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Role of spore-pollen species in demarcating the Permo-Triassic boundary in Raniganj Coalfield, West Bengal

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An attempt is made to delimit Permo-Triassic boundary in Raniganj Coalfield on the basis of selected palynofossils. *Densipollenites invisus, D. indicus* and *D. densus* decline while *D. magnicorpus* and *Gondisporites raniganjensis* disappear at the close of Raniganj Formation; *Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites ovatus, L. diffusus* and cf. *L. pellucidus* appear at Lower Panchet. Lithological and palynological changes at Raniganj/Panchet boundary help to draw the Permo-Triassic boundary at this level.

Key-words—Palynology, Raniganj Coalfield, Permo-Triassic Boundary (India).

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सारांश

पश्चिम बंगाल में रानीगंज कोयला-क्षेत्र में परमी-त्रिसंधी सीमा के परिसीमन में बीजाणु-परागकणों की भूमिका

विजया एवं राम शंकर तिवारी

कुछ छाँटे गये अश्मित बीजाणु-परागकणों के आधार पर रानीगंज कोयला-क्षेत्र में परमी-त्रिसंधी सीमा परिसीमित करने का प्रयास किया गया है। रानीगंज शैल-समूह के अन्त में डेन्सीपोलिनाइटिस इन्वीसस, डे० इन्डिकस और डे० डेन्सस की संख्या कम हो जाती है जबकि डे० मैग्नीकॉर्पस एवं गोंडिस्पोराइटिस रानीगन्जेन्सिस विलुप्त हो जाते हैं; डेन्सोइस्पोराइटिस कॉन्टेक्टस, लुन्ब्लाडिस्पोरा माइक्रोकोनेटा, लु० ब्रेविकुला, प्लेफ़ोर्डियास्पोरा कैन्सेलोसा, ल्यूनाटिस्पोराइटिस ओवेटस, ल्यू० डिफ़्यूसस एवं सजातीय ल्यू० पेल्यूसिडस अधरि पंचेत में आविर्भूत होने लगते हैं। रानीगंज/पंचेत सीमा पर शैलिकीय एवं परागाणविक परिवर्तन परमी-त्रिसंधी सीमा को सुनिश्चित करने में सहायता प्रदान करते हैं।

EFFORTS during the last decade to delimit Permo-Triassic boundary in Peninsular India on the basis of palynological studies have proved successful (Tiwari & Singh, 1986). Palynological boundary demarcations were, so far, based on generic distinctions. The present work has been undertaken to achieve a finer and precise boundary demarcation on the basis of distribution pattern of significant species which could be used as marker taxa.

AREA OF STUDY

Subsurface material from the eastern most part of Raniganj Coalfield have been used for the present study. Recent palynological investigations of bore-core samples in this area (Rana & Tiwari, 1980; Singh & Tiwari, 1982; Tiwari & Singh, 1983; Tiwari & Rana, 1984) have demonstrated palynofloral changes marking the Raniganj/Panchet sequences (Table 2). Following samples have been used for this study (Table 1), allowing a lateral comparative distributional pattern of species.

Quantitative determination of miospores at generic level has revealed the sequential arrangement of palynological assemblages at Raniganj/Panchet boundary (Table 2; after Tiwari & Singh, 1986).

EVALUATION OF SPORE-POLLEN SPECIES FOR ZONATION

Quantitative determinations for palynological assemblage at generic level in bore-holes NCRD-6 (Bharadwaj & Tiwari, 1977), RAD-2 (Singh & Tiwari,

Table 1—List of samples studied representing the sequence encompassing the Raniganj/Panchet boundary in various bore-holes in Raniganj Coalfield

S. No.	Depth in m	Lithology	Lithological boundary	Miofloral zones (Tiwari & Singh 1986)
I	*B.H. NCRD-6 (Bharadwaj & Tiwari, 1977)*			
1.	215.00	Greenish Shale		P-II B
2.	280.00	Greenish Shale	Raniganj/Panchet	
3.	287.30	Greenish Shale		R-IB
II	*B.H. RAD-2 (Singh & Tiwari, 1982)*			
1.	430.00	Greenish Shale		P-IVA
2.	450.47	Sandstone	Raniganj/Panchet	
3.	460.00	Sandstone		P-IIIB
4.	545.00	Sandstone with coal		R-IB
5.	550.00	Carbonaceous Shale	R-IA	
III	*B.H. RAD-5 (Tiwari & Singh, 1983)*			
1.	481.00	Greenish shale+Sandstone		P-IIB
2.	493.50	Sandstone	Raniganj/Panchet	
3.	505.00	Greenish shale+Sandstone		P-IA

Table 2—Showing the quantitative change-over in palynological assemblages at Ranigani-Panchet boundary (modified after Tiwari & Singh, 1986)

LOWER PANCHET			P-IB	*Striatopodocarpites*, cf. *Lunatisporites, Klausipollenites, Chordasporites, Inaperturopollenites, Crescentipollenites, Lundbladispora*
	Assemblage P-I	*Striatopodocarpites Klausipollenites*	P-IA	*Striatopodocarpites-Klausipollenites, Alisporites, Nidipollenites, Verrucosisporites, Densipollenites, Playfordiaspora, Satsangisaccites*
BOUNDARY				
UPPER RANIGANJ			R-IB	*Striatopodocarpites-Crescentipollenites, Densipollenites, Scheuringipollenites, Klausipollenites*, cf. *Lunatisporites, Gondisporites, Lundbladispora*
	Assemblage R-I	*Striatopodocarpites Densipollenites*	R-IA	*Striatopodocarpites-Densipollenites, Faunipollenites, Crescentipollenites, Gondisporites, Lundbladispora, Playfordiaspora*, cf. *Lunatisporites.*

1982) and RAD-5 (Tiwari & Singh, 1983), exhibit definite change at Raniganj-Panchet level. It has been observed that a large number of taxa, which qualify the Lower Raniganj Formation continue to occur even at the closing phase of the Raniganj Formation; although a few genera, viz., *Densipollenites* and *Crescentipollenites*, gain abundance at this younger level, apiculate trilete genera proliferate in variety, while a few cavate-taeniate pollen appear at the close of Raniganj. The most significant change is observed in the frequency of *Densipollenites* which suddenly records its prominence in the Upper Raniganj. It is thus obvious that except the two genera, i.e. *Densipollenites* and *Crescentipollenites*, none of the other genera exhibits striking variability in their occurrence within the Raniganj palynological succession because of their percentage frequency which is more or less similar throughout this sequence. The genus *Densipollenites* gets further significance due to the characteristic behaviour of its species.

Consequently, for the record of specific variations, it was preferred to search thoroughly the occurrence pattern of certain species in *Striatopodocarpites-Densipollenites/ Crescentipollenites* palynozone (i.e. R-1 of Tiwari & Singh, 1986), which is the youngest zone at the close of Raniganj palynoflora. It is difficult to evaluate various species for the use of boundary delimitation because most of the species have a long range distribution throughout the Permian. For this reason striated pollen (including *Crescentipollenites*) and

apiculate trilete spores have been excluded from the present determination.

The presence of *Ephedripites* and *Weylandites* is also not always consistent at this level; they may or may not be present in *Densipollenites/Crescentipollenites*-Phase. Parallel to this change-over *Gondisporites* plays an effective role by its sudden prominence and subsequent decline at the Raniganj/Panchet boundary level. Therefore, the genera thus remain for determination of boundary delimitation by virtue of the change in their species are—*Densipollenites* and *Gondisporites*. Beside these significant indicators, few species of cavate spores and monosaccate and taeniate pollen signify the younger aspect within the Raniganj palynoflora because these taxa virtually qualify the Lower Panchet horizons. Such genera are *Densoisporites, Lundbladispora, Playfordiaspora* and *Lunatisporites*.

On the basis of such an evaluation supported by a thorough search for the incidence of species, the following species are considered important for boundary demarcation :

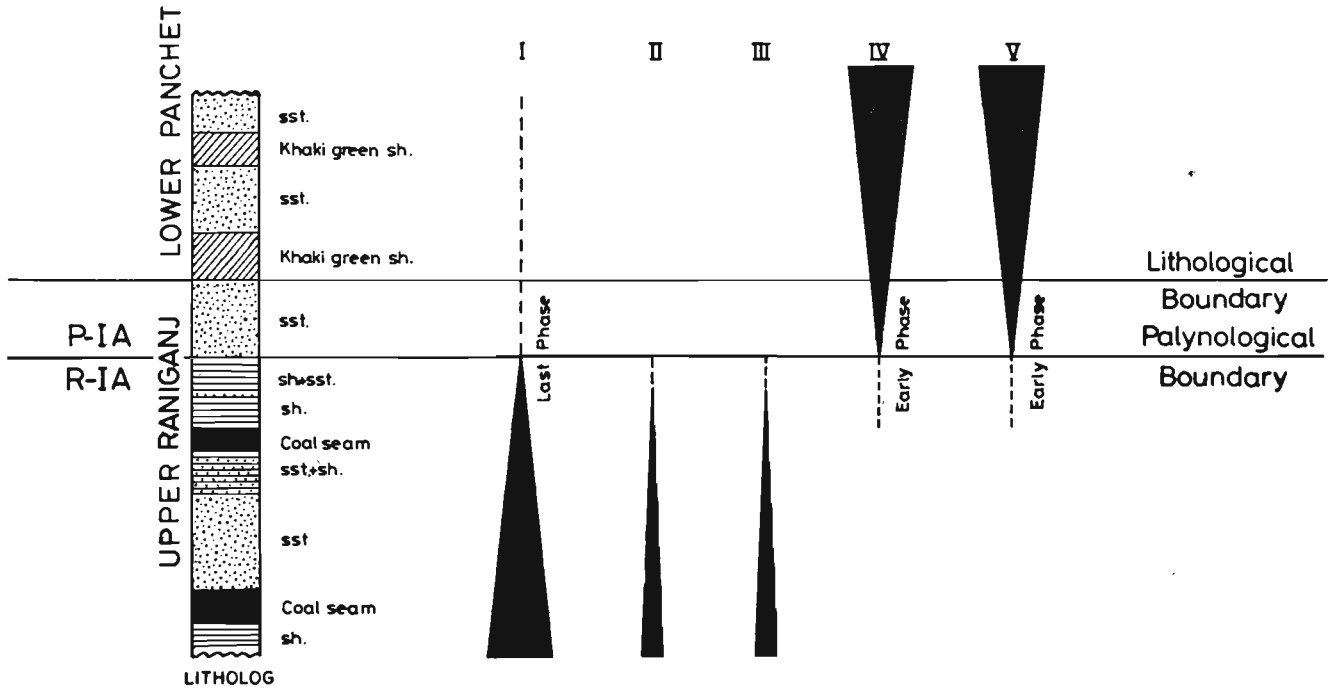
Densipollenites Bharadwaj 1962
D. indicus Bharadwaj 1962
D. invisus Bharadwaj & Salujha 1964
D. densus Bharadwaj & Srivastava 1969
D. magnicorpus Tiwari & Rana 1981
Gondisporites Bharadwaj 1962
G. raniganjensis Bharadwaj 1962
Densoisporites Weyland & Krieger emend. Dettmann 1963
D. contactus Bharadwaj & Tiwari 1977
Lundbladispora Balme emend. Playford 1965
L. brevicula Balme 1963
L. microconata Bharadwaj & Tiwari 1977
Playfordiaspora Maheshwari & Banerji 1975
P. cancellosa (Playford & Dettmann) Maheshwari & Banerji 1975
Lunatisporites Leschik emend. Scheuring 1970
L. ovatus Maheshwari 1975
L. diffusus Bharadwaj & Tiwari 1977 cf. *L. pellucidus* Maheshwari & Banerji 1975

These species can be indentified on the basis of characters as *Densipollenites* includes monosaccate alete non-striate pollen where saccus envelops the central body loosely from all the sides and is attached at one point, the saccus being intrareticulate, variously folded and usually with radiating folds from the point of attachment among its species; *D. indicus* has a thin, small circular central body with distinct outline; *D. invisus* possesses a very thin body with almost ill-defined outline; *D. densus* exhibits a small dark brown, dense and well demarcated body, while in *D. magnicorpus* a big, dark brown and well-defined body occupies more than half the area of pollen. *Gondisporites raniganjensis* includes roundly triangular to subcircular, trilete spores with denticulate equatorial ridge, surrounding a large central body with granulose as well as sparsely spinulate or baculate exine. In *Densoisporites contactus* broadly triangular, cavate, cingulate, trilete spores are incorporated which have distinct contact area and finely micropunctate unsculptured exine. *Lundbladispora brevicula* includes roundly triangular, cavate, cingulate, trilete spores, exine being 2-3 μm thick, finely spongy, distally bearing $\pm$ 2 μm wide, 2-4 μm long spines; *L. microconata* has been circumscribed for broadly triangular, cavate, cingulate trilete spores whose exine is finely spongy, distally bearing 1×1 μm short, rare coni. In *Playfordiaspora cancellosa* more or less circular monosaccate pollen are included which enclose dense brown central body with trilete mark; its rays are body radius long and saccus is regularly intrareticulate forming honey-comb pattern. *Lunatisporites ovatus* includes bisaccate pollen, central body being distinct, vertically oval and proximally bearing 4-6 taeniae; distally, saccus attachment are accompanied with wide lunar folds. *L. diffusus* are bisaccate pollen, central body being diffused but apparently rhomboidal; proximally bearing unevenly wide 6-8 taeniae, distally narrow lunar folds along the zone of saccus attachment present. cf. *Lunatisporites pellucidus* includes bisaccate pollen, with vertically oval to rhomboidal central body, which proximally bearing 4-6 taeniae; distally, lunar folds absent.

DISTRIBUTION PATTERN OF SIGNIFICANT SPECIES

Determination of Raniganj-Panchet boundary on the basis of percentage frequency of spores and pollen (Tiwari & Singh, 1986) has revealed prominence of *Densipollenites/Crescentipollenites* combination at the closing phase of Raniganj Formation. Transitional trend is marked by the incoming of *Lundbladispora, Lunatisporites, Densoisporites* and *Playfordiaspora* at the top most assemblage in Raniganj Formation. Quantitative change in the assemblage at this level is distinct, and it corroborates with the change in lithology where carbonaceous and sandstone facies die out while khaki-green shales come in to prominence (Tiwari & Singh, 1983).

Relative positioning of the lithological boundary and the palynological boundary (based on percentage frequency of pollen & spore genera) have been depicted in Text-fig. 1. Keeping the objective of the present work of refinement and precision the marking of Permo-Triassic boundary on the basis of spore-pollen distribution, it has been found that the taxa listed on p. 000 shows greater degree of



Text-figure 1—Species behaviour pattern. Index : I—*Densipollenites invisus, D. indicus, D. densus*; II—*Densipollenites magnicorpus*; III—*Gondisporites raniganjensis*; IV—*Lundbladispora microconata, L. brevicula, Densoisporites contactus, Playfordiaspora cancellosa*; V—*Lunatisporites ovatus, L. diffusus, L. pellucidus.*

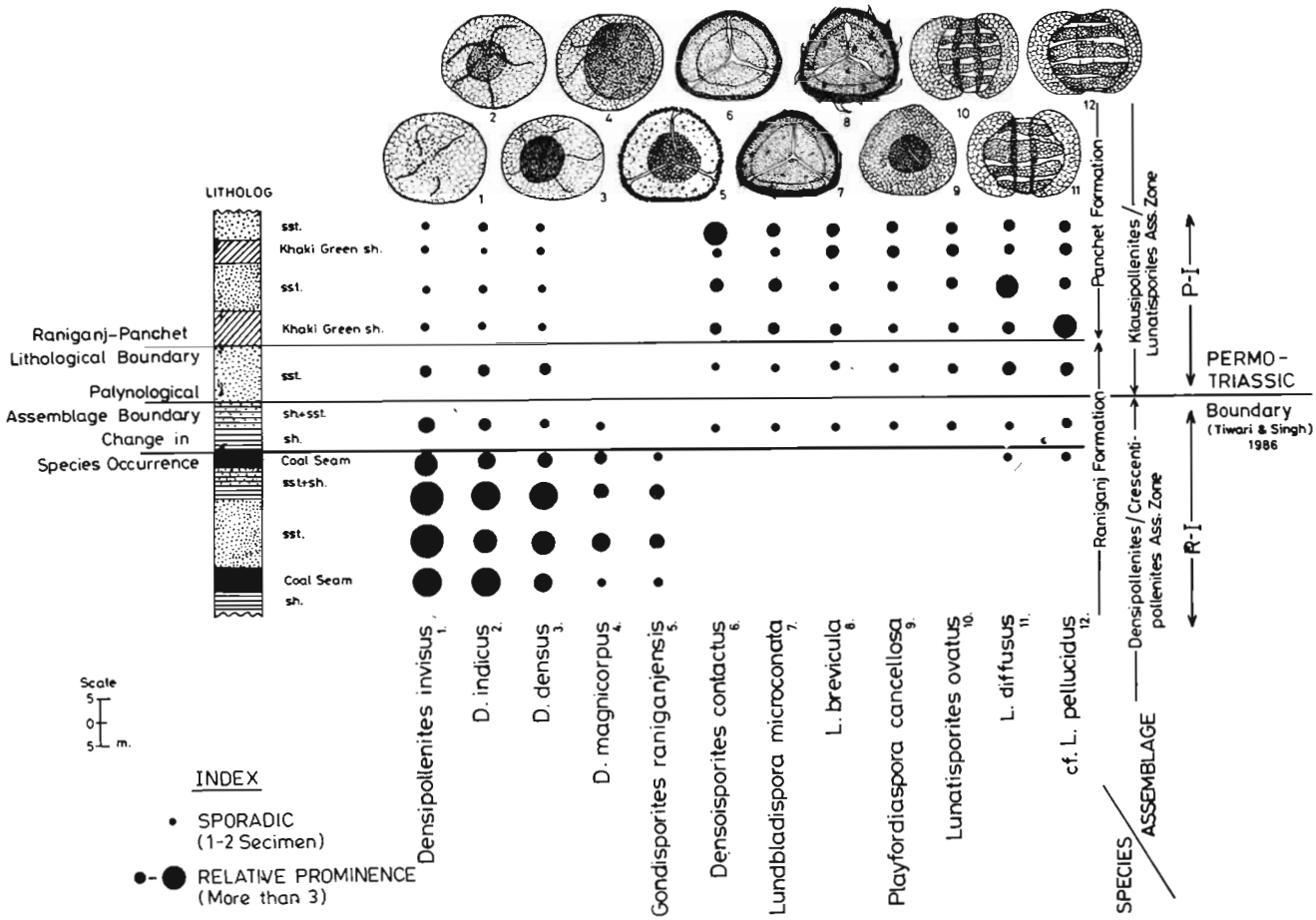
certainity and hence could be utilized in determination of this boundary.

Range of individual representative species is shown in a standard profile through Raniganj-Panchet boundary (Text-fig. 2) exhibiting lithological succession composed of coal seams, carbonaceous shale and sandstone beds (classified in Raniganj Formation) followed by khaki-green shale and sandstones (Panchet Formation). This profile has been compiled on the basis of lithologs prepared by Geological Survey of India from a number of bore-holes in this area and represents a generalized section for Raniganj-Panchet transitional level.

The distribution pattern of selected species through this profile was finalised after a thorough search of fossil taxa in scores of slides of each sample. Absence of any species at any particular level was put on record only when a number of samples in the entire series in the log were thoroughly checked. Thus, the absence is effectively considered a positive evidence. The behaviour pattern is as follows :

1. Densipollenites—This genus exhibits maximum species diversity at close to the Raniganj-Panchet transition as expressed by the fair record of *D. indicus, D. invisus, D. densus* and *D. magnicorpus*, in assemblage zone R-I of Tiwari and Singh (1986) which qualifies the uppermost part of Raniganj Formation. The first three species are also recorded from still older assemblages of the Lower Gondwana. Further search in the succeeding younger assemblage (i.e. in the shale and sandstone unit above the topmost coal seam of the Raniganj Formation) shows a sudden decline in the frequency of these species (Text-fig. 2), although the presence of these species of *Densipollenites* continues in the lowest bed of the khaki-green shales of Lower Panchet Formation, where they are scanty as well as sporadic. *D. magnicorpus* has been identified to be the most important species because its prominence is recorded only in the Raniganj Formation and not in the younger sequences. As it is evident from the Text-fig. 2, decline in the frequency of *Densipollenites* spp. on one hand and emergence of certain species (viz. of cavate spores and taeniate pollen) characteristic of Panchet assemblage on the other, are concurrent. Although three species of the genus *Densipollenites* are transgressive, the palynological boundary drawn on the basis of generic dominance, their qualified occurrence (i.e. sporadicity and inconsistency) further supportingly depicts a definite change at this time plane.

2. Gondisporites—*G. raniganjensis* is found in Raniganj palynoflora, within R-I and R-II assemblage zones proposed by Tiwari and Singh (1986). Extensive search for this species in the R-I assemblage zone reveals its sporadic presence in the sequence up to the top most coal seam of Raniganj Formation; it hardly crosses the shale unit above this



Text-figure 2—General lithological section at Raniganj/Panchet Boundary and variation in species occurrence.

seam (Text-fig. 2). In Panchet sediments it has not been recorded. Evidently, its extinction is significant at the palynological boundary (i.e. R-I/P-I zone) already drawn on the basis of percentage frequency of spore-pollen genera.

Beside the above discussed taxa, there are certain other species (given below) which are quanti-tatively significant in Panchet palynoflora. These show their first appearance almost at the begining of Panchet and get diversified (Text-fig. 2).

3. Densoisporites—It is an important genus of Panchet palynoflora and is represented by two species—*D. playfordii* and *D. contactus*. An extensive search of these species in R-I assemblage zone (Tiwari & Singh, 1986) revealed the presence of only one species, i.e. *D. contactus* in the shale and sandstone unit (above the topmost coal seam), and not below it. But in the younger strata above this lithological unit, other species of *Densoisporites* also start making their appearance (Text-fig. 2). Evidently the incidences of *D. contactus* in the topmost sandstone shale bed of the Raniganj Formation indicates a Panchet affinity for this level.

4. Lundbladispora—Its maximum specific diversification is identified in the Panchet palynofloras (Tiwari & Singh, 1986). The species generally met within the Panchet are : *L. willmotti, L. brevicula, L. microconata, L. densispinosa, L. raniganjensis* and *L. warti*. Within R-I assemblage zone of Raniganj palynoflora, presence of this genus is recorded by the species *L. brevicula* and *L. microconata* only. All the more, their occurrence is restricted only to the shale and sandstone unit, above the topmost coal seam of the Raniganj Formation (Text-fig. 2). Again, its occurrence indicates a Panchet affinity for this level. It is, therefore, clearly evidenced that the species of *Lundbladispora* can play a deciding role in deciphering the Raniganj-Panchet boundary.

5. Playfordiaspora—This genus usually makes its appearance in the Lower Panchet (khaki-green shale unit) but, however, very sporadically and sparingly it has been recorded in the shale and sandstone unit above the topmost coal seam of the Raniganj Formation. Till now two species—*P. cancellosa* and *P. annulata* are identified. An extensive search in the topmost coal seam of Raniganj Formation and above has revealed the presence of *P. cancellosa* in shale and sandstone bed overlying the topmost coal seam. It is not recorded in the topmost

coal seam of the Raniganj Formation (Text-fig. 2). Obviously, *Playfordiaspora* can be relied upon as a good indicator of the Raniganj/Panchet transition along with other floral elements.

6. Lunatisporites—This taeniate-disaccate pollen is an important component of Triassic palynofloras (Tiwari & Singh, 1986). When an immense search for the occurrence of its species was made through Raniganj-Panchet transitionary zone, only three species, i.e. *L. diffusus* cf. *L. pellucidus* and *L. ovatus*, stood out to show their qualified occurrence. *L. ovatus* generally appear above the topmost coal seam of the Raniganj Formation and gradually acquires a better numerical importance in younger horizons. However, sporadic and inconsistent occurrence of *L. diffusus* and cf. *L. pellucidus* has been recorded in the topmost coalseam of Raniganj Formation but hardly below it (Text-fig. 2). These three species, therefore, demarcate a level of change at the close of R-I (*Densipollenites/Crescentipollenites*) Assemblage zone.

REMARKS

Distribution pattern of the species discussed (Text-fig. 2) brings out two major events at Raniganj/Panchet boundary. The first is the declination of *Densipollenites* phase (Text-figs 1, 2), above the coal facies of Raniganj Formation and the second is the simultaneous appearance of species of *Lundbladispora, Densoisporites, Playfordiaspora* and *Lunatisporites* heralding a new phase in the palynoflora associated with a change in lithofacies. Change in species distribution occurs in shale/sandstone unit on the top of uppermost coal seam (Text-figs 1, 2). Other noteworthy record is the occurrence of nonstriate-bisaccate taxa, assignable to *Satsangisaccites* and *Nidipollenites*, in the shale and sandstone unit above the topmost coal seam. Beside the well-logged data from bore-cores discussed above, the occurrence of certain taxa of importance (viz. *Lundbladispora, Playfordiaspora, Densoisporites*) has been reported from the outcrop sections in Hoharo River, Machkanda Jhor and Nonia Nala sections (Bharadwaj, Tiwari & Anand Prakash, 1979). These taxa at places, appear to occur in the older strata than what has been determined in the subsurface of above account. However, more precise study of measured section in the outcrop of this type is needed for ascertaining their distribution.

DISCUSSION

The Raniganj/Panchet boundary based on lithological change has been established at the top of sandstone which overlies the topmost coal seam. Thus, the sandstone/khaki-green shale marks the boundary. Palynological boundary drawn on quantitative determination of palynotaxa precedes this line of lithological boundary (Tiwari & Singh, 1986). The search for the role of palynotaxa at species level in determining the boundary has revealed a definite pattern of occurrence. The change in species starts in shale/sandstone unit above the topmost coal seam of Raniganj Formation (Text-fig. 2). This analysis reveals that the various boundary lines could be drawn in the following order : lithology, generic assemblage and spore pollen species. These events represent Permian/Triassic time boundary.

Palynological boundary always precedes lithological boundary (Tiwari & Singh, 1986). The boundary based on species distribution, i.e. the first appearance/ extinction or declination in frequency precedes to the palyno-assemblage boundary. The dwindling of already present species and simultaneous appearance of certain new species at the level of change is important (Text-fig. 2).

CONCLUSIONS

Following conclusions have been drawn from the present study:

1. All species in a palynological assemblage are not suitable for precise palynological age determination, particularly with regard to age boundaries. In order to find the qualifying species, intensive search is needed involving in recording trace occurrence, on both the sides of the expected boundary level. It is not the first appearance of a species which provides a clue to demarcate boundary but the package of their behaviour pattern including extinction patterns.
2. In the area understudy, considering the stratal sequences from older to younger units particularly with regard to the Raniganj-Panchet boundary, the incoming as well as disappearance of certain species has been recorded at the earliest level; the demarcation in palynological assemblages is evidenced after a time-lapse and subsequently the change in lithology is the last factor to become evident.
3. Lithological and biostratigraphical boundaries are marked at a close range of each other. This level is in the sandstone unit which is subjacent to the khaki-green shale. This is considered to demarcate the Permo-Triassic time boundary.
4. Sudden decline of *Densipollenites invisus, D. indicus* and *D. densus* and disappearance of *D. magnicorpus* and *Gondisporites raniganjensis* heralds the close of Permian. Simultaneously, the incoming of *Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites ovatus, L. diffusus* and cf. *L. pellucidus* ushers a new floral phase

signifying the Triassic. This trend in species occurrence (i.e. just above the topmost coal seam of Raniganj Formation) definitely foreshadows the time boundary because it is an expression of benchmark change at this level.

5. The change in species behaviour at Raniganj/Panchet boundary is an important evolutionary event. Remarkable change in the percentage frequency of palynoflora alongwith substantial incoming of newer one, marks the palynological boundary. It indicates a clear cut change in the quality of floral elements and its major genetic as well as ecological alteration. This biological boundary closely precedes the lithological boundary which denotes the change in regional tectonic set up and the area of provinence. The change in certain species—appearance or disappearance is, however, first to occur. Obviously, these three indications of a change over are suggestive of definite time boundary, i.e. Permo-Triassic boundary at this level of events.
6. The coal facies ceases to develop in this basin at Raniganj/Panchet boundary when the area became tectonically static and subsequently khaki-green shales appear as the major dominating lithology. The species distributional design imparts a figurative appearance of two patterns of cluster, one is decreasing and the other is increasing (Text-fig. 1) pattern. In the declining cluster pattern, the group of species *Densipollenites indicus, D. invisus, D. densus, D. magnicorpus* and *Gondisporites raniganjensis* is projected which qualify the Permian palynofloras. These die out gradually. Other cluster pattern which is reversed and emerges at the side of the first one, depicts a slow but continuous progressive increase of Triassic species, such as—*Densoisporites contactus, Lundbladispora microconata, L. brevicula, Playfordiaspora cancellosa, Lunatisporites diffusus* and *L. pellucidus*. These two cluster patterns are complementary to each other and therefore is suggestive of a major change at this level.

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