts basic similarity-trends (De Jekhowsky and Goubin, 1964; Goubin, 1965; Helby *et al.*, 1987; Zavattieri and Batten, 1996).

Jurassic

The status of continental Jurassic on peninsular India is emerging to indicate that the sequence is not totally absent in spite of hiatuses (Verma and Mehra, 1993; Mitra, 1993; Vijaya and Tiwari, 1996; Sen Gupta, 1996; Ravi Shanker *et al.*, 1996). The absence-of-Jurassic-syndrome started when the *Ptilophyllum*-flora of Rajmahal Intertrappean beds — classically known as Jurassic flora of India — was suggested to be of Late Neocomian age by Spath (1933) on the basis of its correlation with the *Ptilophyllum*-bearing sequence on the East Coast which has intercalations of Early Cretaceous ammonite-containing beds. So far so good! But Arkell (1956) streched this observation too far and concluded that the Jurassic period is represented on the Indian peninsula as major *nonsequence*. It is disappointing to note that none of these workers has made any field observation himself and without analysing the stratigraphic relationship of strata, such a sweeping remark was made. Unfortunately, in recent years it has become fashionable to negate total Jurassic sequence and so also the Gondwana Sequence temporally above the Upper Triassic; such derivations are based on inadequate reasoning and twisted evidences (Singh and Venkatachala, 1988; Venkatachala and Maheshwari, 1991; Venkatachala *et al.*, 1993). In actuality, the so-called "index" FAD of certain palynomorphs (*Aequitriradites spinulosus, Cicatricosisporites australiensis, Contignisporites dettmani*) — taken for granted for Cretaceous age — starts well within the Upper Jurassic; the distribution of the so-designated Cretaceous "index"plant fossil taxon *Weichselia* is inconsistent, and so also the record of *Onychiopsis* starts in the Middle Jurassic of Madagascar.

The exact location and the rediometric age of the earliest trap are not yet known either in the Rajmahal Basin or Bengal Basin. However, recent palynological studies of the subsurface intertrappean and infratrappean horizons strongly suggest that the earliest lava-flow must have occurred in the Late Jurassic time (Tiwari and Tripathi, 1995). Further, a rigorous analysis of data on palynology, plant megafossils/fauna, and lithostratigraphic relational affinity indicate that the nonmarine Jurassic sequence is present in several basins on the Indian subcontinent, e.g. — Kota Formation in Pranhita-Godavari Basin; Lathi Formation in Rajasthan; Mochu Formation in Bhutan; Infratrappean beds (a well defined sequence between the Dubrajpur Formation and the oldest trap) and some Intertrappean beds in the lower reaches of the "Rajmahal Formation" at certain regions of the Rajmahal and Bengal basins (e.g. Domra Sub-basin); Bandhavgarh and Hartala formations in the northern Son Valley; and certain levels in the Upper Gondwana Sequence of the Narmada Valley (for detailed discussion *see* Vijaya and Tiwari, 1996; Sen Gupta, 1996; Ravi Shanker *et al.*, 1996).

The palynological tie-points for Jurassic-Cretaceous succession could be located in the Assemblage-zones defined in fig. 3. The *Classopollis minor* Assemblage-zone could be taken as benchmark for Early Jurassic (Pliensbachian) in Lower Kota Formation in Pranhita-Godavari Basin, Lathi Formation in Rajasthan and Banni Well in Kachchh. The Lower Jurassic nonmarine Gondwana sediments, denoted by Kota Formation, record the presence of *Ptilophyllum, Equisetites, Otozamites* and *Araucarites cutchensis*, as well as animal fossils comprising fishes (*Tetragonolepsis*, *Paradapedium*), sauropod dinosaur, crocodiles, ostrocods and mammals (Datta and Mitra, 1982). The palynoflora of Lower Kota Formation is dominated by *Callialasporites, Classopollis* – the circumpollis group of pollen being in dominance (Ramanujam, 1987, 1993).

The relationship of palynozones — *Murospora florida* (Kimmeridgian), *Callialasporites turbatus* and *C. segmentatus* (Tithonian), *Cicatricosisporites australiensis* (Berriasian), *Foraminisporis wonthaggiensis* (Valangian), *Microcachryidites antarcticus* (Hauterivian) and *Cyclosporites hughesii* (Barremian-Aptian) in unified succession across the Late Jurassic-Early Cretaceous sequence from Rajmahal, Domra, Narmada, Satpura, Pranhita-Godavari, Krishna-Godavari, Palar and Kachchh basins, with comparable palynozones tagged with marine fossils at several levels in coeval succession in Australia projects an impressive palynochronological scale for the Indian nonmarine Upper Jurassic (Helby *et al.*, 1987; Burger, 1990; a,b; Tiwari and Tripathi, 1992; Prasad *et. al.*, 1995; Vijaya and Tiwari, 1996; Vijaya, 1997 a, b; Tiwari, 1999 a).

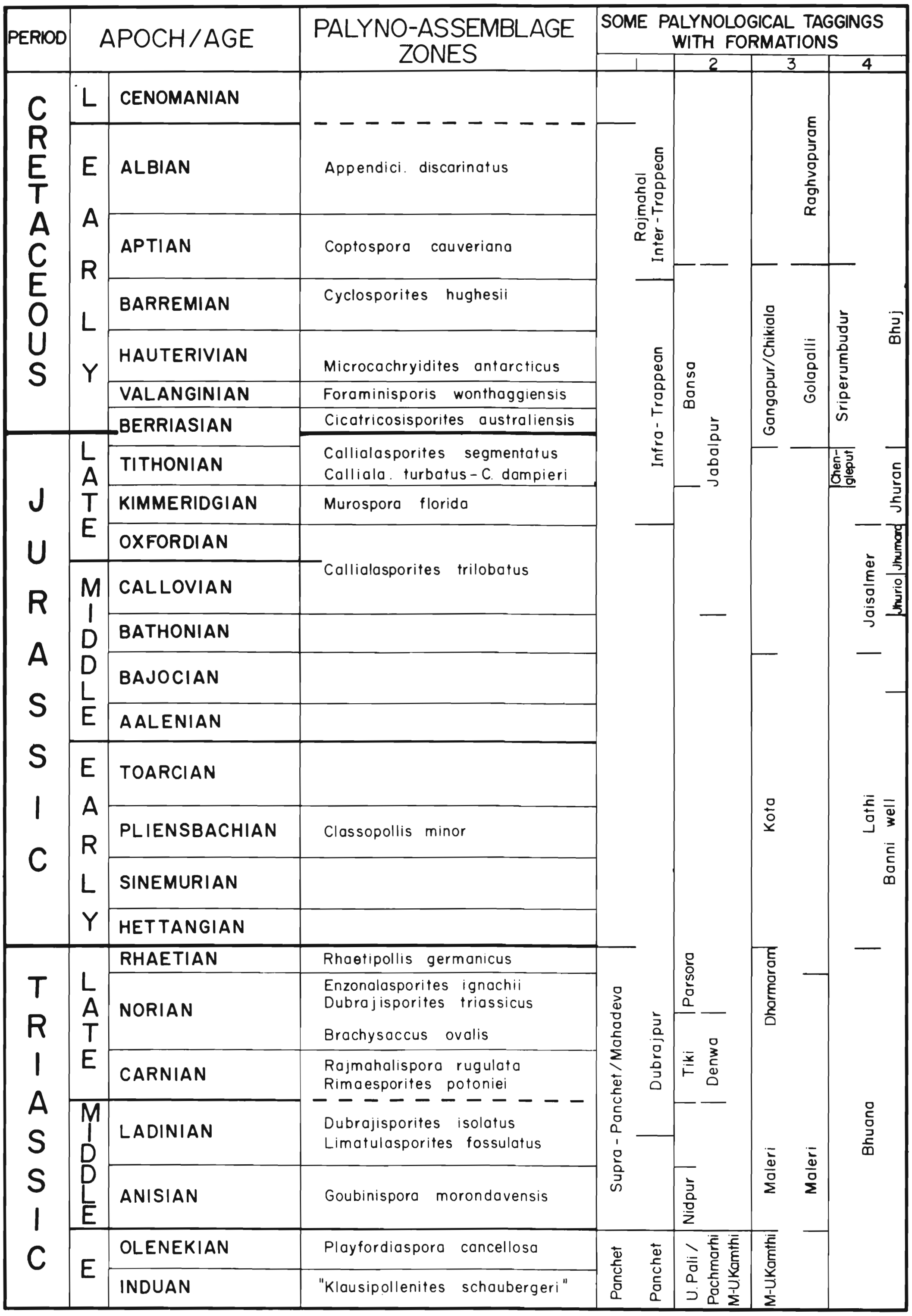
The palynoflora known from Callovian (Lapthal Member) and Tithonian (Spiti Member) of the Kiogod Formation in the Jurassic sequence of Painkhand, Niti Area, Central Himalaya shows close correlation with the coeval levels on the peninsula. Although species-level identification of spores and pollen in the sections from Niti Area could not be attempted because of taphonomic factors, the generic composition could as well be utilized effectively in such comparisons. The Lapthal Member (Callovian) contains *Callialasporites, Dubrajisporites, Infernopollenites, Araucariacites, Podocarpidites*, with a fauna (*Macrocephalites, Dolikocephalites*, etc.) in the thinly bedded limestone full of Lumachelle. In black shales with calcarious nodules and rich in ammonites in the Spiti Member (Tithonian), importnat palynotaxa present are — *Cooksonites, Klukisporites, Contignisporites, Cicatricosisporites, Callialasporites, Araucariacites, Laricoidites*; and the faunal remains are represented by *Blanfodiceras* Assemblage, *Himalayites-Corongoceros-Aulacosphincites* Assemblage, *Hildoglochiceras* Assemblage, etc., in the complete sequence of Tithonian (Tiwari *et al.*, 1996).

Such tie-points are very important for cross-correlation and palynochronological links of the zones in the nonmarine Upper Jurassic on the peninsula.

Early Cretaceous

The ^{40}Ar / ^{39}Ar age of the Rajmahal Traps in the Rajmahal Basin and the recovery of well-preserved palynofloras in the Intertrappean beds have ascertained palynochronological data-points for this level. The radiometric age of six basalt flows being 118-116 Ma, the associated spore-pollen assemblage comprising *Callialasporites monoalasporus, Aequitriradites verrucosus, Contignisporites cooksoniae, Cicatricosisporites australiensis, C.ludbrooki, Foraminisporis asymmetricus*, and FAD of angiospermic pollen qualify for an Aptian age of the studied package. This benchmark is reliable for relative positioning of other zones as well (Tiwari *et al.*, 1984; Tiwari and Tripathi, 1992, 1995). A close relationship of the intertrappean palynoflora with the Aptian *Cyclosporites hughesii* zone in Australia further enhances the significance of palynodating for nonmarine Aptian on peninsular India.

From amongst the isotopically dated flows, the oldest trap may not represent the oldest one in the basin, yet the infratrappean sequence — shales just below the available oldest trap — exhibits a Jurassic-Cretaceous aspect in its palynoassemblage.



PERIOD	APOCH/AGE		PALYNO-ASSEMBLAGE ZONES
CRETACEOUS	L	CENOMANIAN	
	EARLY	ALBIAN	Appendici. discarinatus
		APTIAN	Coptospora cauveriana
		BARREMIAN	Cyclosporites hughesii
		HAUTERIVIAN	Microcachryidites antarcticus
		VALANGINIAN	Foraminisporis wonthaggiensis
		BERRIASIAN	Cicatricosisporites australiensis
JURASSIC	LATE	TITHONIAN	Callialasporites segmentatus Calliala. turbatus - C. dampieri
		KIMMERIDGIAN	Murospora florida
		OXFORDIAN	Callialasporites trilobatus
	MIDDLE	CALLOVIAN	
		BATHONIAN	
		BAJOCIAN	
		AALENIAN	
	EARLY	TOARCIAN	
		PLIENSBACHIAN	Classopollis minor
		SINEMURIAN	
		HETTANGIAN	
TRIASSIC	LATE	RHAETIAN	Rhaetipollis germanicus
		NORIAN	Enzonalasporites ignachii Dubrajisporites triassicus Brachysaccus ovalis
		CARNIAN	Rajmahalispora rugulata Rimaesporites potoniei
	MIDDLE	LADINIAN	Dubrajisporites isolatus Limatulasporites fossulatus
		ANISIAN	Goubinispora morondavensis
	E	OLENEKIAN	Playfordiaspora cancellosa
		INDUAN	"Klausipollenites schaubergeri"

Fig. 3. Suggested tagging of palynosassemblage-zones, formations and SGCS through Upper Gondwana Sequence of India. The upper and lower limits of zones kept open in order to depict a relative positioning with the SGCS. Only major stratigraphic units have been indicated which show important palynological levels of correlational value in different basins : 1. Damodar, Koel, E.Son; Rajmahal, Domra. 2. Rewa; Satpura; Mahanadi. 3. Pranhita-Godavari; Krishna-Godavari. 4. Palar; Rajasthan; Kachchh (adapted after Tiwari, 1999 a).

PERIOD	EPOCH/AGE		FORMATIONS (on peninsula)	PALYNOZONES (on peninsula)	TETHYAN REGION		OTHER AGE INDICES (on peninsula)	CONCHOSTRACANS (on peninsula)	HIMALAYAN EPISODES
					SPORE-POLLEN	ANIMAL FOSSILS			
TRIASSIC	EARLY	OLENEKIAN	PANCHET	*Playfordiaspora cancellosa*	*Arcuatipollenites* *Callumispora* *Goubinispora* *Satsangisaccites* *Krempipollenites* *Playfordiaspora* *Densoisporites* *Lundbladispora*	*Flemingites*, *Pseudomonotis himaica*, *Meakocers*, *Otoceras woodwardi*, *Ophiceras tibeticum*, *O. sakuntala*	*Lystosaurus* *Chasmatosaurus* *Brachyops leticeps* *Amblypteris*	Vertexidae Estheriellidae *Palaeolimnadia*	VII Marine transgression, thick sequence of shale sandstone, limestone, rich in ammonites, bivalves, brachiopods, (Upper Permian to Upper Triassic)
		INDUAN		*Krempipollenites indicus*				*Cyzicus* *Estheriina*	
PERMIAN	LATE	TATARIAN	RANIGANJ	*Densipollenites magnicorpus* *Guttulapollenites gondwanensis* *Gondisporites raniganjensis*	*Krempipollenites* *Densipollenites* *Scheuringipollenites* *Faunipollenites* *Striatopodocarpites* *Crescentipollenites* *Weylandites* *Arcuatiplenites*	*Etheripecten*, *Sprifierella rajah* *Marginifera himalayensis* *Chonetid* *Bryozones* *Mourlonia* *Neospirifer*	Gondwanosaurus bijoriensis Rhinosuchus wadiai Dicynodonts Detocephalus	*Palaeolimnadia-Cyzicus-Monoleaia* Leaiid III	
		KAZANIAN							
		UFIMIAN	KULTI	*Densipollenites indiicus*			Corophioides (Ichno) *Skolithos; Phycodes*	*Cyzicus*	
	EARLY	KUNGURIAN	BARAKAR	*Faunipollenites varius* *Scheuringipollenites barakarensis* *Crucisaccites monoletus*	*Faunipollenites varius* *Scheuringipollenites barakarensis*		*Palaeophycus* *Skolithos* *Arenicolites*		VI widespread marine transgression, conglomerate, sandstone, shale, appearance of *Eurydesma*, *Deltopectean* (Lower Permian)
		ARTINSKIAN						Leaiid II	
		SAKMARIAN	KARHARI-BARI	*Virkkipollenites obscurus* *Rugasaccites obscurus* *Parasaccites korbaensis* *Plicatipollenites indicus*	*Parasaccites kobaensis*	*Eurydesma*, *Productus*, *Peruvispira*, *Linoproductus* *Spirifer*, *Dielasma*, *Streptorhynchus*, *Deltopecten*	*Palaeophycus* *Scoyenia*		
		ASSELIAN	TALCHIR	*Plicatipollenites gondwanensis* *Patonieisporites neglectus*	*Potonieisporites neglectus*		*Stephenoviella* *Eurydesma* *Deltopecten*	Leaiid I	

Fig. 4. An example of some parameters having age-linkage with palynoassemblage-zones in the Permian and Lower Triassic sequences.

Obvioiusly a hiatus is indicated at this level.

POINTS TO PONDER

In addition to a few important levels discussed above as evidences for erecting the main palynochronological framework, there are several other observations which may further enhance the degree of confidence in such determinations. By inferential extrapolation, such data may be utilized to strengthen the model, or to fill the intermittent gaps.

Dealing the chronostratigraphy of world Permian, Waterhouse (1976) concluded that on the Gondwanaland, the glacial tillite is overlain by bivalve *Eurydesma* fauna of Kurmaian (i.e. Late Asselian) age. Such conclusion conforms with that drawn on the basis of palynozones of the Talchir Formation, as discussed above.

The benchmark level at the Permian-Triassic interval is represented by the nonmarine Raniganj-Panchet boundary in the Domodar Basin on the peninsula which can be broadly tagged with the marine sequence of Chhidru Formation and Kathwai Member of Mianwali Formation in the Salt Range-Surgarh Range. Although there exists a low degree hiatus in the latter region, palynologically the general pattern in the occurrence of taxa *Densoisporites playfordii, Callumispora fungosa, Lundbladispora* *obsleta, 'Lunatisportes noviaulensis', Falcisporites stabilis, Playfordiaspora concellosa,* and others, connects these levels closely (for details *see* Balme, 1970; Nakazawa, 1992; Tiwari, 1999 a,b,c).

In addition to the Tethyan regime of Himalaya on the Indian subcontinent, there are several sections in the Permian, Triassic, Jurassic and Cretaceous sequences of the neighbouring regions, on the Gondwanaland, outside of the Indian peninsula, which record marine control as well as precisely delineated palynozones. For example — in the Moronadava Basin of Madagascar, the Sakamena Formation includes few marine beds in the primarily a nonmarine sequence (marine particularly in the Middle Sakamena Formation) having fossils of amphibians, reptiles, lamellibranchs and fishes, which show a correlation with Majunga marine deposits dated by ammonites giving the Sakamena an Upper Permian-Lower Triassic bracket. Similarly, from amongst the overlying Isalo I and Isalo II, the Isalo II Formation is dated to be Early Jurassic on the basis of ammonites. The Middle and Upper Jurassic sequence in the Morondava Basin is independently well-dated on the basis of brachiopods, lamellibranchs, ammonites, ostracoda and foraminifera. The palynozones of this basin, covering the Upper Carboniferous to Cretaceous sequence are well-defined and precisely delimited for marine and nonmarine units in the formations (De Jackhowsky and Goubin, 1964; Goubin, 1965), and these palynozones are intimately related, even at the species-level and also in the structure of the palynoflora, with those in the Gondwana Sequence of India. Thus, a linkage-value for palynochronology is evident.

The strings for a sound palynochronology in the nonmarine sequence of Mesozoic Gondwana of India could be knotted with the coeval strata of Australia where most of the levels are dated by ammonites and conodonts (*see* Helby *et al.*, 1987). However, meticulous comparison and identification of trend in variation at the finer scale in the zones of both the regions (i.e. India and Australia) are required. It has been observed that in spite of certain differences, attributable to regional factors, there exists a remarkable parallelism in the spore-pollen assemblages and in their pattern of occurrences through this sector of time in India and Australia.

From the survey of reviews on radiometric ages of Late Palaeozoic and Mesozoic periods, it becomes clear that there is an immense variation in both quantity and quality of data (Forster and Warrington, 1985). For the Permian, very few reliable dates are available from the areas where satisfactory stratigraphic control exists, but for the Triassic and Jurassic the data is satisfactory. To cite examples – several volcanic horizons in the Middle to Late Permian sequence in Sydney Basin, Australia have been dated by conventional K-Ar methods (Evernden and Richards, 1962). The Shoalhaven Group, at the base of Permian-Triassic, comprises clastic marine sediments which contain Kazanian brachiopods; it is overlain by Illawara Coal Measures of Tatarian age, having a palynoflora which could be closely linked with the Raniganj assemblage. An age of 255 ±5 Ma is proposed for Kazanian-Tatarian level on the basis of radiometry.

From Anisian to Ladinian strata from Toogoolawah Group, Queensland a well-defined palynoflora is documented (De Jersey, 1972), and the radiometric date could be fixed only at 240 Ma in the Neera Volcanics of the same age. The Ipswich Coal Measures in the Ipswich Basin in south east Queensland have been assigned a Carnian age on the basis of palynological evidence (De Jersey, 1971), and the basalt in the basin has yielded an average K-Ar age of 230 ±7 Ma. This makes a reliable point of comparison for the Indian Carnian palynoflora.

In spite of continued efforts, it appears that more reliable and detailed age determinations on radiometric data are required which must have closely associated palynofloras; such information shall be useful for dating the nonmarine sequence and, therefore, requires a critical analysis (*see also*: Harland *et al.*, 1982; Foster, 1983; Carr *et al.*, 1984; Forster and Warrington, 1985).

Finally, it may be mentioned that the aim of global stratigraphy should be to determine Stages, and their divisions, on the basis of well-studied sedimentary sequences, and then to correlate the levels of the same age and boundaries between them. The global correlation must be attained irrespective of facies (marine, transitional, or continental) because the attributes of facies indicate relation between physical and geographical conditions and sedimentation process and tactonics, rather than the temporal and spatial relationship between widely separated sedimentary sectors of stratigraphic subdivisions. (Burove *et al.,* 1996). Obviously a scale drawn on the basis of marine sections only may not serve the purpose for nonmarine tagging.

Thus, a rigorous palynozonation scheme with finer details and flexible comparability should be attempted for the Gondwana, which when framed in view of the palaeogeography, morphographic evolution and migration in plant communities, will lead to a global system of palynochronology.

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REFERENCES

Anderson, J.M.1977. The biostratigraphy of the Permian and Triassic, Part 3 - A review of Gondwana Permian palynology with particular reference to the northern Karoo Basin, South Africa. *Bot. Surv. S. Africa Mem.* **41** : 1-67.

Arkell, W. J. 1956. *Jurassic Geology of the World.* Oliver and Byod Ltd. London.

Azcuy, C.L. 1979. A review of the early Gondwana palynology of Argentina and South America, p. 175-185. In : *Proc. IV Int. Palynol. Conf. Lucknow* (1976-77) (Eds. Bharadwaj, D.C. *et al.*), **2**, Birbal Sahni Institute of Palaeobotany, Lucknow.

Backhouse, J.1991. Permian palynostratigraphy of the Collie Basin, Western Australia. *Rev. Palaeobot. Palynol.* **67** : 237-314.

Backhouse, J.1993. Palynology and correlation of Permian sediments in the Perth, Collie, and Officer basins, Western Australia. *Geol. Surv. W. Australia Rep.* **34** : 111-128.

Balme, B.E. 1970. Palynology of Permian and Triassic strata in the Salt Range and Surghar Range, West Pakistan, p. 306-452. In : *Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan* (Eds. Kummel, B. and Teichert, C.), *Univ. Kansas, Dept. of Geol. Spl. Publ.* 4, *University Press, Kansas.*

Balme, B.E. and Playford, G. 1967. Late Permian plant microfossils from the Prince Charles Mountains, Antarctica. *Rev. Micropaleont.* **10** (3) : 179-192.

Blanford, W.T., Blanford, H.F. and Theobold, W.1856. On the geological structure and relation of the Talcher Coalfield in dist. Cuttack. *Mem. Geol. Surv. India,* **1** (1) : 23-43.

Burger, D. 1990 a. Australian Phanerozoic timescales : 8. Jurassic biostratigraphic charts and explanatory notes. *Bur. Min. Resour. Australia Rec.* 1989/38, p.38.

Burger, D. 1990 b. Australian Phanerozoic timescale : 9. Cretaceous biostratigraphic charts and explanatory notes. *Bur. Min. Resour. Australia. Rec.* 1989/39, p.36.

Burov, B.V., Gusev, A.K., Esaulova, N.K., Khalimbadzha, V.G. and Shevelev, A.I.. 1996. On the problem of International Stratigraphy of the Permian System. *Permophiles* No. **29** : 6-7.

Carr, P.F., Jones, B.G., Quinn, B.G. and Wright, A.J. 1984. Towards an objective Phanerozoic timescale. *Geology,* **12** : 274-277.

Chandra, S.K. 1996. Marine signatures in the Gondwana of peninsular India and Permian palaeogeography, p. 529-538. In : *Gondwana Nine* **1**, Proc. 9th Int. Gondw. Symp. Hyderabad, 1994 (Eds. P.K.S. Guha *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Chatterjee, S. and Roy Chowdhury, T. 1974. Triassic Gondwana vertebrates from India. *Jour. Earth Sci.* **1**(1) : 96-112.

Datta, N.R. and Mitra, N.D. 1982. Gondwana geology of Indian plate – its history of fragmentation and dispersion. *Proc. Int. Centen. Symp.*Geol. Surv. Japan, Tsukuba, Japan 1982. Preprint, pp.1-31.

Datta, N.R., Mitra, N.D. and Bandyopadhya, S.K. 1983. Recent trends in the study of Gondwana basins of peninsular and extrapeninsular India. *Petroliferous Basins of India. Petrol. Asia Jour.* **6** : 159-169.

De Jekhowsky, B. and Goubin, N. 1964. Subsurface palynology in Madagascar : A stratigraphical sketch of the Permian, Triassic and Jurassic of Morondava Basin. *Palynol. Oil Explor. Soc. Econ. Paleontol. Mineralog. Spl. Publ.* **11** : 116-130.

De Jersey, N. J. 1971. Triassic miospores from the Tivoli Formation and Kholo Sub-group. *Publ. Qld. Geol. Surv.* **353** : 1-24.

De Jersey, N. J. 1972. Triassic miospores from the Esk beds. *Publ. Qld. Geol. Surv.* **357** : 1-21.

De Jersey, N. J. and Raine, J.I. 1990. Triassic and earliest Jurassic miospores from the Murihiku Supergroup, New Zealand. *N.Z. Geol. Surv. Palaeont. Bull.* **62** : 1-64.

Du Toit, A.L. 1937. *Our Wandering Continents.* Oliver & Boyd., Glasgow.

Evans, P.R. 1969. Upper Carboniferous and Permian palynological stages and their distribution in eastern Australia. *Gondwana Stratigraphy,* IUGS. Ist Gondwana. Symp. Buenos Aires. 1967, UNESCO, Paris, pp. 41-54.

Evernden, J.F. and Richards, J.R. 1962. Potassium-Argon ages in eastern Australia. *Jour. Geol. Soc. Australia,* **9** : 1-49.

Forster, S.C. and Warrington, G. 1985. Geochronology of the Carboniferous, Permian and Triassic, p. 99-113. In : *The Chronology of the Geological Record* (Ed. Snelling, N.J.). *Geol. Soc. Lond. Mem.* **10**.

Foster, C.B. 1979. Permian plant microfossils of the Blair Athol Coal Measures, Baralaba Coal Measures and Basal Rewan Formation of Queensland. *Geol. Surv. Qld. Publ.,* 372. *Palaeont. Pap.* **45** : 1-244.

Foster, C.B. 1982. Spore-pollen assemblages of the Bowen Basin, Queensland (Australia) : Their relationship to the Permian/Triassic Boundary. *Rev. Palaeobot. Palynol.* **36** : 165-183.

Foster, C.B. 1983. Palaeontology : Review of the time frame for the

Permian of Queensland. *Permian Geology of Queensland. Geol. Soc. Australia, Qld. Div.* pp. 107-120.

Foster, C.B., Balme, B.E. and Helby, R. 1994. First record of Tethyan palynomorphs from the Late Triassic of East Antarctica. *AGSO J. Austral. Geol. Geophys.* **15** (2) : 239-246.

Fox, C.S. 1931. The Gondwana System and its related formations. *Mem. Geol. Surv. India,* **58** : 1-113.

Ghosh, S.C. and Dutta, A. 1996. A critical review of fossil conchostraca of Permian-Triassic periods in Gondwana realm, p. 195-206. In : *Gondwna Nine* **1**, *Proc. 9th Int. Gondw. Symp. Hyderabad, 1994* (Eds. Guha, P.K. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Ghosh, S.C., Dutta, A., Nandi, A. & Mukhopadhyay, S. 1988. Estherid zonation in the Gondwanas. *Palaeobot.* **36** : 143-153.

Goubin, N. 1965. Description et répartition des principaux pollenites Permiens, Triasiques et Jurassiques des sondages du Bassin de Morondava (Madagascar). *Rev. Inst. Francaise Pétrole*, **20** : 1415-1461.

Harland, W.B., Cox, A.V., Llewellyn, P.G., Pickton, C.A.G., Smith, A.G. and Walters, R. 1982. *A Geologic Time Scale.* Cambridge University Press, Cambridge.

Hedberg, G.H.D. 1976. *International Stratigraphic Guide.* Wiley-Inter-Science, New York.

Helby, R.J., Morgan, R. and Partridge. A.D. 1987. A palynological zonation of the Australian Mesozoic, p 1-94. In : *Mem. Ass. Australian Palaeontol.* (Ed. Jell, P.A.), **4**.

Kemp, E.M., Balme, B.E., Helby, R.J., Kyle, R.A., Playford, G. and Price, P.L. 1977. Carboniferous and Permian palynostratigraphy in Australia and Antarctica : A review. *Bur. Min. Resour. Jour. Australian Geol. Geophys.* **2** : 177-208.

King, L.C. 1958. Basic palaeogeography of Gondwanaland during Late Palaeozoic and Mesozoic Eras. *Quart. Jour. Geol. Soc. Lond*, **114**: 47-70.

Koshal, V.N. 1975. Palynozonation of Mesozoic subsurface sediments of Banni, Kutch, Gujarat. *Quart. Jour. Geol. Min. Metall. Soc. India*, **47** (2) : 79-82.

Kutty, T.S., Jain, S.L. and Roy Chowdhury, T.K. 1988. Gondwana sequence of northern Pranhita-Godavari Valley : its stratigraphy and vertebrate faunas. *Palaeobot.* **36** : 214-229.

Kutty, T.S. and Roy Chowdhury, T. 1970. The Gondwana sequence of the Pranhita-Godavari Valley, India and its vertebrate fauna. *Proc. II Int. Gondw. Symp. S. Africa, Johannesberg*, pp. 303-308.

Lindström, S. 1995. Early Permian palynostratigraphy of the northern Heimefrontfjella Mountain-range, Dronning Maud Land, Antarctica. *Rev. Palaeobot. Palynol.* **89** : 359-415.

Lindström, S. 1996. Late Permian palynology of Fossilryggen, Vestfjella, Dronning Maund Land, Antarctica. *Palynol.* **20** : 15-48.

Lucas, S. 1994. Toward a nonmarine Triassic timescale. *Albertiana*, **13** : 43-49.

Marques-Toigo, M. 1991. Palynobiostratigraphy of the southern Brazilian Neopalaeozoic Gondwana sequence, p. 503-515. In : *Gondwana Seven* (Eds. Ulbrich, H. and Rocha-Campos, A. C.), Inst. Geocien. Univ. Sao Paulo.

Medlicott, H.B. and Blanford, W.T. 1879. *A Manual of Geology of India, Peninsular area.* Geol. Surv. India, Calcutta Publ.

Mitra, N.D. 1993. Stratigraphy of Pali-Tiki Formation of South Rewa Gondwana Basin and Permo-Triassic Boundary problem, p. 41-48. *Gondw. Geol. Mag. Spl. Vol.* Birbal Sahni Centenary National Symposium on Gondwana of India, Gonwana Geological Society, Nagpur.

Mitra, N.D. and Raja Rao, C.S. 1987. Recent advances in the study of Gondwana stratigraphy of India, p. 136-145. In : *Three Decades of Development in Palaeontology and Stratigraphy of India.* Geol. Surv. India Misc. Publ. no. **11**.

Mukhopadhyay, S.K. 1996. Trace fossils as palaeoevironmental and sedimentological indices of coal-bearing Gondwana Sequence, p. 505-528. In : *Gondwana Nine* **1** : *Proc. 9th Int. Gondwana. Symp. Hyderabad, 1994* (Eds. Guha P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Nakazawa, K. 1992. The Permian-Triassic Boundary. *Albertiana.* **10** : 23-30.

Oldham, R.D. 1893. *A Manual of Geology of India : Stratigraphical Structural Geology.* 2nd Edn., Govt. of India Press, Calcutta.

Pascoe, E.H. 1959. *A Manual of the Geology of India and Burma*, II. Govt. of India Press, Calcutta.

Playford, G. 1990. Proterozoic and Palaeozoic palynology of Antarctica: a review, p. 51-70. In : *Antarctic Palaeobiology : Its role in the reconstruction of Gondwana* (Eds. Taylor, T.N. and Taylor, E.L.), Springer-Verlag, New York.

Prasad, B.1997. Palynology of the subsurface Triassic sediments of Krishna-Godavari Basin, India. *Palaeontogr.* B. **242** : 91-125.

Prasad, B., Jain, A.K. and Mathur, Y.K. 1995. A standard palynozonation scheme for the Cretaceous and pre-Cretaceous subsurface sediments of Krishna-Godavari Basin, India. *Geosci. Jour.* **16** (2) : 155-233.

Rakotoarivelo, H. 1960. Étude palynologique de quelques échantillons de houille du basin de la Sakoa (Madagascar). *Surv. Géol. Tananarive*, pp. 49.

Ramanujam, C.G.K. 1987. Perspective and problems of Upper Gondwana and Tertiary palynology of southern India : a reconnaissance, p. 1-8. In : *Proc. 5th All India Symp. Palynol.* Dept. (Eds. Patil, G.V. *et al.*), Bot. Inst. Sci., Nagpur.

Ramanujam, C.G.K. 1993. Spore and pollen suits of some Upper Gondwana deposits of South India—A critical appraisal. *Gond. Geol. Mag. Spl. Vol.* Birbal Sahni Centenary National Symposium on Gondwana of India, Gonwana Geological Society, Nagpur, pp. 462-478.

Ravi Shanker, Singh, G. & Kumar, G. 1996. The sequence stratigraphy of Himalaya and its reflection in Gondwana sedimentation, p. 1159-1176. In : *Gondwana Nine* **2**, *Proc. 9th Int. Gondwana Symp. Hyderabad, 1994* (Eds. Guha, P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Sastry, M.V.A., Acharyya, S.K., Shah, S.C., Satsangi, P.P., Ghosh, S.C., Raha, P.K., Singh, G. and Ghosh, R.N. 1977. Stratigraphic Lexicon of Gondwana Formations of India. *Geol. Surv. India Misc. Publ.* **36** : 1-170.

Satsangi, P.P. 1987. Vertebrate faunas from the Indian Gondwana Sequence. *Palaeobot.* **36** : 245-253.

Sen Gupta, S. 1996. Does continental Jurassic sequence occur in India ?, p. 299-309. In : *Gondwana Nine* **1**, *Proc. 9th Int. Gondwana Symp. Hyderabad, 1994* (Eds. Guha, P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Singh, H.P. and Venkatachala, B.S. 1988. Upper Jurassic-Lower Cretaceous spore-pollen assemblages in the peninsular India. *Palaeobot.* **36**:168-196.

Singh, T., Tiwari, R.S., Vijaya and Ram-Awatar 1995. Stratigraphy and palynology of Carboniferous-Permian-Triassic succession in Spiti Valley, Tethys Himalaya, India. *Jour. Pal. Soc. India.* **40** : 55-76.

Spath, L.F. 1933. Revision of the Jurassic cephalopod fauna of Kutch. *Mem. Geol. Surv. India, Pal. Ind.* N. S. **9** (6) : 656-945.

Tewari, R.C. and Casshyap, S.M. 1996. Mesozoic tectonic events including rifting in peninsular India and their bearing on Gondwana sedimentation, p. 865-880. In : *Gondwana Nine* **2**, *Proc. 9th Int. Gondwana Symp. Hyderabad, 1994* (Eds. Guha P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Tiwari, R.S. 1974. Miofloral succession in the African Lower Gondwana, p. 130-134. In : *Proc. III Int. Palynol. Conf.* Novosibirsk, 1971. (Eds. Naumova, S.N.), Akad. Nauka SSSR, Moscow.

Tiwari, R.S. 1996. Palynoevent stratigraphy in Gondwana Sequence of India, p. 3-20. In : *Gondwana Nine* **1**, *Proc. 9th Int. Gondwana Symp. Hyderabad, 1994.* (Eds. Guha, P.K.S.*et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., Calcutta.

Tiwari, R.S. 1999 a. The palynological succession and spatial relationship of the Indian Gondwana Sequence. In : *Gondwana Assembly : Current Issues and Problems* (Ed. Ashok Sahni), Indian National Science Academy Publ., New Delhi (*in press*).

Tiwari, R.S. 1999 b. Definition of the problem of Permian-Triassic Boundary on Indian peninsula. In : *Prof. C.G.K.Ramanujam Commemoration Vol.* (Ed. Bir Bahadur), Bot. Dept. Kakatiya Univ, Warangal (*in press*).

Tiwari, R.S. 1999 c. Paradigm of FAD, LAD and DOD of some miospore taxa in Late Permian and Early Triassic successions on the Indian peninsula. *Jour. Pal. Soc. India,* **44** : 69-88.

Tiwari, R.S., Kumar, P. and Tripathi, A. 1984. Palynodating of Dubrajpur and Intertrappean beds in subsurface strata of northeastern Rajmahal Basin, p. 207-225. In : *Proc. IV Indian Geophytol. Conf. Lucknow,1983* (Ed. Tiwari, R.S.), The Palaeobotanical Society, Lucknow, Spl. Publ.

Tiwari, R.S. and Tripathi, A. 1992. Marker assemblage-zones of spore-pollen species through Gondwana Palaeozoic and Mesozoic Sequence in India. *Palaeobot.* **40** : 194-236.

Tiwari, R.S. and Tripathi, A. 1995. Palynological assemblages and absolute age relationship of Intertrappean beds in the Rajmahal Basin, India. *Cret. Res.* **16** : 53 - 72.

Tiwari, R.S., Tripathi, A. and Vijaya 1995. Organic-walled microfossils of doubtful origin in Permian and Triassic sequence on peninsular India. *Palaeobot.* **43** (1) : 1-38.

Tiwari, R.S. and Vijaya 1992. Permo-Triassic Boundary on the Indian Peninsula, p. 37-45. In : *Permo-Triassic Events in the Eastern Tethys : Stratigraphy, Classification and Relations with the Western Tethys.* (Eds. Sweet, W. C., Zunyi, Y. , Dickins, J. M. and Hongfu, Y.), World & Regional Geology 2, Cambridge Univ. Press, Cambridge.

Tiwari, R.S., Vijaya, Mamgain, V.D. and Misra, R.S. 1996. Palynological studies on a Late Palaeozoic-Mesozoic Tethyan sequence in the Niti Area of the Central Himalaya, Uttar Pradesh, India. *Rev. Palaeobot. Palynol.* **94** : 169-196.

Truswell, E.M. 1980. Permo-Carboniferous palynology of Gondwanaland : Progress and problems in the decade to 1980. *Bur. Min. Resour. Jour. Australian Geol. Geophys.* **5** : 95-111.

Venkatachala, B.S. & Maheshwari, H.K. 1991. Indian Gondwana redefined, p. 539-547. In : *Gondwana Seven, Proc. VII Int. Gondw. Symp. Brazil, 1988* (Eds. Ulbrich, J. and Rocha-Campos, A.C.). Inst. Geocien. Univ. Sao Paulo.

Venkatachala, B.S., Rajnikanth, A. and Maheshwari, H.K. 1993. The Gondwana Supergroup. *Gondw. Geol. Mag. Spl. Vol.* Birbal Sahni Centenary National. Symposium on Gondwana of India. Gondwana Geological Society, Nagpur, pp. 80-92.

Verma, K.K. and Mehra, S. 1993. Mesozoic Gondwana of Kutch : affinity and correlation. *Gond. Geol. Mag. Spl. Vol.* Birbal Sahni Centenary National Symposium on Gondwana of India, Gondwana Geogical Society, Nagpur, pp. 70-79.

Vijaya 1996. Advent of Gondwana deposition on Indian peninsula : a palynological reflection and relationship, p.283-298. In : *Gondwana Nine* **1**. *Proc. 9th Int. Gondw. Symp., Hyderabad, 1994,* (Eds. Guha, P.K.S. *et al.*), for GSI, Oxford & IBH Publisher Co. Pvt. Ltd., Calcutta.

Vijaya 1997 a. Palynoflora from subsurface Lower Cretaceous Intertrappean beds in Domra Sub-basin of the Raniganj Gondwana Basin, West Bengal, India. *Cret. Res.* **18** : 37-50.

Vijaya 1997 b. Palynological dating of Infra- and Inter-trappean sediments in the Mesozoic succession of Bore-hole PGD-6, Domra Sub-basin, West Bengal, India. *Cret. Res.* **18**: 833-848.

Vijaya and Tiwari, R.S. 1996. Status of continental Jurassic on the Indian peninsula, p. 379-393. In : *Continental Jurassic, Mus. Northern Arizona Bull.*(Ed. Morales, M.), **60**.

Warrington, G. 1996 a. Permian spores and pollen, p. 607-619. In : *Palynology : Principles and Application.* (Eds. Jansonius, J. and McGregor, D.C.), American Association of Stratigraphic Palynologists Foundation, Vol. 2.

Warrington, G. 1996 b. Triassic spores and pollen, p. 755-766. In : *Palynology : Principles and Application.* (Eds. Jansonius, J. and McGregor, D.C.) American Association of Stratigraphic Palynologists Foundation, Vol. 2.

Waterhouse, J.B. 1976. World correlation for marine Permian faunas. *Qld. Univ. Dept. Geol. Pap.* **7**(2) : pp.232.

Zavattieri, A.M. and Batten, D.J. 1996. Miospores from Argentinian Triassic deposits and their potential for intercontinental correlation, p. 767-778. In : *Palynology : Principles and Applications.*(Eds. Jansonius, J. and McGregor, D.C.), American Association of Stratigraphic Palynologists Foundation, Vol. 2.

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