Journal of The Palaeontological Society of India
Vol. 44, 1999, pp. 69-89

PARADIGM OF FAD, LAD AND DOD OF SOME MIOSPORE TAXA IN LATE PERMIAN AND EARLY TRIASSIC SUCCESSIONS ON THE INDIAN PENINSULA

R.S. TIWARI

EMERITUS SCIENTIST, CSIR, DEPARTMENT OF APPLIED GEOLOGY, BARKATULLAH UNIVERSITY, BHOPAL-462 026, INDIA

ABSTRACT

First and Last Appearance Datums and Dominance Datums (DODs) of selected miospore taxa have been located in the Late Permian and Early Triassic marine sequences of the Himalayan region and nonmarine successions in several bore-holes as well as outcrop sections of the Gondawana basins in central and eastern India. The paradigm of such occurrences has been compared for the purpose of possible biochronological correlations. The DODs show some deviations amongst the long distance correlation-points indicating different palyonfacies. However, in spite of fluctuations and lateral variations, the patterns of appearance and DODs of palynotaxa indicate a proximity with the position of the Permo-Triassic Boundary in both the marine and nonmarine sequences.

Key words : Permo-Triassic Boundary, Tethyan Himalaya, Peninsular India, Miospores, First and Last Appearance and Dominant Datums.

INTRODUCTION

Miospores provide an effective parameter for cross-correlation between marine and nonmarine sediments, and thus immensely aid in developing the relational biochronology between the two. For locating the Permo-Triassic Boundary (PTB) in the nonmarine sequence of the Gondwana basins on the Indian peninsula, such a tagging is significant. However, so far an uncertainty prevails about the marine Global Stratotype Section Point (GSSP) for precise PTB because of the incompleteness of the sequence, mixed fauna in the interval zone, or difference of opinion on the importance of ammonoid and conodont biochronology (Sweet *et al.,* 1992; Nakazawa, 1993,1996; Wang, 1994; Hongfu *et al.,* 1994; Hongfu, 1997; Xulang, 1997). Besides this, a long range palynological correlation for PTB between Gondwana realm on one hand and the Euramerican, Cathaysian or Angarian realms (where the GSSP is being sought) on the other may not be very purposeful because of the inherent genetic differences in palaeo-floral populations of these realms. This is more so for the Permian and Triassic times because during these periods sharply defined, four floral provinces existed on the earth. The Gondwanaland was exclusively characterized by the *Glossopteris* flora in Permian and the *Dicroidium* flora in Early Triassic. Such floras did not occur outside of this realm which fact is also reflected in palynofloras.

It is now established that there has been a definitive influence of the Gondwana floras on to the Tethys Himalayan region of the Indian subcontinent (Tiwari and Vijaya, 1987; Vijaya and Tiwari, 1991). Therefore, relating the Permian-Triassic palynosequences from the Indian peninsula with that in the Tethyan Himalaya is an aid to achieve better resolution for nonmarine Gondwana chronostratigraphy at the PTB interval and may improve Permian-Triassic correlations in the region.

The palyno-assemblage zonation scheme in Late Permian and Early Triassic succession on the Indian peninsula has been evolved in several exclusively continuous sections or unified sequences (Tiwari and Tripathi, 1992). On the basis of palynostratigraphy, the Raniganj Formation in the Damodar Basin and its correlative formations in other basins are generally affiliated to Late Permian and the overlying Panchet Formation, or broadly equivalent strata in other basins, to Early Triassic. Besides palynology, there are well-established independent evidences for these datings based on plant megafossils, and vertebrate and invertebrate animal fossils including conchostraca (Table 1; Tripathi and Satsangi, 1963; Kutty, 1972; Chatterjee and Roy-Chowdhury, 1974; Shah, 1976; Sastry *et al.,* 1977; Satsangi, 1987; Ghosh *et al.,* 1996; Ghosh and Dutta, 1996), having a potential for long-range correlation on the Gondwanaland and to certain extent beyond.

Table 1: Distributional pattern of palynozones, and plant and animal fossils in the Raniganj-Panchet formational sequence (or in their inferred correlative formations on the peninsula) indicating an end Permian-early Triassic affinity. At finer levels, the lithostratigraphic boundary may not coincide precisely with the biochronological boundary, as depicted in the last two columns.

PERIOD	PALYNO-ASSEMBLAGE ZONES	PLANT MEGAFOSSILS	VERTEBRATE ANIMAL FOSSILS	CONCHOSTRACANS	LITHOLOGY	FORMATION
EARLY TRIAS	Playfordiaspora cancellosa	Dicroidium flora	Lystosaurus Chasmatosaurus Brachyops' leticeps Amblypteris fauna	III - Cornea Biozone II - Palaeolimnadia Biozone I - Cyzicus Biozone	Khaki-green Sh. Siltst., Clay, Chocolate Sh.	PANCHET
	Krempipollenites indicus					
LATE PERM	Densipollenites magnicorpus	Glossopteris flora	Gondwanosaurus bijoriensis Rhinosuchus wadiai Dicynodonts Detocephalus fauna	Cyzicus - Monoleaia Biozone	Coal-Carb & Gray Sh., Sand-stone	RANIGANJ
	Gondisporites raniganjensis					

The palynological assemblage zones of the Permian and Triassic sequences on the Indian peninsula show fair correlative resemblance with those in the marine as well as nonmarine sequence in Antarctica, Australia, Madagascar, Southern Africa and Tethyan Himalaya (Goubin, 1965; Evans, 1969; Balme, 1970; Helby, 1974; Anderson, 1977, 1981; Foster, 1982; Helby *et al.,* 1987; Singh *et al.,* 1995; Lindstrom, 1996). In view of this, the passage from the Raniganj Formation to the Panchet Formation in the Damodar Basin (or that in other correlative sequence of other basins on the peninsula) provides promising areas for defining biochronology for the proximity of the Permian-Triassic Boundary (Tiwari, 1999a).

As there are mixed lithologies, or varying degrees of hiatuses at plăces, across the transition of the Raniganj-Panchet Boundary, the litho- and biostratigraphical boundaries are to be located independently of each other to interpret the chronostratigraphic datum. In view of such a situation, a tagging of marine and nonmarine sections all the more provides an enhanced confidence in the biochronology of nonmarine sequence.

With such an aspect in view, in the present communication a detailed analysis of the Dominant Datum (DOD), First Appearance Datum (FAD) and Last Appearance Datum (LAD) of some important taxa in the Tethys Himalayan region and Gondwana basins of the Indian peninsula has been done which aids recognition to the proximity of the boundary between Permian and Triassic systems.

MATERIAL AND TECHNIQUE FOR ANALYSIS

The study is based upon published miospore record from various sections in the Tethys Himalayan region of the Indian subcontinent and the eastern and central peninsular India (Table 2). The FAD, LAD and DOD of miospore taxa are drawn against the lithological sequences indicating the temporal extent of formations.

The palynological data from the Tethyan zone of Himalaya in the extra-peninsular Indian subcontinent are taken from the Salt Range and Surgarh Range (Pakistan), and Spiti, Niti and Malla Johar regions in Himachal and Uttar Pradesh (India); from the peninsula the record comes from Damodar, South Rewa, Son-Mahanadi, Satpura and Godavari basins (figs. 1-14).

The analyses of the palynological data from the peninsular basins reveal that in most of the areas

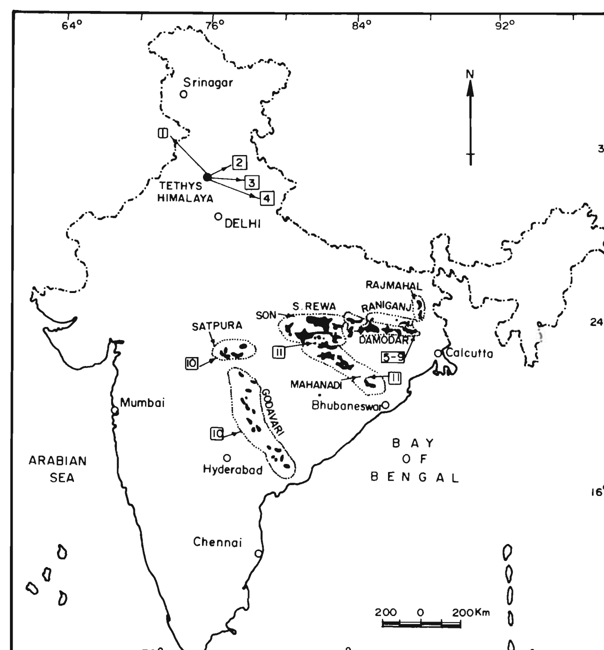


Fig. 1. Map of Indian subcontinent showing locations of Tethys Himalayan region and areas of Gondwana basins on the peninsula form where the data on Permian-Triassic palynology has been taken for the present analysis. *Tethys Himalaya*: 1. Salt Range and Surgarh Range (Pakistan); 2. Spiti, 3. Niit, & 4. Malla Johar (Himachal & Uttar Pradesh, India). *Indian Peninsula*: 5-9 : Ranignaj Coalfield, Damodar Basin; 10 : Satpura Basin & Pranhita-Godavari Basin; 11. Gopad River section, Nidpur Bed, South Rewa Basin (in northern part of Son-Mahanadi Valley Basin), and Madalia River section in Talcher Basin (in southeast part of Son-Mahanadi Valley basins). For other details see Table 2.

Table 2: Source material for the present analysis. General indications for locations are given in fig. 1. For details see 'references' cited.

Figure Numbers	Sections/Bore-holes	Location	Formation	Age Affiliation	Reference
2	Salt Range	Salt Range (Himalaya)	Mianwali Chhidru	Early Triassic Late Permian	Balme, 1970
3	Spiti Valley	Mandaksa Nala Ganmachidam Lingti Hill (Himalaya)	Kuling Group Lilang Group Kuling Group	Permian Triassic Permian	Singh *et al*., 1995
4	Niti Region	Niti Pass Hoti Gad Raulybagar (Himalaya)	Kuling Shale Shal Shal Kuling Shale	Late Permian Early Triassic Late Permian	Tiwari *et al* ., 1996
5	Malla Johar	Malla Johar Region (Himalaya)	Kioto Passage Kuti Shale Kalapani Chocolate Kuling	Triassic Late Permian	Tiwari *et al*., 1984; Vijaya *et al*., 1988
6	Bore-hole RAD-5	Raniganj Coalfield, East	Panchet Raniganj	Early Trassic Late Pemian	Tiwari & Singh, 1983
	Bore-hole RAD-2	Raniganj Coalfield, East	Panchet Raniganj	Early Triassic Late Permian	Singh & Tiwari 1982
	Bore-hole RNM-3	Raniganj Coalfield, East	Panchet Raniganj	Early Triassic Late Permian	Rana & Tiwari, 1980
7	Bore-hole NCRD-6	Raniganj Coalfield, West	Panchet Raniganj	Early Triassic Late Permian	Bharadwaj & Tiwari, 1977
	Noonia Nala	Raniganj Coalfield, East	Panchet Raniganj	Early Triassic Late Permian	Bharadwaj *et al*., 1979
	Bore-hole RD-1	Raniganj Coalfield, East	Panchet	Early Triassic	Tiwari, 1979
8	Saburband Nala	Raniganj Coalfield, South of Damodar River	Panchet Raniganj	Early Triassic Late Permian	Bharadwaj *et al*., 1979
	Machhkanda Jhor Section A	Raniganj Coalfield, South of Damodar River	Raniganj	Late Permian	Bharadwaj *et al*., 1979
	Machhkanda Jhor Section B	Raniganj Coalfield, South of Damodar River	Panchet Raniganj	Early Triassic Late Permian	Bharadwaj *et al*., 1979
9	Bore-hole RKJ-1A	Raniganj Coalfield, East, Jaydev	Raniganj	Late Permian	Tiwari, 1990
	Bore-hole RKJ-2 A	Raniganj Coalfield, East, Jaydev	Raniganj	Late Permian	Tiwari, 1990
	Bore-hole RKJ-3	Raniganj Coalfield, East, Jaydev	Raniganj	Late Permian	Tiwari, 1990
10	Bore-hole DNJ-11	Raniganj Coalfield, East, Dewanganj	Panchet Raniganj	Early Triassic Late Permian	Tiwari, 1990
	Bore-hole DNJ-12	Raniganj Coalfield, East, Dewanganj	Panchet Raniganj	Early Triassic Late Permian	Tiwari, 1990
	Bore-hole DNJ-13	Raniganj Coalfield, East, Dewanganj	Raniganj	Late Permian	Tiwari, 1990
11	Sukhtawa River	Satpura Basin	Upper Bijori	Permo-Triassic	Bharadwaj *et al*., 1978
	Bore-hole GJ-3	Godavari Basin, Chelpur Area	Lower to Middle Kamthi	Late Permian	Srivastava & Jha, 1986
	Bore-hole GAM-7	Godavari Basin, Mailaram Area	Middle Kamthi Lower Kamthi	Early Triassic Late Permian	Srivastava & Jha, 1990
12.	Bore-hole UKD-8	Korar Coalfield, South Rewa Basin	Middle Pali	Late Permian	Tiwari & Ram-Awatar, 1987
	Gopad River, Nidpur Bed	South Rewa Basin	Upper Pali	Early Triassic Late Permian	Tiwari & Ram-Awatar, 1990
	Madalia River	Talcher Coalfield, Mahanadi Basin	Upper Raniganj	Late Permian	Tiwari *et al*., 1991

DODs occur in the following order : *Striatopodocarpites* in combination with *Faunipollenites/ Gondisporites* (or *Verticipollenites*)/ *Densipollenites/Crescentipollenites* (or *Guttulapollenites*) in latest Permian succeeded by *Krempipollenites* (or *Falcisporites*)/ *Arcuatipollenites/ Verrucosisporites-Callumispora/ Lundbladispora/Densoisporites* in lowermost Triassic (figs. 13-14).

The FAD and LAD of characteristic taxa in each DOD are determined in order to reinforce the structure of assemblage for age determination. Thus, comparisons of various levels of palynofloras in Tethyan region having other palaeontological controls at the Permo-Triassic Boundary interval are made with the sequence of events in sections of the Damodar Basin. For mutual correlation of PTB interval amongst the sections in other nonmarine strata of the peninsula, other palaeontological records have also been considered besides palynology.

SALT RANGE & SURGARH RANGE

			PALYNO - COMPOSITIONS	FADs and LADs
LOWER TRIASSIC	MIANWALI FORMATION	NARMIA MEMBER	Playfordiaspora, Arcuatipollenites **Densoisporites**, **Falcisporites** Lundbladispora, Osmundacidites Verrucosisporites, **Aratrisporites** Vitreisporites, **Alisporites**	↑ Aratrisporites
		MITTIWALI MEMBER	Playfordiaspora, **Arcuatipollenites** **Densoisporites**, Falcisporites **Lundbladispora**, (Cordaitina +) Vitreisporites Guttulapollenites	↓ Guttulapollenites ↑ Cordaitina
		KATHWAI MEMBER	Playfordiaspora, **Arcuatipollenites** **Densoisporites**, Falcisporites Lundbladispora, Osmundacidites Vitreisporites, Callumispora (**fungosa**) Krempipollenites	↑ Callumispora fungosa
UPPER PERMIAN	CHHIDRU FORMATION		Striatopodocarpites, Playfordiaspora (Arcuatipollenites +) Crescentipollenites (Ringosporites) (Falcisporites +) **Faunipollenites**, Iraquispora, **Weylandites** Guttulapollenites (Densoisporites+) (Tigrisporites +) Indospora (Lundbladispora+) **Polypodiisporites** Scheuringipollenites **Vitreisporites** **Dicappipollenites** Densipollenites (Krempipollenites+) Navalesporites Pretricolpipollenites +)	↓ Striate bisaccate Plicatipollenites Densipollenites Dicappipollenites ↑ Ringosporites, Arcuatipollenites Krempipollenites, Osmundacidites Lundbladispora Densoisporites
	WARGAL LIMESTONE		Striatopodocarpites, **Dicappipollenites** Crescentipollenites **Faunipollenites** **Guttulapollenites** **Scheuringipollenites** Playfordiaspora Vitreisporites **Weylandites**	

Fig. 2. General palynological composition of Upper Permian and Lower Triassic sequences of Salt Range and Surgarh Range, Tethys Himalaya, Pakistan. The FAD of Triassic precursor and the LAD of Permian taxa in the Chhidru Formation denote a trend which compares closely with that in the Raniganj Formation, Damodar Basin. Names of taxa in bold-face: abundant; names in parenthesis with a plus-mark: important taxa with fair presence; upward arrow: FAD; downward arrow : LAD. A hiatus could be interpreted between the Chhidru Formation and the Kathwai Member of the Mianwali Formation as the palynofloral change is sharp.

TETHYAN HIMALAYA

Salt Range and Surgarh Range

The FAD of *Arcuatipollenites*, *Krempipollenites*, *Lundbladispora* and *Densoisporites* in the Upper Permian Chhidru Formation (fig. 2) could be related with similar trend in the Raniganj Formation of the Damodar Basin (Balme, 1970; Tiwari, 1999b). There is an abrupt change in the palynoflora between the Chhidru Formation and the Kathwai Member of the Lower Triassic Mianwali Formation (for example, absence of striate bisaccate pollen in the latter). Hence, a gap at the PTB could be envisaged (also Baud *et al.*, 1996).

The FAD of *Aratrisporites* in the Salt Range is recorded at the end of Early Triassic while it appears in the earliest Triassic on the peninsula. The record of *Ringosporites* and *Vitreisporites* in the Upper Permian of the Salt Range is unlike that of the Damodar Basin where they appear only in the Early

SPITI VALLEY

			MANDAKSA NALA SECTION	GANMACHIDAM SECTION	LINGTI HILL SECTION
TRIASSIC	LILANG GROUP	BASAL PART			Krempipollenites Arcuatipollenites Lundbladispora Kraeuselisporites Verrucosisporites Chordasporites Dicappipollenites (Striatopodocarpites Crescentipollenites Densipollenites)
PERMIAN	KULING GROUP	GUNGRI FORMATION	Densipollenites (Densoisporites +)	Striatopodocarpites Faunipollenites Crescentipollenites Densipollenites Kamthisaccites Distriatites Weylandites (Krempipollenites +) (Arcuatipollenites +)	Striatopodocarpites Faunipollenites Crescentipollenites Densipollenites (Simeonospora +) (Lundbladispora +) (Goubinispora +) (Arcuatipollenites +)
		GECHANG FORMATION	Jayantisporites Dentatispora Potonieisporites Microbaculispora Microfoveolatispora Faunipollenites Striatopodocarpites Scheuringipollenites Parasaccites		
		GANMACHIDAM FORMATION			

Fig. 3. Available palynological data from three sections of Permian-Triassic sequence in Spiti Valley. Plus-mark with names in parenthesis : record of Triassic precursor taxa in the Gungri Formation which are absent from the older Gechang Formation. In the Basal Part of Lilang Group (Early Triassic) some Permian taxa continue to occur (names in parenthesis). The pattern is well correlated with that in the Raniganj-Panchet formations on the peninsula for approximation of PTB.

Triassic. So also the FAD of *Playfordiaspora* is located in the Lower Permian of the Salt Range while it does not appear till the latest Permian in the Damodar Basin.

In the overall aspect of palyno-assemblage structure, the Chhidru Formation could be correlated with the Raniganj Formation in having shared forms, like *Crescentipollenites, Faunipollenites, Guttulapollenites, Indospora, Densipollenites* and *Navalesporites.* Similarly, the Kathwai Member of the Mianwali Formation and the Panchet Formation are correlative on the basis of common record of *Playfordiaspora, Densoisporites, Lundbladispora, Arcuatipollenites, Callumispora, Krempipollenites* as abundant taxa (figs. 2, 6-10).

Spiti Valley

The Gungri Formation of the Kuling Group and the Basal Part of the Lilang Group constitute the Permian-Triassic passage in the Spiti Valley (Singh *et al.*, 1995; fig. 3). The appearance of *Lundbladispora* and *Arcuatipollenites* in the Gungri Formation and a continuation of *Striatopodocarpites, Crescentipollentites* and *Densipollenites* into the Basal Part of the Lilang Group do not suggest a hiatus of major magnitude between the two. Palynologically there exists a close cross-correlation between this sequence in Spiti Valley and that of the Raniganj-Panchet formations in the Damodar Basin, by way of abundance of characteristic taxa shown in fig. 3.

NITI REGION

			NITI PASS SECTION	HOTIGAD SECTION	RAULYBAGAR SECTION
EARLY TRIASSIC	SHAL SHAL FORMATION	RAMBAKOT MEMBER		**Krempipollenites** **Arcuatipollenites** Lundbladispora Densoisporites Verrucosisporites Satsangisaccites Goubinispora Cyathidites (Striatopodocarpites Crescentipollenites +)	**Krempipollenites** **Arcuatipollenites** Lundbladispora Densoisporites Verrucosisporites Satsangisaccites Goubinispora (Striatopodocarpites Densipollenites Horriditriletes +)
LATE PERMIAN	KULING SHALE FORMATION		**Striatopodocarpites** **Crescentipollenites** **Densipollenites** Cyclogranisporites (Arcuatipollenites +)	**Striatopodocarpites** **Crescentipollenites** **Corisaccites** Horriditriletes Microbaculispora Verticipollenites Cordaitina (Krempipollenites Satsangisaccites +)	**Striatopodocarpites** **Crescentipollenites** Densipollenites Cyclogranisporites (Lundbladispora +)

Fig. 4. Palynological assemblages in three sections of Permian-Triassic sequence in the Niti Region, Tethys Himalaya. Sporadic occurrences of Triassic elements in the Kuling Shale Formation and remnant taxa of Permian in the Rambakot Member of the Shal Shal Formation are shown by names in parenthesis, with a plus-mark. Names in bold-face indicate abundance. The pattern is closely comparable with that in the Raniganj-Panchet passage in the Damodar Basin and also in the equitable horizons in other basins.

MALLA JOHAR

MALLA JOHAR SUPERGROUP	RAWALI BAGGAR GROUP	KIOTO FORMATION	Rhaetian	Goubinispora morondavensis Krempipollenites schaubergeri Callumispora fungosa Lundbladispora wartii Arcuatipollenites
		PASSAGE FORMATION	Norian	Verrucosisporites Krempipollenites schaubergeri Satsangisaccites Alisporites
		KUTI SHALE		Arcuatipollenites pellucidus, ovatus Alisporites parvus, opii, tenuicorpus Lundbladispora, Densoisporites playfordii Krempipollenites schaubergeri Pretricolpipollenites
		KALAPANI LIMESTONE	Anisian to Carnian	**Tethysispora**, Falcisporites, Colpectopollenites, Arcuatipollenites, **Alisporites**, Dacrycarpites, **Lundbladispora**, Densoisporites, Simeonosporites, Playfordiaspora, Krempipollenites, Microreticulatisporites, Satsangisaccites, Cadargasporites, Araucariacites
		CHOCOLATE FORMATION	Induan to Olenekian	(Palynoflora not known)
		KULING SHALE	Permian	Striatopodocarpites (rotundus, venustus, decorus, megnificus) Crescentipollenites Densipollenites indicus Faunipollenites Lacinitriletes Callumispora fungosa (Lundbladispora +)
	SUM-NA Gr	MUTH FORMATION	Devonian	

Fig. 5. Palynocomposition of the Permian Kuling Shale and well-defined Middle and Upper Triassic palynofloras, to project the contrast, in the Malla Johar Region of Tethys Himalaya. The Lower Triassic Chocolate Shale Formation is barren of miospores. Plus-mark: rare record of Triassic taxa in the Kuling Shale; names in bold-face—abundant. The Kuling Shale assemblage is closely related with that of the Raniganj Formation in Damodar Basin.

Niti Area

The palynological data from the Kuling Shale Formation and the Shal Shal Formation (fig. 4) reveals that the former is characterized by the DOD of *Striatopodocarpites, Crescentipollenites, Corisaccites* and *Densipollenites* together with FAD of *Arcuatipollenites, Krempipollenites, Lundbladispora,* and *Satsangisaccites,* the precursors of Early Triassic miofloras. The assemblage from the Shal Shal Formation shows DOD of *Krempipollenites* and *Arcuatipollenites* along with the occurrence of *Lundbladispora, Densoisporites, Verrucosisporites* and *Goubinispora* and a continuance of several Permian forms, such as *Striatopodocarpites* and *Densipollenites.* This suggests that there is no major palynological break between the Kuling Shale Formation and the Rambakot Member of the Shal Shal Formation, and also that the Permian-Triassic Boundary occurs around this level. It is noteworthy that the DOD of *Krempipollenites/Arcuatipollenites* characterizes lowermost Triassic in the marine sequence of the Niti area, a pattern resembling that in the Gondwana basins on Indian peninsula (Tiwari *et al.,*1996).

Malla Johar Area

No precise palynological data on the PTB are available from this area but the Permian Kuling Shale contains *Striatopodocarpites, Faunipollenites, Densipollenites* and *Crescentipollenites* as abundant taxa (fig. 5). The DOD could not be determined because of a general low frequency of specimens. The recorded presence of *Lundbladispora*—a precursor Triassic genus in the Permian, is significant . The overall composition of the available data on palyno-assemblage in Kuling Shale thus provides a tie-point for Permian sequence in nonmarine sections on the Indian peninsula (Tiwari *et al.,* 1984).

The overlying Chocolate Shale of Early Triassic age is barren of miospores, and in the rest of the younger sequence of Triassic no typical form of the Permian Kuling Shale has been recorded. Although the data at the PTB is not complete in this region, the figure illustrates how the Middle and Upper Triassic palyno-assemblages develop their identity, without the influence of the Upper Permian forms. However, in the sections of the Spiti and Niti areas described above, a continuance of a few characteristic Permian forms is recorded in Early Triassic.

PENINSULAR INDIA

Damodar Basin

In the basin, the Raniganj Formation is characterized by coal-shale-sandstone cycles while the overlying Panchet Formation comprises khaki-green shales, green sandstones, clays, siltstones and chocolate-red shales. At the transition, mixed lithologies do occur to a certain extent and therefore the base of the first khaki-green shale is taken as datum for the boundary of Raniganj-Panchet formations.

In the bore-hole RAD-5 (fig. 6), the khaki-green facies of the Panchet Formation starts at about 50 m above the topmost coalseam of the Raniganj Formation. The FADs of *Weylandites, Callumispora fungosa* and *Alisporites,* and the LADs of

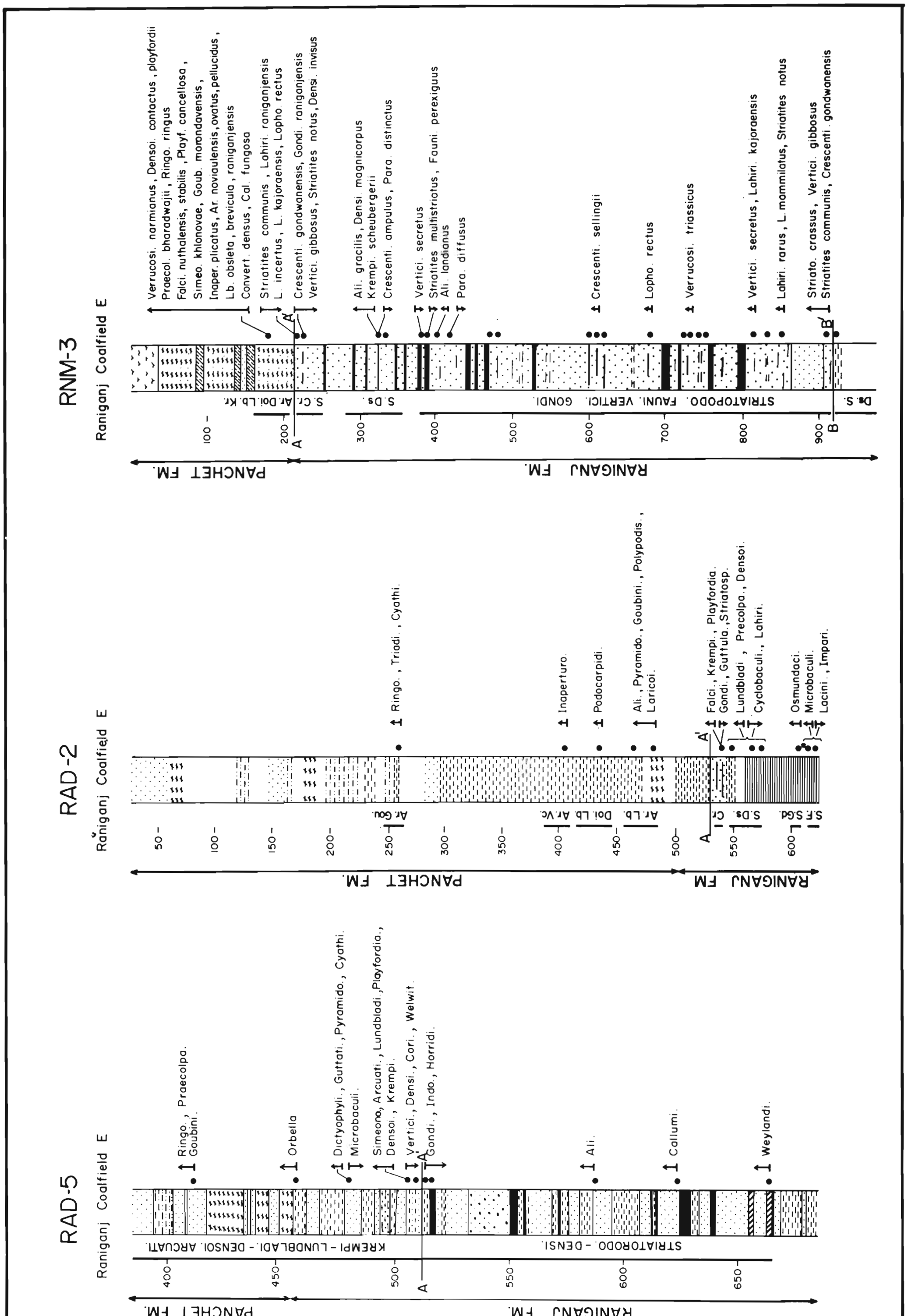


Fig. 6. Bore-holes RAD-5, RAD-2 and RNM-3 from eastern extension of the Raniganj Coalfield, West Bengal. The FADs of spore-pollen species in bore-hole RNM-3 make it an important sequence for a detailed comparison.

Gondisporites, Indospora, Horriditriletes, Verticipollenites, Densipollenites and *Corisaccites* define the assemblage in the coal-bearing shale-sandstone units. Between the topmost coal and the first khaki shale, the profile contains gray shale, sandy shale and sandstone, and therefore included in the Raniganj Formation but a well-defined DOD of *Krempipollenites* along with FAD of *Simeonospora, Dictyophylidites, Guttatisporites, Orbella, Playfordiaspora, Densoisporites* and *Lundbladispora* in this sector of sequence give it an Early Triassic aspect.

In bore-hole RAD-2 (fig. 6), the lithological characters are variable as compared with those in the bore-hole RAD-5 because there are no coal-bands in the former. The DODs of *Striatopodocarpites/Densipollenites* followed by *Crescentipollenites* are present in the carbonaceous shales and gray shales. In this portion, most of the Permian taxa record their LAD while the precursor miospores for the Early Triassic show their FAD. The first chocolate-red shale contains the FAD of *Pyramidosporites, Goubinispora, Laricoidites*, etc., from where upwards the DODs of *Arcuatipollenites, Lundbladispora, Densoisporites* and *Verrucosisporites* are recorded in succession indicating an Early Triassic affinity. The bed below the chocolate-red shales of the Panchet Formation and above the shale-sandstone beds of the Raniganj Formation is non-yielding, yet it may be ascertained

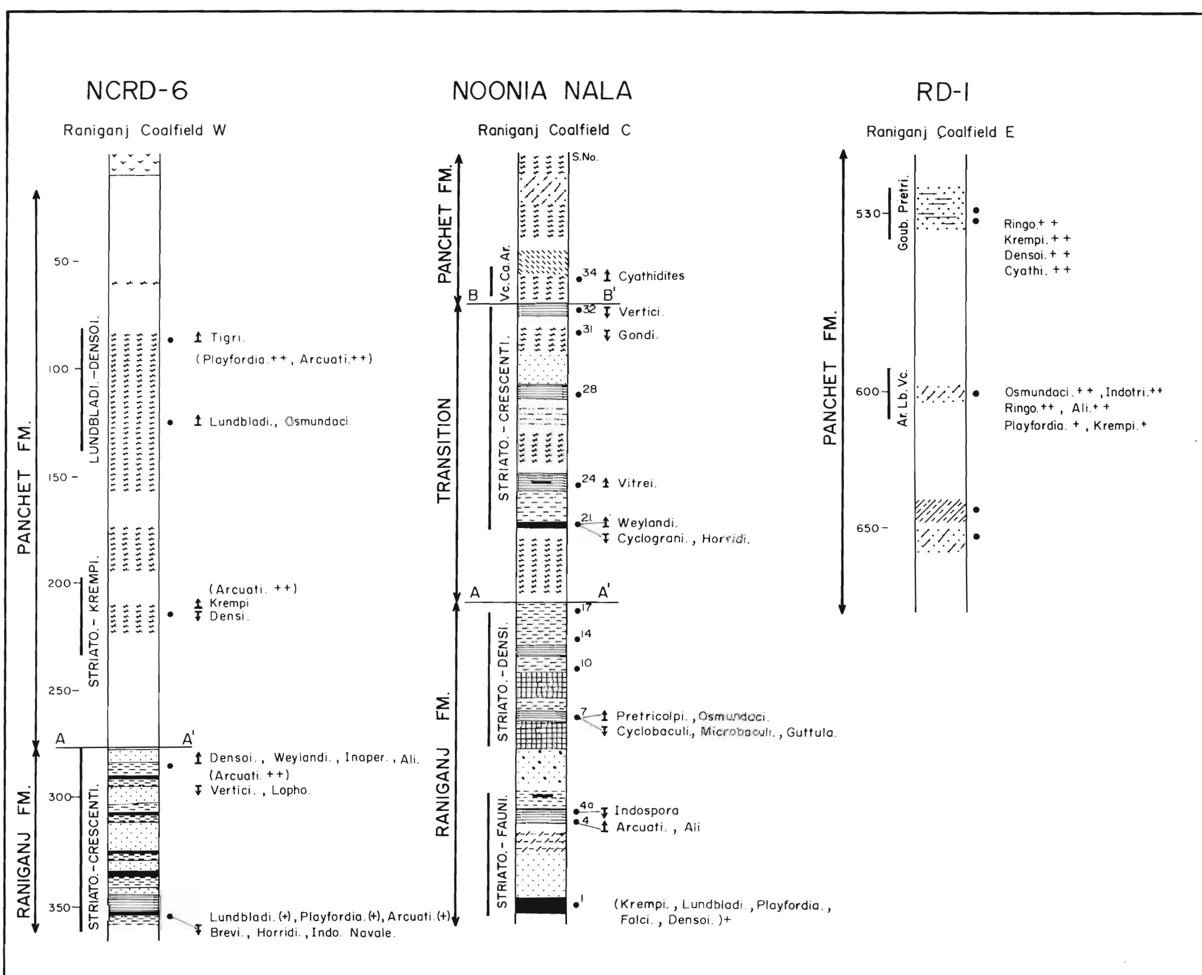


Fig. 7. Bore-hodle NCRD-6 (Western Raniganj Coalfield); Noonia Nala outcrop section (north of Damodar River, East Raniganj Coalfield, the Type Area for the Panchet Formation); and bore-hole RD-I (Eastern extension of Raniganj Coalfield). In cases where FAD could not be determined because of the paucity of continuous data along the sequence, the + denotes the presence of a taxon and ++ marks the abundance.

that definite shift in assemblages from Permian to Triassic has occurred in this zone.

From the data available, the record of distribution of palynomorphs at species level is known only from the bore-hole RNM-3 (fig. 6). Most of the miospore species, such as *Verticipollenites secretus, Gondisporites raniganjensis, Densipollenites invisus, Lahirites* spp. characteristic of Upper Permian, show their LAD by the end of the Raniganj Formation. On the other hand, in the first khaki-green shale bed of the Panchet Formation (just above line A-A' in fig. 6) many species of Early Triassic affinity appear for the first time, examples—*Verrusocisporites narmianus, Falcisporites nuthalensis, Simeonospora khlonovae, Arcuatipollenites pellucidus*. Thus, a major palynofloral change, including that in DODs corresponding to the Permian-Triassic interval is evident at this level. A closely comparable situation exists in Australia where the transition is defined by *Protohaploxypinus microcorpus* and *Lunatisporites pellucidus* Oppel Zones (Helby, 1974).

In bore-hole NCRD-6 (fig. 7), the topmost coaliferous sequence represents a part of the end Raniganj Formation. The ascending sequence of DOD includes *Crescentipollenites/Krempipollenites/Lundbladispora/Densoisporites,* the last three being represented in the khaki-green shales of the Panchet Formation. The PTB is interpreted to occur between the *Crescentipollenites* and *Krempipollenites* DODs. (line A-A').

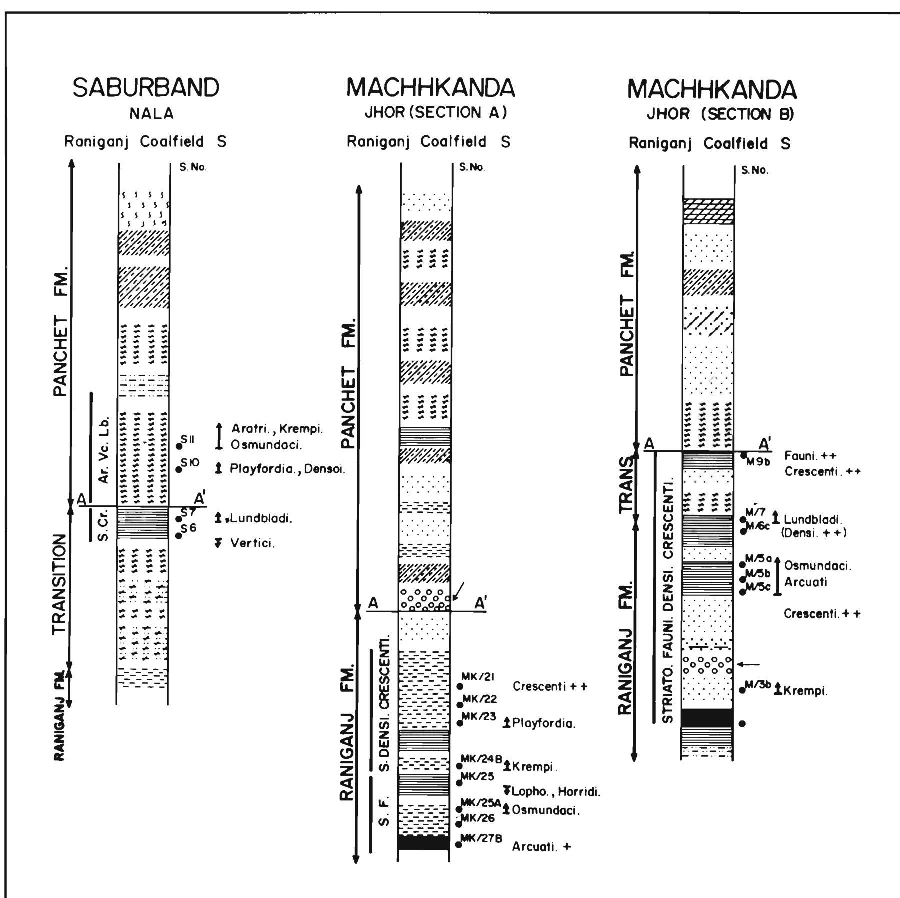


Fig. 8. Outcrop sections from Saburband Nala and Machhkanda Jhor Sections A & B (both in the South of Damodar River, Raniganj Coalfield) representing the Raniganj to Panchet transition . In the Saburband Nala, FADs are meagerly known but the sequence of DODs with respect to lithology is noteworthy. In Machhkanda Jhor, the palyno-datum is shown only for the topmost Raniganj Formation. (+) presence recorded; (++) abundance; thin arrow - pebbly bed.

The Noonia Nala section, the Type Section for the Panchet Formation (fig. 7), shows a sequence of *Faunipollenites/Densipollenites/ Crescentipollenites* and *Verrucosisporites-Callumispora-Arcuatipollenites* DODs across the topmost Raniganj to basal Panchet formations. The base of the first khaki-green shale represents the Raniganj-Panchet Boundary, but in the sequence above this also, up to the level A-A', mixed lithologies of khaki-green shale and shale-coal-carbonaceous shale occur showing the latest Permian palynoflora. The DOD of *Crescentipollenites,* having LAD of *Verticipollenites, Gondisporites* and *Horriditriletes* points that even though the lithosequence possesses Panchet type of shales with intercalation of coal-bands, the transitionary zone belongs to Upper Permian. However, above the line A-A', in the suit of pure Panchet lithology, the palyno-assemblage is of Early Triassic affinity. Thus, the PTB is interpreted to be present between the *Crescentipollenites* and the *Verrucosisporites-Callumispora-Arcuatipollenites* DODs (line A-A').

In the bore-hole RD-1 (fig. 7), only a part of the Panchet Formation is represented, having mainly greenish sandstones, chocolate-red shales, and sandstone with coal-streaks. The DOD indicates an Early Triassic level with *Arcuatipollenites/ Lundbladispora/Verrucosisporites* present below the DOD of *Goubinispora-Pretricolpipollenites.* The latter DOD is equated with the Middle Triassic.

In the Saburband Nala section, south of Damodar River, Raniganj Coalfield (fig. 8), the mixed lithology, comprising khaki-green, gray, and carbonaceous shales, below the line A-A', yielded the *Crescentipollenites* DOD with the FAD of *Lundbladispora,* thus showing latest Permian affinity. This level is succeeded by the *Arcuatipollenites/ Verrucosisporites/ Lundbladispora* DOD in a suit of khaki-green shales. The

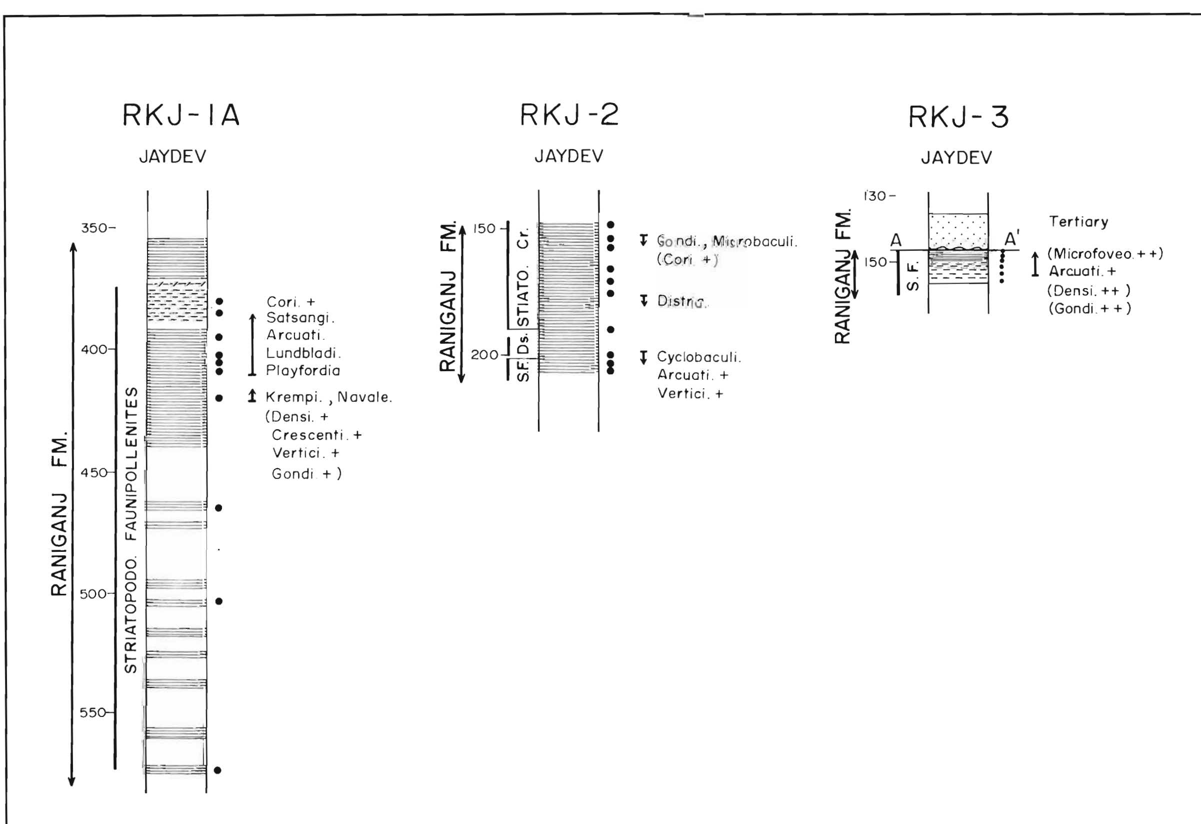


Fig. 9. Bore-holes RKJ-1 A, RKJ-2, and RKJ-3 in Jaydev Area, eastern extension of the Raniganj Coalfield, representing parts of Upper Raniganj Formation with available palynological datum. The presence (+), and abundance (++) of characteristic taxa, and FAD and LAD broadly indicate a closing phase of Upper Permian in the sequence.

Permian-Triassic Boundary may be interpreted to occur between the two DODs—above the *Crescentipollenites* dominant zone (line A-A').

In Machhkanda Jhor sections, south of Damodar River, Raniganj Coalfield (fig. 8), the palynological data is available only from the topmost coal-carbonaceous shale-sandstone suite of the Raniganj Formation in the section A, and with a khaki-green shale between two carbonaceous shale beds in the section B. In both the sections, the DOD of *Faunipollenites/ Densipollenites/ Crescentipollenites,* occurring in a sequence, contain FAD of *Playfordiaspora, Krempipollenites, Arcuatipollenites* and *Lundbladispora* - all precursor taxa of Early

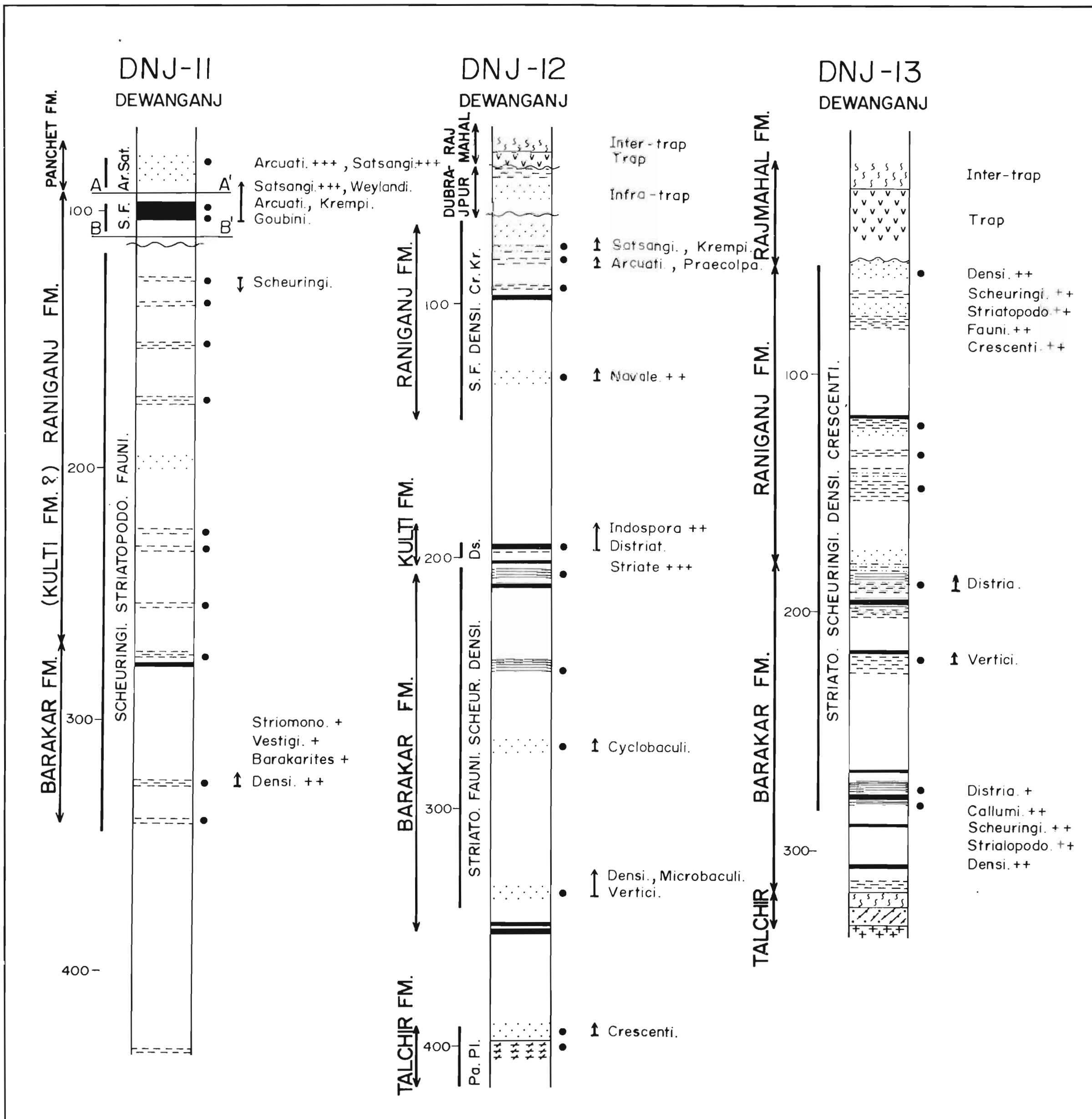


Fig. 10. Bore-hole DNJ-11, DNJ-12 and DNJ-13 in the Dewanganj Area, eastern extension of the Raniganj Coalfield. DNJ 11 : the *Striatopodocarpites-Faunipollenites* (S.F.) DOD defines Upper Permian level as several Triassic precursor taxa also show their FAD at this level. The Permian-Triassic Boundary approximates at the line A-A'. Presence (+); abundance (++) of important taxa. Line B-B' : end of Lower Permian. DNJ-12 : log below the 200m depth show Lower Permian; above this, Upper Permian passing into Lower Triassic (*Krempipollenites* DOD). DNJ-13 : sequence of DODs representing Lower Permian to Upper Permian. No Triassic precursor miospores recorded.

Triassic, appearing sporadically and suggesting a latest Permian affinity. This trend is comparable with those in other areas of the Damodar Basin. In both the sections, the levels A-A' are qualified by the occurrence of the Late Permian palyno-assemblages and also the FAD and LAD of taxa which identify the closing phase of the Raniganj Formation.

Figs. 9 and 10 show the records from bore-hole RKJ-1A, RKJ-2, RKJ-3 (Jaydev) and DNJ-11, DNJ-12, DNJ-13 (near Dewanganj) from Dewanganj Area (40° 9' 15": 87° 35' 03"; Tiwari, 1990) in the Eastern Extension of the Raniganj Coalfield, West Bengal. Palynologically, except for bore-hole DNJ-11, there is no indication of Early Triassic levels in these sequences, but all the bore-holes show the DOD, FAD and LAD of such taxa which qualify for the latest Permian. In the bore-holes DNJ-11 (fig. 10), the DOD of *Arcuatipollenites-Satsangisaccites* (Ar. Sat.) occurs just above the DOD of *Striatopodocarpites-Faunipollenites* (S.F.) indicating a gap between the two, when compared to the succession of DODs in other sections. As such, the

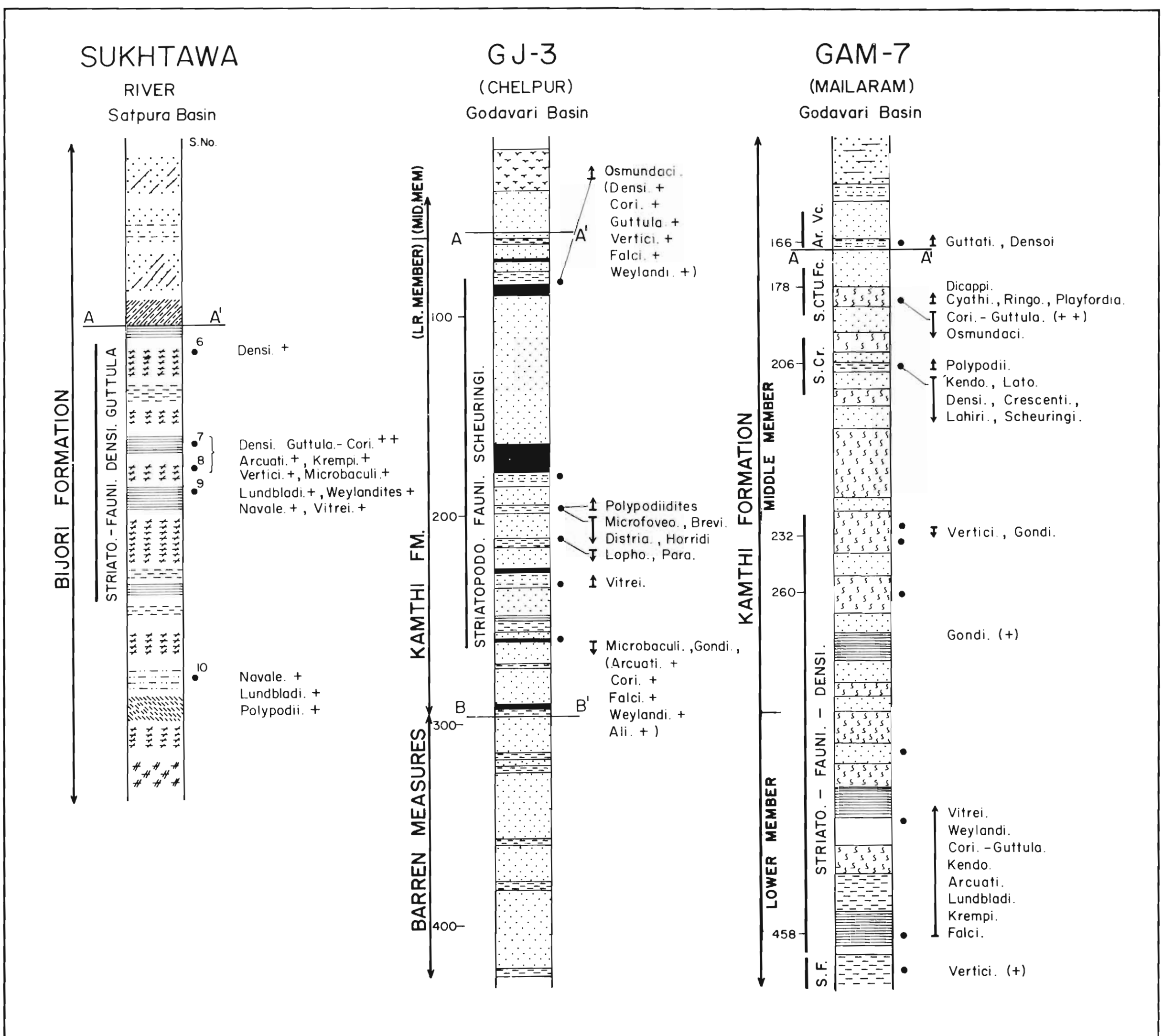


Fig. 11. Sukhtawa section, Satpura Basin, and bore-hole GJ-3 (Chelpur Area) and GAM-7 (Mailaram Area) of the Godavari Basin. In Sukhtawa section, the DOD of *Densipollenites/Guttulapollenites* represents Upper Permian as the genera *Arcuatipollenites, Lundbladispora, Krempipollenites, etc.*, also mark their presence at this level. In GJ-3, the strata above the topmost coal represent the closing phase of the Permian. In GAM-7, line A-A' approximates the transition from Permian to Triassic. Presence (+), abundance (++) of important taxa.

DODs of *Gondisporites/ Densipollenites/ Crescentipollenites* and *Krempipollenites/ Lundbladispora/Densoisporites* are missing from the intermediate sequence. The pattern of FAD supports this conclusion, indicating a hiatus at the Permian-Triassic interval.

In DNJ-12 (fig. 10), DOD and FAD indicate proximity to the PTB in the topmost coal-shale-sandstone sequence of the Raniganj Formation which is abruptly overlain by the Infratrappean and Traps of the Dubrajpur-Rajmahal formations (Jurassic-Cretaceous). The FAD of *Satsangisaccites, Krempipollenites, Arcuatipollenites* and *Praecolpipollenites* evidences for the uppermost Permian level as well as a beginning of earliest Triassic in the sediments between the Infratrappean and the topmost coal-band in this bore-hole. The PTB interval is indicated at the line A-A'.

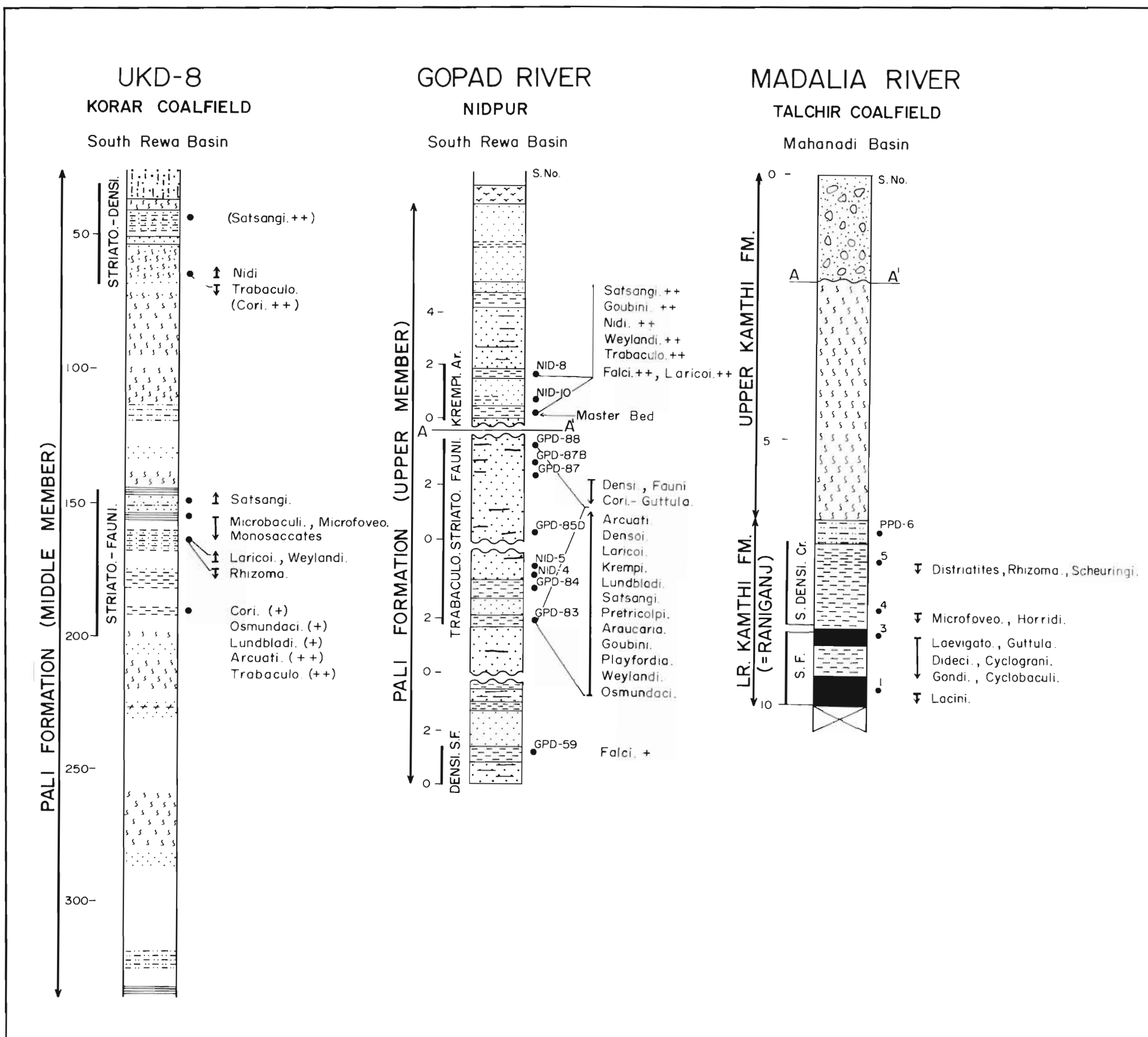


Fig. 12. Bore-hole UKD-8 (Korar Coalfield, South Rewa Basin); Nidpur bed in Gopad River section (South Rewa Basin); and Madalia River section (Talcher Coalfield, Mahanadi Basin). In UKD-8 the gradual LAD of Permian taxa and FAD or mere occurrence of the Early Triassic precursors in the two successive DODs indicate a closing phase of the Upper Permian for the sequence. In Nidpur Bed, the *Trabeculosporites/Striatopodocarpites/ Faunipollenites* DOD records the FAD of most of the Early Triassic miospore taxa; in the Master Bed and sample no. NID-8 the Lower Triassic forms become abundant (++), in the *Krempipollenites/Arcuatipollenites* DOD. The level A-A' approximates the PTB. In the Madalia River section, the DOD in coal-shale sequence shows only the LAD of Permian taxa but the presence of Triassic precursor taxa has not been recorded in the *Densipollenites/ Crescentipollenites* DOD.

In the bore-hole DNJ-13 (fig.10), the DOD indicates the Upper Permian sequence but not of the uppermost level because the FAD of Lower Triassic precursor taxa has not been recorded. The Raniganj Formation is overlain by Traps, as in the bore-hole DNJ-12.

Satpura Basin

In the Sukhtawa section (fig. 11), the sequence of DOD of *Striatopodocarpites-Faunipollenites/ Densipollenites/ Guttulapollenites* characterizes the Bijori Formation from where a labyrinthodont—*Gondwanosaurus bijoriensis,* of Upper Permian affinity is already on record (Satsangi, 1987). Based on available palaeontological evidences, including palynological ones, this formation is considered to be broadly homotaxial with the Raniganj Formation of the Damodar Basin (Bharadwaj *et al.,* 1978: Datta and Mitra, 1982). The dominance of *Guttulapollenites* is correlatable with the similar event of the end Permian in the Morondava Basin, Madagascar (Goubin, 1965) and Chhidru Formation of the Salt Range (Balme, 1970).

The Bijori Formation is overlain by the Pachmarhi Formation from where, although much higher in the sequence, a *Falcisporites* dominant palynoflora is reported indicating an Early Triassic age (Kumar, 1995). This age is also supported by the *Palaeolimnadia* estheriid biozone identified in the Pachmarhi Formation (Ghosh and Dutta, 1996). Although a precise bed for PTB could not be determined for the want of detailed data from the latter, yet palynology demarcates a level for the end Permian sequence in the Bijori Formation, Sukhtawa section (fig. 11), which indicates an approximation to the PTB.

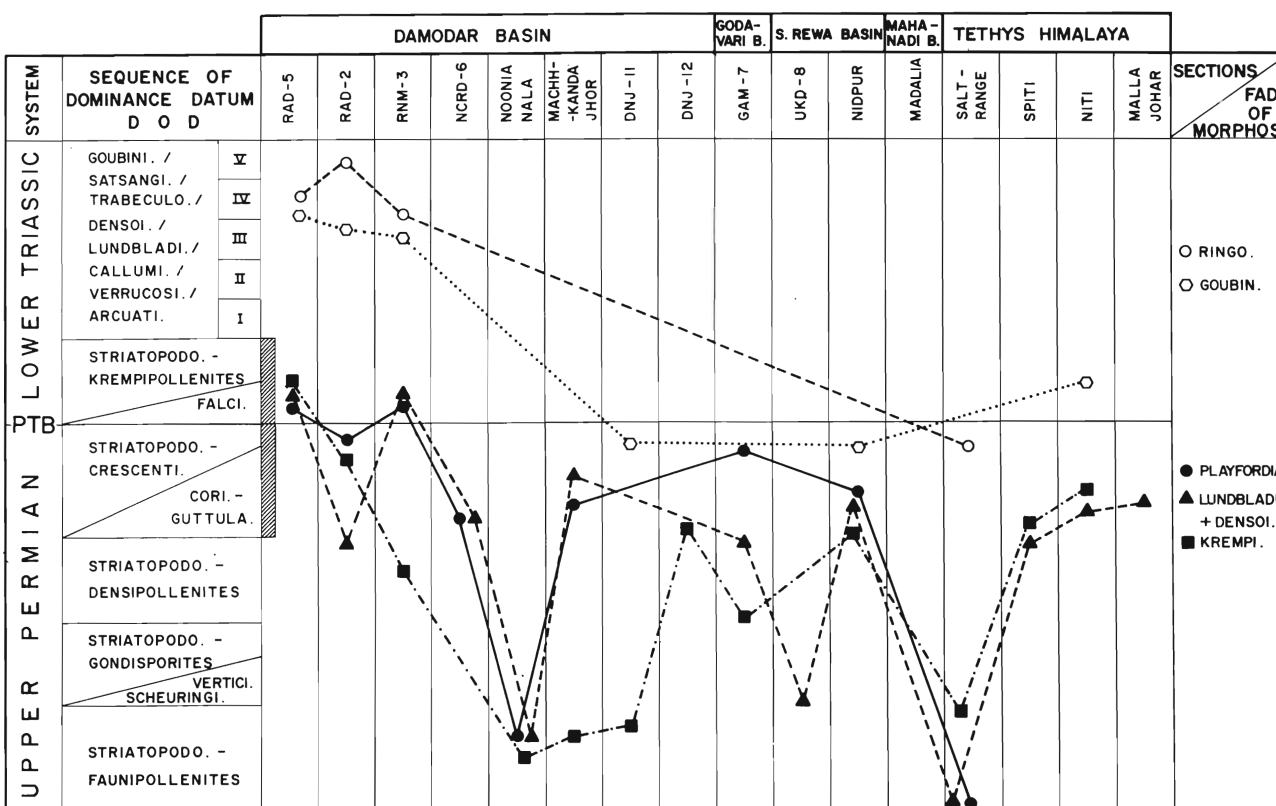


Fig. 13. Showing the generalized sequence of DODs (in a colum on left-hand side) with alternative bio-facies at some levels through Upper Permian-Lower Triassic succession. Mixed lithology may occur in the interval zone, shown by oblique lines. Palynozones represented by numbers I to V in the upper part of Lower Triassic denote a sequence of DODs in varying combinations of taxa in ascending order. The FADs of five palynotaxa in bore-holes/sections studied, with relation to various DODs establish a general trend of similarity between marine and nonmarine sequences.

Godavari Basin

In Godavari Basin (fig. 11), the DODs in the Lower Member as well as the lower part of the Upper Member of the Kamthi Formation are varied in comparison to those in the Raniganj Formation of the Damodar Basin. In bore-hole GJ-3 (fig. 11), in the Chelpur area, the DOD of *Striatopodocarpites/ Faunipollenites/ Scheuringipollenites* indicates that the level is older than youngest Permian. The FAD of *Osmundacidites, Polypodiidites* and *Vitreisporites,*and the absence of *Playfordiaspora, Lundbladispora* and *Krempipollenites* in the assemblage of the Lower Member of the Kamthi Formation in this bore-hole probably reflects a different provinciality than that of the Raniganj Basin. A consistent presence of *Dicappipollenites, Corisaccites* and *Guttulapollenites* broadly compares well with the palynoflora of the Upper Permian Chhidru Formation in the Salt Range (Balme, 1970; Srivastava and Jha, 1986).

In the sequence of the Kamthi Formation represented in the bore-hole GAM-7 (fig. 11) from the Mailaram Area, the DOD signals towards a proximity with PTB (line A-A'). Most of the Upper Permian taxa record LAD by the level of *Guttulapollenites/ Falcisporites* DOD which at the line A-A' delineates the overlying *Arcuatipollenites/ Verrucosisporites* DOD. The FAD of *Guttatisporites* and *Densoisporites* in the *Arcuatipollenites*-rich zone equates this level with Early Triassic.

Son-Mahanadi Basins

In bore-hole UKD-8, Korar Coalfield, South Rewa Basin (fig. 12) only the Upper Permian is indicated in the sequence of the Middle Pali Formation by the DOD of *Faunipollenites* and *Densipollenites*. The FAD of *Laricoidites, Weylandites, Satsangisaccites,* and *Nidipollenites,* and records of *Arcuatipollenites, Lundbladispora* and *Osmundacidites* suggest that this sequence is

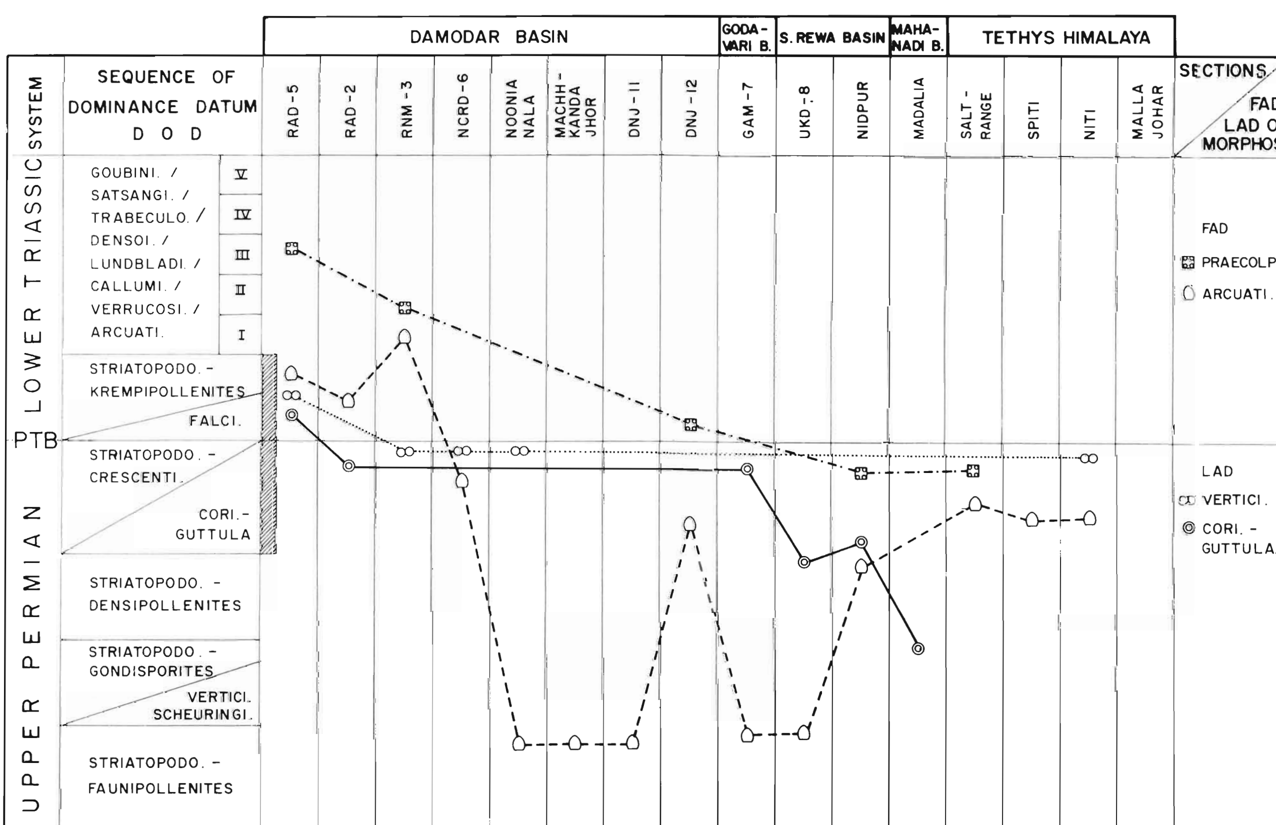


Fig. 14. LAD of *Verticipollenites, Corisaccites, Guttulapollenites* (the Permian forms) and FAD of *Praecolpatites* and *Arcuatipollenites* (the Triassic forms) in relation to the main sequence of DOD in Permian-Triassic succession. Other details same as in fig. 13.

latest Permian in age.

In the Gopad River section, the Nidpur Bed (fig. 12) shows the presence of *Trabeculosporites/ Striatopodocarpites/ Faunipollenites* DOD, with FAD of *Playfordiaspora, Lundbladispora, Densoisporites, Krempipollenites, Arcuatipollenites* and LAD of *Densipollenites, Corisaccites, Guttulapollenites,* below the line A-A'. This tags this part of the sequence with the latest Permian age because several of the Early Triassic precursor taxa start appearing here. In the overlying *Krempipollenites/ Arcuatipollenites* DOD, the characteristic Permian forms are absent while the Triassic forms are prominently represented. The leaf-genus *Dicroidium* also records FAD at the level of 'Master Bed' (fig. 12) supporting a Triassic age for this DOD of the Upper Pali Formation. The palynoflora in the Master Bed (Sample nos. NID-8, NID-10; fig. 12) of the Nidpur section resembles that of the Triassic Kathwai Member and Mittiwali Member of the Mianwali Formation in the Salt Range, and also partly with that in the Kalapani Limestone of the Spiti Valley (Tiwari and Ram-Awatar, 1990; Singh *et al.,* 1995); evidently, the Master Bed palynoflora could be dated as Triassic. It could, however, be visualized that the PTB may occur between the two DODs recorded in beds on either side of the level A-A', and the Master Bed lies in the Upper Pali Formation, much above the PTB.

In Madalia River section, Talcher Coalfield, Mahanadi Basin (fig. 12) the *Striatopodocarpites-Faunipollenites* DOD and the *Striatopodocarpites/ Densipollenites/Crescentipollenites* DOD are recorded in succession from the topmost coal-shale beds. In these levels, several taxa which are characteristic of Upper Permian, such as *Microfoveolatispora, Guttulapollenites, Gondisporites, Distriatites,* record their LAD but the precursor taxa of Early Triassic affinity (e.g. *Playfordiaspora, Arcuatipollenites, Krempipollenites*) do not show their FAD, as is the case in other areas discussed above. This may indicate that the levels of the assemblages recorded here, although show an Upper Permian relationship, are not in a close stratigraphic vicinity of the PTB. The barren nature of the overlying strata does not provide any biostratigrahic evidence for the age but lithostratigraphically the clay-bed up to the line A-A' is broadly equated with the Raniganj Formation of the Damodar Basin and the topmost ferruginous, pebbly bed of the Kamthi Formation could be correlated with the Panchet Formation.

SEQUENCING OF DODS, FADS, AND LADS

A unified general sequence of Dominance Datums (DODs) across the latest Permian and the earliest Triassic in the sections of the Gondwana basins on Indian peninsula described above is given in figs. 13 and 14.

Some deviations in the compositions of DODs have been recorded in different basinal regions; for example—the *Crescentipollenites* DOD of the Damodar Basin (fig. 6: bore-hole RAD-2, RAD-3; fig. 7: Noonia Nala; fig. 8: Saburband Nala, Machhkanda Jhor; fig. 10: bore-hole DNJ-13) is replaced by the *Corisaccites-Guttulapollenites* DOD at the top of Permian in Satpura and Godavari basins (fig. 11: Sukhtawa and bore-hole GAM-7, respectively). So also, *Verticipollenites* shares the DOD of *Gondisporites* in bore-hole RNM-3 (fig. 6) and *Falcisporites* replaces *Krempipollenites* in Godavari Basin (fig. 11: GAM-7). The *Krempipollenites* DOD is the lowest Triassic marker but its vertical span may be restricted to a thin bed, and hence, at places, this could be replaced by the *Arcuatipollenites* DOD. The alternative combinations of dominant taxa reflecting palynofacies variation are depicted in the left-side column of figs. 13 and 14.

Lithologically, the passage from *Crescentipollenites* DOD to *Krempipollenites* DOD could be present in the sedimentary sequence of mixed nature; thus at finer level, the palynological change-over does not coincide with the lithological boundary in most of the cases. So also, with respect to the PTB, the interbasinal correlation cannot be proposed on the basis of lithostratigraphy alone. The DODs of miospore taxa, although controlled by the factors governing the general variations in floras which may be eco-biased, indicate a fairly correlatable pattern of events on the peninsula which could be effectively linked with the marine sequence

Table 3 : Index Palynotaxa for DOD, FAD and LAD in latest Permian and earliest Triassic of Indian Peninsula and the extra-peninsular Tethyan Himalaya. The datums may, however, show subtle variable palynofacies regionally or in few discrete sections. Asterisk marked— mainstream forms; other— supportive forms, may occur.

DOD	FAD	LAD
Early Triassic Affinity		
*Arcuatipollenites**	*Alisporites*	*Densipollenites**
*Densoisporites**	*Aratrisporites*	*Faunipollenites**
*Goubinispora**	*Callumispora* sp.	*Microobaculispora**
*Krempipollenites**	*Concavissimisporites*	*Trabeculosporites*
*Lundbladispora**	*Cyathidites*	*Weylandites*
*Satsangisaccites**	*Falcisporites**	
*Striatopodocarpites**	*Inaperturopollenites*	
*Verrucosisporites**	*Laricoidites*	
	Nidipollenites	
	*Orbella**	
	Osmundacidites	
	Podocarpidites	
	Praecolpatites	
	*Pyramidosporites**	
	*Ringosporites**	
	Simeonospora	
	Triadispora	
	Vitreisporites	
DOD	FAD	LAD
Late Permian Affinity		
*Crescentipollenites**	*Arcuatipollenites**	*Brevitriletes*
Corisaccites	*Corisaccites*	*Corisaccites**
*Densipollenites**	*Densoisporites**	*Cyclobaculisporites*
*Faunipollenites**	*Goubinspora*	*Gondisporites**
Gondisporites	*Krempipollenites**	*Guttulapollenites*
*Guttulapollenites**	*Lundbladispora**	*Horriditriletes*
*Striatopodocarpites**	*Navalesporites*	*Indospora**
Trabeculosporites	*Playfordiaspora*	*Imparitriletes*
*Verticipollenites**	*Polypodiisporites*	*Lacinitriletes*
	Trabeculosporites	*Microfoveolatispora*
	Waylandites	*Navalesporites**
		Parasaccites
		*Striatosporites**
		*Verticipollenites**

and used for chronological correlation of the PTB. In most of the sections, a proximity to the systemic boundary is indicated by DODs and FADs in the interval zone (figs. 13, 14).

The FADs of selected genera drawn against the sequence of DODs (figs. 13,14) reveal that *Playfordiaspora, Lundbladispora, Densoisporites, Krempipollenites* and *Arcuatipollenites* start appearing, although sporadically, in the Upper Permian. These palynomorphs are the characteristic constituents of the Early Triassic assemblage where they occur abundantly. Evidently, they play a role of precursor taxa of Triassic in the end Permian DODs of palynomorphs signalling a proximity to the Permian-Triassic transition. The FADs of *Ringosporites, Goubinispora* and *Praecolpatites* occur at younger levels than those of the above mentioned precursor taxa, and also point toward the commencement of a change-over indicating a stratigraphic vicinity to the PTB. The LAD of *Verticipollenites* and *Corisaccites-Guttulapollenites,* besides several other Upper Permian forms, coincides with the changes occurring at the end of Permian and the beginning of Early Triassic (fig. 14;

Table 3). Broadly, the marine and nonmarine sequences show matching trends in these patterns (Tiwari and Vijaya, 1992; Singh *et al.*, 1995; Tiwari *et al.*, 1996). Thus, the location of the biochronlogical levels for the PTB in the proximity of the transition of the Raniganj and Panchet Formations (or their equivalent strata in other basins) could be ascertained by structuring the datums of the palynomorph taxa.

ACKNOWLEDGEMENTS

The author is grateful to CSIR, New Delhi for financial assistance to run an Emeritus Scientist Scheme No. 21/ (O373)/96/EMR-II, at the Department of Applied Geology, Barkatullah University, Bhopal, under the aegis of which this work has been done. Thanks are also due to the authorities of the university for providing facilities to the author.

REFERENCES

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

Anderson, J.M. 1981. World Permo-Triassic correlation. Their biostratigraphic basis. In : *Gondwana Five* (Eds. Cresswell, M.M. & Vella, P.) *Proc. V Intn. Gondw. Symp.* Wellington, N.Z. 1980. A.K. Balkema, Rotterdam.

Balme, B.E. 1970. Palynology of Permian and Triassic strata in the Salt Range and Surgarh Range, West Pakistan, p. 305-454. In: *Stratgraphic Boundary Problems : Permian and Triassic of West Pakistan.* (Eds. Kummel, B. & Teichert, C.) Univ. Kansas, Dept. of Geol. Special Publication 4, University Press, Kansas.

Baud, A., Atudorei, V. and Sharp, Z. 1996. Late Permian and Early Triassic evolution of the northern Indian margin : Carbon isotope and sequence stratigraphy. *Geodinamica Acta (Paris),* **9(2):** 57-77.

Bharadwaj, D.C. and Tiwari, R.S. 1977. Permian-Triassic miofloras from the Raniganj Coalfield, India. *Palaeobot.* **24 (1) :** 26-49.

Bharadwaj, D.C., Tiwari, R.S. and Anand-Prakash 1978. Palynology of Bijori Formation (Upper Permian) in Satpura Gondwana Basin, India. *Palaeobot.* **25:** 70-78.

Bharadwaj, D.C., Tiwari, R.S. and Anand-Prakash 1979. Permo-Triassic palynostratigraphy and lithological characteristics in Damodar Basin, India. *Biol. Mem.* **4** : 49-82.

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. *Intn. Cenn.—Symp. Geol. Surv. Japan, Tsukuba ; Prepr.* pp. 1-31.

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

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

Ghosh, S.C. and Dutta, A. 1996. A critical review of fossil conchostraca of Permian-Triassic periods in Gondwana relam, p. 195-206. In : *Gondwana Nine* **1** (Eds. Guha, P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Ghosh, S.C., Nandi, A., Ahmed, G. and Roy, B.K. 1996. Study of Permo-Triassic Boundary in Gondwana Sequence of Raniganj Basin, India, In : Guha, P.K.S. *et al.,* (eds), *Gondwana Nine* **1,** (Eds. Guha, P.K.S. *et al.*), p. 179-194. for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Goubin, N. 1965. Description et repartition des principaux pollenites Permiens, Triassiques et Jurassiques des sondages du Bassin de Morondav (Madagascar). *Rev. Inst. Francaise Petrole,* **20 :** 1415-1461.

Helby, R.J. 1974. Review of Late Permian and Triassic palynology of New South Wales. *Spl. Publ. Geol. Soc. Austr.* **4.** 141-155.

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

Hongfu, Y., 1997. Permian-Triassic Boundary : A discussion on *Hindeodus parvus* and the Meishan Section. *Albertiana,* **20** : 19-24.

Hongfu, Y., Shunbao, W., Meihua, D., Kexing, Z., Jinnan, T, and Fengquing, Y. 1994. The Meishan Section—Candidate of the Global Stratotype Section and Point (GSSP) of Permian-Triassic Boundary (PTB). *Albertiana,* **14 :** 15-31.

Kumar, P. 1995. Permo-Traissic palynofossils and depositional environment in Satpura Basin, Madhya Pradesh. *Geophytol.* **25 :** 47-54.

Kutty, T.S. 1972. A Permian reptilian fauna from India. *Nature, London* **237** (No. 5356): 462-463.

Lindstrom, S. 1996. Late Permian palynology of Fossilryggen, Vestfjella, Dronning Maud Land, Antarctica. *Palynology,* **20 :** 15-48.

Nakazawa, K. 1993. Stratigraphy of the Permian-Triassic transition and Palaeozoic/Mesozoic Boundary. *Bull. Geol. Surv. Japan,* **44 :** 425-445.

Nakazawa, K. 1996. Lower Triassic bivalves from the Salt Range region, Pakistan, p 207-230. In : *Gondwana Nine* **1** (Eds. Guha, P.K.S. *et al.*), for GSI, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Rana, V. and Tiwari, R.S. 1980. Palynological succession in Permian-Triassic sediments in bore-hole RNM-3, East Raniganj Coalfield, W. Bengal. *Geophytol.* **10** (1) : 108-124.

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. Misc. Publ.* **36 :** 1-170.

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

Shah, S.C. 1976. Climates during Gondwana era in peninsular India : Faunal evidences. *Geophytol.* **6 :** 186-206.

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.

Singh, V. and Tiwari, R.S. 1982. Pattern of miofloras through Permo-Triassic transition in bore-hole RAD-2, East Raniganj Coalfield, W. Bengal. *Geophytol.* **12** (2) : 181-186.

Srivastava, S.C. and Jha, N. 1986. Palynology of Kamthi Formation from Chelpur area, Godavari graben, Andhra Pradesh, India. *Palaeobot.* **35** (3) : 342-346.

Srivastava, S.C. and Jha, N. 1990. Permian-Triassic palynofloral transition in Godavari graben, Andhra Pradesh. *Palaeobot.* **38 :** 92-97.

Sweet, W.C., Zunyi, Y., Dickins, J.M. and Hongfu, Y. (eds.). 1992. *Permo-Triassic Events in the Eastern Tethys : Stratigraphy, Classification and Relations with the Western Tethys.* World & Regional Geology 2, Cambridge University Press, Cambridge.

Tiwari, R.S. 1979. Palynological dating of subsurface Triassic strata near Durgapur, W. Bengal. *Palaeobot.* **26** (2) : 190-197.

Tiwari, R.S. 1990. Palynological dating and correlation of newly identified coal-bearing strata in Birbhum-Dewanganj area, West Bengal. *Rep. CSIR Project 24 (172)/86/EMR-II,* New Delhi (unpublished).

Tiwari, R.S. 1999a. Definition of the problem of Permian-Triassic boundary on Indian peninsula. *Prof. C.G.K. Ramanujam Commemoration Volume,* Bot. Dept., Kakatiya Univ., Warangal, India (*in press*).

Tiwari, R.S. 1999 b. Palynofloral changes at Permian-Triassic transition in Tethyan sequence of Himalaya in Spiti Valley, Himachal Pradesh and Niti region, Uttar Pradesh, India. *Gondw. Geol. Mag.* **12** (1) : 1-14 (1997).

Tiwari, R.S. and Ram-Awatar 1987. Palynostratigraphic studies of subsurface Supra-Barakar sediments from Korar Coalfield, Son Valley, Madhya Pradesh. *Geophytol.* **17** (2) : 256-264.

Tiwari, R.S. and Ram-Awatar 1990. Palynodating of Nidpur beds, Son graben, Madhya Pradesh. *Palaeobot.* **38 :** 105-121.

Tiwari, R.S. and Singh, V. 1983. Miofloral transition at Raniganj-Panchet boundary in East Raingani Coalfield and its implication on Permo-Triassic time boundary. *Geophytol.* **13** (2) : 227-234.

Tiwari, R.S., Singh, V., Kumar, S. and Singh, I.B. 1984. Palynological studies of the Tethys sequence in Malla Johar area, Kumaon Himalaya, India. *Palaeobot.* **32** (3) : 341-367.

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

Tiwari, R.S., Tripathi, A. and Jana, B.N. 1991. Palynological evidence for Upper Permian Raniganj coals in western part of Talcher Coalfield, Orissa, India. *Curr. Sci.* **61** (6) : 407-410.

Tiwari, R.S. and Vijaya 1987. Reflection on relationship of Tethyan palynoflora. *Palaeobot.* **36 :** 339-353.

Tiwari, R.S. and Vijaya 1992. Permo-Triassic Boundary on the Indian peninsula, p. 37-45. In : *Permo-Triasic Events in the Eastern Tehtys : Stratigraphy, Classification and Relations with the Western Tethys* (Eds. Sweet, W.C. *et al.*), World and Regional Geology 2. Cambridge University 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.

Tripathi, C and Satsangi, P.P. 1963. *Lystosaurus* fauna of the Panchet Series of the Raniganj Coalfield. *Mem. Geol. Surv. India, Pal. Ind.* N.S., 37.

Vijaya, Kumar, S., Singh, M.P. and Tiwari, R.S. 1988. A Middle to Late Triassic palynoflora from the Kalapani Limestone Formation, Malla Johar area, Tethys Himalaya, India. *Rev. Palaeobot. Palynol.* **54 :** 55-83.

Vijaya and Tiwari, R.S. 1991. Impact of Gondwanic playnofloras on the East Tethyan realm during Permian and Triassic times, p. 101-122. In : *Proc. Intn. Symp. Shallow Tethys 3* (Eds. Kotaka, *et al.*), Sendai, Japan. Saito Ho-on Kai Mus. Nat. Hist. Sendai.

Wang, C. 1994. A conodont based high resolution evento-stratigraphy and biostratigraphy for the Permo-Triassic boundaries in South China. *Palaeoworld*, **4:** 234-248.

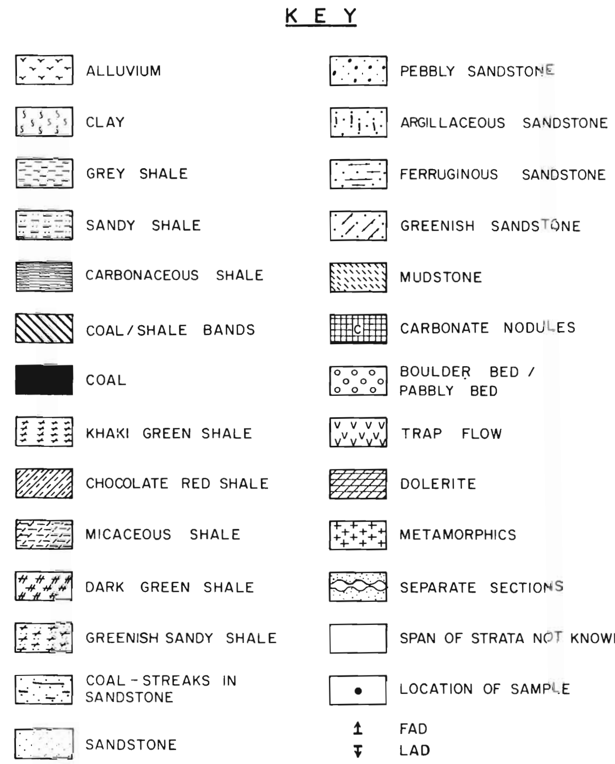
Xulong, L. 1997. A discussion on Permian-Triassic conodont studies. *Albertiana*, **20** : 25-30.

Manuscript Accepted June 1999

APPENDIX

Check list of spore and pollen taxa with author(s) and year used in text :

Alisporites Daugherty em. Jansonius 1971
Aratrisporites Leschik em. Playford & Dettmann 1965
Arcuatipollenites (= *Lunatisporites*) Tiwari & Vijaya 1995
Brevitriletes Bharadwaj & Srivastava 1969
Callumispora Bharadwaj & Srivastava 1969
Concavissimisporites Delcourt & Sprumont em. Delcourt, Dettmann & Hughes 1963
Corisaccites Venkatachala & Kar 1966
Crescentipollenites Bharadwaj, Tiwari & Kar 1974
Cyathidites Couper 1953
Cyclobaculisporites Bharadwaj 1955
Cyclogranisporites Potonié & Kremp 1954
Densipollenites Bharadwaj 1962
Densoisporites Weyland & Krieger em. Dettmann 1963
Dicappipollenites (=*Lueckisporites*) Tiwari & Vijaya 1995
Falcisporites Leschik em. Klaus 1963
Faunipollenites Bharadwaj 1962
Gondisporites Bharadwaj 1962
Goubinispora Tiwari & Rana 1981
Guttulapollenites Goubin em. Venkatachala, Goubin & Kar 1967
Horriditriletes Bharadwaj & Salujha 1964
Imparitriletes Tiwari & Singh 1981
Inaperturopollenites Thomson & Pflug em. Potonie 1958
Indospora Bharadwaj 1962
Indotriradites Tiwari 1964
Krempipollenites (= *Klausipollenites*) Tiwari & Vijaya 1995
Lacinitriletes Venkatachala & Kar em. Tiwari & Singh 1981
Laricoidites Potonié, Thomson & Thiergart ex Potonié 1958
Lophortiletes Naumova ex Potonié & Kremp 1954
Lundbladispora Balme em. Playford 1965
Microbaculispora Bharadwaj 1962
Navalesporites Sarate & Ram-Awatar 1984
Nidipollenites Bharadwaj & Srivastava 1969
Orbella Maljavkina 1949
Osmundacidites Couper 1953
Parasaccites Bharadwaj & Tiwari 1964
Playfordiaspora Maheshwari & Banerji em. Vijaya 1995
Podocarpidites Cookson ex Couper 1953
Polypodiisporites Potonié & Gelletich ex Potonie 1956
Praecolpatites Bharadwaj & Srivastava 1969
Pretricolpipollenites Danze-Corsin & Laveine 1963
Pyramidosporites Segroves 1967
Ringosporites Tiwari & Rana 1981
Satsangisaccites Bharadwaj & Srivastava 1969
Simeonospora Balme 1970
Striatopodocarpites Soritscheva & Sedova ex. Sedova em. Bharadwaj 1962
Striatosporites Bhardwaj 1954
Trabeculosporites Trivedi & Mishra em. Tiwari & Ram-Awatar 1992
Triadispora Klaus 1964
Verrucosisporites Ibrahim ex Potonié & Kremp em. Smith 1971
Verticipollenites Bharadwaj 1962
Weylandites Bharadwaj & Srivastava 1969



Key to lithologies in logs

General explanation for figures 6 to 14

Lithostratigraphical sections/successions in bore-holes/outcrops considered for the present analysis, showing inter-calibration of palyno-levels for DOD (solid vertical lines on the left side of the logs), FAD (arrow pointed upwards), and LAD (arrow pointed downwards); lines with arrow-heads at both ends : span of formations ; horizontal lines A-A' mark the level of palynofloral change based on FAD, LAD, and DOD pointing a Permian-Triassic interval with a proximity to the PTB. Solid circles : sites of samples; numbers on the left side of logs : depth in meters from surface in case of bore-holes; where no measured thickness is available in a section, a log represent only the order of samples having few controls for thickness, with sample numbers (S.No.) given by the original authors (see Table 2). Discontinuity within the lithological symbols in a sequence between lithounits suggests unknown thickness and other details for that portion of the run.

Name of taxa abridged variously at places for reasons of graphics. Generally the first syllable of generic names used; for full names see above in the check list. Other abbreviations : S. or Striato-*Striatopodocarpites;* F.-*Faunipollenites;* Gd.-*Gondisporites;* Ds.-*Densipollenites;* Cr.-*Crescentipollenites;* Ar.-*Arcuatipollenites;* Lb.-*Lundbladispora;* Doi.-*Densoisporites;* Vc.-*Verrucosisporites;* Kr.-*Krempipollenites;* Ca.-*Callumispora;* Gtu.-*Guttulapollenites;* Fc.-*Falcisporites;* Sat.-*Satsangisaccites;* Goub.-*Goubinispora;* Petri.-*Pretricolpipollenites;* Scheur.-*Scheuringipollenites.*