Revision of the Late Permian-Triassic pollen genus *Playfordiaspora* Maheshwari & Banerji 1975

Vijaya

Vijaya 1995. Revision of the Late Permian-Triassic pollen genus *Playfordiaspora* Maheshwari & Banerji 1975. *Palaeobotanist* 43(1) : 54-67.

The genus *Playfordiaspora* was proposed by Maheshwari and Banerji (1975) to accommodate trilete, "apparently monosaccate" miospores with very fine reticulate "flange". The present study reveals that it bears an enveloping single layered, endoreticulate, empty monosaccus without an in-fill. This records the occurrence of eusaccate pollen during Late Permian- Triassic from widely separated palaeogeographical areas of the Gondwanaland, Europe and America. Although, the affinity of *Playfordiaspora* is difficult to ascertain, a pteridospermous relationship seems probable on the basis of above morphographic features.

Key-words — *Playfordiaspora*, Morphotaxonomy, Eusaccate pollen, Late Permian, Triassic.

Vijaya, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

साराँश

अनंतिम परमी-त्रिसंधी परागकण प्रजाति *प्लेफोर्डियास्पोरा* माहेश्वरी एवं बैनर्जी 1975 का संशोधन

विजया

बहुत पतले जालिकावत् फ्लेंज से युक्त त्रिअरीय, "स्पष्ट एक कोष्ठीय" बीजाणुओं को व्यवस्थाबद्ध करने के लिए माहेश्वरी एवं बैनर्जी (1975) ने *प्लेफोर्डियास्पोरा* नामक प्रजाति प्रस्तावित की थी। वर्तमान अध्ययन से व्यक्त होता है कि इसमें एक पर्त वाला आवरण, अन्तःजालिका तथा रिक्त एक कोष्ठ विद्यमान है। इससे अनंतिम परमी-त्रिसंधी युग में गोडवानाभूमि, यूरोप एवं अमेरिका के पृथक-पृथक दूरस्थ पुराभौगोलिक क्षेत्रों से सुकोष्ठीय परागकणों की उपस्थिति व्यक्त हुई है। तथापि, *प्लेफोर्डियास्पोरा* की सजातीयता सुनिश्चित करना कठिन है, उक्त आकारिकीय लक्षणों के आधार पर सम्भवतया टेरीडोस्पर्मी पौधों से इसका सम्बन्ध प्रतीत होता है।

BALME (1970) remarked that the nature of sexine infrareticulum in *Guthoerlisporites cancellosus* Playford & Dettmann 1965 from Salt Range is extremely fine, regular and sharply defined and does not compare with the genus *Guthoerlisporites* which is understood to have a fairly coarse and irregular saccus structure. Subsequently, a formal name — *Playfordiaspora* gen. nov., was proposed by Maheshwari and Banerji (1975) to accommodate such pollen grains under *P. (Guthoerlisporites) cancellosa* (Playford & Dettmann, 1965) as its type species.

Based on the morphographic interpretation, Playford and Dettmann (1965), Balme (1970), Maheshwari and Banerji (1975) and also Foster (1979) considered the taxonomic placement of the genus *Playfordiaspora* under the Suprasubturma – *Perinotriletes*, Subturma–*Monosaccites*, and Suprasubturma–*Pseudosaccitriletes*, respectively. This kind of varied treatment was the result of different views derived from the same set of morphographic characters of this taxon.

It has been now observed that this taxon does not possess any perine or zona around the body, hence its placement under the Suprasubturma–*Perinotriletes* or *Pseudosaccitriletes* is untenable. With the organization derived in the present analysis the following classification for the genus *Playfordiaspora* is considered to be most suitable :

Anteturma – *Pollenites* Potonié 1931

Turma – *Saccites* Erdtman 1947

Subturma – *Monosaccites* Chitaley emend. Potonié & Kremp 1954

Infraturma – *Triletesacciti* Leschik 1955

Subinfraturma – *Intrornati* Butterworth & Williams 1958

Genus — *Playfordiaspora* Maheshwari & Banerji 1975

Foster (1979) expressed doubts about the comparison made by Playford and Dettmann (1965) and also by Balme (1970) between the two species – *Guthoerlisporites cancellosus* and *Endosporites velatus*. He also did not accept *cancellosus* as the type species for the genus *Playfordiaspora* because of a probable similarity between *Guthoerlisporites cancellosus* and *Endosporites velatus* that seem to possess finely infrareticulate sexine of the same nature, and hence a re-examination of the type of *E. velatus* was recommended to confirm whether these two species are conspecific. *E. velatus* Leschik 1956, has a priority over *G. cancellosus* Playford & Dettmann 1965, but the type specimen of the former is broken and not properly described. Because of these "discrepancies", Foster (1979) proposed *Nuskoisporites crenulatus* Wilson 1962 as the type species for *Playfordiaspora*, and mentioned that single figured specimen of *E. velatus* was not suited to be the type specimen for this genus.

In view of these varied ideas, the morphographic characters of *Guthoerlisporites cancellosus; Endosporites velatus, E. hexareticulatus* and *Nuskoisporites crenulatus* have been critically assessed in this paper. On the basis of the study of type specimen as well as several other specimens from European material it has been concluded that *E. velatus* Leschik 1956 is distinct from *G. cancellosus* in having infragranulose inter-ray areas. *Nuskoisporites crenulatus* also stands apart in possessing prominent crenulate body margin.

DESCRIPTIVE MORPHOLOGY

Genus – *Playfordiaspora* Maheshwari & Banerji 1975 emend.

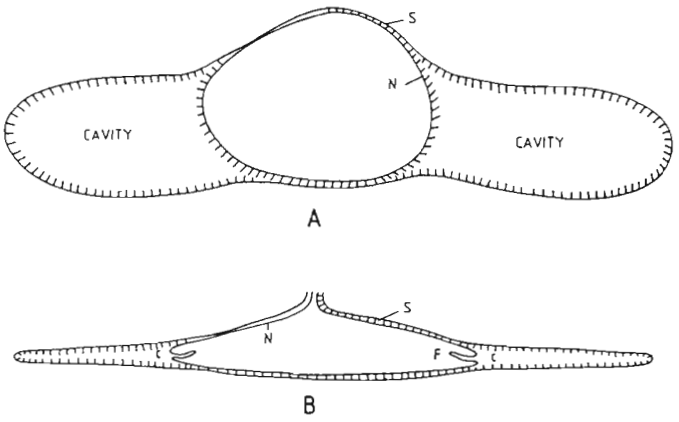
Pl. 1, figs 1-3; Pl. 2, figs 1-6; Pl. 3, figs 1-7; Text-figs 1, 2

Type species — *Playfordiaspora (Guthoerlisporites) cancellosa* (Playford & Dettmann) Maheshwari & Banerji 1975.

Original generic diagnosis — (see Maheshwari & Banerji 1975), p.158.*

Observations — In the presently studied specimens* of the genus *Playfordiaspora*, it has been observed that the sexinal extension is not a flange; structurally it is a saccus. The finely structured infrareticulate sexine is differentiated from the nexine on the proximal face of the specimens, excepting the trilete mark; however, at times sexinal continuity above trilete mark is also observed; the trilete rays are generally distinct, simple with thin lips and defined suture, sometimes may be slightly open. The sexine spans beyond the nexinal margin in the form of a thin enveloping monosaccus (Pl. 1, fig. 3; Pl. 2, figs 4, 5) Structurally the saccus is eusaccate, where the endoreticulum forms a single layer in the subtectate surface of sexine and there is no infilling of endoreticulum or alveoli (Pl. 2, figs 1, 2). The infrareticulum in the saccus exhibits distinct patterns of very fine, uniformly disposed hexagonal or subcircular muri. No limbus is present in the saccus. Shifting of body (i.e., nexine) in relation to the saccus outline is not a common feature, being present in 2-3 per cent of the total population. The L-O analyses and SEM studies reveal that on distal face of the body, the sexinal layer is loosely attached with the nexine and during flattening it may get separated leading to the acentric position of nexine (Pl. 2, fig. 6; Text-figure 1A, B). Radially directed microfolds in the saccus may be present. Had there been no inflation in the expanded sexine, no radiating fold could have been formed in the flattened specimens. In a sheet-like sexinal spread no prominent folds are formed; obviously they are the results of compression of inflated saccus. The overall shape of pollen is circular to roundly-triangular. Nexine may or may not conform the shape of amb. The surface area of the nexine on the distal face is more than that of the proximal face, therefore on flattening the body folds are formed distally. In some species, however, there is well-

* Specimens of the genus *Playfordiaspora* studied presently are illustrated in Plates 1-3 to show variations in body shape, size, and nature of sexine infrareticulation. The slides having these specimens are deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

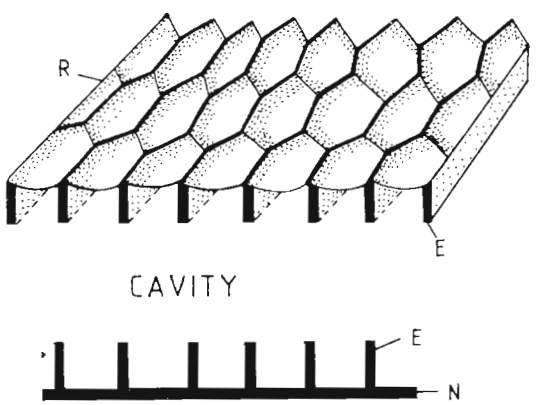


Text-figure 1 — **A.**Semi-diagrammatic sectional view of the specimen to illustrate the nature of trilete mark and exine structure; extension of finely infrareticulate structured sexine, spreading on to the nexine on proximal face(s) leaving free only trilete ray, and cavation (c) in saccus, which seems relatively more around equatorial region of the nexine (body); **B**. Semi-diagrammatic sectional view of flattened specimen to show the possibility of formation of secondary fold (F) around nexine (N), and extent of cavation in saccus (c).

defined equatorial thickening in the nexine, appearing as annular ring (Pl. 3, fig. 4).

The organization of the genus is depicted semi-diagrammatically in Text-figures 1 and 2. In view of the above observations, the diagnosis of *Playfordiaspora* originally described by Maheshwari and Banerji (1975) is emended here.

Emended generic diagnosis — Monosaccate, radially symmetrical, trilete, eusaccate pollen; amb more or less circular to roundly triangular. Trilete mark simple, rays generally extending 3/4 of body radius, distinct to perceptible. A faintly differentiated contact area may be present. Exine two layered. Sexine detached from nexine to form a saccus which is almost uniformly cavate in between two layers; sexine loosely attached on distal central face, and also extends on the proximal face up to the margins of trilete rays, at times covering the trilete mark as well. Sexine eusaccate in nature, externally psilate, with a distinctly defined fine, and thin single layered subtectate endoreticulum. Muri of endoreticulation in saccus uniformly thick, extremely fine, < 1 µm thick, mostly regular and perfect; meshes very small, < 1 µm width, tending to impart inframicroreticulte pattern of honeycomb-like hexagonal or circuloid areas. Fineness of infrareticulation increases towards centre on proximal surface of the body, where in some cases, becoming infragranulose Nexine circular to ubtriangular in polar view, relatively thicker than sexine, generally placed in centre, rarely slightly acentric. Radiating folds on distal part may be present.



Text-figure 2 —Nature of sexinal infrareticulation (R) resulting into a pattern of honey-comb-like meshes. The hanging endoreticulate rodlets (E) around nexine (body) equator (N).

Comparison – Monosaccate pollen dispersed in the Permian and Triassic sequences do not show a combination of characters described above. The comparable miospores are : *Guthoerlisporites* Bhardwaj 1954, *Endosporites* Wilson & Coe emend. Bharadwaj 1965 and *Teichertospora* Balme 1988; McGregor & Playford 1990. However, the differences are well marked as *Guthoerlisporites* is separable on the grounds of its organization (Bhardwaj, 1954), and in having coarse and irregular sexinal infrareticulum which fills the saccus. *Endosporites* possesses, in most of the cases, a prominent limbus along the saccus margin, sculptured exine, fairly marked contact area, and elongated trilete rays reaching up to the curvaturae. *Teichertospora* is distinguished by having orthotriangular amb, elevated trilete mark, and protosaccate fill in the saccus with partial cavit, interpreted as secondary in nature.

The Early Permian monosaccate pollen from Gondwana, viz., *Plicatipollenites* and *Parasaccites*, are radially or bilaterally symmetrical and trilete, monolete or alete. The saccus in all such forms is protosaccate with a filling of endoreticulum. Thus *Playfordiaspora* is organizationally dissimilar from all such taxa.

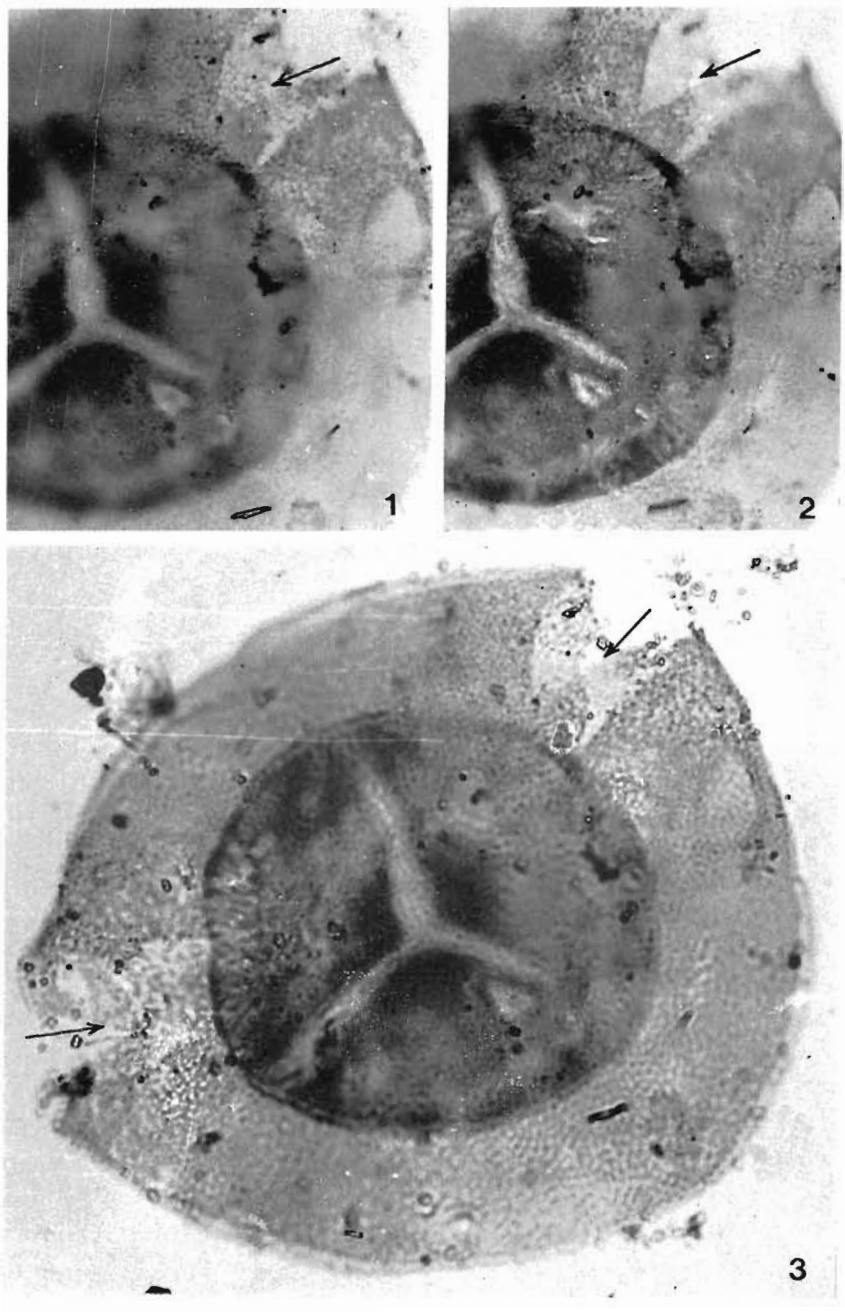


PLATE 1

1-3 *Playfordiaspora cancellosa* emended here. Specimen enlarged to show sexine infrareticulation that is polygonal in nature. A portion of the saccus is illustrated to show saccus structure in low, mid and top foci in 1, 2 and 3

1. Arrow indicates bottom layer of saccus. x 1000.

2 Cavation between sexine layers in saccus without an in-fall of infrareticulum. x 1000

3 In a distally-up preserved specimen, the sexinal cover all over the body surface is seen in top focus. x 1500 Slide no. BSIP 11347.

SPECIES RESOLVED

Based on distinction of sexine and neine on the proximal face of the pollen, nature of contact area, radiating folds in saccus and presence or absence of a rim or crenulation at the nexinal outline, following

species have been circumscribed in the genus *Playfordiaspora*:

P. (Guthoerlisporites) cancellosa (Playford & Dettmann) Maheshwari & Banerji, emend.

P. (Nuskoisporites) crenulata (Wilson) Foster emend.

P. annulata Tiwari & Rana 1980

P. (Endosporites) velata (Leschik) comb. nov.

P. (Endosporites) hexareticulata (Klaus) comb. nov.

Playfordiaspora cancellosa (Playford & Dettmann) Maheshwari & Banerji emend.

Pl.1, figs 1-3; Pl. 2, figs 4, 5; Pl. 3, figs 1-3, 5, 6, 9, 12

Holotype – Playford & Dettmann, 1965; pl. 14, fig. 34.

Type locality – South Australia, Leigh Creek, Northern Basin, Leigh Creek Coal Measure, sample NF7.

Horizon & age – Rhaeto-Liassic, Late Triassic.

Emended diagnosis – Radial, monosaccate pollen, amb more or less circular. Trilete mark generally distinct, slit without raised lips. Exine two-layered, consisting of a smooth homogeneous less than 1 µm thick nexine, and equatorially detached sexine forming a saccus. Saccus typically eusaccate, single layered, fine and uniform endoreticulate structure having < 1 µm wide muri, and < 1 µm across meshes, not symmetrically hexagonal but polygonal to circular, distally loosely attached on the central part of the nexinal body, proximally extending up to the margins of the trilete rays.

Remarks – Emendation is proposed here to incorporate the observation that single layered endoreticulate sexine extends proximally on to the body (nexine), eusaccate, and also attached on its distal face. These features were not described in the diagnosis given by Playford and Dettmann (1965, p. 147).

Playfordiaspora crenulata (Wilson) Foster 1979 emend.

Pl. 3, fig. 7

1962 *Nuskoisporites crenulatus* Wilson, p. 14, pl. 14, fig. 1.

Holotype – Wilson, 1962; pl. 14, fig. 1.

Type locality – Flowerpot Mound, southwest Medicine Lodge, Kansas.

Horizon & age – Flowerpot Formation, Middle Permian.

Emended diagnosis – Radial monosaccate pollen. Amb broadly circular to roundly triangular, oblately flattened. Trilete mark not prominent, rays reaching 1/3 of body radius. Central body roundly triangular, 2 µm thick, infragranular proximally. Saccus finely infrareticulate, eusaccate, proximally overlapping on body surface up to nearly half of the total area covering sub-equatorial region. Body-saccus contact edge deeply crenulate.

Remarks – This species is distinct in having crenulate nature of zone around body equator and the inter-ray area free from sexine.

Playfordiaspora annulata Tiwari & Rana 1980

Pl. 3, fig. 4

Holotype – Tiwari & Rana, 1980; pl. 2, fig. 37.

Type locality – Bore-hole RNM-4, sample 5, depth 59 m, Raniganj Coalfield, West Bengal, India.

Horizon & age – Supra-Panchet (Mahadeva) Formation, Middle Triassic.

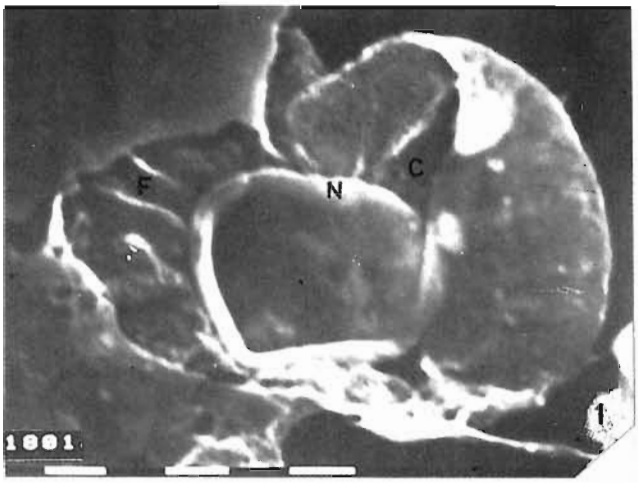
PLATE 2

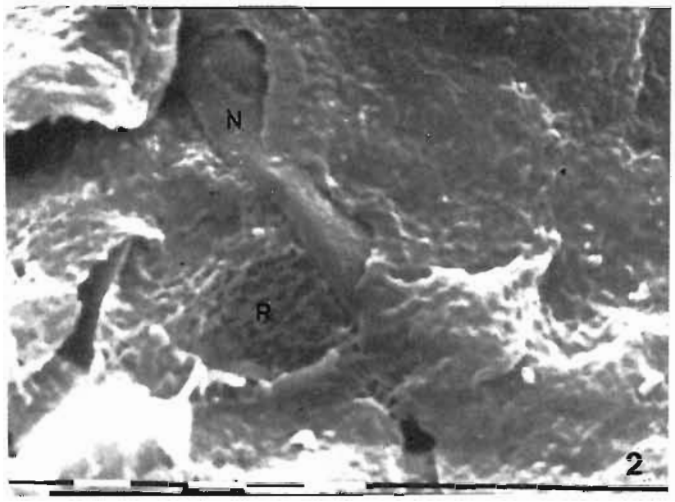
All specimens are assigned to *Playfordiaspora cancellosa* emended here to show partial nexinal folds on body, varied overall shapes and also that of the body: in figures 4 and 5, the specimens are enlarged to show the nature of sexinal infrareticulation and spread of sexine on body surface, covering the trilete mark in figure 5. Nature of infra-reticulation in saccus remains polygonal to circulo-hexagonal; 4. x 1000; 5. x 1500. Slide no. BSIP 11347.

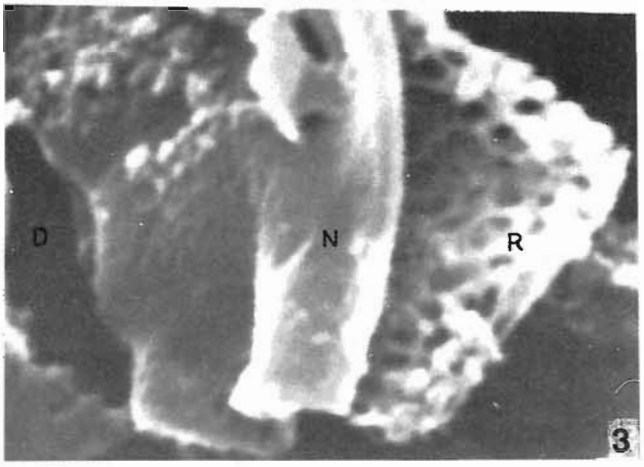
1-3, 6. SEM photomicrographs of the specimens to illustrate the structure of saccus. The specimens were broken with the help of ultrasonic vibrator

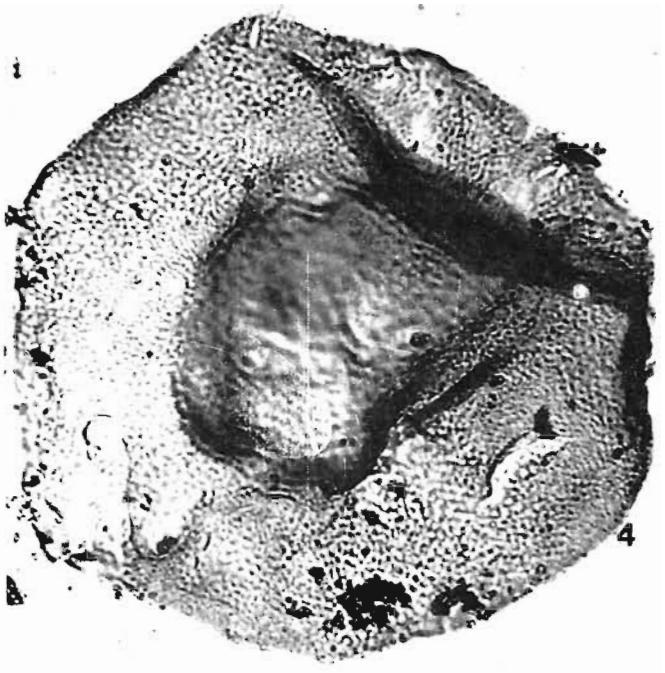
1. A complete specimen of *Playfordiaspora* under SEM, broken to show cavation (C) in saccus without any in-fill of reticulum (eusaccate condition); nexine (N) smooth; saccus surface does not exhibit any pattern; and radiating microfolds (F) are seen around body equator in saccus. x 1800.

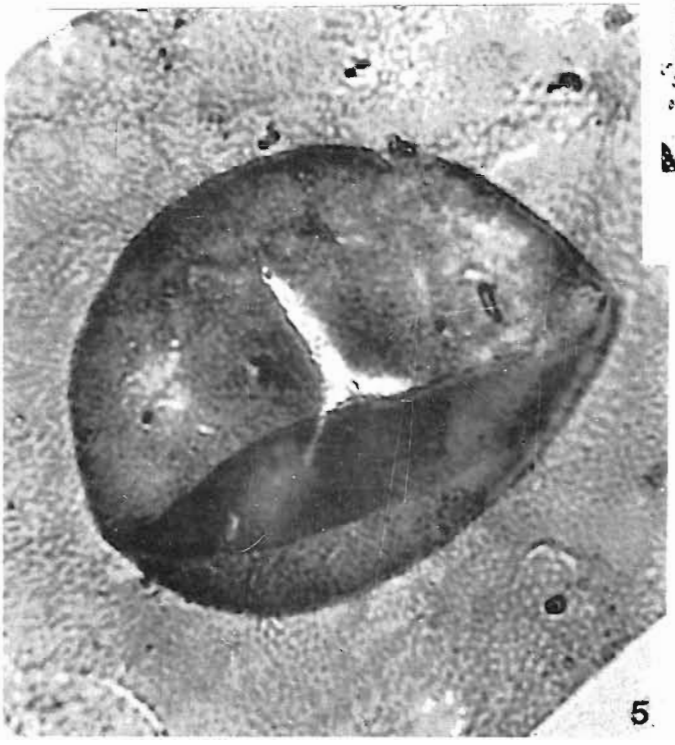
2, 3, 6. A part of the broken specimen to show cavation (C), nature of endoreticulum (E) within the saccus, part of body (nexine) (N), and relative depth between sexinal layers (D). x 1800.











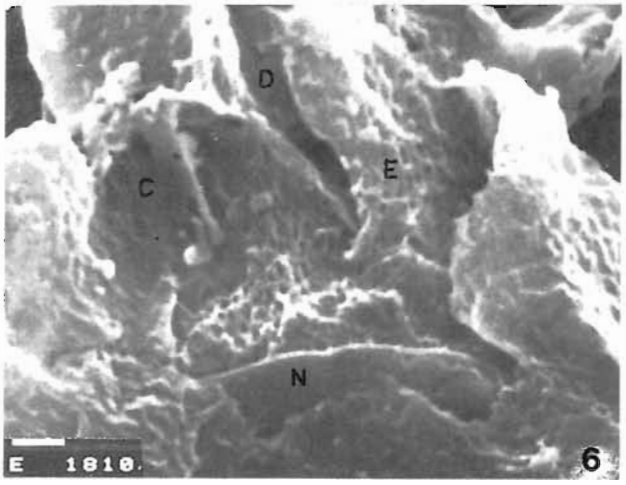


PLATE 2

Enlarged diagnosis – Radial, monosaccate pollen, roundly subtriangular. Body distinct, subtriangular with a well-defined 2-4 µm thick rim at the equator. Trilete mark distinct and well defined, rays reaching up to the rim. Saccus spread on proximal face of body reaching almost up to the margin of trilete ray, distally completely enveloping. Structure of saccus hollow, eusaccate with single layered fine infrareticulation. Body-saccus ratio mostly 1:2.

Remarks – This species is similar to *P. cancellosa* in all characters, except the annular ring around the central body

Playfordiaspora velata (Leschik) comb. nov.

Pl. 3, figs 10, 11

1956 *Endosporites velatus* Leschik, p. 127, pl. 20, fig. 7

1963 *Nuskoisporites* sp. Schaarschmidt, p 43, pl. 11, fig. 2.

Holotype – Leschik, 1956; pl. 20, fig. 7; slide no. III, 2.

Type locality – Neuhof (bei Fulda), Germany.

Horizon & age – Lager Hessen & Salzton Zechstein (Ref Leschik, 1956 : 123; Late Permian).

Emended diagnosis – Subcircular to triangular pollen, 100 µm across the diameter with distinct roundly triangular body, ± 55 µm in size. Trilete rays sharp, ± 20 µm long with simple low lips, straight, linear, 2/3 - 4/5 body-radius long with rounded ends. Contact area apparently concave, occupying 2/3 proximal face of the body, subtriangular, infragranulose in structure. Saccus showing very fine infrareticulation proximally beyond the contact area at the body region, outside of body equator infrareticulation relatively coarser yet fine meshes and muri being < 1 µm in thickness, with uniform regular hexagonal, sharp pattern. No regular prominent folds in body or saccus seen.

Remarks – The type specimen of *Endosporites velatus* Leschik 1956 is incomplete, broken with complete body and about one-half of the saccus; light yellow in colour with several pieces of detritus adhering to it. At saccus equator 1-2 µm wide zone-like area differentiated; it it not a limbus but so visible due to double layers of saccus edge folding. The saccus continues distally to cover the body where infrareticulation being relatively smaller (distal side showing preservational artefact in the form of reticuloid pattern in the exine).

This species, thus, finds its place neither with the genus *Endosporites* Wilson & Coe emend. Bhardwaj 1965, nor *Guthoerlisporites* Bhardwaj 1954. The genus *Playfordiaspora* accommodates these forms very well on the grounds of morphography and organization; hence a new combination has been made here.

Comparison – From *P hexareticulata* (Klaus, 1963) comb. nov. the present species is differentiated on the basis of the presence of infragranulate contact area; moreover the former species has relatively bigger meshes in saccus and typical sun-rays like radiating folds. *P. cancellosa* (Playford & Dettmann) Maheshwari & Banerji emend. also does not show differentiation of the contact area. *P. annulata* Tiwari & Rana 1980 can be distinguished by having a

PLATE 3

1. *Playfordiaspora cancellosa* specimen in surface view under SEM, no reticulate pattern is seen on exine surface. x 1800.
2, 3, 6, 9, 12. *Playfordiaspora cancellosa* emended here; 2. Showing big body with narrower saccus. x 500. 3. A broken specimen under transmitted light showing saccus nature, and cavity with in the saccus. x 500. 6. Shifted nature of (nexine) body. x 750. 9, 12. Centrally placed big body. x 500, 1000. Slide nos. BSIP 11348, 11347.
4. *Playfordiaspora annulata* Tiwari & Rana 1980; annular rim around nexine and open trilete mark, saccus broken at places exhibiting nature of saccus infrareticulum. x 750, Slide no. BSIP 11348.
5. *Playfordiaspora cancellosa* specimen under transmitted light having thin body (nexine), enveloping saccus and microfolds in saccus. x 750. Slide no. BSIP 11348.
7. *Playfordiaspora crenulata* (Wilson) Foster emended here, showing restricted spread of sexine on proximal face of body. x 750. Slide no. BSIP 11348.
8. *Playfordiaspora hexareticulata* (Klaus) comb. nov.; holotype specimen in Klaus, 1963; pl. 4, fig 9; reproduced here to show prominent peripheral folds on body-surfacealong inter-radial area, relatively coarse saccus infrareticulation and prominent radiating microfolds in saccus. x 300.
10. *Playfordiaspora velata* (Klaus) comb. nov, the sexinal infrareticulation is relatively fine on proximal surface of body, distinct triangular contact area is delimited; sexine structure in this area is faintly infragranulose. x 750. Slide no. BSIP 11348.
11 *Playfordiaspora velata* (Leschik) comb nov.; a portion of Holotype specimen in Leschik, 1956; pl. 20, fig. 7; reproduced here to show apparently infragranulose sexine structure in contact area and honey-comb pattern in saccus endoreticulum. x 1000.

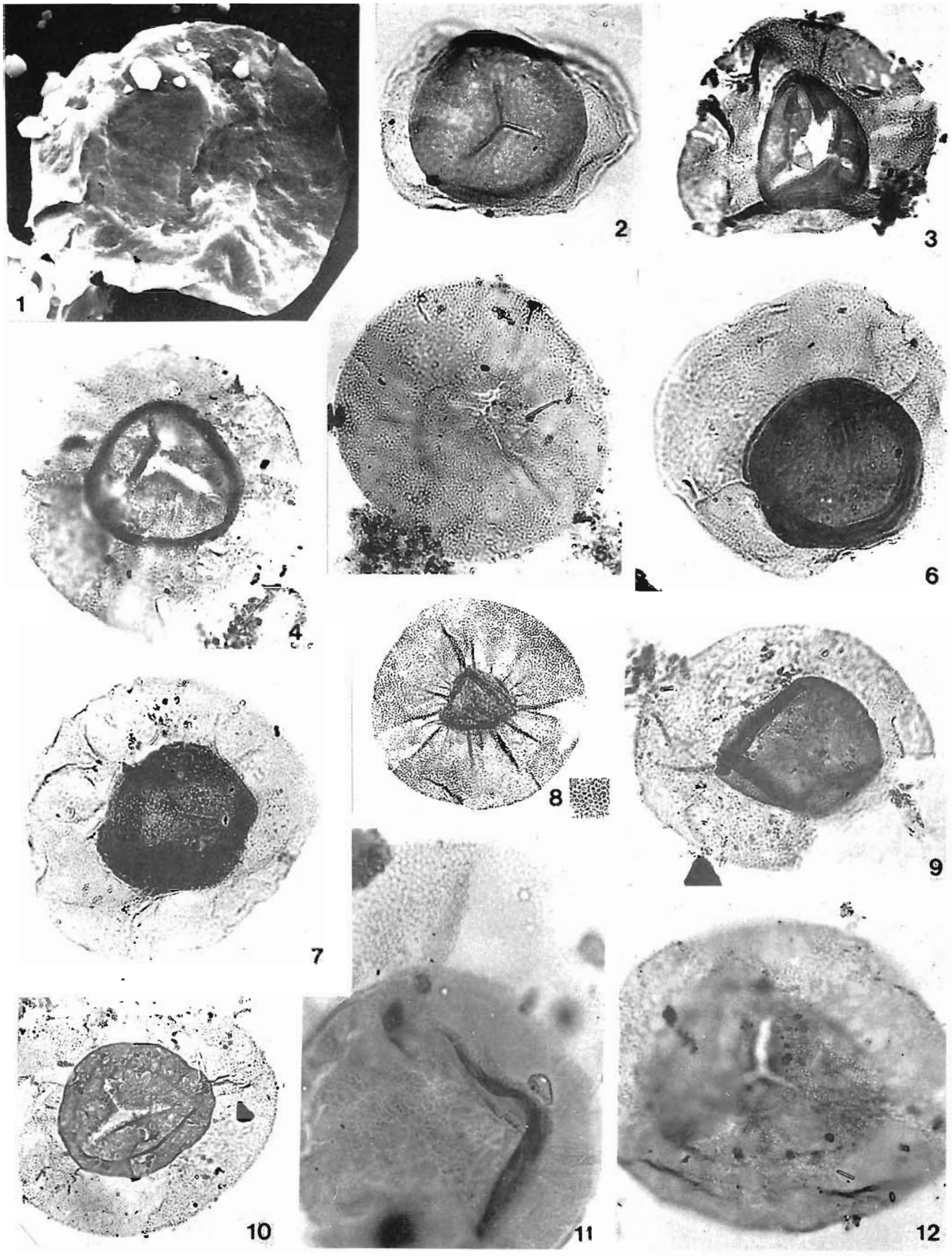


PLATE 3

prominent equatorial ring-like thickening at the central body equator; and *P. crenulata* (Wilson, 1962) comb. nov. differs by having crenulate body equator.

Playfordiaspora hexareticulata (Klaus) comb. nov.

Pl. 3, fig. 8

1963 *Endosporites hexareticulata* (Klaus), p. 266, pl. 4, figs 9-11.

Holotype – Klaus, 1963; pl. 4, fig. 9.

Type locality – Butterloch, Bletterback - Klamm unweit Fontana fredde (Kaltenbrunn). Grödner Sandstein, tiefere dunkle Tonlage.

Horizon & Age – Grödner Sandstein; Unteres Ober-Perm.

Emended diagnosis – Radial, big, circular, monosaccate pollen. Trilete mark distinct, rays slightly elevated, straight, extending up to 2/3 of body radius. Central body triangular, prominent peripheral folds in inter-radial region seen. Saccus infrareticulation single layered with distinct meshes; more fine towards centre, proximally differentiated up to margin of trilete rays. Sun-rays like prominent radiating folds in saccus, arising from body-saccus contact edge entering into the saccus.

Remarks – *Endosporites hexareticulatus* Klaus 1963 (p. 266, pl.4, fig. 9) reveals comparable structure and organization as described above for other species of the genus *Playfordiaspora* except that the infrareticulation is slightly coarser and relatively more uniform, reduced in size on the body area; the central body exhibits the presence of peripheral folds – one each along the inter-radial side; and the saccus has prominent radiating folds appearing to emerge from the central body equator. Hence, *E. hexareticulatus* has been transferred to the genus *Playfordiaspora*. *Nuskoisporites* sp. described by Schaarschmidt (1963, pl. 11, fig. 2), and re-studied by the present author, has been found to be similar to Leschik's specimen in all essential characters. The specimens designated as cf. *Florinites* and cf. *Endosporites* by Grebe (1957, pl. 4, figs 4, 5) also possess characters similar to this group of pollen.

COMPARATIVE KEY OF SPECIES

Monosaccate pollen, trilete, sexine eusaccate, single layered endoreticulum; saccus proximally and distally attached:

Playfordiaspora

1.1	Sexine developed proximally up to trilete ray margin		
1.11	Contact area not developed		
1.111	No prominent body folds		
		Annular body ring absent	***P. cancellosa***
		Annular body ring present	***P. annulata***
1.112	Prominent radiating saccus folds present		***P. hexareticulata***
1.12	Contact area with faintly infragranulate sexine		
		No saccus folds	***P. velata***
1.2	Sexine restrictedly developed up to 2/3 on body surface from equator		
1.21	Contact area not developed		
1.211	Saccus-body junction crenulately edged		***P. crenulata***

AFFINITY

Vijaya and Tiwari (1992) have discussed the relationship among the morphography of saccate pollen based on cladistic analysis, in which the combination of primitive and advance morphographic character-states in *Playfordiaspora* has been identified. It is clear that *Playfordiaspora* shares many of its characters with the genus *Teichertospora*, except complete eusaccate nature. In the comparison made below, numbers (1) and (3) represent primitive and advance character-state, respectively; number (2) stands for transitionary state.

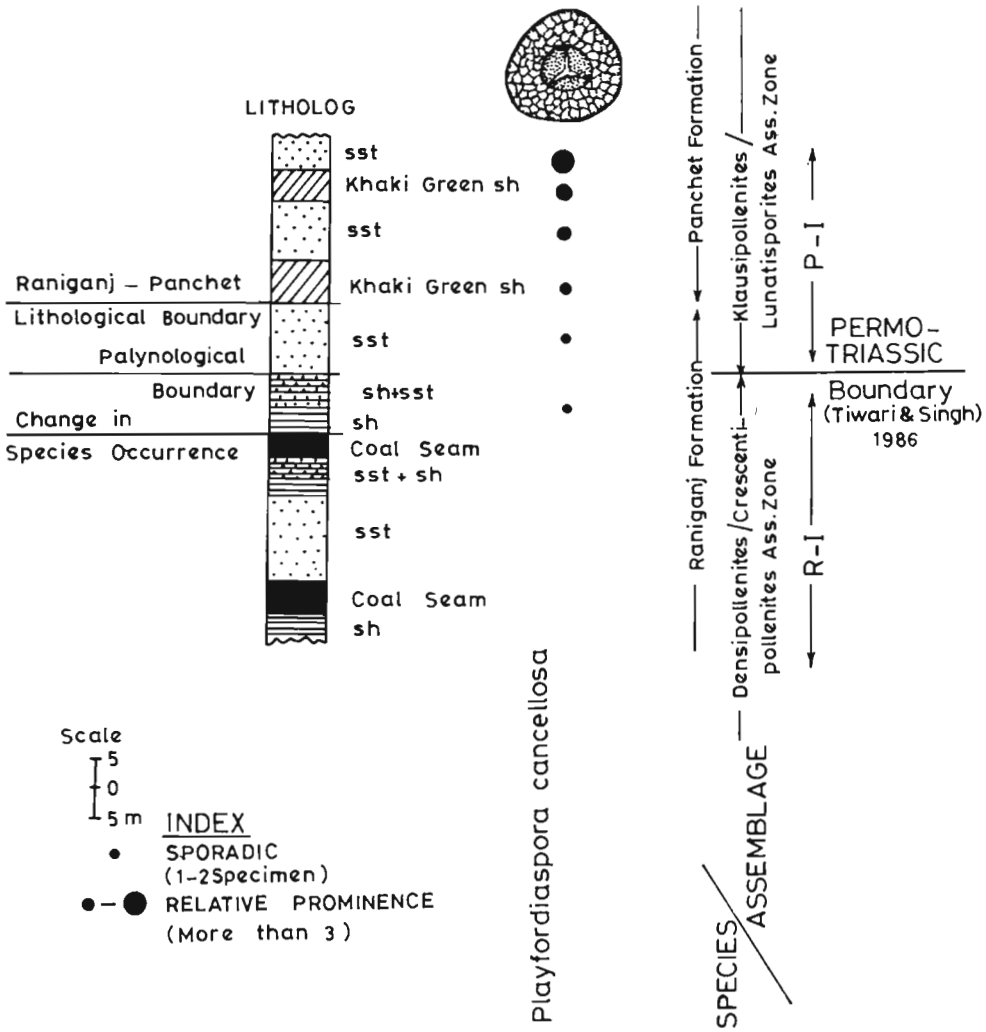
	Teichertospora	***Playfordiaspora***
Symmetry	Radial (1)	Radial (1)
Tetrad mark trilete	Present (1)	Present (1)
Saccus state	Monosaccate (1)	Monosaccate (1)
Body-sccus relationship	Continuous cover (1)	Continuous cover (1)
Saccus nature	Structured (3)	Structured (3)
	Infra-reticulate (3)	Infra-reticulate (3)
	Little inflated (3)	Little inflated (3)
	Enveloping (1)	Enveloping (1)
	Protosaccate, partially eusaccate (2)	Total eusaccate (3)

Foster and Balme (1994) opine that *Teichertospora* is protosaccate with complete fill of en-

doreticulum in the saccus. However, the present author is of the opinion that the partial cavity is primary rather than a secondary feature, as interpreted by Foster and Balme (1994), and hence it is a transitionary character-state.

The affinity of *Teichertospora* has been discussed in detail by Balme (1988), and Foster and Balme (1994) wherein it is indicated that it could be a cordaitalean pollen with closer morphological resemblance with *Plicatipollenites*. However, no affiliation could be established with certainty — apparently because no *in situ* record of similar pollen is yet available. It must be noted that there are no resemblance between *Teichertospora/Playfordiaspora* and *Plicatipollenites* or other girdling monosaccates of Lower Permian in saccus construction, distal attachment of saccus, infold system or infrastructure of sexine.

Notwithstanding, in view of the combination of character-states, *Playfordiaspora* seems more to be a pteridospermous pollen, rather than a spore. In the morphographic organization it is unique and possesses all characters of a "prepollen". The function of germination seems to take place through the trilete mark, which is situated on the proximal face of the body, as there is no other thinning on body surface to act as a germinal gate.



Text-figure 3 — Schematic lithological suit at Raniganj/Panchet formational boundary in Raniganj Coalfield, Damodar Basin to show FAD (First Appearance Datum) of *Playfordiaspora* in Raniganj Formation and relative occurrence in subsequent sediments of Lower Panchet Formation (after Vijaya & Tiwari, 1987).

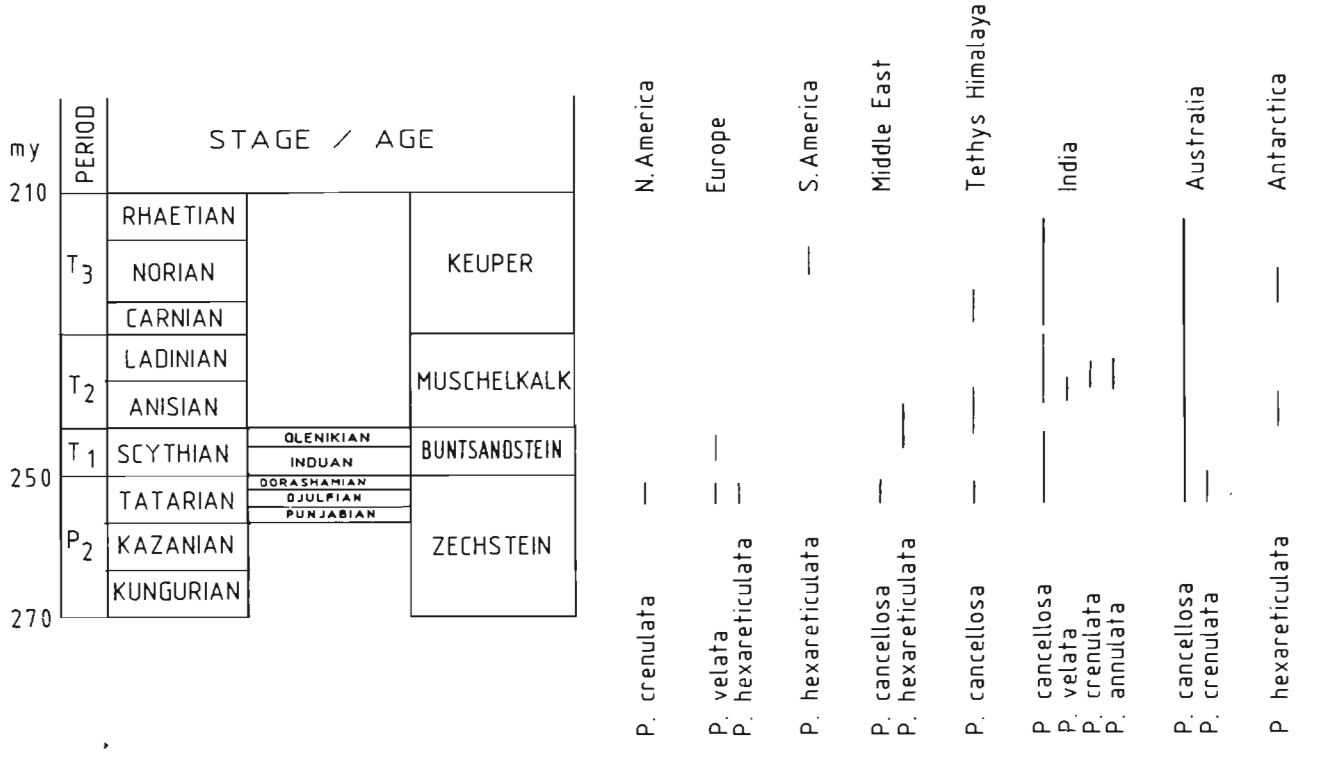
STRATIGRAPHIC AND PALAEOGEOGRAPHIC DISTRIBUTION

The genus *Playfordiaspora cancellosa* first appears in the late Late Permian sediments of Damodar Basin (Raniganj Coalfield), Rajmahal Basin, Son-Mahanadi Basin, Satpura Basin and Godavari Basin of peninsular India. At this level it occurs sporadically in grey shale and sandstone litho-unit overlying just above the topmost coal seam in the Raniganj Formation or equivalent sediments. Thereafter, it continues through the transitional passage of Raniganj-Panchet boundary (Vijaya & Tiwari, 1987) and occurs steadily as the marker pollen of Early Triassic (Tiwari & Vijaya, 1993) in the khaki green shale-sandstone suit at the onset of Panchet Formation (Text-figure 3). In the younger Triassic sequence, relatively increased percentage and species diversity have also been observed in almost all the Gondwana basins of India (Table 1).

During the present investigation, two more species, i.e., *P. velata* amd *P. crenulata* are recorded in the upper part of Panchet Formation (late Early Triassic) in Damodar Basin and its eastern region in Panagarh Basin. This analysis also reveals that *P. cancellosa* is more frequent and widely distributed on the Indian peninsula, while the other three species, *P. annulata, P. velata* and *P. crenulata* are rare and appear during late Early to Middle Triassic.

The distribution of various species of *Playfordiaspora* (Text-figure 4) also reveals that *P. cancellosa* was confined to the southern hemisphere while *P. crenulata, P. velata* and *P. hexareticulata* were restricted to the northern hemisphere during late Late Permian. Subsequent record of species is scanty in the Triassic of Europe. However, the genus flourished in the Triassic of Southern Hemisphere, particularly the eastern Gondwanaland.

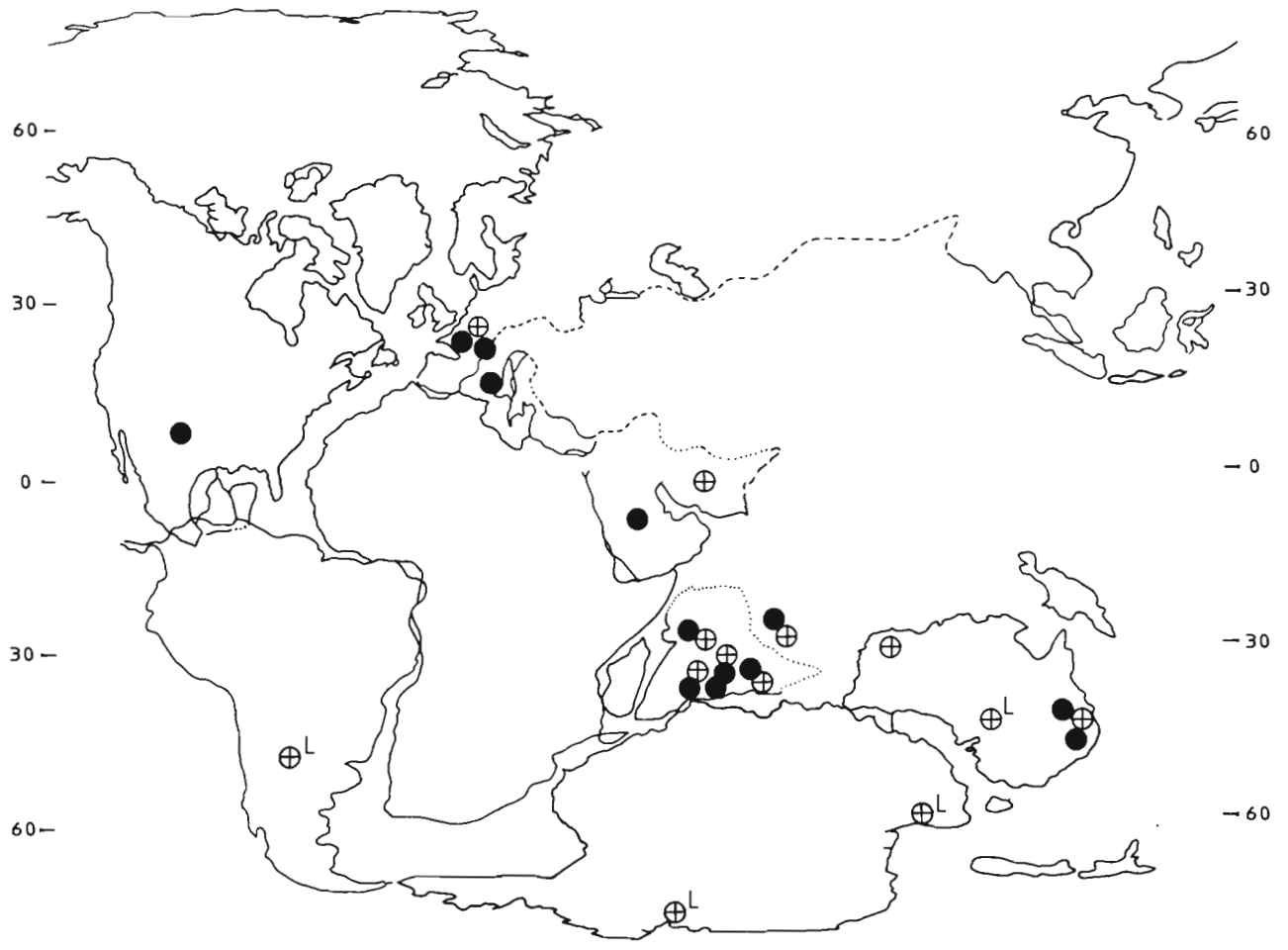
The palaeogeographical distribution (Text-figure 5) appears to be climatically controlled since the occurrence of *Playfordiaspora* during Late Permian ranges, in spatial extent, from Europe to South-East Australia. Thus, in the northern hemisphere it extends



Text-figure 4 — Record of species in genus *Playfordiaspora*, both in Northern and Southern hemispheres through time and space, which exhibits the impact of palaeoclimate on their occurrences. As shown here, the species which were present in Northern Hemisphere during Late Permian, scantily present in Triassic in this region. Their migration to southern part indubitably evidences that less warm climate had suited best for the existence of the parent plant of this taxon (Geological time after Haq & Van Eysinga, 1987).

Table 1 — Details of occurrences of genus *Playfordiaspora* in geographically disparate regions

Country	Basin/Area	Age	Formation	Species	Reference
U.S.A.	Western Oklahoma	Late Permian	Flowerpot Formation	*P. crenulata*	Wilson, 1962
Southern Alps	Dolomiten region	Late Permian	Grödner sandstein	*P. hexareticulata*	Klaus, 1963
Germany	Neuhof	Late Permian	Lager Hessen	*P. velata*	Leschik, 1956
Argentina	Malargue Basin	Upper Triassic	Chihuido Formation	*P. cancellosa* *P. crenulata*	Volkheimer & Papu, 1993
Hungary	Transdanubian Central Range	Late Permian to Early Triassic	Wuchiapingian to Lower Induan	*P. crenulata*	Go'czan *et al.*, 1987
Western Tethys	Dolomiten region in Southern Alps	Late Permian	Bellerophon	*P. hexareticulata*	Klaus, 1963.
	South-Alpine Segment in Bletterbach gorge	Late Permian	Val Gardena & Bellerophon	*P. crenulata* *P. annulata*	Conti *et al.*, 1986
Israel		Late Permian	Argov & Yamin	*P. cancellosa* *P. crenulata*	Eshet, 1992
Saudi Arabia		Late Permian	Khuff	*P. cancellosa*	Hemer, 1965
Tethys Himalaya	Salt & Surghar Ranges	Late Permian to Triassic	Chhidru, Mianwali, Tredian	*P. cancellosa*	Balme, 1970
	Mallajohar	Late Permian to Carnian	Kalapani	*P. cancellosa*	Vijaya *et al.*, 1988
India	Rajmahal	Late Permian	Dubrajpur	*P. cancellosa*	Tripathi, 1989
	Purnea	Early Triassic		*P. cancellosa*	Venkatachala & Rawat, 1978
	Damodar	Late Permian to Triassic	Raniganj, Panchet, Supra-Panchet	*P. cancellosa* *P. annulata* *P. velata* *P. hexareticulata*	Vijaya & Tiwari, 1987 Present study
	Satpura	Late Permian	Bijori	*P. cancellosa*	Bharadwaj *et al.*, 1978
	Son Valley	Late Permian to Triassic	Middle Pali Upper Pali	*P. cancellosa*	Tiwari & Ram-Awatar, 1990
		Late Triassic	Tiki		Maheshwari & Kumaran, 1979 Kumaran & Maheshwari, 1980
	Mahanadi	Late Permian	Kamthi	*P. cancellosa*	Tiwari *et al.*, 1991
	Godavari	Late Permian to Early Triassic	Middle Kamthi	*P. cancellosa*	Srivastava & Jha, 1990
Sri Lanka	Kurunegala	Permo-Triassic?		*P. cancellosa*	Dahanyake *et al.*, 1989
Australia	Queensland	Late Permian to Triassic		*P. cancellosa*	Helby *et al.*, 1987
	Bowen	Late Permian to Early Triassic		*P. crenulata* *P. cancellosa*	Foster, 1982
	Leigh Greek C.F.	Rhaeto-Liassic		*P. cancellosa*	Playford & Dettmann, 1965
Antarctica	Beardmore Glacier Area	Middle and Late Triassic	Upper Fremouw-Lower Falla	*P. hexareticulata*	Kyle & Fasola, 1978
	S. Victoria Land	Early to Late Triassic	Lashly	*P. cancellosa*	Kyle, 1977



Text-figure 5 — Palaeogeographical distribution of genus *Playfordiaspora* during Late Permian, and Early to Late Triassic times is shown on the base Map (after Smith *et al.*, 1981); whereas the palaeogeographic positions of continents have changed in this time span. This distribution pattern reveals climatically controlled occurrences of the taxon. The symbols used here indicate — black filled circle = Late Permian cross in circle = Early to Middle Triassic; L with crossed circle = Rhaetic (Late Triassic).

up to subtropical region but in the southern hemisphere it has been found at higher latitude entering into the cool temperate zone. This indicates that the plants producing this pollen had a tolerance or even better adaptability for the cooler climate than in the warmer belt.

The glaciation on the Gondwanaland was at its maximum during earliest Permian and its influence of cooling was experienced up to low latitude. However, the withdrawl of glaciers during late Early Permian created amelioration of climate and luxuriant vegetation leading to thick coal deposits on the Gondwanaland. By the time of late Late Permian the plants producing *Playfordiaspora* had appeared in southern as well as northern landmasses with relatively less cool climate. As the Triassic began with warmer climate even on the Gondwanaland, the genus *Playfordiaspora* continued to exist significantly. This was perhaps due to the fact that high latitude on Gondwanaland were still relatively cooler than the Northern Hemisphere. The record of these forms up to cool temperate zone in South America and Antarctica suggests a southward migration where the plant community found suitable climate during Triassic. In the Southern Hemisphere during Triassic, *Playfordiaspora*-bearing plants exhibit species diversity, and the group became extinct by the end of Triassic.

ACKNOWLEDGEMENTS

The author is grateful to Dr R.S. Tiwari, Director,

B.S.I.P., Lucknow for useful discussions during the progress of this work and critically going through the manuscript.

REFERENCES

Balme BE 1970. Palynology of Permian and Triassic strata in the Salt Range and Surghar Range, west Pakistan. *In* Kummel B & Teichert C (Editors) – *Stratigraphic boundary problems : Permian and Triassic of west Pakistan,* Special Publication **4** : 305-453. University of Kansas.

Balme BE 1988. *Teichertospora* n. gen., an endoreticulate miospore from the Late Devonian of Western Australia. *Senkenberg. leth.* **69** : 159-169.

Bhardwaj DC 1954. Einige neue Sporengattugen des Saarkarbons. *N. Jb. geol. Palaont.* **11** : 512-525.

Bhardwaj DC 1965. On the organization of *Spencerisporites* Chaloner and *Endosporites* Wilson & Coe with remarks on their systematic position. *Palaeobotanist* **13**(1) : 85-88.

Bharadwaj DC, Tiwari RS & Anand-Prakash 1978. Palynolgy of Bijori Formation (Upper Permian) in Satpura Gondwana Basin, India. *Palaeobotanist* **25** : 70-78.

Conti MA, Fontana D, Mariotti N, Massari F, Neri C, Nicosia U, Pasini M & Pittau D 1986. In Permian and Permian - Triassic boundary in the South Alpine segment of the Western Tethys. *Excursion Guide Book compiled by Italian Research Group-IGCP Project No.* 203 : 91-110.

Dahanyake K, Jayasena HAH, Singh BK, Tiwari RS & Tripathi A 1989. A Permo-Triassic ? plant microfossil assemblage from Sri Lanka. *Rev. Palaeobot. Palynol.* **58**(2-4) : 197-204.

Eshet Y 1992. The palynofloral succession and palynological events in the Permo-Triassic boundary interval in Israel. *In* Sweet WC *et al.* (Editors) — *Permo-Triassic events in the eastern Tethys* : 134-145. Cambridge University Press, Cambridge.

Foster CB 1979. Permian plant microfossils of the Blair Athol Coal Measures, Baralaba Coal Measures, and Basal Rewan Formation of Queensland. *Geol. Surv. Qld Publ.* **372**, *Palaeontological paper* **45** : 1-154.

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

Foster CB & Balme BE 1994. Ultrastructure of *Teichertospora torquata* (Higgs) from the Late Devonian : Oldest saccate palynomorph. *In* : Kurmann MH & Doyle JA (Editors) — *Ultrastructure of fossil spores and pollen* : 87-97. Royal Botanic Gardens, Kew.

Góczan F, Oravecz-Schefeer & Haas J 1987. The Permian-Triassic boundary in the Transdanubian central range. *Acta geol. Hungarica* **30**(1/2) : 35-58.

Grebe H 1957. Zur Mikroflora des niederrheinischen Zechsteins. *Geol. Jb.* **73** : 51-74.

Grebe H & Schweitzer HJ 1962. Die Sporae dispersae des niederrheinischen Zechsteins. *Fortschr. geol. Rheinld Westf.* : 1-24.

Haq BU & Van Eysinga FWB 1987. *Geological tim table.* Elsevier Science Publisher B.V

Helby R, Morgan RH & Partridge AD 1987. A palynological zonation of the Australia Mesozoic. *Mem. Assoc. Australasia Palaeont.* **4** : 1-94.

Hemer DO 1965. Application of palynology in Saudi Arabia. *Fifth Arab Petroleum Congress, Cairo* : 29.

Klaus W 1963. Sporen aus dem südalpinen Perm. *Jb. Geol.* **106** : 229-363.

Kumaran KP & Maheshwari HK 1980. Upper Triassic sporae dispersae from the Tiki Formation-2: Miospores from the Janar Nala section, South Rewa Gondwana Basin, India. *Palaeontographica* **B172** : 26-84.

Kyle RA 1977. Palynostratigraphy of the Victoria Group of South Victoria Land, Antarctica. *N.Z. Jour. Geol. Geophys.* **20**(6) : 1081-1082.

Kyle RA & Fasola A 1978. Triassic palynology of the Beardmore Glacier area of Antarctica. *Palynologia* **1** : 313-320.

Leschik G 1956. Sporen aus dem Saltzton des Zechsteinsvon Neuhof (bei Fulda). *Palaeontographica* **B100** : 122-142.

Maheshwari HK & Banerji J 1975. Lower Triassic palynomorphs from the Maitur Formation, West Bengal, India. *Palaeontographica* **B 152**(4-6) : 149-190.

Maheshwari HK & Kumaran KPN 1979. Upper Triassic sporae dispersae from the Tiki Formation - 1 : Miospores from the Son River section between Tharipathar and Ghiar, South Rewa Gondwana Basin. *Palaeontographica* **B171**(4-6) : 137-164.

Mcgregor DC & Playford G 1990. Morphology and distribution of the miospore *Teichertospora torquata* comb. nov. in the Upper Devonian of Euramerica and Australia. *Palynology* **14** : 7-18.

Playford G & Dettmann ME 1965. Rhaeto-Liassic plant microfossils from the Leigh Creek Coal Measures, South Australia. *Senckenberg. leth.* **46**(2/3) : 127-181.

Schaarschmidt F 1963. Sporen und Hystrichosphaerideen aus dem Zechstein von Budingen in der Wetterau. *Palaeontographica* **B113**(1-4) : 38-91.

Smith AG, Hurley AM & Briden JC 1981. *Phanerozoic palaeocontinental World maps.* Cambridge Univ. Press, Cambridge.

Srivastava SC & Jha N 1990. Permo-Triassic palynofloral transition in Godavari graben, Andhra Pradesh. *Palaeobotanist* **38** : 92-97.

Tiwari RS & Ram-Awatar 1990. Palynodating of Nidpur beds, Son Graben, Madhya Pradesh. *Palaeobotanist* **38** : 105-121

Tiwari RS & Rana V 1980. A Middle Triassic mioflora from India. *Biol. Mem.* **5**(1) : 30-55.

Tiwari RS, Tripathi A & Jana BN 1991. Palynological evidence for Upper Permian Raniganj coals in westrn part of Talcher Coalfield, Orissa. *Curr. Sci.* **61**(6) : 407-410.

Tiwari RS & Vijaya 1993. Synchroneity of palynological events and patterns of extinctions at Permo-Triassic boundary in terrestrial sequence of India. *In* Guex J & Band A (Editors) — *Proc. Symp. Triassic Stratigraphy* (1991) : 139-154. Lausanne.

Tripathi A 1989. Palynological evidence for the presence of Upper Permian sediment in the northern part of Rajmahal Basin, Bihar. *Jour. geol. Soc. India* **34** : 198-207.

Venkatachala BS & Rawat MS 1979. Early Triassic palynoflora from the subsurface of Purnea, Bihar, India. *J. palynol.* **14**(1) : 59-70.

Vijaya, Kumar S, Singh MP & Tiwari RS 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 & Tiwari RS 1987. Role of spore pollen species in identification of Permo-Triassic boundary in Raniganj Coalfield, West Bengal. *Palaeobotanist* **35** : 242-248.

Vijaya & Tiwari RS 1992. Morpho-evolutionary biohorizon stratigraphy and cladistics in saccate pollen through Gondwana sequence of India. *Palaeobotanist* **40** : 157-193.

Volkheimer W & Papu OH 1993. An Upper Triassic mioflora from the Malargue Basin, Llantenes locality, Mendoza Province, Argentina. *Ameghiniana (Rev. Assoc. Palaontol. Argent.)* **30**(1) : 93-100.

Wilson LR 1962. Plant microfossils from Flowerpot Formation. *Oklahoma geol. Surv.* **49** : 5-40.

Wilson LR & Coe EA 1940. Description of some unassigned plant microfossils from the Des Moines series of Iowa. *Amer. Midl. Naturalist* **23**: 182-186.