

IN SITU SPORES FROM LOWER GONDWANA FERNS — THEIR MORPHOLOGY AND VARIATION

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ABSTRACT

The paper deals with the study of morphology and variation of *in situ* spores of four fern species of the Raniganj Stage, Lower Gondwana, viz., *Dizeugotheca phegopteroides* (Feistmantel) Maithy, *Dichotomopteris lindleyi* (Royle) Maithy, *Dichotomopteris major* (Feistmantel) Maithy and *Neomariopteris hughesii* (Zeiller) Maithy. The variation exhibited by the spores in their size, shape, tetrad-mark and sculpture has been biometrically assessed for a better definition of the species. Study of the spores by SEM has further helped in elucidating their morphological characters.

Dizeugotheca phegopteroides has trilete to monolete, conate spores comparable with *Apiculatisporis*, *Punctatosporites* and *Ghoshiasporites*. *Dichotomopteris lindleyi* is now shown to have microbaculate sculpture comparable with *Cyclobaculisporites*. *Dichotomopteris major* and *Neomariopteris hughesii* possess closely similar spores characterized by a heterogeneous mixture of cones, spines and bacula and the spores are referable to dispersed spore genera like *Lophotriletes*, *Acanthotriletes* and rarely *Horridotriletes*. The strong overlap between the spore characters of two species is biometrically evaluated. The evidences indicate that there can hardly be any correlation between megafossil and microspore taxa found in dispersed state. The quality of sculpture in the Lower Gondwana spores is by and large distinct from that of the north hemispheric (Carboniferous) ferns.

Key-words — Morphology, Pteridophytes, *Dizeugotheca*, *Dichotomopteris*, *Neomariopteris*, Lower Gondwana (India).

सारांश

अधर गोंडवाना से प्राप्त फर्न के स्वस्थाने बीजाणु — इनकी आकारिकी एवं विभिन्नता — केशव मुकुन्द लेले, प्रभात कुमार माइती एवं जगन्नाथ प्रसाद मंडल

प्रस्तुत शोध-पत्र अधर गोंडवाना के रानीगंज चरण की चार फर्न-जातियों अर्थात् डाइज्यूगोथीका फ्रीगॉप्टे-रॉयडिस (फाइस्टमॅन्टेल) माइती, डाइकोटोमॉप्टेरिस लिन्डलेयाई (रायल) माइती, डा० मेजर (फाइस्ट-मॅन्टेल) माइती तथा निओमैरिऑप्टेरिस ह्यूजेसाई (जाइलर) माइती के स्वस्थाने बीजाणुओं की आकारिकी एवं विभिन्नता से संबंधित है। इन जातियों की और सुस्पष्ट परिभाषा हेतु बीजाणुओं द्वारा प्रदर्शित उनके आकार, आमाप, चतुष्क-चिन्ह तथा निरेखण की विषमताओं का जीवसांख्यिकीय निर्धारण किया गया है। क्रमवीक्षण-इलेक्ट्रॉन-सूक्ष्मदर्शी द्वारा किये गये बीजाणुओं के अध्ययन से इनके आकारिकीय लक्षणों के स्पष्टीकरण में और सहायता मिली है।

डाइज्यूगोथीका फ्रीगॉप्टे-रॉयडिस के बीजाणु शंक्वाकार, त्रिअरीय से एक अरीय तथा ऐंपिकुलेटिस्पोरिस, पंचटोस्पोराइटिस एवं घोषिआस्पोराइटिस से तुलनीय हैं। डाइकोटोमॉप्टेरिस लिन्डलेयाई को साइक्लोबैक्यूलिस्पोराइटिस से तुलनीय सूक्ष्म-बाकुलायुक्त गठन वाली जाति प्रदर्शित किया गया है। डाइकोटोमॉप्टेरिस मेजर एवं निओमैरिऑप्टेरिस ह्यूजेसाई में कटकों, कोनों एवं बाकुलों के विजातीय मिश्रण से अभिलक्षणित काफी मिलते-जुलते बीजाणु मिलते हैं। ये लोफोट्राइलिटोज, अकैन्थोट्राइलिटोज तथा कुछ-कुछ होरिडिट्राइलिटोज के विकरणीत बीजाणु-वंशों से भी निरूपणीय हैं। दो जातियों के बीजाणुओं के लक्षणों में दृढ़ व परस्पर-छादन का जीवसांख्यिकीय दृष्टि से मूल्यंकन किया गया है। इस अध्ययन से प्राप्त प्रमाण यह व्यक्त करते हैं कि विकरणीत अवस्था में पाये जाने वाले गुरुपादपाश्म एवं बीजाणु वर्गकों में शायद ही कोई सहसंबंध होगा। अधर गोंडवाना के बीजाणु उत्तर गोलार्द्धीय (कार्बोनिफेरस) फर्नों से गठन की विशेषता में हर प्रकार से भिन्न हैं।

INTRODUCTION

TILL recently the Lower Gondwana ferns were attributed to north hemispheric taxa like *Sphenopteris*, *Ptychocarpus*, *Pecopteris*, *Alethopteris*, etc. on the basis of gross exomorphic similarities. Doubts, however, existed as to their true affinities with northern forms, but the problem remained unresolved due to lack of knowledge about fertile structures and details of external morphological features of the Indian ferns.

In recent years Maithy (1974a, 1974b, 1975, 1977) published results of his morphological studies on the Lower Gondwana ferns and it emerged that almost all of our southern ferns are distinct from those of the northern hemisphere. Maithy (1974a, 1974b, 1977) erected the new genera *Neomariopteris*, *Dichotomopteris* and *Santhalia* to accommodate a majority of Indian ferns and assigned some other forms to *Dizeugotheca* Archangelsky & Sota (1960)—a South American Lower Gondwana genus. During the same period Pant and his associates (1974, 1976, 1977) also published their work on the Lower Gondwana ferns and erected new taxa like *Asansolia*, *Damudopteris*, *Trithecopteris* and *Damudorosorus*. Although Maithy and Pant and his school seem to differ in their interpretations and identification of these fern fossils, their studies now leave no doubt as to the distinctiveness of the Indian ferns from the northern ones.

Spores of the aforesaid ferns have been briefly described by Maithy as well as by Pant *et al.*, but no intensive study has so far been made. In the present work we have carried out detailed morphological studies on *in situ* spores of four fern species both under the Light microscope and the Stereoscan microscope. Besides, various aspects of spore variation within a sporangium have been biometrically evaluated. The facts thus brought out would be useful, we hope, in the study of dispersed spores and their taxonomy. The four fern species here dealt with are (i) *Dizeugotheca phegopteroides* (Feist.) Maithy, (ii) *Dichotomopteris lindleyii* (Royle) Maithy, (iii) *D. major* (Feist.) Maithy, and (iv) *Neomariopteris hughesii* (Zeiller) Maithy.

MATERIAL AND METHODS

Observations are based on the specimens described earlier by Maithy (1974a, 1974b, 1975) and also on fresh collections from the Damodar Colliery, Raniganj Coalfield, West Bengal (Raniganj Formation, Lower Gondwana).

Dizeugotheca phegopteroides—B.S.I.P. nos. 35349, 35103, 35104.

Dichotomopteris lindleyii—B.S.I.P. nos. 35350, 35109, 35110.

Dichotomopteris major—B.S.I.P. nos. 35351, 35105, 35106.

Neomariopteris hughesii—B.S.I.P. no. 35113.

Sporangia were pulled off from compressions by the usual cellulose acetate method and macerated with 10% HNO₃ for 18-36 hrs followed by 0.5% NaOH treatment for 10 minutes. After several washing with water, the sporangia were teased on a slide. Spores did not separate easily; in *Dizeugotheca phegopteroides* the separation of spores was particularly difficult. To overcome this, sporangia were kept in very dilute alkali for about 10 minutes in oven at 40°C. After again washing with water the sporangia were subjected to vibration in ultrasonic cleaner for about one minute. This procedure helped considerably to separate spores from one another. Only few spore masses were left.

To study under Scanning Electron Microscope (SEM), clean spores were mounted in a drop of water on a piece of photographic paper and subsequently fixed on a stub by aluminium fixer. Specimens were vapour-coated with gold (approx. 150 Å thickness) evaporated from a tungsten filament in a conventional vacuum evaporator. The photographs were taken with a Cambridge-132 Stereoscan microscope located in the Central Drug Research Institute, Lucknow.

METHOD OF BIOMETRIC ANALYSIS

For biometric study of spore variability certain parameters of variation have to be recognized in each taxon. The variations are measured and recorded through random selection of spores under optical microscope. In the present case tetrad mark and the sculptural elements are chosen as parameters to analyse the variations. Beside these two parameters, "spore

shape (Symmetry)" is also recognized as a suitable parameter in *Dizeugotheca phegopteroides* spores. Most species studied here show a trilete tetrad mark. However, in the case of *D. phegopteroides* a wide range of variation from trilete to monolete is noticed. To assess this variation quantitatively the following four categories of tetrad mark are selected.

A. Trilete Group

1. *Trilete Mark* — All the three rays of the mark are equal in length and the angles between the rays are also equal.

2. *Trileteoid Mark* — The rays of the trilete mark are unequal in length and/or angles between the rays are also unequal. The longest ray has no preferential relation with the longer axis of the spore.

B. Monolete Group

3. *Monoleteoid Mark* — Rays of the tetrad are unequal and longest ray and/or the broadest angle formed between the rays lies parallel to longer axis of spore (i.e. monoleteoid trilete condition). In extreme cases, one arm of the tetrad mark may be lost and the remaining two rays, with a wide angle between them, lie parallel to the longer axis of spore. This condition is designated as 'bilete'.

4. *Monolete Mark* — Tetrad mark is represented by a single suture, extending parallel to the longer axis of spore.

Sculptural elements play a major role in biometric analysis. In all the studied genera, the exine is sculptured by various types of elements. However, where the elements are too small or very crowded, as in *D. lindleyii*, no precise biometrical analysis is possible. Selected parameters for the sculptural elements analysis are (i) number of elements projecting from spore margin, (ii) length, breadth of elements and their ratio, and (iii) distance between elements.

The triangular, circular or oval spores represent either a radial or a bilateral symmetry. For the determination of spore symmetry, the ratio-called 'Spore circularity ratio' has been followed (Lele & Shukla, 1978).

Spore circularity ratio $\left(\frac{X}{\bar{Y}}\right) = \frac{\text{Longer axis of spore (X)}}{\text{Axis at right angle to longer axis of spore (Y)}}$

Spores having a ratio 1 ± 0.05 are considered as radial. Where the X/Y ratio exceeds 1.05, the spore is taken as bilateral.

Genus — *Dizeugotheca* Archangelsky & Sota, 1960

Dizeugotheca phegopteroides (Feistm.) Maithy, 1975

Pl. 1, figs 1-9; Pl. 5, figs 43, 44; Text-figs 1-6

Fronde Morphology — A fairly large specimen of this species, figured in Pl. 1, fig. 1 and Text-fig. 1, shows about 9 pinnac on the left side of the main rachis. The pinnules are characterised by a stout midvein which persists up to the apex. All lateral veins except the basal pair are simple and straight; the basal pair, arising from the base of midvein, is curved upward.

The fertile and sterile pinnules are mixed. The sori are small, ovoid, up to 1 mm in size, arranged in contiguous marginal/submarginal rows continuing throughout the sinuses between the pinnules but discontinuous over their apices (Pl. 1, fig. 2; Text-fig. 2). The sorus is tetra-sporangiate and exindusiate. Sporangia are free, egg-shaped and exannulate. They are arranged in two pairs lying laterally, the upper pair being larger than the lower.

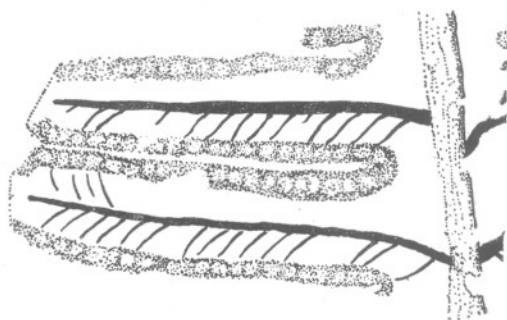
Spore Morphology — Miospores planoconvex; amb rounded triangular, circular or oval. Size range for triangular spores 15.5-21.2 μm ; for circular spores 15.6-21.8 μm and for oval spores 12-19.5 μm . Tetrad mark shows transition from trilete to monolete in a series of intermediate stages, viz., trileteoid, monoleteoid, trilete or bilete (Pl. 1, figs 6, 8; Text-fig. 3A-E). Triangular grains are always trilete; circular grains are trilete, monolete or monoleteoid (monoleteoid in higher percentage); oval grains are always monolete/bilete. Tetrad mark generally faint, rays not traceable in more than 50% spores. Trilete rays simple, slightly raised, 2/3-3/4 of spore radius (Pl. 1, fig. 3). Monolete mark generally 3/4 of spore radius, often bent, parallel with longer axis in oval spores. Exine thickly covered with coni; coni pointed, often falcate, nearly as high as wide or wider, generally 0.6-1.2 μm high, rarely up to 3 μm ; distance between coni variable on the same spore, spacing varies from 1.2-3 μm , rarely up to 10 μm ;



TEXT-FIG. 1—*Dizeugothea phegopteroides* (Feistm.) Maithy. An incomplete frond showing mixed fertile and sterile pinnules $\times 1.5$.

where crowded, the bases of conii may almost touch and appear to be confluent. Number of conii projecting from margin varies from 16-33, mostly within 21-28.

SEM Observations—The conate nature of sculptural elements is clearly brought out by Scanning Electron Microscope study. A few elements appear like bacula. Conii are mostly pointed, straight or falcate and



TEXT-FIG. 2—*Dizeugothea phegopteroides* (Feistm.) Maithy. Pinnules enlarged to show sori arrangement $\times 4$.

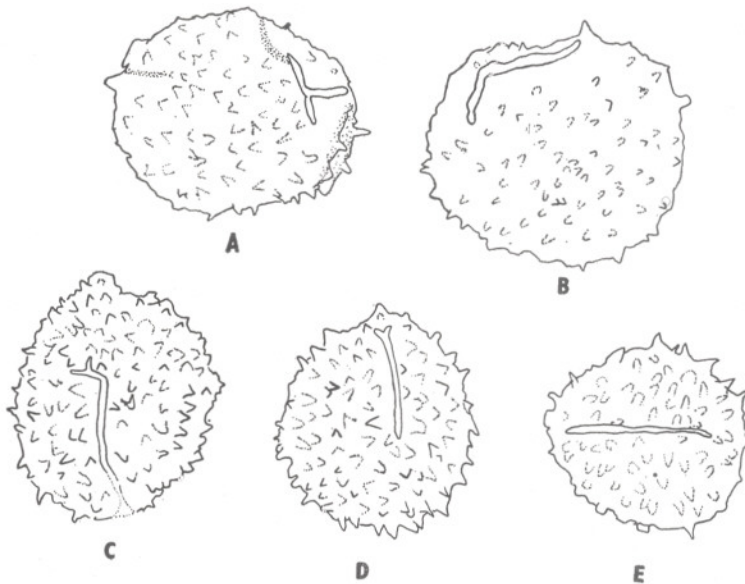
their bases are often enough close to touch each other (Pl. 5, fig. 43). Ornament on proximal side is generally reduced (Pl. 5, fig. 44).

Biometric Evaluation—The wide range of variation in the tetrad mark was biometrically analysed. The following statistics are based upon a random count of 200 spores.

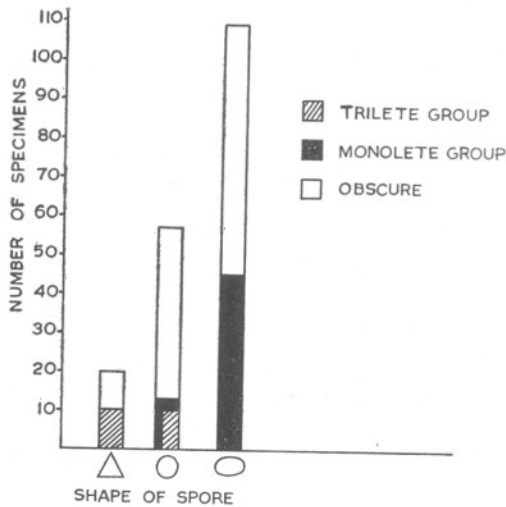
Tetrad mark	Per cent
Trilete	8.5
Trileteoid	4
	} Trilete group
Monoletoid trilete	2.5
Bilete	2.5
Monolete	29
	} Monolete group
Spores showing no mark	53.5

From the above statistics it is clear that the mark of monolete group dominates over the trilete group. Similar transitions in the tetrad mark, which seem to have evolutionary significance, are well known in living ferns (Kremp, 1966).

The spores of *D. phegopteroides* also vary in shape from triangular to circular to oval, i.e. from radial to bilateral in symmetry. Statistics of spore circularity reveal that 55% spores are oval, 33% circular and 12% triangular. A significant correlation has been found between the variation of tetrad mark and spore symmetry (Text-fig. 4). Triangular spores have always a trilete mark; on the contrary oval (bilateral) spores have a monolete or monoletoid mark. It is only in the circular spores that we come across all sorts of transitions



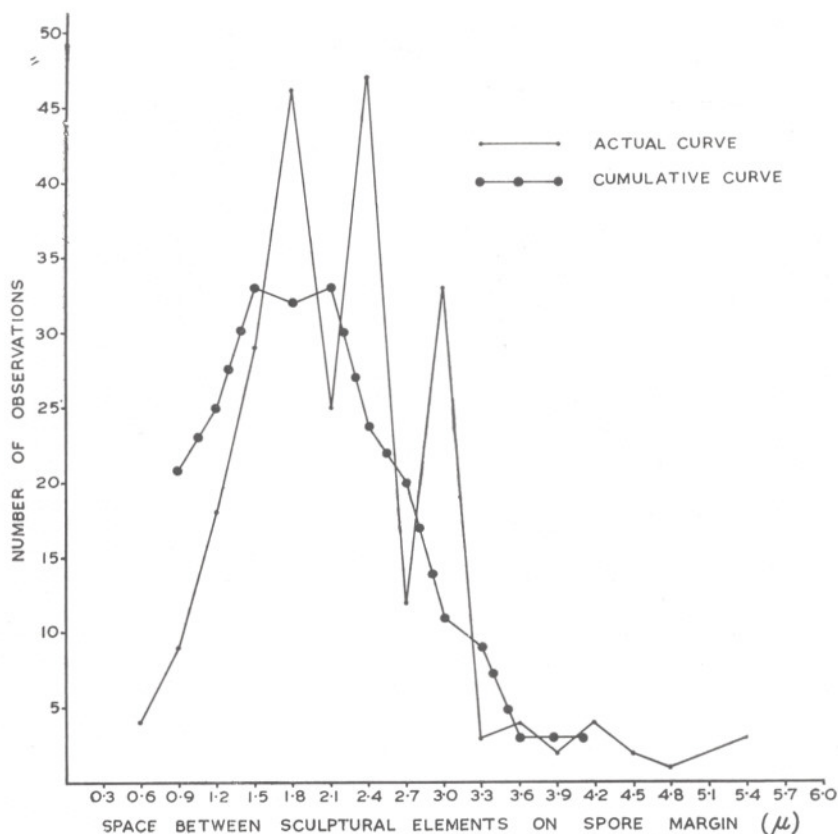
TEXT-FIG. 3 A-E — *Dizeugotheca phegopteroides* (Feistm.) Maithy showing variation in the tetrad mark and shape of spores. A, B — trilete; C-E — monolete/monoletoid. A $\times 1750$; B-E $\times 1500$.



TEXT-FIG. 4 — *Dizeugotheca phegopteroides* (Feistm.) Maithy. Frequency of triangular, circular and oval spores and their correlation with tetrad mark.

from the trilete to the monolete condition. These results strongly suggest that the shift in the mark is related to a corresponding shift in the spore tetrad symmetry.

The size of the sculptural elements and the spacing between them were biometrically assessed. Although the length and breadth of elements individually vary a great deal, the length/breadth ratio generally remains below 2 (100 counts on 27 spores). Thus L/B ratio of sculptural elements has a greater taxonomic value. Similarly the spacing between the elements as seen along the margin is very variable in the same or different spores. 250 observations of sculptural spacing were made on 27 spores and frequency curves were plotted (Text-fig. 5). A number of peaks appear in the curve. The spacing data is also plotted separately for triangular, circular and oval spores but the curves are equally irregular although they show a striking parallelism with the trend of the actual frequency curve. The cumulative curve, however, gives a better expression of the ornament spacing. It also appears that the most frequent spacing is between $1.5-2.1 \mu\text{m}$. The number of sculptural elements along the equator may also vary very widely. This is evident from the number of peaks appearing in the curve. The highest peak is at 25 (Text-fig. 6). To confirm this, a group-average curve as well as a cumulative curve



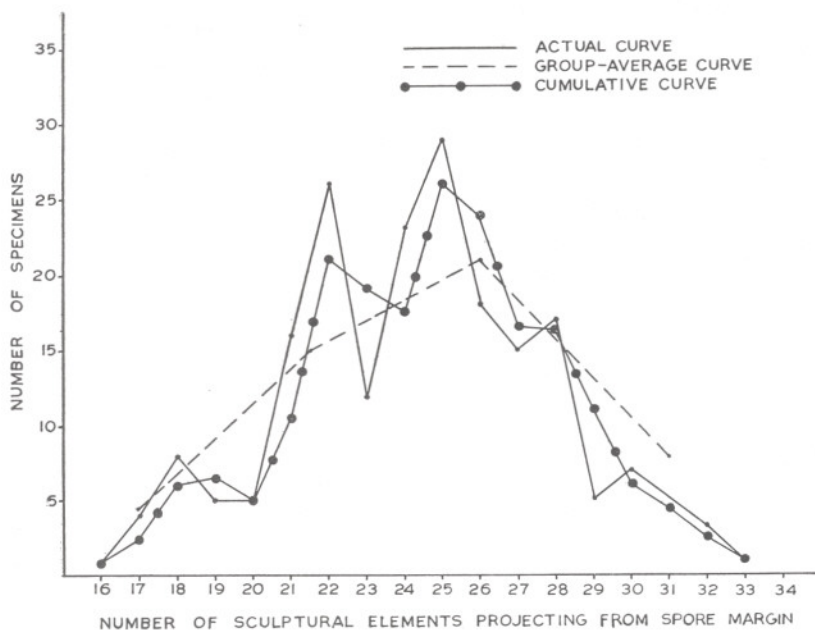
TEXT-FIG. 5 — *Dizeugotheca phegopteroides* (Feistm.) Maithy. Frequency curves showing variation in the space between sculptural elements.

are also drawn. These curves suggest similar trends. The plots are based on 200 counts. The results are likely to be better if the number of readings is further increased.

Discussion — In 1975, Maithy recognized *D. phegopteroides*. His recognition was closely followed by Pant and Misra (1976) in which *Asansolia phegopteroides* was erected. The type specimen of both the taxa is same (5183, Geological Survey of India, Calcutta) but unfortunately the specimen is sterile. Evidently the information on the sporangia and spores is based by these authors on other fertile specimens which we presume closely similar to the type.

Maithy (1975) described *D. phegopteroides* as tetrasporangiate with free sporangia

whereas Pant and Misra (1976) mentioned tetrasporangiate synangiate condition in *A. phegopteroides*. We have made new preparations and checked again to our satisfaction that the sporangia are free although aggregated in a group of four. Perhaps the term "synosorus" may be more apt for such arrangement. If they were synangia, as Pant and Misra believe, the individual sporangium would not separate easily in normal maceration. However, we find that in normal maceration about 30% sporangia separate out clean with intact, undamaged wall. Rest separate gradually during subsequent washing. Plate 3, fig. 18 of Pant and Misra (1976) also represents a clear separated intact sporangium. It may be argued that under drastic treatment even a synangium wall may break up into



TEXT-FIG. 6 — *Dizeugotheca phegopteroides* (Feistm.) Maithy. Frequency curves showing variation in the number of sculptural elements along spore margin.

parts (sporangia) but such portions will surely show remnants of the fused lateral wall or some kind of damage. This, however, is not the case.

It may be further pointed out that in the original diagnosis of *Dizeugotheca* by Archangelsky and Sota (1960) there is no mention of 'synangia'. Their description and diagnosis suggest that the structures are sporangia ("Capsulas"). Pant and Misra (1976) have, however, assumed that *Dizeugotheca* is synangiate and transferred *D. neubergiae* to *Asansolia*.

In our opinion *Dizeugotheca* is a fairly homogeneous and useful taxon. The sporangial row may be at the margin (*D. neubergiae*) or close to it (*D. waltonii*). Archangelsky and Sota (1960) have obviously used these criteria for specific distinction which seems reasonable. We believe that *Asansolia phegopteroides* Pant & Misra is not different from *D. phegopteroides* (Feistm.) Maithy.

Maithy (1975) described the spores of *D. phegopteroides* as more or less circular, 19-24 μm in diameter and with a trilete mark. The exine is ornamented with

closely arranged coni, about 1 μm long and broad. The spores are compared with the dispersed species *Apiculatisporis inconspicuous* Salujha (1965). But the present restudy shows that there is a wide range of variation in the tetrad mark of *D. phegopteroides* from trilete to monolete and all such spores have identical ornament of coni. It is evident that in dispersed condition the trilete spores would fall under *Apiculatisporis* while the monolete ones would go to different other genera, e.g. *Verrucosporites* (Knox) Pot. & Kr., *Punctatosporites* Ibrahim or *Ghoshiasporites* Kar (1969). Pant and Misra (1976) described the spores of *Asansolia phegopteroides* as monolete, echinate and compared them with *Verrucosporites* Bharadwaj (1962) which occurs dispersed in the Raniganj Stage. In our opinion the sculptural elements of these spores are typically conical and very rarely a few echinate or verrucate elements are seen. These spores are essentially identical with those of *Dizeugotheca phegopteroides*. It seems very likely that while Maithy (1975) has missed monolete spores from his preparation, Pant and

Misra (1976) have missed the trilete ones. The present evidence enables to bridge the gap between *D. phegopteroides* and *A. phegopteroides*.

Genus — *Dichotomopteris* Maithy, 1974b

Dichotomopteris lindleyii (Royle) Maithy, 1974b

Pl. 2, figs 10-19; Pl. 5, figs 45, 46; Text-figs 7, 8

FronD Morphology — The isotype of the species is reillustrated here (Pl. 2, fig. 10; Text-fig. 7). An additional small fertile fragment which has yielded good information on spores is shown in Pl. 2, fig. 11. The pinnules of this species are dimorphic. Fertile pinnules are crenulate or lobed and have thick, unforked secondary veins which arise from a persistent midvein. Sori are superficial, arranged in the median row on either side of midvein. The number of sporangia in a sorus (6-8, according to Maithy, 1974b) could not be ascertained.

Spore Morphology — Spores trilete, amb circular or subtriangular, smaller spores

generally circular. Size range 21-58.5 μm but mostly 40-50 μm . Pl. 2, figs 12-17 represent a variety of spores. Smaller grains (Pl. 2, figs 16, 17) have under-developed ornament (nearly smooth or with fine granula to con). Trilete rays simple, thin, with raised lips (Pl. 2, fig. 15). Exine thin, unstructured, irregularly folded, modifying spore shape (Text-fig. 8A-F). Both sides of spore ornamented with mostly bacula and some interspersed con, verrucae, pila or rugae. Sculptural elements more or less uniform in height closely set, may fuse near base. Bacula and verrucae broader than high, apices truncated or rounded, 0.6-1.2 μm long and 0.6-2.4 μm broad; spacing variable from 0.6-8 μm . Coni with round or pointed apices; 60-80 elements at equatorial margin.

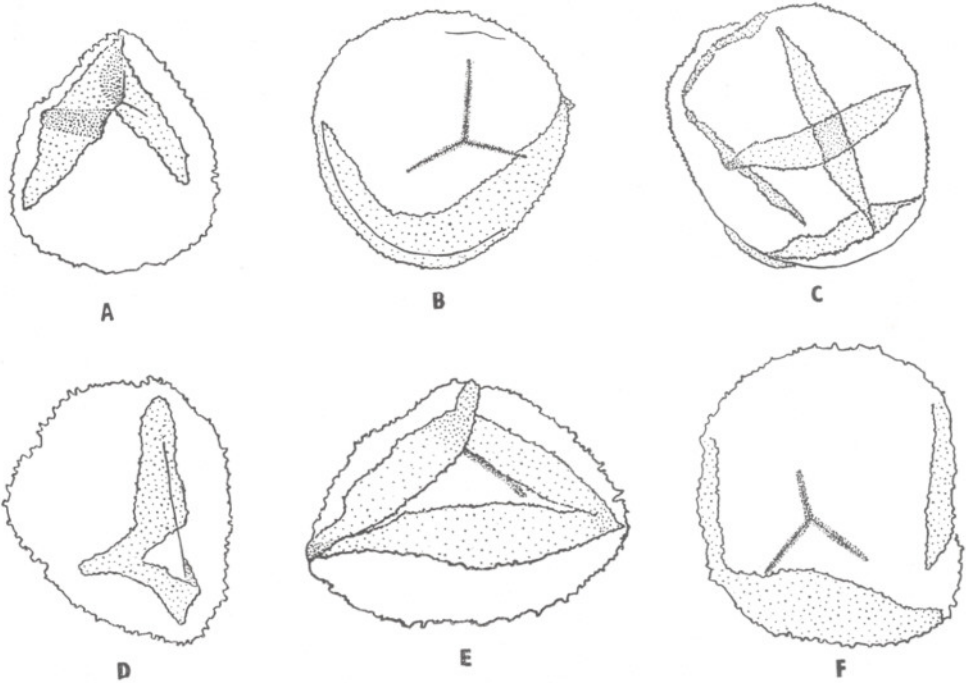
SEM Observations — The photographed specimens show small protuberances which are akin to bacula or verucae. The elements appear to be much less uniform in height under SEM observations. Fusion of elements near base and their irregular spacing also become more evident. Sometimes the sculpture has a rugose appearance (Pl. 5, fig. 45). In the photograph the shadows of the dense elements have interfered to partly obscure the sculpture. The other photograph (Pl. 5, fig. 46) brings out the elevated nature of the mark and shows that sculptural elements are also present over the elevated regions of the trilete, a feature not discernible under light microscope.

Discussion — Srivastava (1955) first reported the granulate spores from ?*Ptychocarpus* sp. which was later transferred by Maithy to *Dichotomopteris lindleyii*. Maithy (1974b) described the spores of *Dichotomopteris lindleyii* as having puncta, and referred them to the dispersed taxon *Eupunctisporites poniatiensis* Bharadwaj (1962). The present study shows that the sculpture is not punctate but microbaculate on the basis of which the spores can be best referred to the dispersed genus *Cyclobaculisporites* Bharadwaj ex Bharadwaj, 1966.

Pant and Misra (1977) described a new fern, namely *Trithecopteris gondwanensis* which has close exomorphic similarity with *Dichotomopteris lindleyii*. However, *Trithecopteris* seems to differ in having trisporangiate synangia, the sporangia being fused



TEXT-FIG. 7 — *Dichotomopteris lindleyii* (Royle) Maithy. Line-drawing of the isotype (Maithy, 1974b) showing sori arrangement $\times 2$.



TEXT-FIG. 8 A-F — *Dichotomopteris lindleyi* (Royle) Maithy. Patterns of exinal folds and modified spore shapes $\times 700$ (all).

along their stocks. On the other hand, Maithy (1974b) believed that there might be 4-6 free sporangia in *D. lindleyi*. We made several attempts but failed to isolate the intact sori. Therefore, the identity of *Dichotomopteris lindleyi* with *Trithecopteris* remains open in spite of close morphological similarity in these plants and their spores. Like Maithy (1974b), Pant and Misra also described the spores of *Trithecopteris* as punctate but judged from their photographs (Pl. 4, figs 1, 2) that indubitably these spores also have mostly microbaculate sculpture. In our opinion the spores of *Dichotomopteris lindleyi* and *Trithecopteris gondwanensis* are identical and can be closely matched with *Cyclobaculisporites* Bharadwaj (1962, pl. 2, figs 36, 37, 39-42) which is fairly common in the miofloras of the Raniganj Stage.

Dichotomopteris major (Feistmantel) Maithy, 1974b

Pl. 3, figs 20-32; Pl. 5, figs 47, 48; Text-figs 9-12

Fronde Morphology — A good fertile specimen of the species is illustrated in Pl. 3,

fig. 20; Text-fig. 9A. The pinnae arise at wide angle from the main rachis and bear alternate pinnules which have rounded tips and contiguous bases. The terminal pinnule is broadly triangular. Sterile and fertile pinnules are similar in external morphology, although in the latter the lateral veins are obscure. Midvein in the pinnules becomes evanescent towards apex. The sori are superficial, 2-4 on each pinnule on either side of midvein up to 3/4th distance from the base (Pl. 3, fig. 21; Text-fig. 9B). Sori are exindusiate containing 5-6 circular, annulate, stalked sporangia.

The annulus was not previously reported by Maithy. While re-examining the original material and some new specimens we discovered that the sporangia, even in the hand specimen, show the presence of a distinct transverse annulus as well as a short stalk (Pl. 3, fig. 22). The annulus apparently consists of a row of thick-walled cells.

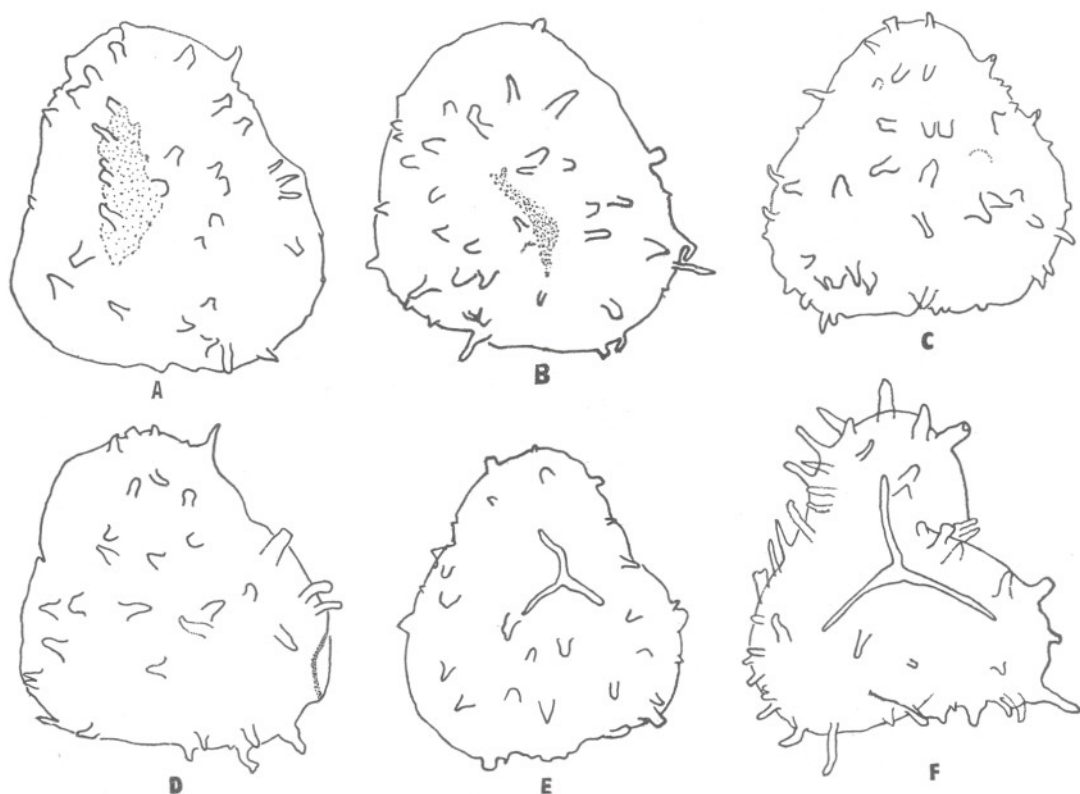
Spore Morphology — Spores trilete; amb triangular, sides straight, concave or rarely convex; angles rounded. Size range 21-



TEXT-FIG. 9 A, B — *Dichotopteris major* (Feistm.) Maithy. A. Line drawing of a fertile specimen $\times 1.5$. B. A pinna enlarged to show the position of sori $\times 2$.

29.6 μm (25-26 μm common). Trilete rays faint, raised, about 1/2 of spore radius long, rays commonly 7 μm long (Text-fig. 10E-F). Exine thin, unstructured commonly folded along sides producing characteristic lobes (Pl. 3, figs 26, 27). Ornament on both surfaces delicate, heterogeneous, predominantly coni with an admixture of spines or bacula. Extreme cases show only coni which are strikingly sparse (Pl. 3, fig. 24; Text-fig. 10A). Rare examples may have predominantly bacula or spines which are strikingly dense (Text-fig. 10F). Sculptural elements straight or variously curved and their tips detectable only by differential focus. Size of coni varia-

ble; length 0.3-3 μm (0.9-1.8 μm common), breadth 0.3-2.4 μm (0.6-1.5 μm common). Length/breadth ratio of elements generally 2 or less and therefore elements assignable to coni; rarely the length/breadth ratio may exceed 2 (spines). Apices of sculptural elements variable (Pl. 3, figs 28-32; Text-fig. 10B-F); round, truncate or blunt to sharply pointed, tips may occasionally become mucronate or show a slight bulge below the apex; hair-like spines or filiform processes rarely present. Bacula apices blunt. Spacing between elements variable from 0.3-12 μm . Elements on equatorial margin range from 7-26 in number (11-17 common).



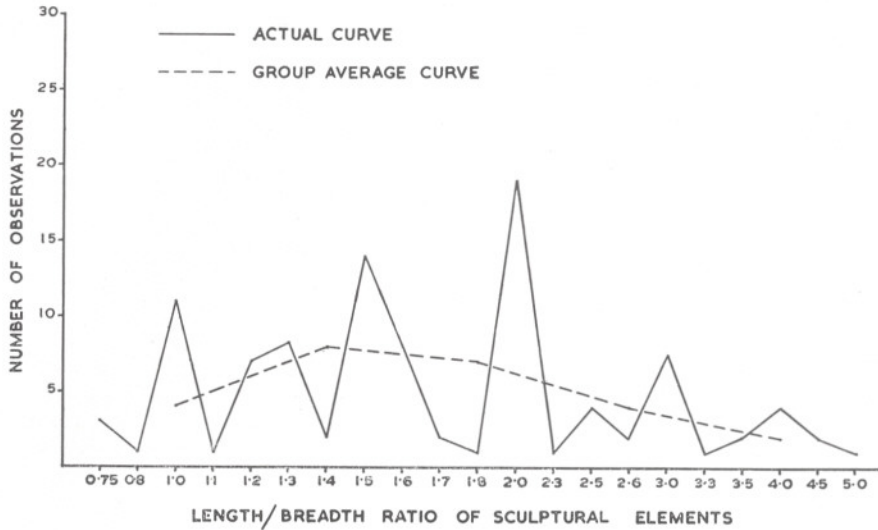
TEXT-FIG. 10A-F — *Dichotomopteris major* (Feistm.) Maithy. Spores showing wide variation in the shape and distribution of sculptural elements $\times 1500$ (all).

SEM Observations — Two specimens, shown on Pl. 5, figs 47, 48, bring out the polymorphous character of the sculptural elements. The elements are variously curved but their fine tips can be made out in several cases. The blunt appearance of a number of elements is because the tips are curved and out of focus. Typical bacula are, however, rarely present. The elements in Pl. 5, fig. 47 are on the borderline of cone and spine. The trilete rays in the photograph (Pl. 5, fig. 48) are slightly raised but they are otherwise simple.

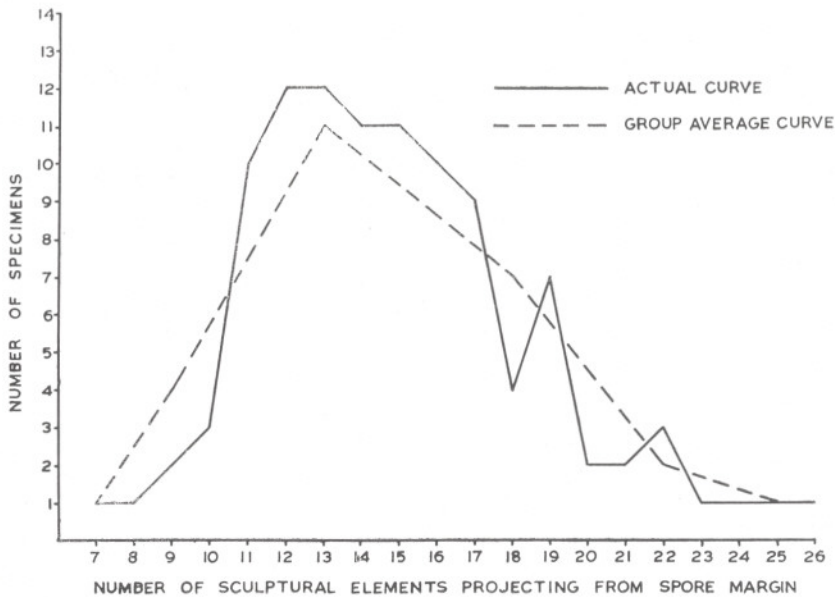
Biometric Evaluation (Ornament Shape) — The prevailing sculpture in the species is conate but quite often the conic appear to be echinate. To determine the exact shape of these elements, whether conic or spines, a biometric analysis of the length/breadth ratio of 115 elements from 25 spores was done and plotted on graph (Text-fig. 11). A large number of peaks

can be seen in the actual curve but the highest peak ($L/B = 2$) indicates that the most frequent elements are just on the border of cone and spine. Statistics shows that in 75% cases the L/B ratio does not exceed 2; of this only 25% cases fall just on the ratio value 2. This means that the sculptured elements are characteristically conic (*sensu stricto*) but there is a strong tendency of the elements towards echinate type of elongation. Although specimens with spines are definitely present, their number, as seen in the graph, is much lower. A group average curve is particularly drawn to provide a better idea of the peak (Txe fig. 11).

Number of elements along Spore Margin — In the taxonomy of dispersed spores the total number of sculptural elements counted along the spore equator is used as an additional criterion to distinguish species. The present material affords an



TEXT-FIG. 11 — *Dichotomopteris major* (Feistm.) Maithy. Length/breadth ratio of sculptural elements of spores.



TEXT-FIG. 12 — *Dichotomopteris major* (Feistm.) Maithy. Frequency curves showing variation in the number of sculptural elements along spore equator.

ideal scope to clarify this point. It is found that there is no hard and fast rule as to the number of elements along the equator at least in this species.

A count on 102 spores showed that the equatorial number of elements varies from

7-26 which is a very wide range. When the data is plotted the curve shows a large number of irregular peaks although the major peak is between 11 and 14 (Text-fig. 12). It is further revealed that there is no correlation between the number of

elements on equator and the diameter of spore (Text-fig. 17A). Similarly the spacing between elements is also found to be inconsistent.

It can be concluded that the number of elements on spore equator as well as the distance between elements are so much variable in the same or different specimens that the taxonomic value of these characters is highly diminished. Yet, if such a variable population is found in dispersed state it will customarily give rise to several distinct taxa.

Discussion—When Maithy (1974b) erected *Dichotomopteris major*, the detailed structure of the sporangia was not known. Subsequently Pant and Misra (1977) instituted *Damudosorus searsolensis* and *D. raniganjensis* which show close similarity with *D. major* in external morphology, arrangement of sporangia and also in the spores. Pant and Misra (1977) were able to show that *Damudosorus* had annulate, stalked sporangia. Re-examination of some better preserved specimens of *D. major* shows the presence of a transverse annulus and a short stalk in the sporangia (Pl. 3, fig. 22). It now seems very probable to us that *D. major* may turn out to be identical with *Damudosorus*.

Maithy described the spore ornament of *D. major* as more or less baculate and referred the spores to the dispersed genus *Horriditriletes* Bharadwaj (1962). Pant and Misra on the other hand, described the spores of *Damudosorus* as echinate. The present study makes it clear that these spores have a prevalingly conate sculpture with a mixture of spines and bacula. Thus the spores typically stand nearest to the dispersed genus *Lophotriletes* (Naumova) Potonié & Kremp (1954). However, a small part of the population may show dominantly spinose ornament and such spores, in dispersed state, are likely to fall under *Acanthotriletes* (Naumova) Potonié & Kremp (1954).

Genus — *Neomariopteris* Maithy, 1974a

Neomariopteris hughesii (Zeiller) Maithy, 1974a

Pl. 4, figs 33-42; Pl. 5, figs 49, 50; Text-figs 13-18

Fronde Morphology—The frond in Pl. 4, fig. 33 and Text-fig. 13 is a reillustra-



TEXT-FIG. 13 — *Neomariopteris hughesii* (Zeiller) Maithy. Line drawing of the isotype of Maithy, 1974a $\times 2$.

tion of the isotype of Maithy 1974a. It is characterised by a winged rachis bearing a number of pinnae at about 45° . The pinnules are lanceolate, lobed or crenulate with narrow contiguous bases. The apical segment is long drawn. Veins are flexuous and sphenopteroid. There is no distinct midvein. Sori are circular, exindusiate and are rather irregularly dispersed over the lower surface, being located at vein endings. By chance in preservation they may appear to be arranged near the margin. Each sorus has 4-6 circular, free, annulate sporangia.

A re-examination of Maithy's original specimen has revealed the presence of annulus on the sporangia of this species. However, the material is not sufficiently well-preserved to yield more details about the fertile structures.

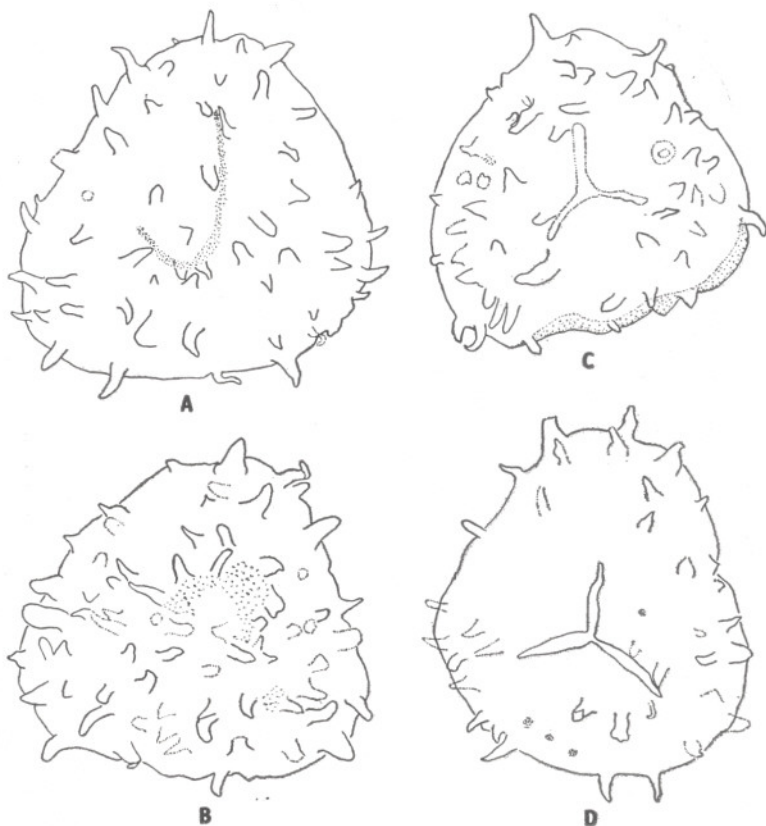
Spore Morphology—Spores trilete, amb triangular, sides mostly convex, angles rounded. Size range 21.5 to 34 μm (28-31 μm common). Trilete rays simple, faint, often open along suture line (Pl. 4, fig. 36), extending up to 1/2 of spore radius. Exine thin, unstructured and sometimes folded into a lobed structure (Pl. 4, fig. 39). Sculptural elements on both surfaces, stout, crowded;

mostly conical to spines intermixed with some bacula or pila (Pl. 4, figs 34-39; Text-fig. 14 A-D), elements up to $4.5\ \mu\text{m}$ long and $3.0\ \mu\text{m}$ wide at base, tapering, apices pointed or blunt; length/breadth ratio of elements ranges from 0.17-8 (1.5-3.0 common); occasionally elements have wide, bulbous base or mamillate apex; longer cones and bacula may show abrupt narrowing in the apical part or may have spatulate or pilose tips; setose processes also present (Pl. 4, figs 40-42). Elements commonly curved in various directions or hooked. Spacing between elements varies greatly from 0.3 to $15\ \mu\text{m}$ (commonly $3\ \mu\text{m}$); 9 to 27 elements project along spore equator (commonly 14-20).

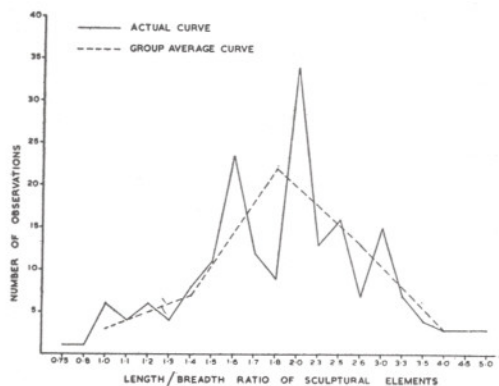
SEM Observations—Two of the photographed specimens are shown in Pl. 5, figs 49, 50. The variation in sculptural elements, specially in their shape, can be

clearly made out. Most elements taper to some sort of a point, but since their tips are often curved they do not come in focus and appear blunt. In fact the blunt processes are relatively a few. Some degree of basal fusion among elements can also be recognized.

Biometrical evaluation (Ornament shape)—The sculptural elements in the species are heterogeneous and very variable in their length and breadth. In order to get an objective idea of the variation, the length/breadth ratio of 190 elements from 25 spore is graphically plotted (Text-fig. 15). The actual frequency curve shows a number of peaks but the major peak is at ratio value 2. A group-average curve is also drawn which seems to have improved the representation of the peak at 1.8 ratio value. The statistics reveals that in most cases, the



TEXT-FIG. 14A-D—*Neomariopteris hughesii* (Zeiller) Maithy. Spores showing wide variation in the shape and distribution of sculptural elements $\times 1500$ (all).



TEXT-FIG. 15 — *Neomariopteris hughesii* (Zeiller) Maithy. Length/breadth ratio of sculptural elements of spores.

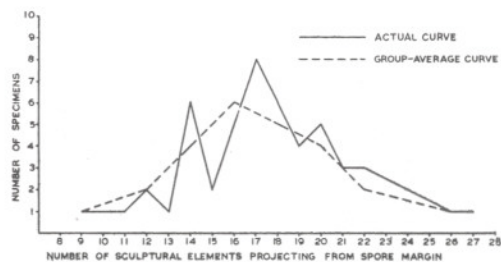
L/B ratio does not exceed 2 (57% cases). Of these, only 16% just fall on 2. All these elements are conic according to the current definition of the term. In 43% cases the L/B ratio exceeds 2 and these elements are spines.

The length of elements is also plotted against breadth; the graph suggests some correlation between the two.

Several other plots have been tried to study other features of variation but no distinct results have emerged. For instance the number of sculptural elements projecting from the spore margin were counted on 50 spores. When plotted, the actual curve shows a number of peaks (Text-fig. 16), though the highest peak stands between 17-18. The group average curve further improves the situation but still a second minor peak remains. The major peak in the group average curve suggests that the most frequent number of elements along spore equator falls between 14-17 (Text-fig. 16). On the whole the number of elements on spore equator is not a very dependable criterion for the specific delimitation of these *in situ* spores and the same may hold true for the dispersed spore species.

Spaces between the elements as seen along equator have also been plotted but no definite conclusion could be drawn. Similarly no correlation is found between the number of elements on spore equator and the diameter of spore.

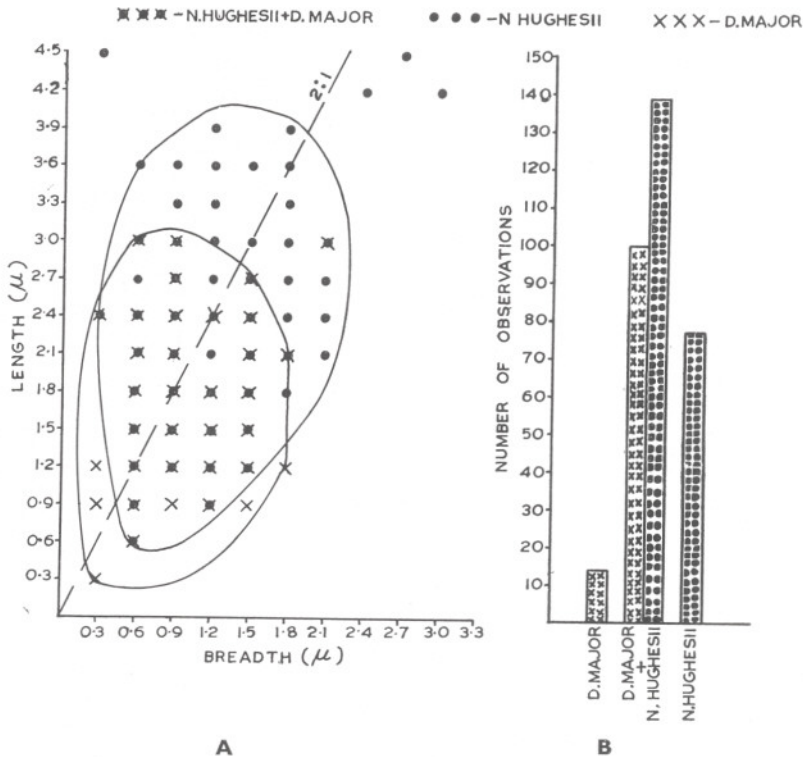
Biometric resolution of D. major and Neomariopteris hughesii—*Dichotomopteris major* and *Neomariopteris hughesii* can be easily



TEXT-FIG. 16 — *Neomariopteris hughesii* (Zeiller) Maithy. Frequency curves showing variation in the number of sculptural elements along spore equator.

distinguished at generic level on the basis of their morphological characters. But the morphology of the spores of these plants is so similar that it may be difficult to create even two species out of them. Both ferns produce spores with a heterogeneous sculpture of conic to spines, intermixed with some baculate elements. Besides, both species exhibit parallel variation trends in the shape, size, spacing and equatorial number of sculptural elements. As this problem has a bearing on the identification of dispersed spore species we have carried out a comparative biometric analysis of the two *in situ* spore populations. The parameters selected for the study are (i) length vs. breadth (of sculptural elements), and (ii) spore diameter vs. sculptural elements.

The length/breadth ratio of sculptural elements of the two species is plotted in the scatter diagram (Text-fig. 17A). The 2:1 ratio line is purposely drawn to demarcate the boundary between cone and spine. The pronounced overlap between the two species is notable. The overlap represents about 80% of cases in which *N. hughesii* slightly exceeds *D. major* (Text-fig. 17B). The diagram also shows that *D. major* has a relatively smaller size range for the ornament as compared to *N. hughesii*. Unfortunately in the overlap free zones the proportion of cones and spines is nearly equal in both the species and does not provide any guideline. Perhaps a feature of some use is the occurrence of higher L/B ratio of both cones and spines in *N. hughesii*. Indeed, these and other interpretations of the diagram could be a good exercise so long as we know for certain that the two taxa are distinct but



TEXT-FIG. 17A, B— Comparison of variation patterns in *Dichotomopteris major* (Feistm.) Maithy and *Neomariopteris hughesii* (Zeiller) Maithy. A. Length vs. breadth of sculptural elements. The pattern shows a rather strong overlap between the two species. B. Histogram showing a number of observations in each species represented in the scatter diagram 17A.

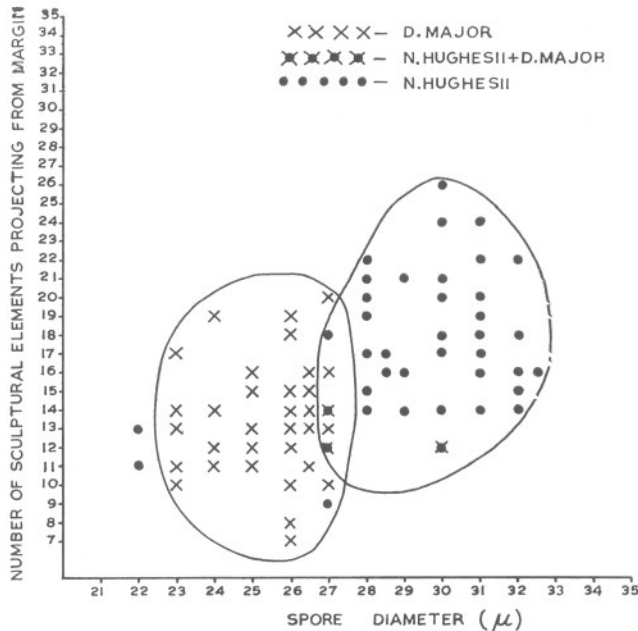
it would be extremely difficult to discriminate the two spore populations if found mixed up as in dispersed state.

The other parameter, i.e. equatorial sculptural number vs. spore diameter is shown in the graph (Text-fig. 18). It is clear that the two criteria show no correlation in *D. major* and *N. hughesii* individually. But when the patterns of the two species are plotted side by side, as in Text-fig. 18, it becomes evident that they form nearly distinguishable groups with slight overlap. On the whole, sculptural number in *N. hughesii* is greater than in *D. major*. This probably also supports the observation that where the longer elements are dominant they are also more crowded.

Discussion— Maithy (1974a) erected *Neomariopteris hughesii* and emended it in 1975 but he could not recover sporangia and spores from his specimens. Maithy's material was studied carefully by us and

it was possible to recover sporangia and sufficient spores. Generally, 5-6 sporangia are arranged in a rosette. It is suspected that they possess some kind of annulus but this needs confirmation by further study. The available information on *N. hughesii* now increases the possibility of its identity with *Damudopteris* Pant and Khare (1974) as already pointed out by Maithy (1977). *Damudopteris* has annulate stalked sporangia (Pant & Khare, 1974). It may, however, be pointed out that fertile specimens described as *Damudopteris polymorpha* by Pant and Khare (1974) are more likely to belong to *N. hughesii*.

The spores recovered by Pant and Khare from the fertile specimens of *D. polymorpha* are identical with those now described by us from *N. hughesii*. Pant and Khare consider the spores as echinate and compare them more closely with the dispersed genus *Acanthotriletes* (specially spores figured by



TEXT-FIG. 18 — Comparison of variation patterns in *Dichotopteris major* (Feistm.) Maithy and *Neomariopteris hughesii* (Zeiller) Maithy. The scatter diagram shows the relationship between spore diameter and sculptural elements along spore margin on the basis of which the two species are distinguishable.

Bharadwaj, 1962, pl. 1, figs 22-28, as cf. *Acanthotriletes* from the Raniganj Stage). There is no denying the fact that at least a part of the population of *N. hughesii* which is dominantly spinose will go to *Acanthotriletes*. But the greater majority would be assignable to *Lophotriletes* on the basis of the prevailing conate ornament.

GENERAL DISCUSSION

The studies carried out by Maithy (1974a, 1974b, 1975, 1977) and almost concurrently by Pant and his associates (1974, 1976, 1977) have considerably advanced our knowledge of the Lower Gondwana ferns. An important result of these contributions is that our ferns are shown to be distinct in their morphology and fertile structures from the north hemispheric taxa like *Sphenopteris*, *Pecopteris*, *Alethopteris*, *Merianopteris*, *Ptychocarpus*, etc. One problem has, however, arisen out of the differences in the interpretation and identification of the fern taxa erected by Maithy on one side and by Pant *et al.* on the other. They have created four taxa each

from the same area and horizon. A taxonomic overlap between the two sets of genera is evident. We have examined, Maithy's material and also some new specimens which have yielded some new information concerning the sporangia and spores. This may partially help to bridge the difference between the genera of Maithy and Pant *et al.* At present we prefer to keep the question open and would consider it more useful to take stock of the existing status of our knowledge on the Lower Gondwana ferns (Table 1).

All the known Lower Gondwana ferns are exindusiate. Some of them have compact groups (sori) of free sporangia which may be scattered over the pinnules (*Neomariopteris* Maithy, *Damudopteris* Pant & Khare) or may be arranged in marginal position (eg. *Dizeugotheca* Archangelsky & Sota) or in rows between the margin and midvein of the pinnules (eg. *Dichotopteris lindleyi* Maithy, *Trithecopteris* Pant & Misra). Sporangia are absent from the apical part of the pinnules but may be continuous in the sinuses between pinnules (eg. *Dizeugotheca* Archangelsky &

TABLE 1

IDENTIFICATION BY MAITHY	IDENTIFICATION BY PANT <i>et al.</i>	PRESENT OBSERVATIONS
1. <i>Dizeugetheca phegopteroides</i>	1. <i>Asansolia phegopteroides</i>	1. <i>Dizeugetheca phegopteroides</i>
Sori marginal with four free sporangia; spores trilete, conate, cf. <i>Apiculatisporis inconspicuus</i>	Tetrasporangiate synangia marginal; spores monolete, echinate, cf. <i>Verrucosporites</i>	Sporangia characters as given by Maithy; spores trilete to monolete, circular to oval, variation wide, dominantly conate, cf. <i>Apiculatisporis</i> , <i>Ghoshiasporites</i>
Lectotype—No. 5183, G.S.I., Calcutta	Lectotype—No. 5183, G.S.I., Calcutta	
Isotype—35104, B.S.I.P., Lucknow	Fertile duplicates—5030, 5068, 5073, 5063, Botany Department, Allahabad University	Material—Maithy's type and others.
2. <i>Dichotomopteris lindleyi</i>	2. <i>Trithecopteris gondwanensis</i>	2. <i>Dichotomopteris lindleyi</i>
Sori in single row between margin and midvein at vein endings, sporangia 6-8, free; spores trilete, punctate, cf. <i>Eupunctatisporites poniatiensis</i>	Sori position as given by Maithy, trisporangiate synangia, stalks fused, exannulate; spores trilete, punctate	Isolation of intact sori was not possible; spores circular trilete, microbaculose, cf. <i>Cyclobaculispores</i>
Holotype—V 4192, British Museum (N.H.), London	Holotype—No. 5302, Botany Department, Allahabad University	Material—Maithy's type and others.
Isotypes—5184, G.S.I., Calcutta & 8669, B.S.I.P., Lucknow		
3. <i>Dichotomopteris major</i>	3. <i>Damudosorus searsolensis</i> & <i>D. raniganjensis</i>	3. <i>Dichotomopteris major</i>
Sori arranged in single row between margin and midvein in the basal part, 5-6 sporangiate, sporangia structure not known; spores triangular; trilete, baculate cf. <i>Horriditriletes curvibaculosus</i>	Four pairs of sori on two sides of midvein, in basal part, sporangia 4-6; annulate, stalked; spores triangular, trilete, echinate	Annulus on stalked sporangia observed; spores rounded triangular, dominantly conate, admixture of spines, bacula, cf. <i>Lophotriletes</i> , <i>Acanthotriletes</i> , rarely <i>Horriditriletes</i>
Holotype—5194, G.S.I., Calcutta	Holotype—5080 & 5072, Botany Department, Allahabad University	Material—Maithy's type and others
Isotype—35105, 35106, B.S.I.P., Lucknow		
4. <i>Neomariopteris hughesii</i>	4. <i>Damudopteris polymorpha</i>	4. <i>Neomariopteris hughesii</i>
Sori on veinlet endings, a little away from margin, probably 4-6 sporangiate, other details not known; spores not described	Sori scattered, sporangia 2-9, incomplete transverse annulus, short stalk; spores triangular, trilete, echinate, cf. <i>Acanthotriletes</i>	Sori scattered, 4-6 sporangiate, probably annulate; spores triangular, trilete, dominantly conate, admixture of spines and rarely bacula, cf. <i>Lophotriletes</i> , <i>Acanthotriletes</i> , rarely <i>Horriditriletes</i>
Lectotype—5207, G.S.I., Calcutta	Lectotype—5165, G.S.I., Calcutta.	Material—Same as of Maithy (1974a).
Fertile duplicate—35113, B.S.I.P., Lucknow	Fertile duplicates—K.P., 7024 K.P. 7206 A.B. Botany Department, Allahabad University	

Sota). Synangiate condition has also been described by Pant *et al.* (*Aasansolia*, *Trithecopteris*). Some genera have exannulate sporangia (cf. *Dizeugetheca*) while others are annulate (*Damudosorus*, *Damudopteris*, *Dichotomopteris*).

The epidermal and other structural features of these ferns have been largely

described by Pant and his associates. The pitted xylem and delicate, acid-nonresistant cuticle, having stomata with two neighbouring cells all go to confirm that the plants are ferns.

A considerable amount of data on the morphology of spores has come out of the present study. All the four species investi-

gated have triangular or circular (rarely oval) spores with well-marked ornamentation of microbacula, coni, spines and rarely bacula and verrucae. All species have trilete spores but in one case (*Dizeugotheca*) a wide range of transition from trilete to monolete has been noted. Similarly a wide variability in spore ornamentation is expressed in some fern species (*Neomariopteris hughesii* and *Dichotomopteris major*) while other species have more or less consistent ornamentation pattern (*Dizeugotheca phegopteroides*, *Dichotomopteris lindleyi*).

The affinities of the Lower Gondwana ferns still remains rather obscure. Maithy (1974a) compared them with the families—Marattiaceae, Gleicheniaceae, Osmundaceae and Schizaeaceae and pointed out that the Marattiaceae, a rather comprehensive group, stands nearer to our ferns than any other families. Pant (1976) and Pant and Misra (1977) have grouped the ferns in two families. The Damudopteridaceae, a new family, contains the ferns characterized by free eusporangia with a transverse annulus. The Damudopteridaceae, notwithstanding its obscure affinity, is set well apart from the northern Palaeozoic ferns. The other family, viz., Asterothecaceae, which includes the synangiate ferns, is apparently close to the Marattiaceae. On the whole, the morphological and reproductive evidences point out that the southern stock of ferns has its own peculiarities. It may also be noted that the northern ferns (Marattiaceae, etc.) are older (Carboniferous) than the Lower Gondwana ferns (Permian). The relationship of the southern ferns (Gondwana) with those of the northern alliance is, therefore, a matter of considerable interest from phytogeographical standpoint as well.

The question of affinities can be viewed from the angle of spore evidence. In Table 2, the salient features of spores of some relevant Palaeozoic fern genera are given family-wise. A glance at the table makes it readily clear that almost all the Asterothecaceae spores are generally smooth or at best have a finer grade of ornamentation (puncta, grana). On the contrary, the Lower Gondwana fern spores, as far as known, have distinctly larger and more varied, apiculate sculpture. Similarly, the spores of other families also differ widely

from our fern spores. Thus, it may be contended that broadly speaking the sculptural quality of the Lower Gondwana fern spores is distinguishable from those of northern Palaeozoic ferns. The spore evidence thus lends support to the distinctiveness of our Lower Gondwana ferns.

We have made an initial attempt to study the spores under the Scanning Electron Microscope. There is no doubt that with proper selection of specimen and good processing, the SEM technique can reveal the details of morphology which can substantiate or improve the observations made under the optical microscope. The SEM has helped us in understanding the exact details of the spore sculpture, especially the tips of the elements, the nature of the trilete mark and other finer morphological details. Such additional data which the SEM can provide, does not in any way lessen the value and application of optical microscopy.

Our experience also indicates that a rational application of biometry is very useful in forming clear-cut ideas about morphological variations which are so natural to plant structures. We have, therefore, made enough use of biometric methods in resolving spore variations which are quite pronounced in the same sporangium of certain fern species. Some significant points which have emerged from the biometric assessment can be summarized here because of their bearing on the study of dispersed spore populations.

1. The species *Dizeugotheca phegopteroides* is an example where trilete to monolete spores occur in the same sporangium and a whole series of gradation can be noticed. The shift in the tetrad mark from trilete to monolete seems to correspond with a shift in the spore shape from circular (radial) to oval (bilateral). The trilete and monolete spores will certainly fall under different genera of dispersed spores although actually they belong to a single plant species. Thus there cannot be any strict correlation between megaplant species and disperse spore species in a fossil association.

2. A situation quite opposed to the above, is demonstrated by the spores of *D. major* and *N. hughesii*. Here the plants are morphologically distinct as genera but their spores are so similar in sculptural pattern

(generally conate to spinose), that the two species can hardly be distinguished. In dispersed state the two populations will almost surely fall within a single species. This result also indicates lack of correlation between mega- and microfossil entities. Similar conclusions have been drawn by Pfefferkorn *et al.* (1971) from a review of 170 species of Marattiaceae (Palaeozoic). For example, the granulate spores are shared by the genera *Asterotheca*, *Acitheca*, *Danaeites*, and *Ptychocarpus*. Even in these, 12 species of *Asterotheca* + *Acitheca* are trilete whereas 18 species of *Asterotheca* + *Danaeites* + *Ptychocarpus* are monolete. A glance at Table 2 will further elucidate the point that spore taxa based on ornament or mark

do not correspond numerically with mega-fossil genera.

3. The number of elements along the spore equator and the distance between the elements are the features which may be very variable at least in some species, for instance, in *D. major* and *N. hughesii*. These features obviously lose their value in characterizing individual species. However, the variation patterns of the two species when plotted side by side, are found to be taxonomically useful (Text-fig. 18).

4. In most cases, the frequency curves are not normal, i.e. like a polygon. Instead, a number of peaks can be noticed in the various graphs. One of these peaks is, however, highest and on its either side the other lower peaks are in a roughly des-

TABLE 2 — SALIENT FEATURES OF *IN SITU* SPORES OF SOME IMPORTANT FOSSIL FERNS (SOURCE OF INFORMATION, POTONIÉ, 1962)

	SHAPE	MARK	ORNAMENT	COMPARABLE GENERA (dispersed)
Eusporangiatae Asterothecaceae				
<i>Asterotheca</i>	circular to oval	trilete to monolete	grana, coni, verrucae	<i>Latosporites</i> , <i>Cyclogranisporites</i>
<i>Pecopteris</i>	circular	trilete	smooth	—
<i>Acitheca</i>	circular	trilete	grana	<i>Cyclogranisporites</i>
<i>Boweria</i>	—	trilete	smooth	<i>Leiotriletes</i>
<i>Cyathotrachus</i>	—	monolete	—	<i>Laevigatosporites</i>
<i>Discopteris</i>	triangular	trilete	smooth	<i>Leiotriletes</i>
<i>Eoangiopteris</i>	circular	trilete	reticulum	—
<i>Marattiopsis</i>	circular	monolete	grana	<i>Punctatosporites</i>
<i>Ptychocarpus</i>	oval to circular	trilete, monolete	smooth, grana	<i>Cyclogranisporites</i>
<i>Scolecopteris</i>	triangular to circular	trilete to monolete	smooth microreti- culum, rugae, tubercles	<i>Microreticulatisporites</i>
Leptosporangiatae Schizaeaceae				
<i>Anemia</i>	—	trilete	canaliculae	<i>Cicatricosisporites</i>
<i>Lygodium</i>	triangular	trilete	smooth grana, fine puncta	<i>Deltoidospora</i>
<i>Pelletieria</i>	triangular	trilete	cicatticules	<i>Cicatricosisporites</i>
<i>Ruffordia</i>				
<i>Schizaeopsis</i>				
<i>Senftenbergia</i>	circular	trilete	crisetae, coni, bacula	<i>Camptotriletes</i> , <i>Raistrickia</i>
Gleicheniaceae				
<i>Gleichenites</i>	triangular	trilete	smooth	<i>Deltoidospora</i>
<i>Oligocarpia</i>	circular	trilete	smooth, puncta	<i>Leiotriletes</i>

ending order. It can be imagined that if all the peak-points are joined, an approximate normal curve will appear. This is why the cumulative curves or the group-average curves are found to be relatively regular and more purposeful. It is our impression that larger the number of observations better is the result.

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EXPLANATION OF PLATES

(All the figured specimens and slides are preserved at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow).

PLATE I

1. *Dizeugotheca phegopteroides* (Feistm.) Maithy. A good fertile specimen showing characteristic features of the species. Regd. no. 35349. × 1.
2. *Dizeugotheca phegopteroides* (Feistm.) Maithy. Two fertile pinnules from the above specimen enlarged to show the marginal, contiguous arrangement of sori, × 6.

- 3-9. Variety of spores from the sporangia of *D. phegopteroides* (Feistm.) Maithy. 3-5. Radially symmetrical spores. Broad-based conate ornament is noteworthy. The trilete mark is off-centre in fig. 3, slide nos. 6051, 6051, 6052. × 2000. 6. Note the trilete mark in which the longer ray is not parallel to the longer spore axis, slide no. 6051. × 2000. 7. Laterally compressed specimen indicating anisopolar nature

of the spore, slide no. 6053. $\times 2000$. 8, 9. Bilaterally symmetrical monolete spores. The monolete is straight or slightly bent in the middle as in fig. 9. A very short ray appears to emerge from the middle of the monolete mark in fig. 8 (Monoletoid). The ornament is typically conate, slide nos. 6053 and 6052. $\times 2000$.

PLATE 2

10. *Dichotopteris lindleyi* (Royle) Maithy. A fertile specimen from Maithy's original study (Maithy, 1974b) rephotographed. The arrangement of sori on pinnules is noteworthy. Regd. no. 35110. $\times 2$.
11. *Dichotopteris lindleyi* (Royle) Maithy. Another small fertile specimen from which spores have been isolated in this study. Regd. no. 35350. $\times 2.5$.
- 12-19. Variety of spores from the sporangia of *D. lindleyi* (Royle) Maithy. 12. A folded specimen showing well-developed microbaculate ornament, slide no. 6054. $\times 1000$. 13. The ornament appears to be more conate in this particular case. slide no. 6055. $\times 1000$. 14. A relatively smaller specimen with smaller grade of microbaculate and rugose sculpture, slide no. 6054. $\times 1000$. 15. The spore shows a well-developed ornament of mostly microbacula mixed with some conate elements. The trilete rays have prominent lips and suture, slide no. 6055. $\times 1000$. 16-17. Two small immature spores showing underdeveloped ornament (grana to coni). In fig. 17 the trilete mark is accompanied by folds, slide nos. 6054 and 6055. $\times 2000$. 18, 19. Enlarged view of microbaculate ornament. The elements tend to become pilose (fig. 18). Smaller coni or verrucae may be seen rarely between the bacula along margin (fig. 19), slide nos. 6056 and 6055. $\times 2000$.

PLATE 3

20. *Dichotopteris major* (Feistm.) Maithy. A good fertile specimen showing characteristic features of the species. Regd. no. 3531. $\times 1$.
21. Part of pinna from the above specimen enlarged to show arrangement of sori on basal 3/4 portion of pinnules. $\times 3$.
22. Two sporangia from the above specimen showing thick transverse annulus and stalk. $\times 40$.
- 23-32. Variety of spores from the sporangia of *D. major*. 23. Dominantly conate ornament, slide no. 6057. $\times 1000$. 24. Fairly sparse coni noteworthy, slide no. 6057. $\times 1000$. 25. Admixture of conate and spinose ornament, slide no. 6057. $\times 1000$. 26, 27. Two laterally compressed spores showing typical folding of exine to form lobe; conate ornament dominant; spines rare, slide no. 6057. $\times 1000$. 28. Mixed ornament of

cones, spines and bacula, tips of bacula are blunt or conate, slide no. 6057. $\times 2000$. 29. Ornament of sparse, sharp pointed cones and a few setose processes, slide no. 6058. $\times 2000$. 30. Ornament of rather irregularly shaped cones bordering on verrucae, slide no. 6058. $\times 2000$. 31. Ornament bordering on cone/spine. Enlargement of spore in fig. 8. $\times 2000$. 32. Conate ornament. Some cones appear to have a bulbous base and a fine apical process, slide no. 6057. $\times 2000$.

PLATE 4

33. *Neomariopteris hughesii* (Zeiller) Maithy. Iso-type of Maithy (1974a) rephotographed. Regd. no. 35113. $\times 2$.
- 34-42. A variety of spores from the sporangia of *N. hughesii*. 34. Curved spinose ornament more common, slide no. 6061. $\times 1000$. 35. Spine-like and setose ornaments distinct, slide no. 6059. $\times 1000$. 36. Conate ornament and open trilete mark notable, slide no. 6060. $\times 1000$. 37. Conate sculpture, slide no. 6059. $\times 1000$. 38. Stout blunt conate ornament and a few setose processes seen, slide no. 6060. $\times 1000$. 39. Spinose ornament and characteristic exinal folding notable, slide no. 6060. $\times 1000$. 40. Admixture of cones, spines with a few bacula and setose elements noteworthy, slide no. 6059. $\times 2000$. 41. Conate ornament, some cones seem to bear a fine apiculate process at the tip, slide no. 6059. $\times 2000$. 42. Processes bordering on cones or spines. A few baculate elements have conate tips, slide no. 6059. $\times 2000$.

PLATE 5

- 43, 44. *Dizegotheca phegopteroides* (Feistm.) Maithy. SEM photograph of two spores. The ornament is generally more pronounced and crowded on the distal side as in fig. 43. $\times 3300$. Broad bases of cones tend to fuse. Monolete mark is clear in fig. 44. $\times 4700$.
- 45, 46. *Dichotopteris lindleyi* (Royle) Maithy. SEM photomicrograph of two spores. The microbaculate elements are short and quite crowded. Through fusion they may produce rugulate appearance. The trilete rays (fig. 46) are distinctly raised and also bear similar ornament. In fig. 45, the raised triradiate fold gives a false appearance of a mark. Fig. 45. $\times 1200$; Fig. 46. $\times 1500$.
- 47, 48. *Dichotopteris major* (Feistm.) Maithy. SEM photomicrograph of two spores. Admixture of coni and spines (curved) is noteworthy. The trilete mark is seen in fig. 48. $\times 2300$ (all).
- 49, 50. *Neomariopteris hughesii* (Zeiller) Maithy. SEM photomicrograph of two spores. Admixture of variously shaped spines, coni and bacula is noteworthy. Fig. 49. $\times 2350$; Fig. 50. $\times 1900$.

