

STUDIES IN THE TALCHIR FLORA OF INDIA: 2. RESOLUTION OF THE SPORE GENUS *NUSKOISPORITES* POT. & KL.

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ABSTRACT

Spores hitherto assigned to *Nuskoisporites* Pot. & Kl. from the Talchir beds of India have been reinvestigated. Similar material described from the Permian (or Permo-Triassic) sediments of India or other Gondwanaland countries is resurveyed. The study reveals that the Southern (Gondwanaland) spores are organizationally distinct from the Northern *Nuskoisporites*. They have been, hence, segregated under two new genera, viz. *Plicatipollenites* and *Virkkipollenites*. A new Series *Apertacorpti* is proposed to receive these genera. The organization of *Nuskoisporites* is reinterpreted with amendments. The vertical and geographical distribution of the new genera is given with remarks on the question of their probable affinities.

INTRODUCTION

THE genus *Nuskoisporites* Pot. & Kl. (1954) was instituted for a monosaccate spore from the Northern Hemisphere found in the Alpine Permian or Triassic sediments of Austria. Potonié & Klaus, however, included under this generic name certain spore types recorded from the Southern Hemisphere (Gondwanaland) by Virkki (1939) and Dulhunty (1946). Southern spores assigned to *Nuskoisporites* have since been recorded from Australia (BALME & HENNELLY, 1956, HENNELLY, 1958), Madagascar (RAKOTOARIVELO, 1960) and the Belgian Congo (PIÉRART, 1959, HÖEG & BOSE, 1960). In their first systematic description of the microspore assemblage from the Talchir beds of the South Rewa Gondwana basin, India, Potonié & Lele (1961) furnished a more detailed account of the species of *Nuskoisporites* which included several specimens earlier described by Virkki (1946) and other authors. It was here that the presence of a limbus in *Nuskoisporites* was regarded as a non-essential character. The authors also included under *Nuskoisporites* certain specimens which showed a monoradiate slit.

Obviously enough, the Talchir *Nuskoisporites* exhibited certain characteristic morphological trends unknown in the Northern species of that genus. It is also note-

worthy that in the recent past, most of the workers who were confronted with the task of classifying these southern monosaccate spores, have rather reluctantly assigned them to *Nuskoisporites* (See BALME & HENNELLY, 1956, PIÉRART, 1959, HÖEG & BOSE 1960, BHARADWAJ 1962). In view of the above consensus of opinion the so-called *Nuskoisporites* of the Talchir beds of the South Rewa basin (described by POTONIÉ & LELE, 1961) and of the Talchir Needle Shales of the Giridih Coalfield (described by SURANGE & LELE, 1956) was critically re-investigated in order to assess the morphological and organizational characters. Similar spores, occurring in the various horizons younger than the Talchir stage, were also observed. Besides, a reappraisal of all *Nuskoisporites* records from the various strata of other Gondwanaland countries was carefully made on the basis of available descriptions and illustrations.

The results of this study clearly point out that the genus *Nuskoisporites*, as understood till now, is a heterogeneous taxon resulting from the indiscriminate assembly of the Northern and the Southern spore types. The Southern spores fall into more than one distinct homogeneous generic groups warranting segregation from the Northern *Nuskoisporites*. Two of these generic groups are represented in the Talchir beds of India and are segregated here under the new designations viz. *Plicatipollenites* and *Virkkipollenites*.

ORGANIZATION OF *NUSKOISPORITES*, Pot. & Kl. (1954)

Although some of the more apparent differences met in the morphology of the Southern and the Northern forms of *Nuskoisporites* were previously expressed by certain workers, the organization of the sac in *Nuskoisporites* was never seriously questioned. If we turn back to the original version of *Nuskoisporites*, an obvious contradiction is noticeable in the statement of

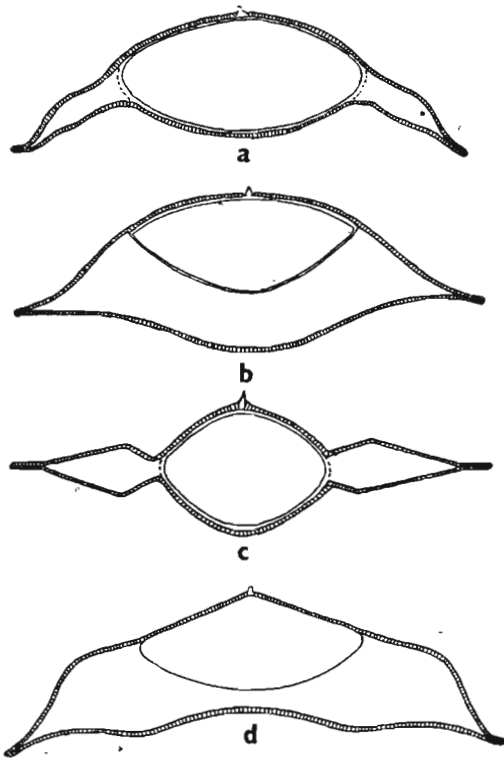
the authors and their illustration regarding the plan of sac construction. Potonié & Klaus (l.c. pp. 528, 529) state that the sac does not cover the two poles of the central body but their text-figure 3 (representing the meridional section) clearly shows the presence of a well-marked sac attached on both the sides of the body and evidently completely enclosing it as in *Microsporites* Dijkstra (see POTONIÉ & KREMP, 1954, PL. 17, FIG. 79). The meridional sections of *Nuskoisporites* and *Microsporites*, as originally conceived, have been resketched here for comparison in Text-figs. 1-a and 1-c.

Only a year after, Piérart (1955, p. 41) pointed out that while in the Southern forms the sac did not cover the two poles of the body, in the case of *Nuskoisporites dulhuntyi*, the sac completely enclosed the body. In spite of this very fundamental difference, Piérart included his Belgian Congo spores

tentatively under ?*Nuskoisporites*. At any rate, it became more evident that the attachment of the sac in the Northern *Nuskoisporites*, as shown by Potonié & Klaus in their text-figure 3 implied a situation which was nearer the truth than their expressed opinion.

I have now examined some preparations, received through the kindness of Dr. H. Grebe, which contain ringed specimens of the other species *Nuskoisporites klausii* Grebe (1957). Grebe & Schweitzer (1962) now believe that *N. klausii* is synonymous with *N. dulhuntyi*. The few specimens that I have reexamined demonstrate that the body of *N. klausii* is proximally attached to a completely enveloping sac but free from it on the distal side. The specimen shown in Pl. 1, Fig. 1 is of particular significance because it lies with its distal face up and curiously enough, its manner of preservation is nearly as good as that of an unflattened spore. Consequently, in the extreme distal view as in Pl. 1, Fig. 1 (when the body is rather out of focus) the specimen shows the unmistakable presence of the enveloping sac which completely encloses the free distal side of the body. Pl. 1, Fig. 2 represents the same view, but is further enlarged to show the sac structure. The other views (Pl. 1, FIGS. 3, 4) show the same specimen in increasingly deeper foci towards the proximal face, during which course the smooth nature of the body and the distal secondary folds (FIG. 3) and the presence of a proximally attached sac (FIG. 4) are revealed. It has thus become apparent that, contrary to the views of Grebe, *N. klausii* has a \pm dense but smooth body and that the reticulum attributed to the body by Grebe belongs, in fact, to the sac.

Another feature of these spores, which was hitherto completely ignored, is their tendency towards off-polar compression. The specimens in Pl. 1, Fig. 4 and more particularly in Pl. 1, Fig. 5 clearly demonstrate it. This fact, although less commonly noticeable, is significant because it not only strengthens the present observations regarding the plan of sac construction in *N. klausii* but also suggests that in this species, the body as well as the sac had a relatively greater distal curvature. It may be added that a specimen attributed to *Nuskoisporites crenulatus* sp. nov. by Wilson (1962, PL. 1, FIG. 2) may be regarded as another example of off-polar compression.



TEXT-FIG. 1 — Meridional sections of *Nuskoisporites*, *Microsporites* and *Endosporites*: a, section of *Nuskoisporites* as originally interpreted by Potonié & Klaus. b, section of *Nuskoisporites* as interpreted here. c, section of *Microsporites* Dijk. (after Pot. & Kr. 1954). d, section of *Endosporites* Wils. & Coe. (after Pot. & Kr. 1954).

Observations indicate that the body of *N. klausii* frequently develops secondary compression folds which run rather boldly on the distal side. Exceptionally, however, the folds may form some regular pattern. For instance, the specimen in Pl. 1, Fig. 3, shows three flexuous folds running from the distal pole towards the body margin like the blades of a fan. Because of the nearly unflattened state of this specimen, these folds appear like obliquely raised flexuous walls and can be seen through the body cavity in progressively deeper foci from the distal to the proximal side (Pl. 1, Figs. 1, 3, 4).

A fold-pattern, different from what is described above is noticeable in the holotype of *N. klausii* Grebe (1957, Pl. 4, Fig. 2). In this case, the folds form a \pm concentric zone near the body periphery. The significant point, however, is that these folds, whatever their disposition, do not bear any relation to the sac, which, as has been demonstrated, freely enclosed the distal side of the body. Grebe has, therefore, erroneously likened the sub-peripheral body folds of the holotype with the fold "rim" (VIRKKI, 1946) found in the Southern spores, in which case, as will be explained later, the body infolds form a regular system in close association with the sub-equatorial zone of sac attachment on the distal side of the body.

The evidence provided by the specimens of *N. klausii* necessitated the examination of the species *N. dulhuntyi* from the type area. This was made possible by the diplotype of *N. dulhuntyi* received through the kindness of Dr. W. Klaus. The diplotype specimen is almost similar to the original illustration of *N. dulhuntyi* by Potonié & Klaus (1954, Pl. 10, fig. 5). In spite of the very flat condition of the spore and the dense nature of the body, one can hardly miss the presence of sac reticulum on both sides of the body which is smooth. There is no evidence of a distal (sub-equatorial) zone of sac attachment. The plan of sac construction and the mode of its attachment in *N. dulhuntyi* is obviously of the same kind as that found in *N. klausii*.

In the light of the above findings, the genus *Nuskoisporites* Pot. & Kl. is amended as below:

"Monosaccate spores, overall outline \pm circular; body \pm circular, smooth, distinct often dense, with or without secondary

folds; trilete mark functional, rays \pm clear, short, never reaching body margin, ray ends often \pm truncated, sac completely enclosing the body, attached on the proximal side but free from the body on the distal side; sac intro-reticulum on the attachment side comparatively somewhat finer and tends to be diffused or evanescent in the close vicinity of the trilete mark; limbus present; off-polar compression of grains not uncommon."

Generotype: *N. dulhuntyi* (Pot. & Kl.) amend.—The revised diagnosis of this species would include most of the amendments proposed for the genus except that the body resists folding and that off-polar compression is rather uncommon.

The species *N. klausii* Grebe, which has recently been merged in *N. dulhuntyi* by Grebe & Schweitzer (1962), is here treated rather separately because the grains suggest a greater tendency to off-polar compression and the distal body exine specially develops prominent folds which may be irregular, radial (centrifugal) or peripheral in their disposition. The Niederrheine specimens observed by me and some others reillustrated by Grebe & Schweitzer may bear this out. The probable significance of the folds in delimiting *N. klausii* has not received enough attention. The distal curvature of the body in *N. klausii* type of grains was apparently greater than the proximal one. In *N. dulhuntyi*, there was presumably little or no difference in the curvature of the two sides.

According to the new interpretation the organization of *Nuskoisporites* (TEXT-FIG. 1-b) approaches that of *Endosporites* (TEXT-FIG. 1-d). The presence of a limboid sac is another feature often shared by the two genera. However, there are relevant points of distinction between *Endosporites* and *Nuskoisporites*. *Endosporites* often tends to become roundly triangular in overall outline, the rays are longer and are frequently associated with folds which extend into the sac and the spores show a greater preference to polar flattening apparently because the sac is fairly adpressed to the distal side of the body. On the contrary, *Nuskoisporites* is circular in outline, the rays are short, never reaching the body margin and the spores may occasionally be compressed quite obliquely suggesting thereby that both the body as well as the sac had a greater outward curvature on the distal side. Besides,

TABLE 1

<i>Nuskoisporites</i> (Northern)	<i>Plicatipollenites</i> & <i>Virkkipollenites</i> (Southern)
1. Outline circular.	1. Outline circular, roundly triangular or sub-circular (Ovalish).
2. Body often dense, circular and conforming to the outline of the grain.	2. Body often thin, outline variable, not necessarily conforming to the outline of the grain.
3. Sac comparatively thin, inflated, and with a limbus.	3. Sac comparatively thick, \pm deflated, and without a limbus.
4. Trilete mark distinct, functional, ray ends usually truncated, length of rays and angles inbetween equal.	4. Trilete mark \pm indistinct or invisible, apparently \pm vestigial, ray ends not as a rule truncated, length of rays and angles inbetween frequently unequal, rays occasionally completely reduced to a bent or straight monoradiate mark.
5. Sac completely enclosing the body, attached proximally but free from body on the distal side.	5. Sac proximally attached at the equator of body; distally along a subequatorial zone. Thus, the two poles of the body remain uncovered by the sac.

the sac structure in the two genera appears to be fundamentally different.

The southern spores (here segregated under *Plicatipollenites* and *Virkkipollenites*) are distinct, both in their morphology and organization, from the Northern *Nuskoisporites*. Table 1 elaborates these differences as now understood.

In addition to the above differences, it may be recalled that *Nuskoisporites* is a genus chiefly of the Northern Hemisphere and a member of the vegetation essentially different from that of Southern Hemisphere (Gondwanaland). Besides, while *Nuskoisporites* is so far known from the upper Permian or Triassic sediments, the Southern spore genera prevail mostly in the older strata ranging from the Upper Carboniferous to the Middle Permian (Talchir stage to the Barren Measures) and tend to almost disappear in the Upper Permian (Raniganj stage). Thus, the stratigraphical distribution of the Northern and Southern genera is also different.

DESCRIPTION

Unless otherwise mentioned, the holotypes designated in the following account are recovered from the shales at Goraia, South Rewa Gondwana basin, India, representing the Talchir stage (Lr. Gondwana). For details see Potonié & Lele (1961).

Super-Division — *Pollenites* R. Pot.
Division — *Saccites* Erdt.
Sub-Division — *Monosaccites* (Chitale) Pot. & Kr.
New Series — *Apertacorpiti*

Diagnosis — Monosaccate spores or pollen showing distal condition of sac attachment, i.e. a single sac is attached proximally along the equator, exposing the whole of the proximal face of the body and is distally attached sub-equatorially, exposing a \pm wide sac-free body area including the distal pole; trilete mark apparently vestigial.

Derivation — *Apertus* (L.), meaning 'uncovered'; *Corpus* (L.), meaning 'body'.

Plicatipollenites gen. nov.

Text-figs. 2 a-c

Generic Diagnosis — Monosaccate spore, outline circular, roundly triangular or subcircular (oval), body variable in shape, not necessarily conforming to overall outline, distinct to indistinct, mostly finely intramicroreticulate, trilete mark not consistently developed, clear to obscure; rays never reach body margin, length of rays and angles inbetween them may or may not be equal, reduction of rays may lead to a monoradiate mark; sac proximally attached at body equator, distal attachment along a more or less narrow sub-equatorial zone, zone of distal attachment associated with a \pm regular body infold system; sac \pm deflated, intrareticulate, surface flat to frilled.

Genotype — *Plicatipollenites indicus* sp. nov. Pl. 1, Fig. 7.

Derivation of Name — *Plicatum* (L.), meaning 'to fold'.

Discussion — *Body infold system*: One of the principal distinguishing characters of the genus is the sub-equatorial body infold system which is more or less regularly

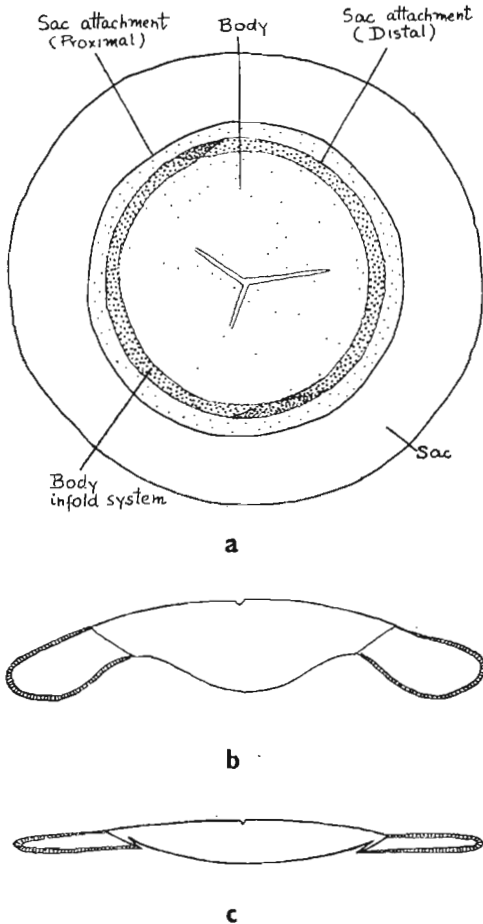
developed on the distal side of the body at or near the zone of sac attachment (TEXT-FIG. 2-a). Virkki (1946, pp. 101, 111) has termed it a 'rim' and appears to consider it as a "thickening" round the body. On the contrary, Balme & Hennelly (1956, p. 253) and Potonié & Lele (1961, p. 27) have considered this structure to be the result of sac folding. In favourable state of preservation, the specimens of the Talchir material reveal that the structure of the exine in the fold region is identical with that of the body which means that the fold system is essentially a part of the body. In many examples, the sac is seen right up to the outer limits of the fold zone (PL. 1, FIGS. 9, 10) while in few others the sac structure could

be detected up to the inner limits of the fold zone, but never beyond it. This suggests that the body exine is folded inwards nearly along the sub-equatorial zone where the sac was distally attached (TEXT-FIG. 2-c). In other words, the body exine develops what may be precisely described as an 'Infold system'. It is evident that the infold system is the result of compression of the body exine which presumably had a greater distal curvature together with a slight angularity at the root of sac attachment (TEXT-FIG. 2-b). There is also reason to believe that the sac was somewhat distally inclined in this genus which favoured the infolding of the comparatively thinner body exine near the sac roots (TEXT-FIG. 2-c).

The infold system is usually continuous and may derive various characteristic shapes which seem to have a certain specific value in conjunction with other criteria. For instance, in *P. gondwanensis*, the infold system is typically polygonal, in *P. indicus* sp. nov. and *P. diffusus* sp. nov., it is commonly circular and in *P. trigonalis* sp. nov. it is essentially triangular. In a circular infold system, individual fold components may be connected with little or no noticeable angularity. In a polygonal infold system, however, the individual fold-components are connected at their tapering ends with a noticeable angularity and overlap. Rarely an infold system is discontinuous or the components are dislocated which is probably because of the unequal pressure on the body exine during flattening.

The regular formation of a body infold system in association with the distal zone of sac attachment is a fact warranting generic significance to *Plicatipollenites*; for it serves to unite a variety of species into a homogeneous group that can be readily distinguished from several other spore forms (here grouped under *Virkkipollenites*) which are invariably devoid of a body infold system. Bharadwaj (1955, 1962), has already recognized the generic value of the body infolds in *Potoniésporites* and *Lunatisporites*. There are several other genera of saccate pollen and spores in which a body infold is present, and in some, notably *Limitisporites*, *Illinites*, and *Sahnites*, this character appears to be appreciably consistent and well recognizable.

Trilete Mark—The trilete mark is not consistently developed. More often it is rather weak and occasionally invisible. The



TEXT-FIG. 2—Organization of *Plicatipollenites* gen. nov.: a, polar view. b, meridional section of unflattened spore. c, meridional section of flattened spore.

rays, when clear, are more like triradiate slits rather than tecta. They may be of nearly equal width and truncate or tapering. Sometimes the mark is eccentric. Another noticeable feature of the rays is the tendency of becoming asymmetrical in their length and angles. Occasionally the trilete may be completely reduced to what appears like a bent or straight monoradiate mark. This tendency was already noted by Potonié & Lele (1961) and I have observed it in similar spores found in strata younger than the Talchir stage. The species *P. indicus* displays this trend more sharply in comparison to other species. The heteromorphy and inconsistent development of the trilete mark suggest that it was more or less vestigial.

It may be recalled, in this connection, that *Potoniésporites neglectus* Pot. & Lele (1961) — another common element of the Talchir sporeflora — also shows similar, but reversed trends. For instance, in the extreme cases, the monoete mark bends or forkes into two short arms producing what appears like an asymmetrical trilete. These grains which are normally bilateral, may occasionally pretend to become more or less circular. Evidently, the extreme variants of *Plicatipollenites* (specially *P. indicus*) seem to overlap those of *Potoniésporites neglectus* and suggest a relationship. It may be added that the sac organization of *Potoniésporites neglectus* is fundamentally similar to *Plicatipollenites* and evidently distinct from what is described for *Potoniésporites* by Bhardwaj (1955). The entire question is being separately investigated.

Body — The body varies in shape and may be distinct, indistinct or diffused. Its outline does not necessarily correspond to the overall outline of the grain. The ornament of the body is internal and in well preserved examples it consists mostly of a fine reticulum (intra-microreticulate) much more finer than that of the sac. More often the grains are variously corroded and the internal structure may be distorted or obliterated to appear variously as microrugose, microverrucose, granulose or even punctate. The task of defining the body ornament is, therefore, not easy and requires very careful observation of various examples under oil immersion optics. Apart from the regular body-infold system, there may occasionally be thin minor secondary folds but they have no definite disposition.

Sac — The sac mostly appears denser than the body and shows little or no inflation. The mode of its attachment exposes the entire proximal face of the body as well as a wide, \pm radially symmetrical distal area which is encompassed by the body infold system. This condition is contrary to that of *Nuskoisporites*. The sac overlap on the distal side of the body is usually narrow. The width of the sac (as measured from its proximal attachment to the outer margin) varies to a certain extent in the same or different species. A fact perhaps of greater significance and utility is the width of the sac in relation to the body radius. This relative proportion, in the case of *P. indicus*, was found to be reasonably consistent and, therefore, its value became evident. The sac may show fine to medium intrareticulum. In some examples a narrow zone of the sac in the vicinity of the body periphery appears thinner and shows relatively finer structure. In some species the muri tend to be more or less radially elongated while in others this may not be very evident. The outline of the sac is smooth or undulated and the surface may be nearly flat or frilled. There is no evidence of a limbus.

Plicatipollenites indicus sp. nov.

Pl. 1, Figs. 6-10; Text-figs. 3 a-f, 12-a

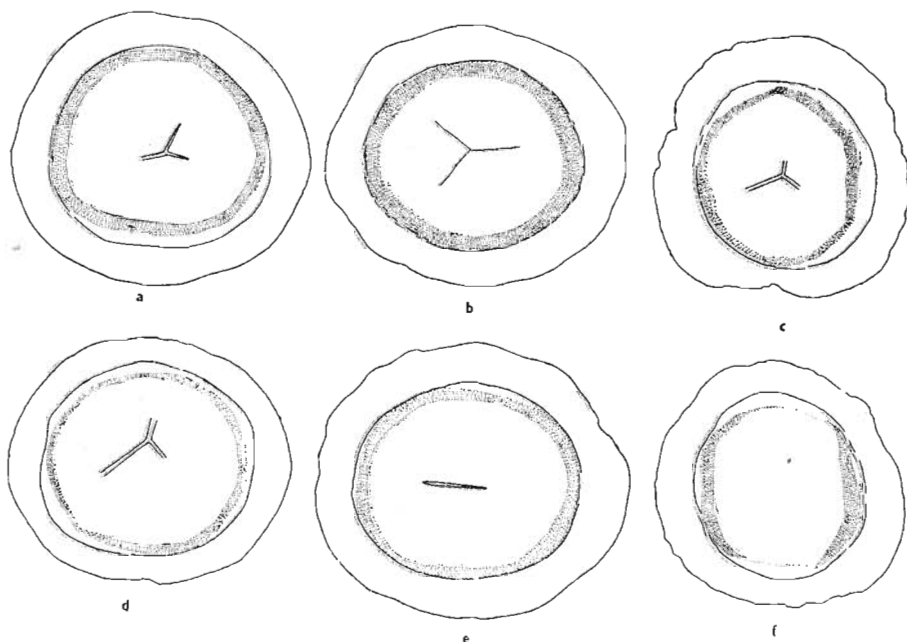
Specific Diagnosis — Known size range 94-163 $\mu \times$ 91-145 μ (mean 128 \times 118 μ), outline circular to sub-circular (ovalish), body distinct, shape \pm corresponding to overall outline, known size range 69-119 $\mu \times$ 65-109 μ (mean 90 \times 83 μ), fine intra-microreticulate; trilete \pm weakly developed, occasionally invisible, rays extending from 1/3-2/3 body radius, tend to be asymmetrical in their length and angles, occasionally the trilete is reduced to a monoradiate mark, ray ends blunt or tapering; sac relatively narrow in comparison to body radius, (about 1/3-1/2 body radius), known range of sac width 8-23 μ (mean 16 μ), distal overlap usually less than 1/3 of body radius, distal zone of sac attachment associated with a well-developed body infold system, body infold system typically \pm circular, situated close apart from or in contact with the body periphery, sac fine intra-reticulate, \pm deflated, surface \pm flat.

Holotype — Pl. 1, Fig. 7; overall size 110 \times 100 μ , body 78 μ , sac width 12-16 μ .

Description — The grains are circular in shape but more often they appear slightly ovalish (TEXT-FIG. 3-b). Occasionally a very rounded triangular shape may be simulated. The body is distinct and has a contour corresponding to the overall outline of the grain. The rays show a noticeable tendency of becoming asymmetrical in their length and angles (PL. 1, FIG. 6). Examples with two shorter rays set at acute angles and a third long ray are not uncommon (TEXT-FIGS. 3-c, d). Some Australian examples of *P. indicus* also reveal the same (cf. BALME, 1952; p. 12, FIG. 45). Reversely, two long rays may be set at very obtuse angles and a third short ray may connect them in the middle. Occasionally a complete reduction of the trilete results into what appears like a bent or straight monoradiate mark (TEXT-FIG. 3-e, also cf. POT. & LELE 1961, PL. 2, FIGS. 46, 56). Well-preserved specimens show an intra-microreticulum in the body (PL. 1, FIG. 9) but frequently due to bad preservation the original regularity of the fine structure is more or less distorted. The sac is relatively narrower in comparison to the body radius. Observations indicate that this relative proportion is retained

within reasonable limits through out the entire known size range of this species. It is obviously because an increase in the overall size of the grain is followed by a corresponding increase in the body diameter. The body infold system is typically circular and nearly conforms to the body outline. The outer margin of the infold zone lies close apart from the body periphery or may be in full or partial contact with it (TEXT-FIGS. 3-a, b). The individual fold components may be imperceptibly connected to form a smooth contour (PL. 1, FIGS. 7, 8), or they may be more or less discernible with slightly angular contacts during course of their circular formation (PL. 1, FIGS. 9, 10). Rarely the continuity of the infold system is lost or distorted due probably to unequal pressure on the body during compression (TEXT-FIGS. 3-f). The sac surface is nearly flat and the outline is typically more or less smooth.

Comparison — Some spores which answer well to the circumscription of *P. indicus* were previously assembled under *Nuskoi-sporites gondwanensis* Balme & Henn. by Balme (1952) and Piérart (1960). From the present studies, however, it has become apparent that *Plicatipollenites* (*Nuskoi-sporites*)



TEXT-FIG. 3.— *Plicatipollenites indicus* sp. nov. a-f, camera lucida drawings of specimens showing variation trends in the outline, trilete mark and the body infold system. Specimens in 3-c, 3-d and 3-e are same as in Pl. 2, figs. 42, 53 & 46 respectively of Pot. & Lele (1961). \times about 333. Slides 697, 711, 697, 692, 707, 703.

gondwanensis (BALME & HENN.) is distinct from *P. indicus*. (see p. 155).

A specimen figured by Datta (1957, FIG. 34), despite its superficial resemblance to *P. indicus* sp. nov., may turn out to be a distinct species of *Plicatipollenites* owing to its characteristically broad and triangular sac which tends to become relatively wider at the angles.

Synonymy — The following specimens are referable to *Plicatipollenites indicus* sp. nov.: VIRKKI (1939) — From Bacchus Marsh Tillite: Pl. 1, Fig. 3; From the Salt Range: Pl. 1, Fig. 6; From Daltonganj Coalfield: Pl. 1, Fig. 10.

VIRKKI (1946) — From 1½ feet above Talchir Boulder Bed, Kathwai, Salt Range, Pl. 2, Figs. 11-12 (Spore 45), Fig. 13 (Spore 47); From 4½ feet above Talchir Boulder Bed, Kathwai, Salt Range: Pl. 3, Fig. 28 (spore 47); From 20-25 feet above Talchir Boulder Bed, Kathwai, Salt Range: Pl. 4, Fig. 46 (spore 49), a good example; From Daltonganj Coalfield, Bihar, Lower Barakar, Lower Gondwana: Pl. 8, Fig. 116 (spore 48), ?Fig. 117 (spore 49); From Pali Beds, Rewa: Pl. 11, ?Fig. 142 (spore 44), Figs. 144-145 (spore 49), Fig. 146 (spore 50), Fig. 147 (spore 51), body shows intramicroreticulum; From Bacchus Marsh Tillite, Victoria: Pl. 14, Fig. 184 (spore 48).

DULHUNTY (1946) — ?Spore Type P 34 A.

BALME (1952) — From Collie Coalfield, Western Australia, Permian: p. 12, Fig. 45 (Type P 34 A of DULHUNTY).

SURANGE & LELE (1956) — From Talchir Needle Shales, Giridih Coalfield, India: Pl. 2, Figs. 13, 17 (one-winged spore types 1 and 2).

POTONIÉ & LELE (1961) — *Nuskoisporites triangularis* (MEHTA); From Talchir stage, South Rewa Gondwana basin, India: Pl. 1, Fig. 38, Pl. 2, Figs. 41, 42, 46 (spore in FIG. 46 shows a monoradiate mark), 52, 53, 56 (infold system distorted; a bent monoradiate mark visible in Fig. 56).

PIÉRART (1959) — *Nuskoisporites ? gondwanensis* Balme & Henn.; From Assise a' couches de houille, Luena, Katanga, Belgian Congo: p. 40, Text-fig. 2, Pl. 8, ?Figs. 1, 2.

RAKOTOARIVÉLO (1960) — *Nuskoisporites gondwanensis* Balme & Henn., From Groupe de la Sakoa, Madagascar: Pl. 2, Fig. 20.

Plicatipollenites gondwanensis (Balme & Hennelly) n. comb. & amend.

Pl. 2, Fig. 11; Text-figs. 4 a-c, 12-b

Amended Diagnosis — Known size range 94-134 μ \times 90-130 μ (mean size 120 \times 110 μ), outline \pm circular; known size range of body 51-98 μ \times 47-94 μ (mean size 72 \times 70 μ), outline circular to subcircular, distinct; fine intramicroreticulate, trilete mark weakly developed or invisible, \pm 1/2 body radius, length of rays or angles inbetween them \pm equal, sac relatively broader in comparison to body radius, known range of sac width 11-35 μ (usually above 1/2 body radius) distal saccus overlap more than 1/3 of body radius, body infold system well-developed, typically \pm polygonal, outer limit of body infold system tends to lie well apart from body periphery, sac intrareticulate, muri tend to be radially elongated, outline of sac \pm undulated.

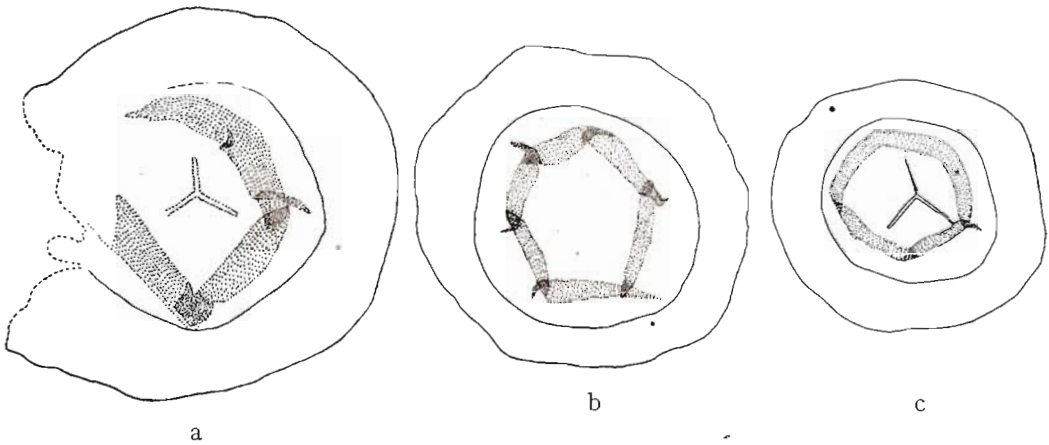
Holotype — *Nuskoisporites gondwanensis* Balme & Hennelly; 1956, Pl. 7, Fig. 66. Big Ben Seam, Bloomfield Colliery, Tomago Stage, N.S.W., Permian. Overall size 150 μ , body ca. 96 μ (See also a tracing from the holotype in Text-fig. 4-a).

Description — The size range for this species given by Balme & Hennelly (1956, p. 253), is greater than in the case of the Talchir spores. The grains of the present material are, however, closely comparable with the holotype. The largest Indian example definitely attributable to this species is recorded by Virkki (1946, PL. 12, FIG. 150) from the Pali beds. This grain measures 228 \times 176 μ and the body is 117 \times 109 μ .

The body is \pm distinct and, if favourably preserved, shows an intramicroreticulate structure. The trilete mark is weakly developed or invisible. The rays are more or less equal in length and do not exhibit any pronounced tendency towards reduction leading to a monoete mark.

The sac is comparatively wider. It is usually greater than 1/2 body radius, in average about 2/3 body radius and may be as wide as the body radius. There is a tendency towards radial elongation of the muri which form the intrareticulum of the sac.

A distinct body infold is developed in close association with the distal sac attachment. In typical cases the infold system is polygonal in contour, made up of 4-6 fold components (PL. 2, FIG. 11; also cf. BALME & HENN. 1956, PL. 17, FIGS. 66-67, PIÉRART



TEXT-FIG. 4—*Plicatipollenites gondwanensis* (Balme & Henn.) n. comb.: a, tracing from the original photograph (holotype) of Balme & Hennelly (1956, Pl. 7, Fig. 66); b, c, camera lucida drawings of specimens showing the polygonal nature of the body infold system. Specimen in 4-b is same as in Pl. 2, Fig. 11. \times about 333. Slides 705, 722.

1959, PL. 7, FIG. 1, VIRKKI 1946, PL. 12, FIG. 149, POTONIÉ & LELE 1961, PL. 2, FIG. 40). The ends of the fold components are \pm tapering and they are connected together with a noticeable angularity and overlap. The infold system tends to lie well apart from the body periphery (TEXT-FIGS. 4-a, b, c).

Comparison and Remarks — Potonié & Lele (1961, p. 27) merged *Nuskoisporites gondwanensis* with *N. triangularis*. While the former species has a distinct, polygonal body-infold system, the latter is completely devoid of any body-infolds. This is considered to be a basic organizational difference which has led to the institution of the genera *Plicatipollenites* (with *N. gondwanensis* as a species), and *Virkkipollenites* (with *N. triangularis* as its type).

Nuskoisporites gondwanensis of Balme & Henn. was also originally rather too broad-based which evidently permitted the inclusion of (1) some specimens lacking body infold system and (2) some other specimens which, contrary to the holotype, possessed a typically circular body infold pattern. While the spores of the first category fall under *Virkkipollenites*, those of the latter category have here been segregated under a new species *Plicatipollenites indicus* (see p. 152). In view of this, the species *Plicatipollenites* (*Nuskoisporites*) *gondwanensis* has now been redefined and amended. The significant features of *P. gondwanensis*

(BALME & HENN.) are that (1) the body infold system is typically polygonal in contour and tends to be situated well apart from the body periphery, (2) the trilete rays remain \pm equal without any noticeable tendency towards reduction (3) the overall outline of the grain is nearly circular and (4) the sac is wider. On the contrary, the salient points of *P. indicus* are that (1) the body infold system is \pm circular in contour and tends to be situated close to or even in contact with the body periphery, (2) the trilete rays tend to be heteromorphic and may reduce to a monolete, (3) the overall outline of the grain may vary from circular to ovalish and (4) the sac is relatively narrower.

Synonymy — The following specimens are referable to *Plicatipollenites gondwanensis* (BALME & HENN.) n. comb.

VIRKKI (1946) — From 20-25 feet above Talchir Boulder bed, Kathwai, Salt Range: Pl. 5, Fig. 52 (spore 54), a good example; from Daltonganj Coalfield, Bihar, Lower Barakar, Lower Gondwana: Pl. 8, Fig. 112 (spore 44); From Pali beds, Rewa: Pl. 12, Fig. 150 (spore 55), a large grain closely similar to the holotype.

PIÉRART (1959) — *Nuskoisporites?* *gondwanensis* Balme & Henn., From Assise a' couches de houille, Luena, Katanga, Belgian Congo: Pl. 7, Fig. 1, a typical specimen similar to the Holotype.

POTONIÉ & LELE (1961) — *Nuskoisporites triangularis* (MEHTA), Pl. 2, Fig. 40: From Talchir stage, South Rewa, India.

RAKOTOARIVELO (1960) — *Nuskoisporites gondwanensis* Balme & Henn., From Groupe de la Sakoa, Madagascar; Pl. 2, ?Fig. 23.

Plicatipollenites diffusus sp. nov.

Pl. 2, Fig. 12; Text-figs. 5 a-b, 12-c

Specific Diagnosis — Known size range 93-148 μ , outline \pm circular, known body size range 55-105 μ (mean 83 μ), outline \pm circular, weakly defined, structure finely intra-microreticulate, trilete mark \pm clear, rays \pm equal, $\pm 1/2$ body radius, sac circular in outline, fairly wide, usually greater than $1/2$ body radius, range in sac width 10-40 μ (mean about 25 μ), distal sac overlap less than $1/3$ body radius, body-infold system usually circular, \pm subdued, situated close apart from or touching body margin; sac

structure fine intra-reticulate, muri often radially disposed.

Holotype — Pl. 2, Fig. 12; Text-fig. 5-a; overall size 112 μ , body ca. 70 μ , width of sac ± 22 μ .

Comparison and Remarks — The grains are mostly characterised by their circular shape and \pm weakly defined circular body. The body infold system is also somewhat subdued and typically circular in shape. The saccus is wide, and may be from $1/2$ to equal body radius. The other species *P. indicus* and *P. gondwanensis* have a well-defined body and a sharp infold system.

Synonymy — The following specimens are referable to *Plicatipollenites diffusus* sp. nov. — VIRKKI (1946) — From $1\frac{1}{2}$ feet above Talchir Boulder bed, Kathwai, Salt Range: Pl. 2, ?Fig. 15 (spore 51).

DATTA (1957) — *Densosporites*, Fig. 32: Barakar Coal, Jhagrakhand Area, M.P., India.

HÖEG & BOSE (1960) — *Nuskoisporites triangularis* (MEHTA); From Assise a' couches de houille, Luena, Belgian Congo: Pl. 32, ?Fig. 4.

DULHUNTY (1946) — ?Type P 34 B; Pl. 7.

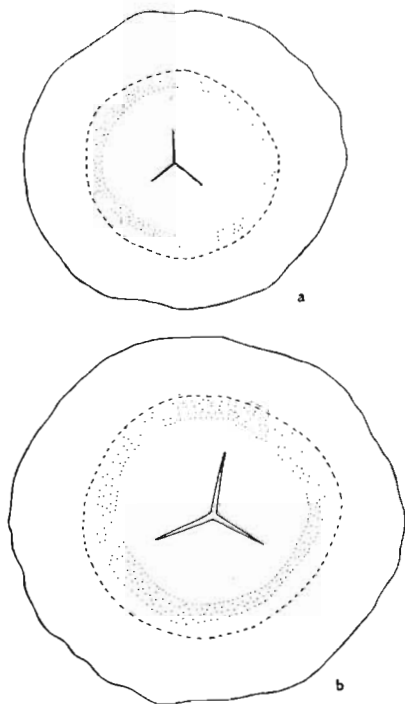
Plicatipollenites trigonalis sp. nov.

Pl. 2, Figs. 13, 14; Text-figs. 6 a-c, 12-d

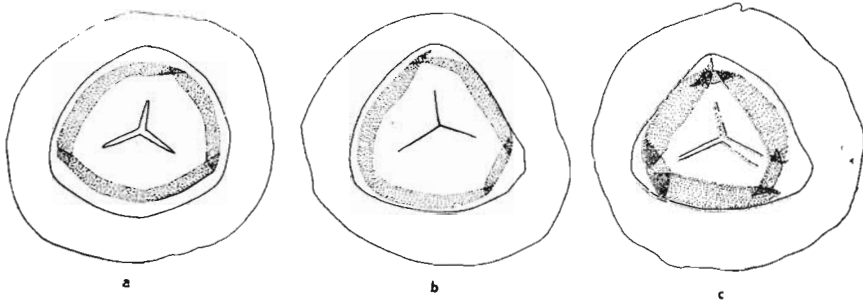
Specific Diagnosis — Known size range 97-145 $\mu \times 94$ -134 μ , outline circular to roundly triangular, body distinct, occasionally denser than the sac, outline triangular to roundly triangular, known size range 60-90 μ , structure finely intra-microreticulate, trilete mark usually \pm clear, rays $1/2$ - $3/4$ body radius, \pm equal, often pointing the angles of the body; sac about $1/2$ to equal body radius, distal overlap less than $1/3$ body radius, body infold system well-developed, typically \pm triangular, conforming to body outline; sac structure fine intrareticulate.

Holotype — Pl. 2, Fig. 13, Text-fig. 6-a (Same as in Pl. 2, Fig. 39 of POT. & LELE 1961); overall size 94 μ , body 64 μ , sac width ± 18 μ .

Description — The grains are distinguished by their distinct, triangular to roundly triangular body which is occasionally \pm denser than the surrounding sac. The sac is circular or roundly triangular in outline with the result that in certain specimens in which the sac is more circular and the body has flatter sides, the sac appears comparatively narrower at the angles of the



TEXT-FIG. 5 — *Plicatipollenites diffusus* sp. nov. a, b, camera lucida drawings of specimens showing the diffused outlines of the body as well as the circular body infold system. Specimen in 5-a is the holotype. Specimen in 5-b is the same as that on Pl. 1, Fig. 37 of Pot. & Lele (1961). \times about 333. Slides 695, 699.



TEXT-FIG. 6 — *Plicatipollenites trigonalis* sp. nov. a-c, camera lucida drawings of specimens showing the variation trends in the outline of sac and the body infold system. Specimen in 6-a (holotype) & 6-b are the same as in Pl 2, Figs. 13 & 14 respectively. \times about 333. Slides 705, 704, 710.

body (TEXT-FIG. 6-c). The trilete mark is usually well seen and the rays generally, though not as a rule, point the interradial angles. The body is externally smooth and internally shows a fine intra-microreticulate structure. The body infold system is typically triangular in outline and the three fold components are disposed along the three sides of the body. Occasionally, however, at some of or all the three angles of the body, additional folds may develop and connect the major lateral fold components. Thus, the infold system may appear to be made up of three lateral and 1-3 angular components (TEXT-FIGS. 6-b, c).

Comparison — The typical triangular shape of the body and the triangular body infold system are the main distinguishing characters of the species. All other species of *Plicatipollenites* have a circular or polygonal infold system and a circular to sub-circular body.

Synonymy — The following specimens are referable to *P. trigonalis* sp. nov.

VIRKKI (1939) — From Bacchus Marsh Tillite: Pl. 1, ?Fig. 4.

VIRKKI (1946) — From Bacchus Marsh Tillite: Pl. 14, ?Fig. 185 (spore 49).

POLONIÉ & LELE (1961) — *Nuskoisporites triangularis* (MEHTA); From Talchir Stage, South Rewa Gondwana basin: Pl. 2, Fig. 39 (Holotype selected here), Figs. 45, 50.

Virkkipollenites gen. nov.

Text-figs. 7 a-c

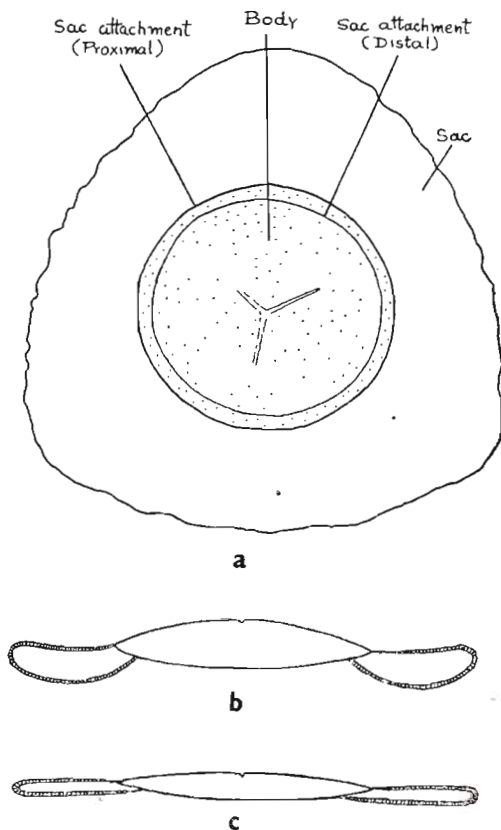
Generic Diagnosis — Monosaccate spore, outline circular to subcircular or roundly triangular, body outline variable, not necessarily conforming to overall outline, in-

distinct to distinct, rarely dense, mostly finely intra-microreticulate, trilete mark weakly developed or invisible, rays not reaching body margin, equal or unequal in length, angles in between rays not always equal; sac attached proximally at body equator, distally along a \pm narrow sub-equatorial zone, distal sac attachment not associated with a body infold system, sac structure intrareticulate, surface flat or frilled, margin smooth or undulated.

Genotype — *Virkkipollenites* (*Hymenozonotriletes*) *triangularis* (MEHTA) n. comb. Mehta 1944, Pl. 1, Fig. 1, India, South Rewa Gondwana Basin, Pali beds, Permian.

Derivation of name — After C. Virkki (now MRS. K. JACOB) who made the first significant contribution to our knowledge of the Lower Gondwana spore floras.

Description and Comparison — The principle basis for separating these spores from *Plicatipollenites* is the characteristic absence of a body infold system near the distal sac attachment (TEXT-FIG. 7-a). From the examination of a large number of specimens it was clear that the grains of *Virkkipollenites* were constructed on a fundamentally distinct plan which did not encourage the development of body infolds near the sac attachment. Evidently, the absence of body infolds in *Virkkipollenites* is a positive character consistently shared by a homogeneous group of spores warranting generic status. It may be remarked that the absence of body infolds near sac attachment appears to be equally characteristic of certain other genera, specially *Vestigisporites* Balme & Henn., *Striomonosaccites* Bharadwaj (1960) and *Striatopodocarpites* (SORITSCH. & SEDOWA) Bharadwaj.



TEXT-FIG. 7 — Organization of *Virkkipollenites* gen. nov. a, polar view. b, meridional section of unflattened spore. c, meridional section of flattened spore.

A plausible interpretation of the organization of *Virkkipollenites* is that the body of the spore was more or less like a flat lens (or even it could have been presumably flatter on the distal side) and the sac (having possibly a plano-convex shape) spread out in a horizontal plane nearly coinciding with that of the body (TEXT-FIG. 7-b). These factors — which are just the reverse of what is interpreted for *Plicatipollenites* — permitted the spores to flatten easily without producing a body infold system near the distal sac attachment zone (TEXT-FIG. 7-c).

It is also observed in some species that the sac shows radial frills which often arise from the distal zone of sac attachment. This feature (which is also shared by some examples of *Plicatipollenites*) can also be reasonably explained by supposing that the distal side of the sac was more or less bulged and

evidently developed frills on compression. The radial disposition of the frills is conditioned by the fact that the zone of sac attachment was also nearly radial in symmetry.

The genus *Virkkipollenites* includes 4 species from the Talchirs of India and one species *V. radiatus* (HENN.) n. comb. from Australia. The principle characters which have led to the specific delimitations are (1) the fundamental relation between the outline of the body and the sac (2) the dense, distinct or indistinct nature of the body as well as the zone of distal sac attachment (3) the width of the sac in relation to the size of the body and the grain and (4) any particular feature noticeable in the structure of the body or the sac.

Some illustrations of the rather poorly-understood genus *Cordaitina* Samoilovich (1953) seem to resemble those of *Virkkipollenites*. *Cordaitina* (which apparently includes *Latensina* Luber) would, however, appear distinct in its organization as it has been proposed for such pollens in which the body is alete and is completely enclosed by the sac. The reassignment of the Australian *Nuskoisporites* forms under *Cordaitina* by Hart (1963) would, therefore, seem far-fetched. *Culleisporites* Leschik (1956) differs in having a multi-layered, dark 'zone' which surrounds the body like an inflated tyre. Besides, in the genotype, the trilete mark almost reaches the body equator. *Accinctisporites* Leschik (1955) is distinguishable by the absence of a trilete or other mark. In *Parasaccites* Bharadwaj & Tiwari (1964) the sac is attached subequatorially on both sides of the body.

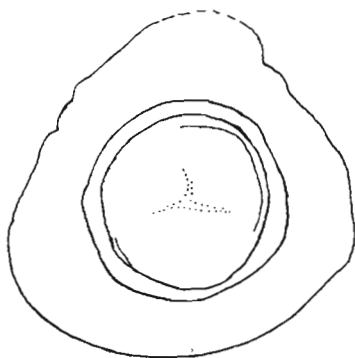
Virkkipollenites triangularis (MEHTA)
n. comb. & amend.

Pl. 2, Fig. 15; Text-fig. 13-a

Amended Specific Diagnosis — Known size range 65-120 μ , outline roundly triangular, body thin, \pm circular, outline clear, intrareticulation of body delicate, known size range 43-68 μ , trilete mark faintly visible, rays $1/2$ - $2/3$ body radius, rarely unequal in length; sac roundly triangular in outline, width usually greater than $1/2$ body radius, distal zone of sac attachment clear, overlap on body narrow, surface \pm frilled, outline often undulated.

Holotype — *Hymenozonotriletes triangularis* Mehta 1944, Pl. 1, Fig. 1; Overall size

125 μ , body about 75 μ . A tracing from the original photograph is represented here in Text-fig. 8.



8

TEXT-FIG. 8 — *Virkkipollenites triangularis* (Mehta) n. comb.: a tracing from the original photograph (holotype) of Mehta (1944; PL. 1, FIG. 1). \times 350.

Description and Comparison — The specimen figured by Mehta (1944, PL. 1, FIG. 1) is sufficiently well-preserved to illustrate the fact that a regular body infold system is not developed near the distal zone of sac attachment. The body, although thin, has a fairly clear outline and the distal overlap of the sac near the body periphery is also discernible. The "dotted" appearance of the body, as described by Mehta (l.c. p. 129) is, apparently, due to the delicate intramicroreticulum of the body. The genotype is here traced in Text-fig. 8. The Talchir specimen (PL. 2, FIG. 15) despite its much smaller size, reveals the same features as noted above for the type specimen. Larger specimens are also present.

A character of diagnostic significance to *V. triangularis* is that while the body remains circular, the sac retains its triangular outline irrespective of its tendency to be somewhat rounded. This fact is clearly implied in the description, drawing and discussion originally given by Mehta (l.c. pp. 129, 130; TEXT-FIG. 1(i)). In recognition of this fact, it has been considered appropriate to attach distinct specific values to such other grains (e.g. *V. mehtae* sp. nov.) which do not exhibit the same relation between the sac and body outline as in *V. triangularis*.

Certain specimens described under *Nuskoisporites triangularis* by Höeg & Bose (1960, p. 79; PL. 2, FIGS. 1, 3, 5) exhibit a kind of sac construction which is quite

distinct from that of *Nuskoisporites*, *Plicatipollenites* or *Virkkipollenites*. They deserve assignment elsewhere, perhaps under a new generic name.

Synonymy — The following specimens are referable to *V. triangularis* (MEHTA) n. comb. VIRKKI (1939) — From the Salt Range: PL. 1, FIG. 8.

VIRKKI (1946) — From 20-25 feet above Talchir Boulder bed, Kathwai, Salt Range: PL. 5, FIG. 51 (spore 53).

POTONIÉ & LELE (1961) — *Nuskoisporites* sp., From Talchir stage, South Rewa Gond. Basin, India; PL. 2, FIGS. ?49, 59 (refigured here on PL. 2, FIG. 15).

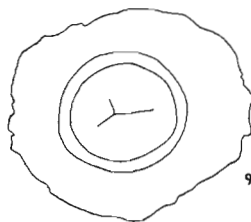
BHARADWAJ & SALUJHA (1964) — cf. *Nuskoisporites triangularis*, From Jambad Bowlah Seam (VIII), East Raniganj Coalfield, Raniganj Stage (Up. Perm.), India: PL. 3, FIG. 70.

Virkkipollenites mehtae sp. nov.

PL. 2, FIG. 16, Text-figs. 9, 13-b

Specific Diagnosis — Known overall size range about 55-100 μ , outline circular to subcircular (ovalish), body thin, \pm circular, outline discernible, known size range of body about 35-45 μ , intra-microreticulum very delicate, trilete mark obscure, rays \pm 1/2 body radius, length of rays and angles inbetween them not consistently equal; sac \pm circular, width greater than 1/2 to equal body radius, zone of distal attachment discernible, overlap on body narrow, surface frilled, outline undulating, muri of sac intramicroreticulum tend to be radially disposed.

Holotype — PL. 2, FIG. 16; Text-fig. 9; overall size 86 \times 74 μ , body 47 \times 42 μ , sac width 16-22 μ in different parts.



9

TEXT-FIG. 9 — *Virkkipollenites mehtae* sp. nov.: camera lucida drawing of the holotype (see PL. 2, FIG. 16). \times about 333.

Description and Comparison — The grains are characterized by a nearly circular shape of the body as well as the sac. Any variation

in the outline, if at all present, is towards a slightly ovalish form (TEXT-FIG. 9). Evidently in some cases (as in the holotype) where the sac tends to be more ovalish than the body, the width of the sac becomes somewhat variable in different parts. The body is thin, but its outline can be made out in all well-preserved examples. The intramicroreticulum of the body is very delicate and often as fine as to appear rather punctate.

The circular shape, both of the body and the sac, distinguishes *V. mehtae* from an otherwise comparable form *V. triangularis*.

Synonymy — The following specimens are referable to *V. mehtae* sp. nov.

VIRKKI (1946) — Pl. 11, Fig. 141 (spore 43): From Pali beds, Rewa.

GOSWAMI (1951-52) — *Hymenozonotriletes triangularis* Mehta (? = *Endosporites angulatus* WILSON & COE), Pl. 13, Fig. 11: From coal of I seam in mine 2, Dhanpuri (Burhar).

BALME & HENNELLY (1956) — *Nuskoisporites gondwanensis*, Pl. 6, ?Fig. 65: From Big Ben Seam, Bloomfield Colliery, Tomago Stage, Permian, Australia.

POTONIÉ & LELE (1961) — *Nuskoisporites triangularis* (MEHTA), Pl. 2, Fig. 43; From Talchir Stage, South Rewa basin, India.

HART (1960) — *Nuskoisporites gondwanensis* Balme & Henn., Pl. 2, Fig. 31: From the Lower Coal Measures (K₂), Tanganyika.

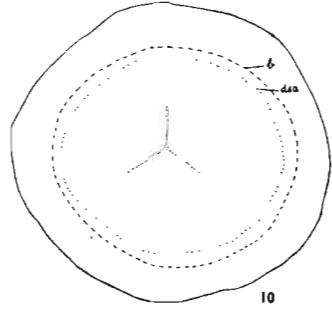
Virkkipollenites obscurus sp. nov.

Pl. 2, Figs. 17, 18; Text-figs. 10, 13-c

Specific Diagnosis — Known size range 94-162 μ \times 94-144 μ , outline circular to subcircular, known body size range 51-105 μ \times 47-90 μ , outline indistinct, circular to subcircular, intramicroreticulate, muri \pm irregular, trilete mark obscure to invisible, rays 1/2 body radius or more, not attaining equator, equal or unequal, sac narrow in comparison to body, usually \pm 1/2 body radius, structure fine intrareticulate, distal saccus overlap narrow, zone of attachment \pm indistinct, frills uncommon.

Holotype — Pl. 2, Fig. 17; overall size 135 \times 130 μ , body \pm 86 μ .

Description — The grains are circular in shape but often tend to be somewhat ovalish. The outline of the thin body is hardly visible. Its surface may be minutely wrinkled and



TEXT-FIG. 10 — *Virkkipollenites obscurus* sp. nov.: camera lucida drawing of a specimen showing the obscure zone of distal sac attachment (dsa), indistinct trilete and the ill-defined body outline (b). \times about 333. Slide 695.

may often appear rather rough due probably to the irregular intra-microreticulum (PL. 2, FIG. 18). The trilete mark is obscure to invisible and may be asymmetric (PL. 2, FIG. 17). The sac is comparatively denser in appearance and narrow as compared to the body radius (\pm 1/2 the longer radius of body). The zone of distal sac attachment is ill-defined; its narrow overlap on the body may be sometimes conjectured. The sac shows fine intra-reticulum and there is no marked tendency towards radial frills.

Comparison — The trilete mark, the outline of the body and the distal zone of sac attachment are all obscure to invisible in *V. obscurus* — which serve to distinguish it from *V. triangularis* and *V. mehtae*. Besides, *V. obscurus* is comparatively larger in size, has a narrower, \pm flat sac and a rougher body structure. It may be further distinguished from *V. triangularis* by the circular-oval outline of the sac.

Certain spores assigned to *Parasaccites* by Bharadwaj and Tiwari (1964, PL. 2, FIGS. 11, 13) may at first sight appear closely similar to those of *V. obscurus*. In both cases the body is too obscure to reveal its outline and the sac is also narrow. Bharadwaj & Tiwari, however, regard that their examples possess what has been described as the paracondition of sac attachment, i.e. the sac is attached subequatorially on both sides of the body. They have further expressed the opinion which would imply that the spores here treated as belonging to *V. obscurus* may be probable members of *Parasaccites*. As far as the present observations go, the Talchir spores under question

fail to reveal a paracondition of sac attachment. As regards the spores of Virkki (1946), Höeg & Bose (1960) and Hart (1960) — see synonymy — it is apparent that no unbiased judgement is possible from the photographs alone as to the mode of sac attachment; obviously most of these records could as much be claimed by *Virkkipollenites* as by *Parasaccites*. The determination of these particular spores with an indistinct body is admittedly somewhat tricky, but it seems, all the same, quite probable that both kinds of sac attachment (as represented by *Virkkipollenites* and *Parasaccites*) were manifested in spores such as those in question. If this was so, as it appears to be, the spores of *Virkkipollenites obscurus* would justify their present status. It is hoped that future investigations would certainly settle this point more satisfactorily.

The species *V. obscurus* occurs frequently in the Talchirs and has been observed in similar abundance in the overlying Karharbaris and younger strata.

Synonymy — The following specimens may be referable to *V. obscurus* sp. nov.

VIRKKI (1939) — From the Salt Range: Pl. 1, Fig. 9.

VIRKKI (1946) — From 4½ feet above the Talchir Boulder bed, Kathwai, Salt Range; Pl. 3, Fig. ?27 (spore 45); From 20-25 feet above the Talchir Boulder bed, Kathwai, Salt Range: Pl. 4, Fig. 45 (spore 48), Fig. 47 (spore 49); From Daltonganj Coalfield, Bihar, Lower Barakar, Lower Gondwana: Pl. 8, Figs. 114-115 (spore 45).

BALME & HENNELLY (1956) — *N. gondwanensis*; Pl. 6, Fig. 63: From main Greata seam, Greata Coal Measures, New South Wales.

GOSWAMI (1951-52) — ?*Florinites* sp., Pl. 12, Fig. 4: From Dhanpuri, Burhar, South Rewa Gondwana basin, India.

POTONIÉ & LELE (1961) — *N. rotatus*; Pl. 2, Figs. 51, 54, 55: From the Talchir beds, South Rewa basin.

HÖEG & BOSE (1960) — *N. rotatus*; Pl. 33, Figs. 1-3: From the Assie e' couches de houille, Greinerville & Lufupa, Belgian Congo.

HART (1960) — *N. rotatus*; Pl. 3, Fig. 32: From the Lower Coal Measures (K₂), Tanganyika.

BHARADWAJ (1962) — cf. *Nuskosporites*; Pl. 5, Fig. 95; Pl. 6, Figs. 97, 98: From Raniganj Stage (Upper Permian), India.

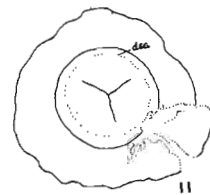
Virkkipollenites densus sp. nov.

Pl. 2, Figs. 19, 20; Text-figs. 11, 13-d

Specific Diagnosis — Known overall size range 70-130 μ , outline circular to roundly triangular; body dense, circular, 40-65 μ , seemingly fine intrapunctate (? intra-microreticulate), trilete mark weakly developed, rays more or less 1/2 body radius; sac circular to roundly triangular in outline, usually more than 1/2 body radius in width, distal overlap narrow, attachment zone obscure, surface of sac commonly frilled, structure fine intrareticulate.

Holotype — Pl. 2, Fig. 19; Text-fig. 11; overall size 66 μ , body 40 μ , sac width $\frac{1}{2}$ 15 μ .

Description — The grains are relatively less common, but are easily distinguished by their well-marked, dense brown, circular body. The body is externally smooth but shows what appears like a delicate intrapunctate structure. It is, however, likely that an intra-microreticulum was present. The sac is circular but occasionally tends to be very roundly triangular. In the holotype specimen (PL. 2, FIG. 19, TEXT-FIG. 11) the rays are simple and about 1/2 body radius. They are faintly seen in the photograph because of their different focal situation and thin nature. The Text-figure is, therefore, supplemented to bring out this feature. Sometimes, the trilete mark is more like a triradiate fissure, in which case the cracks may reach the body periphery (PL. 2, FIG. 20). The distal zone of sac attachment is rather ill-defined which may be further obscured by the denseness of the body; but the sac overlap on that side of the body can be sometimes made out by the frills that radiate out from the attachment zone towards the margin of the sac.



TEXT-FIG. 11 — *Virkkipollenites densus* sp. nov.: camera lucida drawing of the holotype (see Pl. 2, Fig. 19) to show the trilete mark and the obscure zone of distal sac attachment (*dsa*) \times about 333.

Comparison — This species is distinguished by its dense body from other species described here. The body of *V. densus* sp. nov.

is nearly as dense as that of *V. (Nuskoi-sporites) radiatus* (HENNELLY, 1958) n. comb. — an Australian species — but the outline of the body in that species is distinctly roundly triangular so that the circular sac appears wider on the sides. This condition is not met with (in fact, the reverse may be obtained) in *V. densus* (cf. TEXT-FIGS. 13-d & 13-e).

The genus *Bascanisporites* Balme & Henn. (1956) shows a superficial resemblance to *V. densus* in the possession of a dense body. However, it essentially differs in having a lobate, narrow and non-frilled sac as well as in the possession of a very short trilete mark. Besides, spores of the kind of *Bascanisporites* are not observed in the material studied.

Synonymy — The following specimen are referable to *V. densus* sp. nov. —

VIRKKI (1946) — Pl. 12, Fig. 48 (spore 53):
From Pali beds, Rewa.

SEN (1953) — ?Spore type B₅, p. 133, Fig. 1:
From Karharbari coalfield, Karharbari stage.

SURANGE & LELE (1956) — One-winged spore type 1, Pl. 2, Fig. 14: From Talchir Needle Shale Stage, Giridih Coalfield.

BALME & HENNELLY (1956) — *Nuskoi-sporites gondwanensis*, Pl. 6, Fig. ?62:
From Big Ben Seam, Tomago Stage, N.S.W.

CONCLUDING REMARKS

The present studies point out that *Nuskoi-sporites* can be resolved into at least three generic components viz. (1) *Nuskoi-sporites* Pot. & Kl. amend. (2) *Plicatipollenites* gen. nov. and (3) *Virkkipollenites* gen. nov. That more genera could be further segregated is also revealed by the following records: (1) some specimens referred to *N. triangularis* (MEHTA) by Höeg & Bose (1960, p. 79; PL. 2, FIGS. 1, 3, 5); see p. 159 for details (2) the original specimens of *N. rotatus* Balme & Henn. (1956, PL. 8, FIGS. 68-71); these have now been placed under a new genus *Barakarites* by Bharadwaj & Tiwari (1964).

According to our present knowledge, *Nuskoi-sporites* is restricted to the Northern Hemisphere and occurs in the sediments of the uppermost Permian (ZECHSTEIN) or Triassic age. The species are: *N. dulhuntyi* (POT. & KL. 1954), *N. klausii* Grebe (1957) and *N. crenulatus* Wilson (1962).

The genera *Plicatipollenites* (with 4 species) and *Virkkipollenites* (with 5 species) are so far known only from the Southern Hemisphere (Gondwanaland). The following synopsis gives the salient characters of the genera *Plicatipollenites* and *Virkkipollenites* as well as their constituent species (TEXT-FIGS. 12, 13).

Genus — *Plicatipollenites*: Distal zone of sac attachment associated with a well-developed, \pm regular body infold system; trilete mark \pm vestigial.

1. *P. indicus* sp. nov. (Genotype): Outline of sac and body typically circular, tending to be ovalish, infold system \pm circular, lying close to or touching the body periphery, trilete tends to be asymmetric and may be reduced to a monolete, sac narrow ($1/3$ - $1/2$ body radius), frills uncommon (See TEXT-FIG. 12-a).

2. *P. gondwanensis* (BALME & HENN.) n. comb.: Outline of sac and body \pm circular, infold system polygonal, lying well apart from body periphery, trilete \pm symmetrical, sac wide (greater than $1/2$ body radius), muri \pm radially disposed (see TEXT-FIG. 12-b).

3. *P. diffusus* sp. nov.: Outline of sac and body circular, body outline diffused, infold system circular, \pm ill-defined, trilete \pm symmetrical, sac wide (greater than $1/2$ body radius), muri \pm radially disposed (see TEXT-FIG. 12-c).

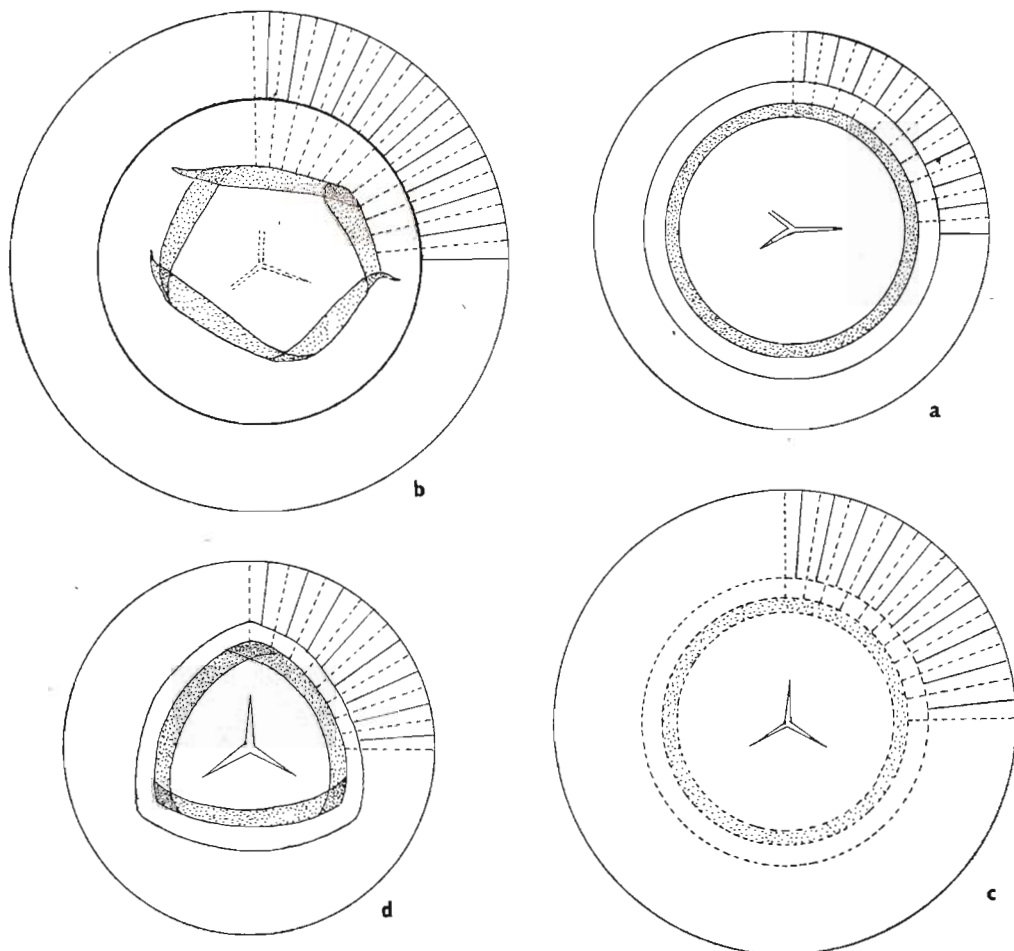
4. *P. trigonalis* sp. nov.: Sac circular to very roundly triangular, body triangular to roundly triangular, distinct, occasionally \pm dense, trilete \pm symmetrical, infold system trigonal, sac \pm wide, greater than $1/2$ body radius (see TEXT-FIG. 12-d).

Genus — *Virkkipollenites*: Distal zone of sac attachment not associated with body infold system; trilete mark \pm vestigial.

1. *V. triangularis* (MEHTA) n. comb., Genotype: Sac triangular to roundly triangular, body \pm circular, thin but clear, distal zone of sac attachment discernible trilete faint, sac \pm wide (greater than $1/2$ body radius), often frilled (See TEXT-FIG. 13-a).

2. *V. mehtae* sp. nov.: Sac and body circular, tending to be ovalish, body thin but clear, distal zone of sac attachment discernible, trilete thin, sac \pm wide (greater than $1/2$ body radius), often frilled (see TEXT-FIG. 13-b).

3. *V. obscurus* sp. nov.: Sac and body circular, tending to be ovalish, body thin, outline indistinct, distal zone of sac attachment



TEXT-FIG. 12 — Diagrammatic synopsis of the known species of *Plicatipollenites*. In each case the basic form of the sac and the body is drawn in polar view. Relative proportion between the size of different species is roughly maintained. The body outline may be well-defined (shown by unbroken lines) or ill-defined (shown by broken lines). Body infold system is stippled. Unbroken and broken radial lines show the extent and attachment of the sac in proximal and distal views respectively. a, *P. indicus* sp. nov. b, *P. gondwanensis* (Balme & Henn.). c, *P. diffusus* sp. nov. d, *P. trigonalis* sp. nov.

obscure, trilete obscure to invisible, sac narrow ($\pm 1/2$ body radius), frills uncommon (see TEXT-FIG. 13-c).

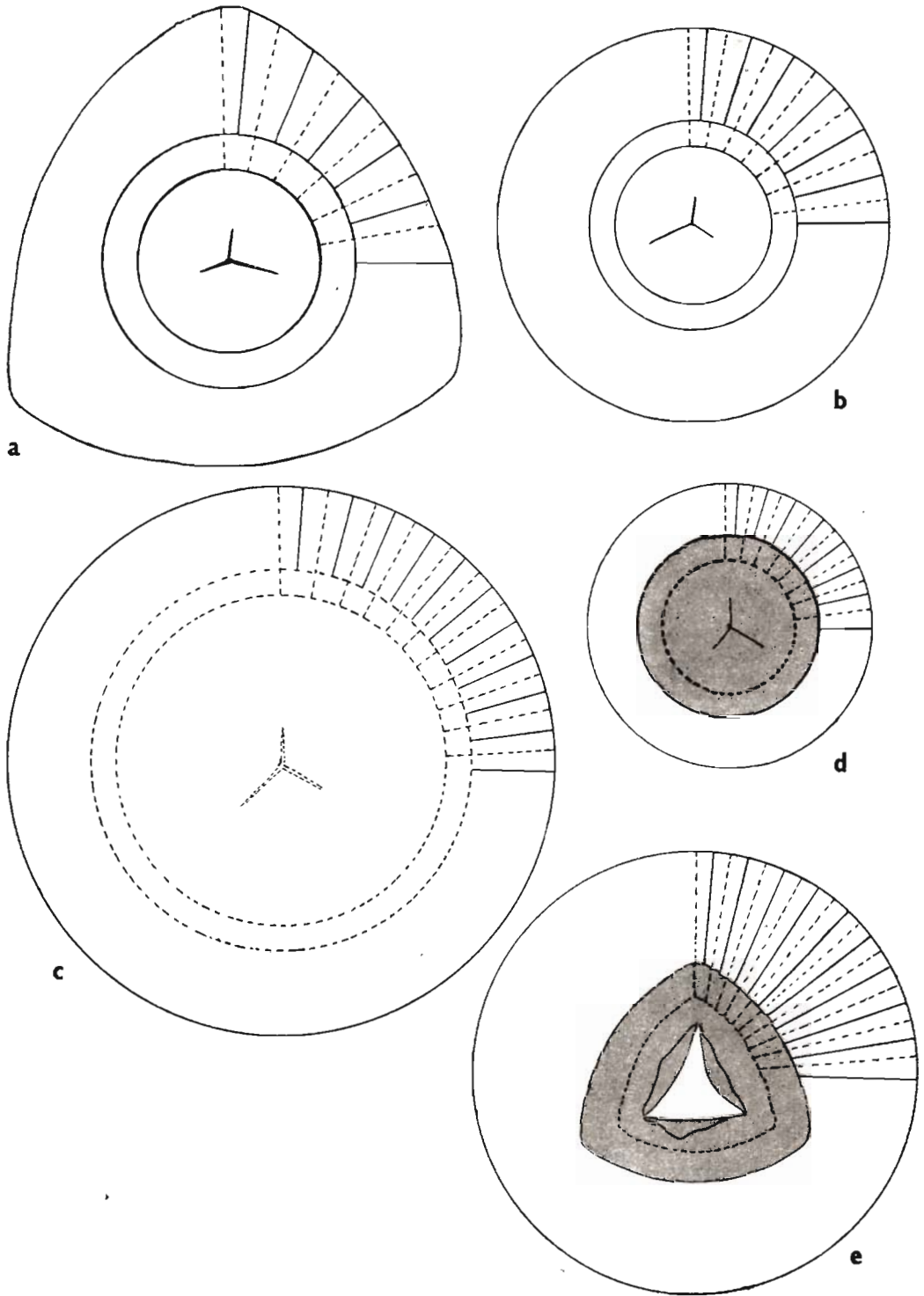
4. *V. densus* sp. nov.: Sac circular to very roundly triangular, body circular, dense, distal zone of sac attachment \pm obscure, trilete faint, tendency to fissure, sac \pm wide (greater than $1/2$ body radius), often frilled (see TEXT-FIG. 13-d).

5. *V. radiatus* (HENNELLY, 1958) n. comb. Lectoholotype — Hennelly 1958, Pl. 5, Fig. 10: Sac circular, body roundly triangular, dense, distal zone of sac attachment obscure,

trilete faint, body exine tends to open and fold along rays, sac wide (about equal to body radius or more), radial folds common (see TEXT-FIG. 13-e).

STRATIGRAPHICAL AND GEOGRAPHICAL DISTRIBUTION

Plicatipollenites occurs abundantly in the Talchir beds of Goraia (South Rewa Basin) and is a common spore of the Talchir needle shales which occur a few feet above the Talchir boulder beds in the Giridih



TEXT-FIG. 13

Coalfield (SURANGE & LELE, 1956). In the Salt Range, the spore flora recorded by Virkki (1946) from a number of horizons above the Talchir boulder bed also contains this genus in abundance. In fact, the monosaccates are the chief constituents of the Talchir stage. *Plicatipollenites* has also been commonly observed in the succeeding Karharbari stage. The flora of the Pali beds (more correctly Ganjra Nalla beds, see SAKSENA, 1952, p. 10) which is presumably of Karharbari age is full of this genus (VIRKKI, 1946). Comparatively little is known about the microspore assemblages of the succeeding Barakar stage. It may be, however, mentioned that some beds of the Daltonganj Coalfield and Jhagrakhand area considered to be Lower Barakar in age, show the presence of *Plicatipollenites* (VIRKKI, 1946, DATTA, 1957). Besides, I have observed this genus in the Barakars of other areas. There is no published account of spores from the Barren Measures which overlie the Barakars, but observations suggest that a sporadic presence of *Plicatipollenites* in these strata is not unlikely. In the succeeding Raniganj Stage (Upper Permian), however, the spore assemblage is dominated chiefly by the disaccates (BHARADWAJ, 1962). None of the grains referred to as cf. *Nuskoisporites* by Bharadwaj (l.c. PL. 5, FIG. 95, PL. 6, FIGS. 96-98) seem to fall under *Plicatipollenites*. Thus from what we know so far, it is clear that *Plicatipollenites* is present in strata ranging from the Talchirs to probably the Barren Measures, but its presence in the Raniganj stage is very doubtful.

In other Gondwanaland deposits, we find that *Plicatipollenites* is present in the Bacchus Marsh Tillite, Victoria (VIRKKI, 1946) and in the Permo-Carboniferous beds of Madagascar and Australia. The spore flora of the Upper Permian (Upper Coal Measures) in Australia is dominated by the disaccates as in the case of India and there is no published account of the occurrence of grains referable to *Plicatipollenites*

from the Australian or Africa Upper Permian sediments.

The genus *Virkkipollenites* is equally abundant in the Talchir sediments of South Rewa and the Giridih Coalfield. Strata younger than the Talchirs (referred to in connection with the distribution of *Plicatipollenites*) also contain *Virkkipollenites*. The grains recorded as cf. *Nuskoisporites* from the Raniganj stage by Bharadwaj (1962, PL. 5, FIG. 95, PL. 6, FIGS. 96-98) are perhaps referable to *Virkkipollenites*. Bharadwaj & Salujha (1964) also record a grain referable to *Virkkipollenites* from the Raniganj Stage (see synonymy of *V. triangularis*).

In other Gondwanaland deposits, *Virkkipollenites* is possibly present in the Bacchus Marsh Tillite of Victoria (VIRKKI, 1946) and the Permo-Carboniferous sediments of Madagascar (RAKOTARIVELO, 1960). The Lower or Middle Permian sediments of New South Wales (BALME & HENNELLY, 1956), the Lower Coal Measures of Tanganyika (HART, 1960), the Assise a' couches de houille of the Belgian Congo (HÖEG & BOSE, 1960) also contain this genus. *Virkkipollenites* seems to persist in the Permo-Triassic Transition beds of Australia (HENNELLY, 1958).

A comparison of the vertical distribution of the two genera in India (TABLE 2) and abroad reveals that *Plicatipollenites* has a smaller range (Permo-Carboniferous to Middle Permian) than *Virkkipollenites* (Permo-Carboniferous to Permo-Triassic). This disparity of distribution of the two genera, as far as we know at present, lends support to their generic distinction. It seems that although both *Plicatipollenites* and *Virkkipollenites* are equally abundant in the Lower Permian, the latter genus probably attains greater persistence during the middle Permian times. In the Upper Permian and Permo-Triassic transition periods only *Virkkipollenites* is known to linger.

The genera *Nuskoisporites*, *Plicatipollenites* and *Virkkipollenites* are found mostly in the

TEXT-FIG. 13 — Diagrammatic synopsis of the known species of *Virkkipollenites*. In each case the basic form of the sac and the body is drawn in polar view. Relative proportion between the size of different species is roughly maintained. The body outline or the distal zone of sac attachment may be clear (unbroken lines) or obscure (broken lines). Light grey tint represents dense body. Unbroken and broken radial lines show the extent and attachment of the sac in proximal and distal views respectively. a, *V. triangularis* (Mehta). b, *V. mehtae* sp. nov. c, *V. obscurus* sp. nov. d, *V. densus* sp. nov. e, *V. radiatus* (Henn.).

TABLE 2—KNOWN VERTICAL DISTRIBUTION OF THE SPECIES OF *PLICATIPOLLENITES* AND *VIKKIPOLLENITES* IN THE LOWER GONDWANA STRATA OF INDIA

SPECIES	TALCHIR STAGE (PERMO-CARB.)	KARHARBARI STAGE	BARAKAR STAGE	BARREN MEASURES STAGE	RANIGANJ STAGE (UPP. PERM.)
Genus — <i>Plicatipollenites</i> (range)	? —				
<i>P. gondwanensis</i> (Balme & Henn.)	+	+	+		
<i>P. indicus</i> sp. nov.	+	+	+		
<i>P. diffusus</i> sp. nov.	+				
<i>P. trigonalis</i> sp. nov.	+				
Genus — <i>Virkkipollenites</i> (range)	—				
<i>V. triangularis</i> (Mehta)	+	+			+
<i>V. mehtae</i> sp. nov.	+	+			
<i>V. obscurus</i> sp. nov.	+	Observed	+	Observed	+
<i>V. densus</i> sp. nov.	+	+			

Permian strata. There are, however, some interesting records of monosaccate spores comparable to these genera from horizons much older or younger than the Permian. Most of these records are, however, in my opinion open to further investigation. Perhaps the oldest record of monosaccate spores is from the Neobolus shales of Kashmir (JACOB et al., 1953). Some of these grains (l.c. p. 3; FIGS. 1, ?9) pretend to be comparable with those of *Virkkipollenites*. This occurrence is particularly surprising as it suggests the presence of vascular plants (Gymnosperms) in strata which are regarded as Cambrian in age. From the other end of the geological scale, Cookson (1955) records the occurrence of *Nuskoisporites*-like spores from the Cretaceous — Tertiary sediments of Australia. Although no categorical statement can be made on this record, it is worthwhile in this connection to mention about the occurrence of *Cannanoropollis* Pot. & Sah (1960) in the Tertiary lignites of India. Re-examination of the type material of Potonié & Sah reveals that the grains of *Cannanoropollis* defy morphographical separation from those of *Plicatipollenites* and *Virkkipollenites*. The same preparations also contain a few grains described as *Limitisporites*, but which are probably more allied to *Vestigisporites* or allied forms. In addition, I have observed in one of these preparations (slide 1) a pollen similar to *Platysaccus*. All these genera are clearly indicative of a Palaeozoic age and therefore appear to be foreign to the Tertiary material of Potonié & Sah. Their number

is also not considerable and it is not unlikely that they were introduced through contamination. Unfortunately, more material was not available to check this doubt which is now shared by Dr. Sah as well.

AFFINITIES

Any opinion as to the probable affinities of *Plicatipollenites* and *Virkkipollenites* cannot be more than a speculation. It is, however, interesting to see what these spores suggest by way of their organization. One of the striking features of these grains is that the entire proximal face of the body as well as a wide \pm radially symmetrical distal area is not covered by the sac. In this aspect, the grains recall the pollen of the conifers more strongly than those of any other group. At the same time, these spores possess a trilete mark which, although more or less vestigial, is a feature reminiscent of the lower plants. Obviously, both *Plicatipollenites* and *Virkkipollenites* tend to fall under the category of 'Prepollen'.

Parallel conditions are also noticeable in *Potoniésisporites neglectus* Pot. & Lele, *Vestigisporites* Balme & Henn., *Limitisporites* Leschik, *Parasporites* Schopf, *Succinctisporites* Leschik, *Sahnisporites* Bhardwaj, *Sahnites* Pant and *Parasaccites* Bharad. & Tiwari. Some of them also develop regular body-folds encompassing the area of the body as in *Plicatipollenites* while others lack this character as in *Virkkipollenites*. These genera, however, show a further advance over *Plicatipollenites* and *Virkkipollenites*,

because in this alliance we find a many-sided approach towards the disaccate condition specially by virtue of their bilateral shape, or their bilateral, distal or para-condition of sac attachment etc. Thus in a broader context, the distal sac-free area of these mono- or disaccate spores (or prepollens) tends to progressively assume the same situation and probably also the same significance as in the grains like *Barakarites* Bharad. & Tiwari and *Striomonosaccites* Bharadwaj (1960) which, in their turn, connect the numerous other striate or non-striate disaccate pollens found in the Lower Gondwana sediments (Glossopteris flora).

From the above account it may be safely postulated that the parent plants of *Plicatipollenites* and *Virkkipollenites* were some gymnosperms. That they could be conifers may at first sight seem more likely on the basis of our knowledge of the fossil and living pollens of this group. However, if this

assumption was really true, one should naturally expect a close correspondence between the stratigraphical distribution of the Indian Palaeozoic conifers and that of the spore genera *Plicatipollenites* and *Virkkipollenites*. Strangely enough, the situation is quite contrary. For instance, the conifer genera *Paranocladus*, *Buriadia*, *Walkomiella* and? *Voltzia* are almost confined to the Talchir, the Karharbari, the Barakar and the Raniganj stages respectively. Does it mean that our present knowledge of the conifers is far from complete or is it that the spores in question could possibly be derived from certain other plants of the Glossopteris flora whose affinities still remain unresolved? Of special interest, in this context, are the two plants *Gangamopteris* and *Noeggerathiosis* because the pattern of their vertical distribution and the degree of their abundance closely matches with that of *Plicatipollenites* and *Virkkipollenites*.

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EXPLANATION OF PLATES

(All photomicrographs, unless otherwise mentioned, are magnified 500 times. The slides are preserved in the museum of the Birbal Sahni Institute of Palaeobotany).

PLATE 1

1. *Nuskoisporites klausii* Grebe. Extreme distal view of the spore showing the surface of the enclosing sac. The outline of the body (which is distally free from sac attachment) is vaguely seen since the specimen is least flattened. Preparation 19534 (from Dr. Grebe). $\times 250$.

2. Extreme distal view of the above specimen further magnified to show the intrareticulate structure of the enclosing sac over the distal side of the body.

3 & 4. Specimen in Fig. 1 as viewed through increasingly deeper focii from the distal towards the proximal pole. The smooth nature of the body and the folds are apparent. The body lies eccentrically. $\times 250$.

5. *Nuskoisporites klausii*, another interesting specimen showing the clearly eccentric position of the body. Preparation 19534 (from Dr. Grebe). $\times 250$.

6. *Plicatipollenites indicus* sp. nov. Note the asymmetry of the angles between the rays. Slide 697.

7. *Plicatipollenites indicus* sp. nov. Holotype. The body infold system is almost circular and hardly shows the individual fold components. Slide 699.

8. *Plicatipollenites indicus* sp. nov. Somewhat roundly triangular infold system; Components hardly noticeable. Slide 704.

9. *Plicatipollenites indicus* sp. nov. Fold components of the body infold system are more or less visible. The body shows a discernible intramicroreticulum. Slide 726.

10. *Plicatipollenites indicus* sp. nov. Fold components connected with slight angularity but still arranged in a circular formation. On the right side, the sac structure can be clearly seen up to the outer limit of the infold system. The trilete is \pm eccentric with rather blunt rays. Slide 726.

PLATE 2

11. *Plicatipollenites (Nuskoisporites) gondwanensis* (Balme & Henn.) n. comb. A typical polygonal infold system situated well apart from the body periphery. Slide 705.

12. *Plicatipollenites diffusus* sp. nov. Holotype. Note the ill-defined nature of the body outline as well as the circular infold system. Slide 695.

13. *Plicatipollenites trigonalis* sp. nov. Holotype. The triangular body infold system has three major components near the three sides of the body. Slide 705.

14. *Plicatipollenites trigonalis* sp. nov. The sac tends to be very roundly triangular. Two subsidiary folds have developed in the two angles of the body. Slide 704.

15. *Virkkipollenites (Hymenozonotriletes) triangularis* (Mehta) n. comb. Note the triangular sac and a circular body. The sac structure with its characteristic radial frills is seen in the portion overlapped by the sac on the distal side of the body. Slide 704.

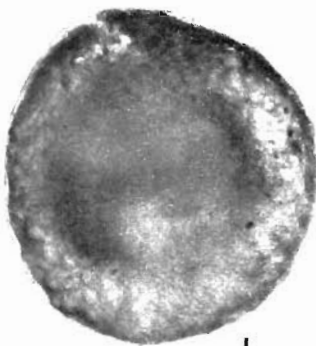
16. *Virkkipollenites mehtae* sp. nov. Holotype. Note the circular body and a nearly circular sac. Frills on the sac are distinct and radiate from the zone of distal sac attachment. Slide 696.

17. *Virkkipollenites obscurus* sp. nov. Holotype. Showing a large, indistinct body, narrow sac and the indistinct distal attachment. The mark is esymmetric. Slide 697.

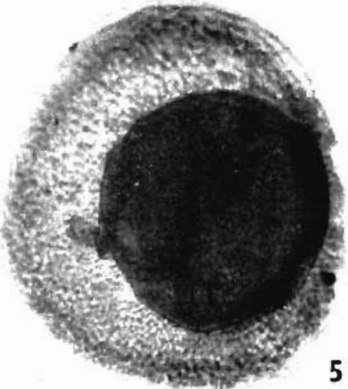
18. *Virkkipollenites obscurus* sp. nov. Note the rather rough appearance of the body structure. Slide 694.

19. *Virkkipollenites densus* sp. nov. Holotype. The sac tends to be very roundly triangular. The body is dense. The trilete although present, is out of focus in this view (see Text-fig. 11). Slide 727.

20. *Virkkipollenites densus* sp. nov. The sac is circular. The trilete has ruptured along the rays and the cracks seam to extend up to the body periphery. Slide 702.



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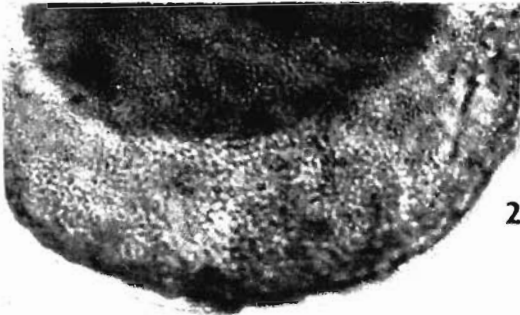
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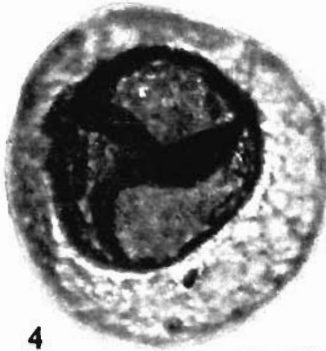
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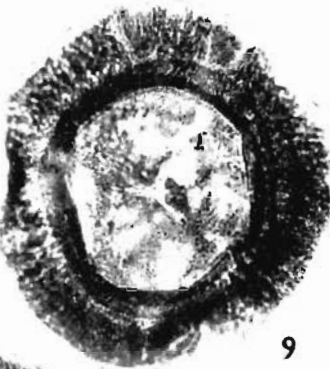
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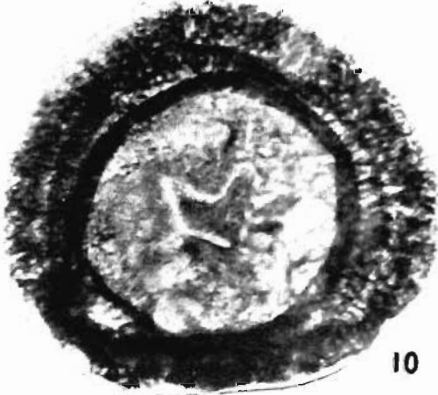
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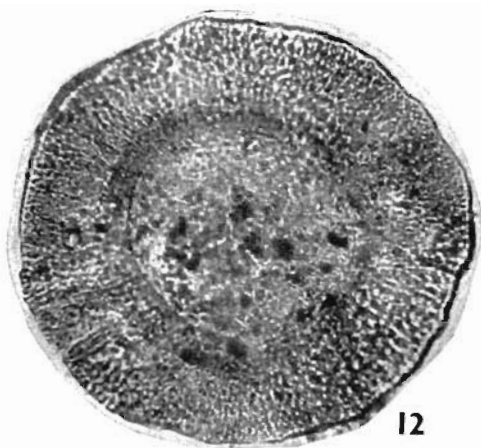
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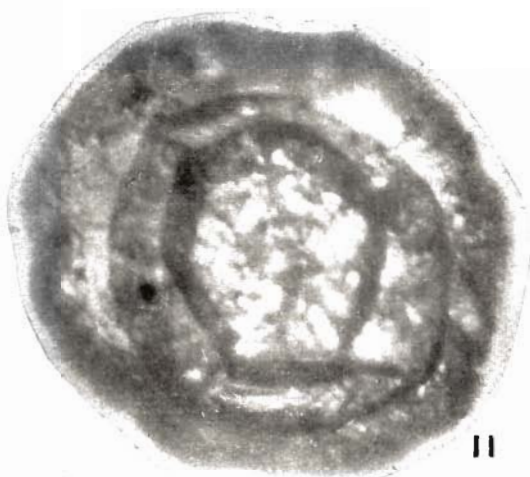
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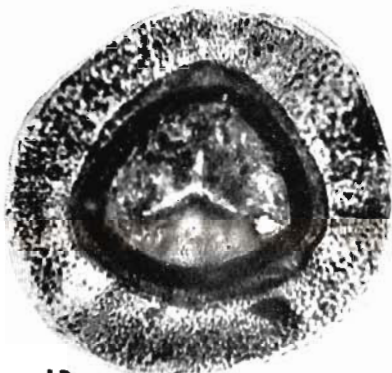
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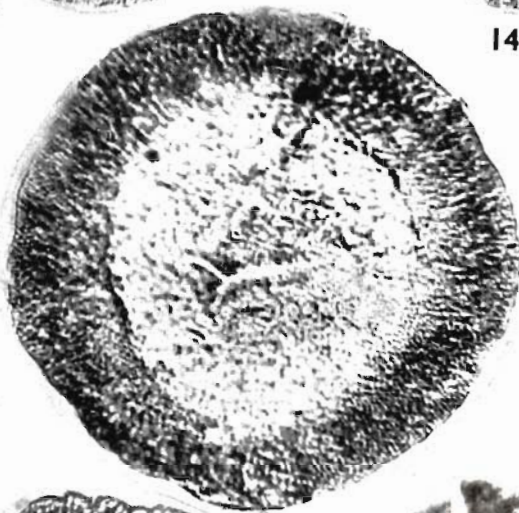
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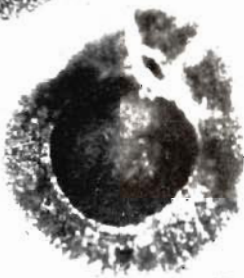
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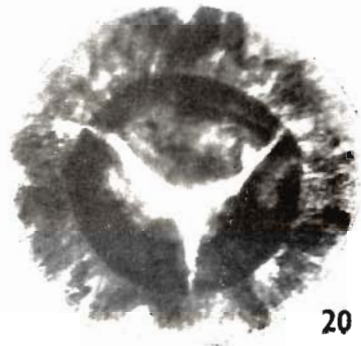
18



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