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MORPHOLOGICAL AND STRUCTURAL STUDIES ON SOME BARAKAR MEGASPORES

K. M. LELE & A. K. SRIVASTAVA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

The paper describes megaspores belonging to the genera *Srivastavaesporites*, *Trilaevipellitis*, *Jhariatriletes*, *Talchirella* and *Barakarella* gen. nov. recovered from the Lower Barakar shales of Churulia area, East Raniganj Coalfield, West Bengal. Megaspores have been studied both under dry as well as under wet conditions through controlled maceration. The exosporium and inner body have been found in all the megaspores. Particular attention has been given to the morphological features of the inner body and their taxonomic value is stressed. *Barakarella* gen. nov. is characterized by a baculose outer exosporium and cushioned inner body.

Key-words — Megaspores, Morphology, *Barakarella*, East Raniganj Coalfield, Lower Permian (India).

सारांश

कुछ वाराकार गुरुबीजाणुओं का आकारिकीय एवं संरचनात्मक अध्ययन – केशव मुकुन्द लेले एवं अश्विनी कुमार श्रीवास्तव

पूर्व रानीगंज कोयला-क्षेत्र (पश्चिमी बंगाल) में चुरुलिया क्षेत्र के अधरि बाराकार शैलों से उपलब्ध श्रीवास्तविस्पोराइटिस, ट्राइलेविपेलिटिस, झरियाट्राइलिटीज़, तालचिरेल्ला एवं बाराकारेल्ला नव वंश के गुरुबीजाणु वर्णित किये गये हैं। नियंत्रित मसृणन द्वारा गुरुबीजाणुओं का शुष्क अवस्था तथा आर्द्र अवस्था में अध्ययन किया गया है। सभी गुरुबीजाणुओं में बीजाणु-बाह्यःचोल एवं आन्तर पिंड पाये गये हैं। आन्तर पिंड के आकारिकीय संलक्षणों को विशेष महत्व दिया गया है तथा इनके वर्गीकर्णिक महत्व पर बल दिया गया है। बाराकारेल्ला नव वंश दंडाकार बीजाणु-बाह्यःचोल एवं आन्तर पिंड से अभिलक्षणित है।

INTRODUCTION

THE presence of different and distinct exine layers in fossil megaspores has been known to palynologists for several decades but the value of these structural features in the taxonomy of megaspores became evident only with the work of Høeg, Bose and Manum (1955) who describes a two-layered megaspore, *Duosporites congoensis*, from the Permian of Zaire. The possibility of separating the layers from each other through a controlled progressive treatment, in mild alkali (1-2%), opened a new scope for studying the characters of the two layers, particularly the inner layer (mesosporium or intexine of authors).

The structural studies carried out by Pant and Srivastava (1962) revealed a number of features, especially the inner layer, which further helped in the identification of megaspores. According to them there could be as many as three layers. They suggested a proposal for classifying those megaspores under Megasporites in which knowledge of layers existed and left others to Triletes wherein only external features were known.

A more comprehensive study of Lower Gondwana megaspores by Bharadwaj and Tiwari (1970), however, revealed that these megaspores have only two layers. The inner layer (innerbody, intexine, etc.) is of two types: (i) with cushions and separated from exoexine in all sides except near the proximal region, and (ii) without cushions and separated or attached to the exoexine.

Lele and Chandra (1974) found that the trilete trace on Talchir megaspores shows variation in its extent and the extension of cushions also correspondingly varies. This probably indicates that while in some megaspores the inner body was attached to the exoexine along the entire proximal region (as evidenced by the full length of mark and cushions on it), in other cases the attachment was partial (as evidenced by the short mark and correspondingly short radial extensions of cushions).

The present investigation of megaspores from the Lower Barakar shales of Churulia in the East Raniganj Coalfield (type locality for all new species) has provided further insight into megaspores wall structure and sculpture. The inner bodies have been separated in a large number of cases to enable a more detailed study of the trilete trace, inter-ray area of attachment and the nature of cushions. All the type slides and figured specimens are preserved in Birbal Sahni Institute of Palaeobotany Museum.

MATERIAL AND METHODS

Samples for the investigation have been collected from a section exposed in a quarry about 250 m east of Churulia Railway Station (23°47′15″/87°:5′16″) in the north-eastern part of the East Raniganj Coalfield. The samples have yielded a rich miofloral assemblage having a Lower Barakar affinity (Srivastava, 1982).

The samples have been treated with Schultz's solution and the megaspores have been picked up with the help of zero number brush under a low power binocular microscope. Dry megaspores have been studied under incident light. The trilete mark and arcuate ridges could be best studied in the dry state but the sculpture was not always very clearly brought out. Sometimes megaspores were moistened with a drop of water to better observe the details of surface ornamentation.

To study the structural details of the exine layers, individual megaspores were treated with 1-5% KOH solution for 2 to 10 minutes. Higher concentration of the alkali and longer treatment was required only for those megaspores which possessed dark-coloured inner body. Photographs have been taken at different stages of controlled maceration which gradually dissolved the exoexine and released the inner membrane. Reaction could be withheld at a particular phase by adding water and both membranes, with some details of each, could be photographed (optimum condition). In general, the inner body comes out easily when most of the exoexine had been dissolved. The inner body is generally thin and transparent but it is resistant enough to alkali treatment. In a few specific cases remains of exoexine would seem to be sticking hard to the intexine in the apical region. Preparations have been mounted in canada balsam with the help of polyvinyl alcohol. Some of the inner bodies have been stored in vials for special studies.

Photographs at different stages of maceration have been taken on 35 mm, 10 Din microfilm under Carl Zeiss Microscope. Some photographs have also been taken under Leitz dialux microscope 20 EB with phase contrast and ordinary light optics.

SYSTEMATIC DESCRIPTION

Genus — *Trilaevipellitis* Kar emend. Bharadwaj & Tiwari, 1970

Type Species — *Trilaevipellitis psilatus* Kar emend. Bharadwaj & Tiwari, 1970.

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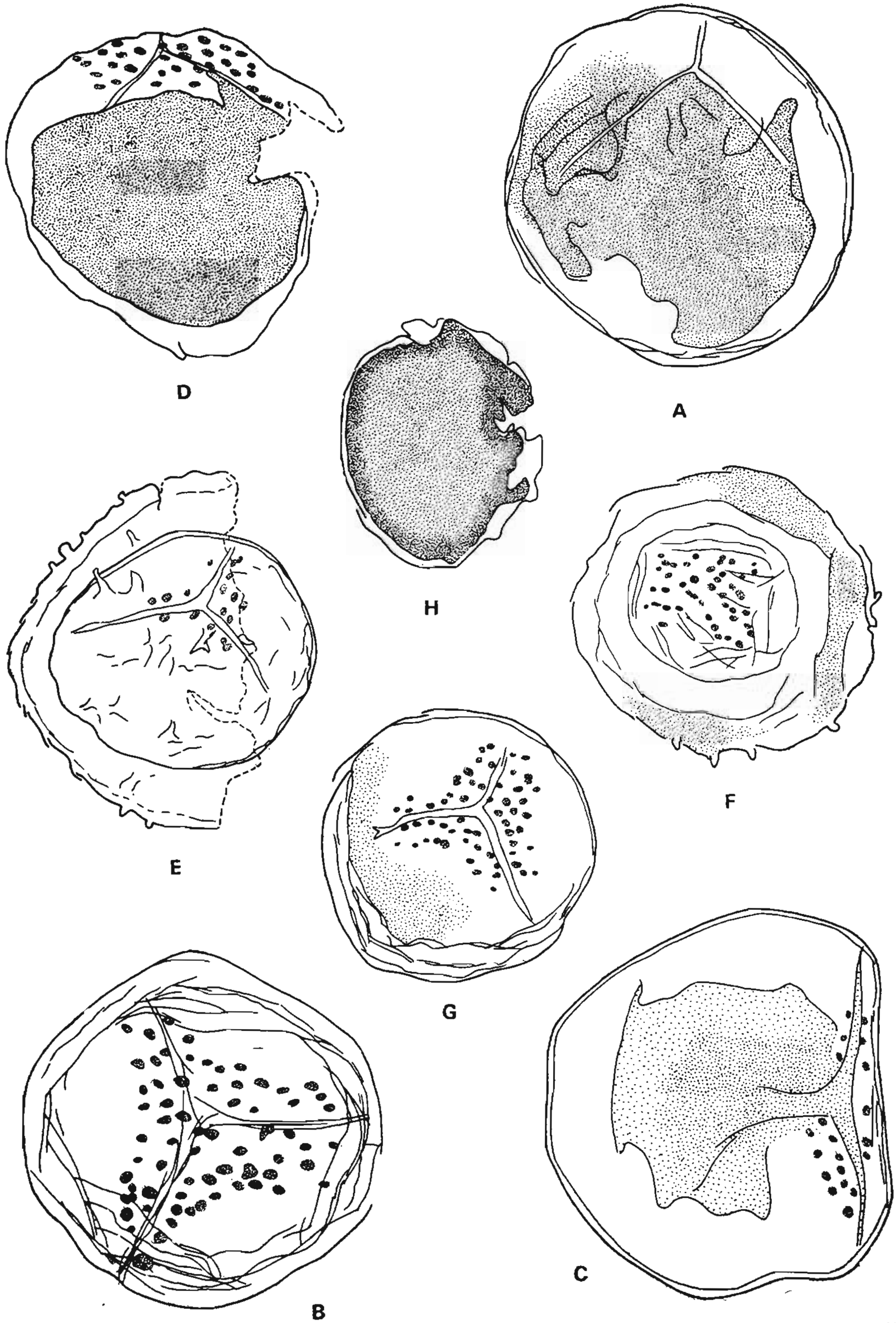
TEXT-FIG. 1 — **A**, *Srivastavaesporites indicus* showing the dark coloured inner body with distinct trilete trace, × 110. **B**, *Talchirella trivedii* showing the inner body where number of cushions are arranged trigonally along the trilete trace, × 110. **C**, *T. raniganjensis* showing the inner body with biseriate arrangement of cushions, × 150. **D**, *T. nigra* sp. nov.— holotype showing the dark coloured inner body with distinct trilete trace and cushions, × 110. **E**, *Barakarella churuliaensis* gen. et sp. nov.— holotype showing the baculate ornamentation and cushioned inner body with distinct trilete trace, × 110. **F**, *B. pantii* sp. nov. — holotype macerated stage of the megaspores where the outer coat and inner body with cusions are clearly visible, × 110. **G**, *B. pantii* sp. nov. showing fine punctate to granulose inner body where the cushions are arranged along the trilete trace, × 110. **H**, *Jhariatriletes densus* sp. nov.— holotpye showing thick dark coloured inner body, × 110.



TEXT-FIG. 1

Trilaevipellitis multipulvinatus sp. nov.

Pl. 1, figs 1, 2; Text-fig. 2

Diagnosis — Circular to subcircular; smooth surface, trilete mark distinct, rays 4/5 radius long, simple, straight delimited by low arcuate ridges; inner body thin, large, circular, well-defined, smooth to fine granulose, trilete trace on inner body distinct, 3/4 to 4/5 of radius; microfolds present; cushions 60-80, small, 5-10 µm in diameter, irregularly distributed in the inter-ray area forming a trigonal zone (Pl. 1, fig. 2; Text-fig. 2).

Holotype — Pl. 1, fig. 1; slide no. B.S.I.P. 6446.

Dimensions — Wet megaspore: 500-650 µm, dry 220-300 µm; inner body 475-600 µm; cushions 60-80, 5-10 µm.

Comparison — The present species differs from *T. psilatus* Kar emend. Bharadwaj & Tiwari in having large number of cushions scattered in the trigonal area. *T. talchirensis* Lele & Chandra (1974) is distinguishable by possessing uniseriate, distinct cushions and also by its indistinct trilete mark.

Remarks — Lele and Chandra (1974) have erroneously compared *Trilaevipellitis talchirensis* with the verrucose-granulose megaspore, *Talchirella nitens* Bharadwaj & Tiwari.

Genus — *Srivastavaesporites* Bharadwaj & Tiwari, 1970

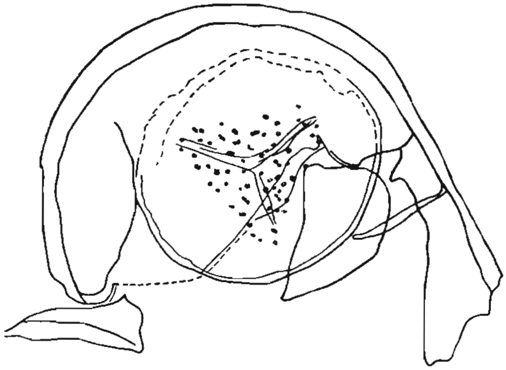
Type Species — Srivastavaesporites karanpuraensis Bharadwaj & Tiwari, 1970.

Srivastavaesporites indicus (Singh) Bharadwaj & Tiwari, 1970

Pl. 1, figs 3, 4; Text-fig. 1A

Dimensions — Wet megaspores 600-800 µm, dry 450-700 µm; inner body 550-750 µm.

Description — Megaspores subcircular to subtriangular in shape. Surface granulose to verrucose, verrucae sparsely distributed. Trilete mark distinct to indistinct, rays 3/4 of radius, simple, raised and straight. Arcuate ridges mediumly curved. Inner body thick, dark brown but not uniform in colour and density, some portions being darker than others, perhaps due to affects of alkali treatment, wall of the inner body infrapunctate and sometimes with the thick secondary folds. Trilete trace faintly discernible in some inner bodies, rays at least 3/4 radius or longer and may be raised by associated folds.



TEXT-FIG. 2 — *Trilaevipellitis multipulvinatus* sp. nov. — holotype showing smooth outer coat and large number cushioned inner body, × 185.

Srivastavaesporites sp.

Pl. 1, figs 5, 6

Dimensions — Wet megaspores 700-750 µm, dry 450-530 µm; inner body 700-725 µm.

Description — Megaspores circular to subcircular in shape with finely verrucose surface. Trilete mark prominent, rays straight, extending 4/5 of radius. Arcuate ridges show low curvaturae. Inner body separating only by drastic alkali treatment, nearly fits within spore cavity, trilete trace distinctly marked on inner body for about 4/5 of radius.

Comparison — In the presence of a finely verrucose exoexine and the absence of cushions on the inner body, the specimen is referable to *Srivastavaesporites*. The distinct trilete mark with low arcuate ridges and the large size of the inner body of the present specimens are comparable with *S. karanpuraensis* but there are some notable differences also. *S. karanpuraensis* has sinuous trilete rays and the inner body and its trilete trace are both indistinct. On the contrary, the present specimens have straight trilete rays, distinct inner body with a well-developed trilete mark. Species of *Banksisporites* Dettman emend. Banerji, Kumaran & Maheshwari described by Banerji *et al.* (1978) are difficult to compare as no details of inner body are given by them.

Genus — *Talchirella* Pant & Srivastava emend. Bharadwaj & Tiwari, 1970

Type Species — *Talchirella trivedii* Pant & Srivastava emend. Bharadwaj & Tiwari, 1970.

Talchirella trivedii Pant & Srivastava emend. Bharadwaj & Tiwari, 1970

Pl. 1, figs 7-10; Pl. 2, figs 11-13; Text-fig. 1B

Dimensions — Wet megaspores 600-800 μm; dry 400-450 μm; inner body 550-675 μm; cushions 40-65, 10-20 μm.

Description — Megaspores circular to roundly triangular in shape, with a finely granulose to verrucose surface. Trilete mark distinct and confined to arcuate ridges, rays 3/4 and 4/5 radius in length. Arcuate ridges low to mediumly curved and show medium relief. Inner body circular and mediumly thick, trilete trace on inner body clearly visible, rays extending up to 3/4 of body radius and raised by folds, folds sometimes involve cushions. Cushions distinct, numerous (40-65), irregularly scattered in inter ray area, sometimes very close even fusing with one another.

Remarks — It is observed that during controlled treatment with mild alkali, the exoexine dissolves out easily but in the proximal region, it still adheres fast to the intexine (inner body) and is left as a dark trigonal patch surrounding the trilete traces on the inner body (cushion-bearing) (Pl. 2, fig. 11). Prolonged drastic alkali treatment may dissolve this dark patch, but still its impression is left to the inner body to some extent (Pl. 2, figs 12, 13). Obviously, the inter-ray area of the intexine is the region which is in intimate contact with the exoexine. The portions peripheral to the inter ray area are perhaps not involved in attachment and therefore are susceptible to secondary compression folds (Pl. 2, fig. 13).

Further, it has been observed by us that the inner body of this species has a distinct trilete mark with long rays. It is also experienced that the maceration of the inner body may reduce the clarity of the trilete trace. However, in optimum conditions a clear trace is seen on the inner body. Specimens of Bharadwaj and Tiwari (1970, pl. 4, fig. 5) as well as of Pant and Srivastava (1961, pl. 30, figs 8, 9) show only a faint impression of the trace. The number of cushions are much greater in the specimens of Bharadwaj and Tiwari (1970, 50-80) and Pant and Srivastava (1961, about 80-125). Besides these differences, the present forms are very similar to *T. trivedii.*

Talchirella raniganjensis Bharadwaj & Tiwari, 1970

Pl. 2, figs 14, 15; Text-fig. 1C

Dimension — Wet megaspores 700-800 μm, dry 480-620 μm; inner body 700-800 μm; cushions 20-35, 8-20 μm.

Description — Megaspores circular to subcircular in shape with finely verrucose to granulose surface. Trilete mark distinct, rays being 3/4 radius long, straight and simple. Inner body thin, occupying nearly whole space of the megaspore, in some cases showing remains of exoexine as a dark patch which is very difficult to remove as in *Talchirella trivedii*, trilete trace distinct over inner body. Cushions biseriately arranged along the trilete trace.

Talchirella media sp. nov.

Pl. 2, figs 16-18; Text-fig. 3

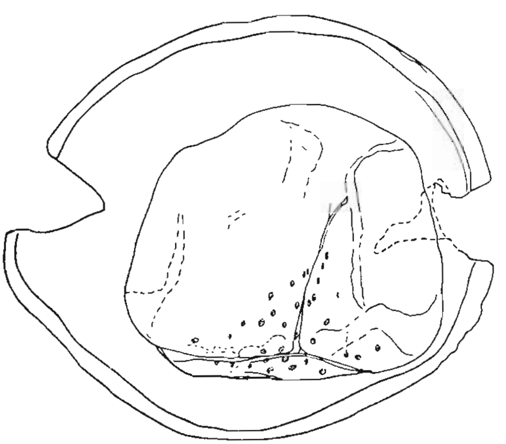
Diagnosis — Subcircular to roundly triangular megaspores, surface verrucose; arcuate ridges and mark in high relief; ridges mediumly curved, rays 3/4 to 4/5 radius long, straight. Inner body thin, subcircular to subtriangular; finely granulose or punctate; trilete trace distinct, rays 3/4-4/5 radius long, straight, associated with folds. Cushions 15-35, bold; irregularly distributed in inter-ray trigonal zone.

Holotype — Pl. 2, fig. 17; slide no. BSIP 6451.

Dimensions — Wet megaspores 560-700 μm; dry 500-650 μm; inner body 450-600 μm; cushions 15-35, 8-20 μm.

Remarks — The inner body in Pl. 2, fig. 18 is broken along the polar axis and both the halves show part of the cushion-bearing proximal area. It can also be noticed that the proximal surface of the inner body is darker than the distal one. It seems possible that the proximal half of the inner body was slightly thicker and differentiated from the distal half.

Comparison — *Talchirella media* sp. nov. compares with *T. vulgata* (Dijkstra) Bharadwaj & Tiwari (1970), *T. notabilis* Bharadwaj & Tiwari (1970) and *T. flavata* Bharadwaj &



TEXT-FIG. 3 — *Talchirella media* sp. nov.— macerated stage of megaspore showing the outer coat and cushioned inner body, × 185.

Tiwari (1970) in having fine verrucose-granulose surface and irregularly distributed cushions in the trigonal area but differs considerably in possessing mediumly curved arcuate ridges and also in the high relief of the ridges and trilete mark. The inner body of *T. media* sp. nov. shows bold cushions while the inner bodies of *T. vulgata*, *T. notabilis* and *T. flavata* have small and distinct cushions. *T. media* sp. nov. differs from *T. trivedii* in the smaller number of irregularly distributed cushions in the trigonal area and in the straight mark. *T. sparsa* Bharadwaj & Tiwari (1970) differs in having much smaller number of cushions (16-20), deeply curved arcuate ridges and sinuous trilete mark.

Talchirella nigra sp. nov.

Pl. 2, fig. 19; Text-fig. 1D

Diagnosis — Circular to subcircular megaspores, surface granulose to verrucose; trilete mark faint, rays 3/4 radius long, arcuate ridges clear, mediumly curved; inner body dense, dark brown, thick. Cushions 15-20, sparse, indistinct, scattered in a trigonal, zone in inter-ray area, trilete trace clear elevated by folds.

Holotype — Pl. 1, fig. 19; slide no. B.S.I.P. 6453.

Dimensions — Wet megaspores 550-700 μm, dry 400-500 μm; inner body 500-700 μm; cushions 15-20, 20-35 μm.

Remarks — The margin of inner body becomes thin during drastic alkali treatment but a large central area remains dark brown (Pl. 2, fig. 19). We suspect that in this species too, the contact region of the inner body was differentiated in a manner comparable with that in *T. trivedii* and *T. raniganjensis*.

Comparison — The thick dark coloured inner body of *T. nigra* sp. nov. and its scattered cushions are comparable with *T. densicorpa* Bharadwaj & Tiwari, 1970 but the former differs in having only a few indistinct and small cushions localized in the inter-ray area whereas the latter is characterized by massive cushions (15-25) distributed all over the inner body. The trilete mark in *T. nigra*, both on the megaspores as well as on the inner body is much more prominent than in *T. densicorpa*.

Genus — ***Barakarella* gen. nov.**

Type Species — *Barakarella churuliaensis* sp. nov.

Diagnosis — Circular to roundly triangular trilete megaspores; surface baculose; bacula ± parallel sided, small and having slightly expanded tips, fine grana or verrucae rarely present in between bacula; trilete mark distinct, rays simple, 3/4 of radius; arcuate ridges clear, mediumly curved, circumscribing the mark. Inner body with cushions.

Comparison — The new genus is closely comparable with *Jhariatriletes* in having baculose exine but the inner body of the latter is devoid of cushions which easily distinguishes it from *Barakarella* gen. nov. *Bacutriletes* v.d. Hammen ex Potonié has a baculose ornamentation. Since the internal features (inner body details) of this genus are not known, it is difficult to compare it with *Barakarella* gen. nov. *Talchirella* and *Duosporites* have cushioned inner bodies but differ in having verrucose-granulose exine sculpture.

Barakarella churuliaensis sp. nov.

Pl. 2, figs 20, 21; Pl. 3, figs 22-24; Text-fig. 1E

Diagnosis — Circular to subcircular megaspores, surface baculose, bacula 30-45 μm long and 10-18 μm broad, closely placed, tips occasionally flattened. Trilete mark prominent, rays 3/4 of spore radius, simple, of almost uniform width throughout; arcuate ridges clear, low relief, mediumly curved, mark confined to arcuate ridges. Inner body thin, circular to subcircular, trilete mark distinct, cushions 10-15 indistinct, scattered in trigonal zone in the inter-ray area, cushions small, ± circular, 8-12 μm in diameter.

Holotype — Pl. 3, fig. 23; slide no. B.S.I.P. 6454.

Dimensions — Wet megaspores 550-700 μm, dry 350-420 μm; inner body 500-650 μm; cushions 10-15, 8-12 μm.

Barakarella pantii sp. nov.

Pl. 3, figs 25-27; Text-fig. 1F, G

Diagnosis — Circular megaspores, surface with sparsely placed small-sized bacula, 15-25 μm long and 8-12 μm broad; fine grana and verrucae intermixed. Trilete mark indistinct, rays 3/4 of spore radius; arcuate ridges indistinct, mediumly curved and delimiting mark. Inner body mediumly thin, finely granulose or punctate, secondarily folded; trilete mark clearly visible; cushions 35-50, distinct, scattered in a trigonal zone within the inter-ray area; cushions circular to subcircular, variable in size, 10-20 μm in diameter.

Holotype — Pl. 3, fig. 26; slide no B.S.I.P. 6455.

Dimensions — Wet megaspores 400-600 μm, dry 250-370 μm; inner body 400-500 μm; cushions 35-50, 10-20 μm.

Comparison — *B. pantii* sp. nov. can be distinguished from *B. churuliaensis* by its sparsely placed small-sized bacula and larger number of bolder cushions. The species has an inner body which is closely similar to that of *Talchirella trivedii* Pant & Srivastava emend. Bharadwaj & Tiwari (1970) but the two megaspores are different in their exoexine characters.

Genus — *Jhariatriletes* Bharadwaj & Tiwari, 1970

Type Species — *Jhariatriletes baculosus* Bharadwaj & Tiwari, 1970.

Jhariatriletes densus sp. nov.

Pl. 3, figs 28-30; Text-fig. 1H

Diagnosis — Circular to subcircular megaspores; surface covered with sparsely placed, short bacula 10 to 20 μm long and 8-15 μm broad. Trilete mark indistinct, rays 3/4 to 4/5 of spore radius, simple; arcuate ridge indistinct, lowly curved. Inner body finely granulose, thick, dark brown in colour and without cushions and trilete trace.

Holotype — Pl. 3, fig. 30; slide no. B.S.I.P. 6457.

Dimensions — Wet megaspores 700-850 μm, dry 400-600 μm; inner body 600-800 μm.

Comparison — *Jhariatriletes densus* sp. nov. is distinct from all the known species in possessing a thick, dark brown inner body.

DISCUSSION

Although the exosporium of megaspore has been studied in the recent past from taxonomic point of view, but enough attention has not been paid to the structure and sculpture of the inner membrane (intexine or inner body). Therefore, we thought to examine the inner bodies more critically. The results of our study are summarized below:

1. *Cushions* — Megaspores possess either a cushioned inner body or a plain inner body or are devoid of inner bodies. The cushions have been considered to be either pit-like depressions on the inner membrane (Pant & Srivastava, 1962) or elevated, lensoid structures (Høeg, Bose & Manum, 1955; Bharadwaj & Tiwari, 1970). From our observations the elevated nature of the cushions seems more plausible. They vary in their pattern of arrangement as well as in size and density and may be arranged in one or more rows along the trilete trace of the inner body or may be scattered in a trigonal zone over the trilete area. The radial extent of the cushions corresponds with the length of the trilete rays (Lele & Chandra, 1974). In the case of trigonal pattern it is observed that the zone is most well-marked where its sides are straight as in *Trilaevipellitis multipulvinatus* sp. nov. (Pl. 1, fig. 2). In such cases, the cushions are also more numerous. However, there are other examples in which the trigonal zone tends to have more or less concave sides, as in *Talchirella trivedii* (Pl. 2, fig. 13) and *Barakarella pantii* sp. nov. (Pl. 3, fig. 27). The number of cushions is reduced (20-30).

It can be well imagined that as the concavity of the sides deepens, the pattern may lose its trigonal shape and the cushions tend to simulate a serial arrangement. Whether a gradation exists between trigonal and serial patterns of cushions remains to be ascertained. At any rate, the two patterns are distinctly observable in the megaspores and their taxonomic value is established. Rarely the cushions may be irregular both in arrangement and size, e.g. in *Duosporites irregularis* Bharadwaj & Tiwari (1970, text-fig. 32).

The number of cushions varies both within and between species. Bharadwaj and Tiwari (1970) used this criterion for distinguishing *Talchirella trivedii* (50-80 cushions) from *T. sparsa* (16-20 cushions). Besides other characters, *T. media* sp. nov. is distinguished by a medium number of cushions (15-35 cushions).

Cushions vary from circular to subcircular to ovalish. Also their prominence seems to differ from species to species. They may be nearly flat and ill-defined as in *T. nigra* and *T. raniganjensis* but in other species, viz., *T. trivedii*, *T. media* and *Duosporites congoensis* they have high relief and become prominent.

The size of cushions may be ± uniform in some species while it may not be so in others. Both small and big cushions occur in *T. trivedii* and it seems that the smaller ones tend to be away from the trilete trace. In some forms cushions tend to fuse with each other or come very close to each other forming oblong fused units. This was particularly noticed in *T. trivedii* and is probably a useful supporting feature for specific differentiation.

2. *Trilete trace* — The trilete trace on the intexine is evidently an impression of the triradiate mark of the outer membrane of megaspore (Høeg, Bose & Manum, 1955; Bharadwaj & Tiwari, 1970). The trace is consistently developed and may even show greater or less degree of prominence and elevation as in the case of a triradiate mark. Some examples show a distinct trilete trace which is difficult to distinguish from a regular trilete mark (Pl. 1, fig. 6; Pl. 2, fig. 13). Folding of intexine may take place along the trace and enhance its prominence (Pl. 1, fig. 8). In such cases the folded region of the intexine may involve some cushions which are close to the trace (Pl. 1, fig. 10). The trilete mark of the intexine may extend up to the margin or close to it while in others it is distinctly shorter (2/3 to 3/4 of radius). Careful dissection of the intexine and exoexine layers has shown that the marks of the two layers are one below the other; however, during maceration the loose-fitting inner body can be readily displaced and the correspondence of the two marks (on inner and outer membrane) is lost.

3. *Intexine : shape, thickness, sculpture and structure* — The general shape of the inner body is either circular or triangular but may be often modified due to secondary foldings. Some inner bodies are thin, transparent to translucent while others are thick, dark-coloured and opaque. Both types are, however, very resistant to maceration treatments. Often in dark-coloured bodies, maceration treatment is not uniform with the result that darker and lighter irregular zones may develop. Transparent inner bodies may be externally smooth or may show fine granulations or puncta, e.g. *Talchirella media* and *Barakarella pantii*. Sometimes these features are so fine as to suggest internal structures. The inner body sculpture or structure should be studied in greater detail (especially with SEM) because it may have relevance to taxonomy.

An interesting feature which we observed for the first time is that the trilete area in certain cases is differentiated by thickness and colour. When stained the differentiated apical area takes a darker shade than the rest of the proximal exine (see *Talchirella trivedii*, Pl. 2, figs 11-13). The cushions are also confined to the differentiated area. It is therefore clear that optical differentiation in the inner bodies may serve as a useful taxonomic criterion.

The accumulated evidence demonstrates that the inner body possesses a number of qualitative and quantitative characters which can be utilized for classifying megaspore genera and species. Further detailed optical and ultramicroscopic studies in this direction would indeed prove very rewarding.

REFERENCES

Banerji, J., Kumaran, K. P. N. & Maheshwari, H. K. (1978). Upper Triassic *Sporae dispersae* from the Tiki Formation. Megaspores from the Janar Nala Section, South Rewa Gondwana Basin. *Palaeobotanist*, **25**: 1-26.

Bharadwaj, D. C. & Tiwari, R. S. (1970). Lower Gondwana megaspores — A Monograph. *Palaeontographica*, **129B** (1-3): 1-70.

Høeg, O. A., Bose, M. N. & Manum, S. B. (1955). On double walls in fossil megaspores with description of *Duosporites congoensis* n. gen. n. sp. *Nytt. Mag. Bot.*, **4**: 101-107.

Lele, K. M. & Chandra, A. (1974). Studies in the Talchir flora of India-9. Megaspores from the Talchir Formation in the Johilla Coalfield, M.P., India. *Palaeobotanist*, **21** (2): 238-247.

Pant, D. D. & Srivastava, G. K. (1961). Structural studies on Lower Gondwana megaspores-Pt. I. Specimens from Talchir Coalfield, India. *Palaeontographica*, **109B**: 45-61.

Pant, D. D. & Srivastava, G. K. (1962). Structural studies on Lower Gondwana megaspores-Pt. II. Specimens from Brazil and Mhukuru, Tanganyika. *Palaeontographica*, **111B**: 97-110.

Srivastava, A. K. (1982). A Lower Barakar miofloral assemblage from the Ranigani Coalfield. India. *Geophytology*., **12** (1): 131-132.

EXPLANATION OF PLATES

Plate 1

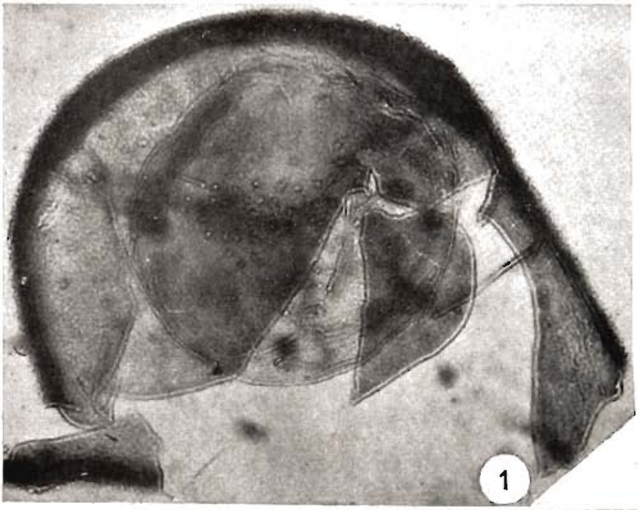
1. *Trilaevipellitis multipulvinatus* sp. nov. Holotype specimen no. 3A and showing outer coat inner body. × 100. Slide no. 6446
2. *T. multipulvinatus* sp. nov. inner body showing cushion mark and trilete area. × 300. Holotype specimen no. 3A. Slide no. 6446.
3. *Srivastavaesporites indicus* (Singh) Bharadwaj & Tiwari. Megaspore in dry condition. Specimen no. 48. × 100.
4. *S. indicus* (Singh) Bharadwaj & Tiwari, showing dark colour. I.B. specimen no. 48. × 100. Slide no. 6447.
5. *Srivastavaesporites* sp. Specimen no. 2; wet megaspore before maceration. × 100.
6. *Srivastavaesporites* sp., inner body in wet condition. × 100.
7. *Talchirella trivedii* — Showing megaspore in wet condition before maceration. × 100. Specimen no. 14.
8. *T. trivedii* showing first stage of maceration. × 100.
9. Shows cushions in the phase contrast. Specimen no. 14. × 600. Slide no. 6448.
10. Shows trilete mark which is elevated and folded beneath the cushions. × 500. Specimen no. 8.

Plate 2

11. *Talchirella trivedii* showing a patch intact over inner body. × 100.
12. Showing I.B. in ordinary light. × 100. Slide no. 6448.
13. Showing I.B. in phase contrast. × 150. Slide no. 6448.
14. *T. raniganjensis* Bharadwaj & Tiwari, specimen in wet condition. × 100. Specimen no. 3.
15. *T. raniganjensis* Bharadwaj & Tiwari — I.B. of the megaspore showing biseriate arrangement of cushions. × 150.
16. *T. media* sp. nov. showing wet specimen under reflected light. × 100. Holotype specimen no. 28.
17. *T. media* sp. nov. Holotype I.B. of the megaspore showing cushions and trilete mark. Exine shows fine grana-puncta. × 100. Specimen no. 28, slide no. 6451.
18. *T. media* sp. nov., another specimen showing broken I.B. × 100. Specimen no. 44, slide no. 6452.
19. *T. nigra* sp. nov., holotype showing dark colour inner body and cushions. × 150. Specimen no. 26, slide no. 6453.
20. *Barakarella churuliaensis* gen. et sp. nov.— megaspore in wet condition. × 100. Holotype specimen no. 18.
21. Showing baculate ornamentation of the outer coat along the margin. × 300. Specimen no. 18.

Plate 3

22. *Barakarella churuliaensis* gen. et sp. nov., holotype after mild alkali treatment. × 100.
23. Showing inner body and outer coat details. × 100. Holotype slide no. 6454.
24. Showing baculate ornamentation over the surface of megaspores. × 300.
25. *Barakarella pantii* sp. nov., Holotype. Wet megaspore in incident light. × 100. Specimen no. 40.
26. Holotype, after alkali treatment and full megaspore shows the inner body with cushions and surrounding outer coat of the spore. × 100. Slide no. 6455.
27. *B. pantii* sp. nov., finely punctate-granulate inner body from another specimen. × 100. Slide no. 6455.
28. *Jhariatriletes densus* sp. nov., Holotype showing baculate ornamentation along the margin in wet condition. × 100. Specimen no. 55.
29. Showing only the outer coat of the holotype. × 100. Slide no. 6457.
30. Inner body of *J. densus* sp. nov. recovered from another specimen. × 100. Specimen no. 47, slide no. 6458.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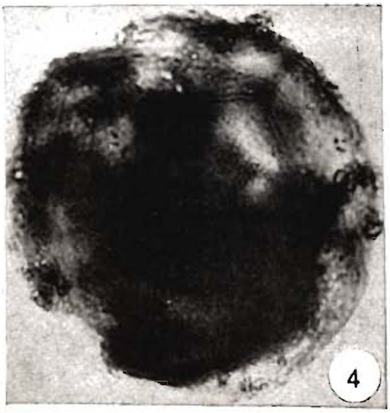
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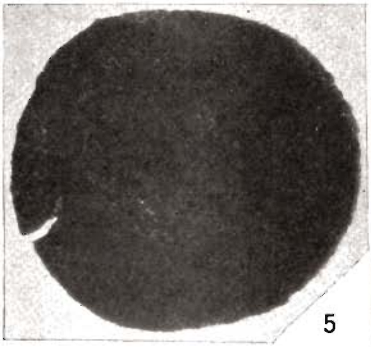
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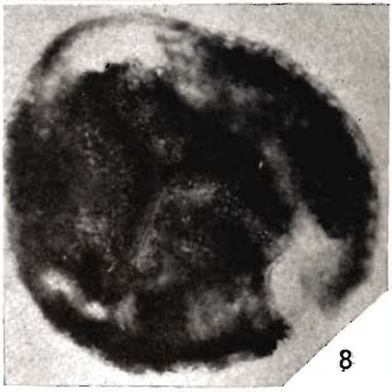
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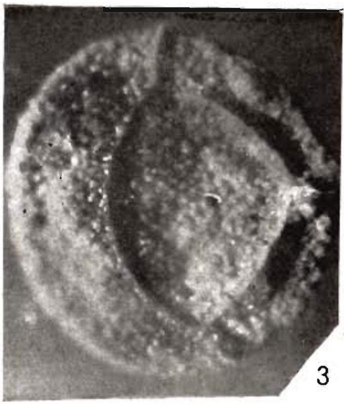
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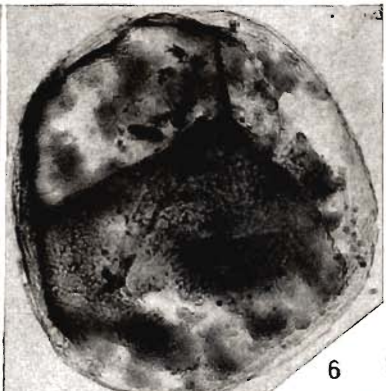
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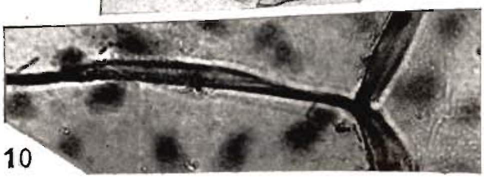
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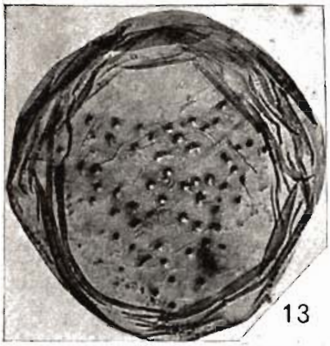
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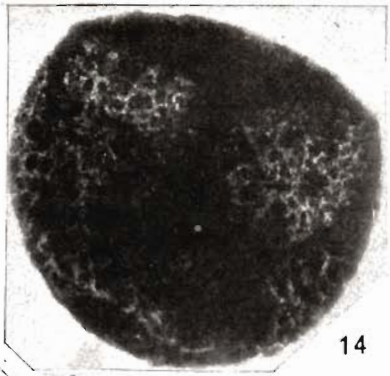
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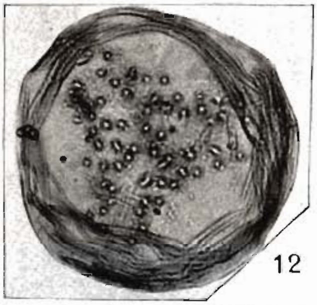
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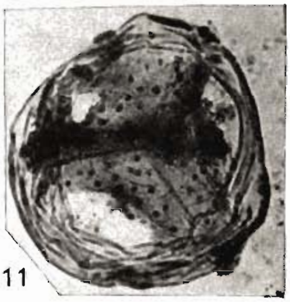
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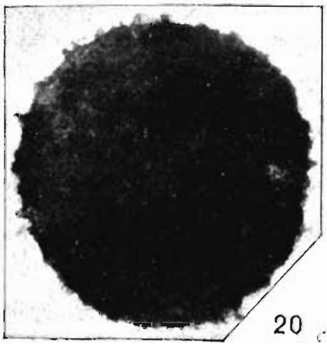
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PLATE 2


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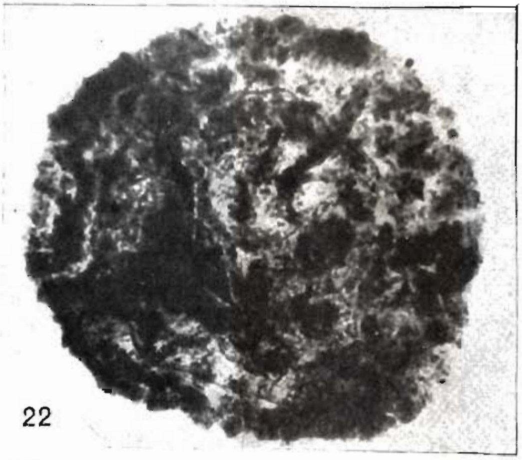
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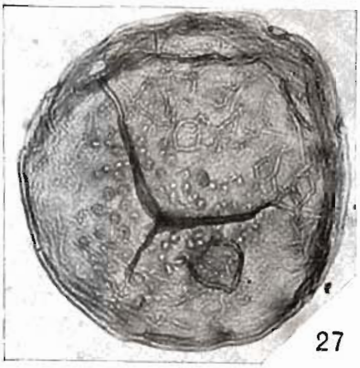
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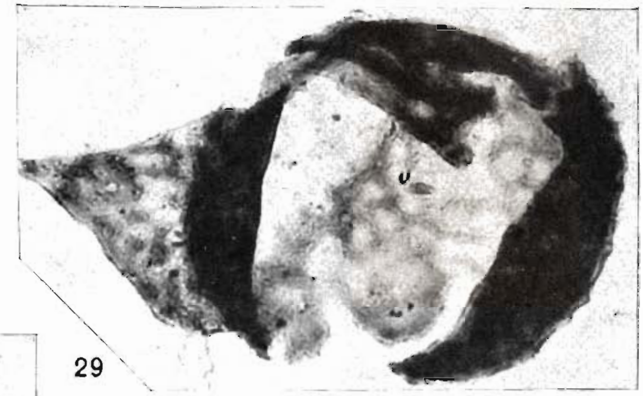
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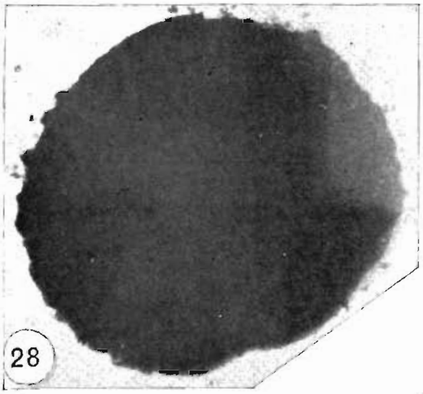
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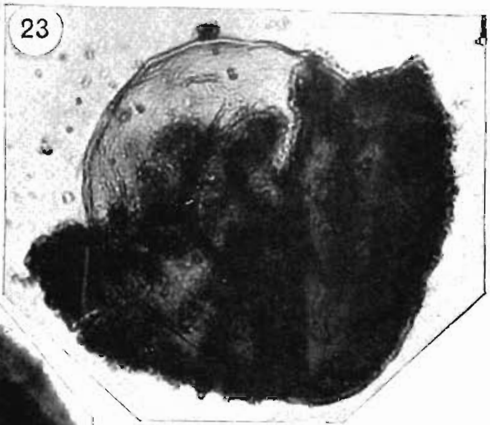
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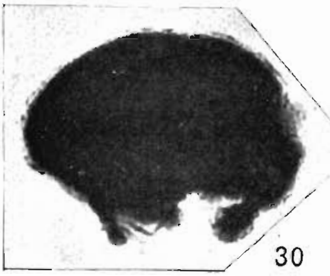
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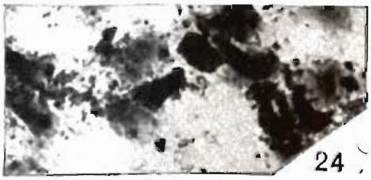
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Plate 3

The Palaeobotanist, **31**(1): 13-29, 1983.

FOSSIL DICOTYLEDONOUS WOODS FROM THE DECCAN INTERTRAPPEAN BEDS NEAR SHAHPURA, MANDLA DISTRICT, MADHYA PRADESH

M. B. BANDE & U. PRAKASH
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

Four fossil dicotyledonous woods, viz., *Sterculioxylon shahpurensis* Bande & Prakash, *Burseroxylon preserratum* Prakash & Tripathi, *Heyneoxylon tertiarum* Bande & Prakash, and *Dracontomelumoxylon mangiferumoides* Ghosh & Roy have been described here from a recently discovered rich Deccan Intertrappean exposure near Shahpura in Mandla District of Madhya Pradesh. These fossil woods are closely comparable with the woods of *Sterculia* of Sterculiaceae, *Bursera* of Burseraceae, *Heynea* of Meliaceae and *Dracontomelum* of Anacardiaceae and suggest the presence of a rich forest flora in the Mandla region during the Early Tertiary times.

Key-words — Xylotomy, *Sterculioxylon*, *Burseroxylon*, *Heyneoxylon*, *Dracontomelumoxylon*, Deccan Intertrappean beds, Early Tertiary (India).

सारांश

मॉंडला जनपद (मध्य प्रदेश) में शाहपुरा के निकटस्थ दक्खिन अन्तर्ट्रैपी संस्तरों से द्विबीजपत्रीय काष्ठाश्म – मोहन बलवंत बाँडे एवं उत्तम प्रकाश

मध्य प्रदेश के मॉंडला जनपद में शाहपुरा के समीपस्थ हाल ही में अन्वेषित एक दक्खिन अन्तर्ट्रैपी अनावरण से चार द्विबीजपत्रीय काष्ठाश्म – स्टरकुलिऑक्सीलॉन शाहपुरेन्सिस बाँडे व प्रकाश, बर्सेरॉक्सीलॉन प्रीसेरेटम् प्रकाश व त्रिपाठी, हेनिऑक्सीलॉन टर्शीयेरम् बाँडे व प्रकाश तथा ड्रेकॉन्टोमिलमॉक्सीलॉन मेंजिफ़ेरुमॉयडिस घोष व रॉय – वर्णित किये गये हैं। ये काष्ठाश्म स्टरकुलिएसी कुल के स्टरकुलिआ, बर्सेरेसी कुल के बर्सेरा, मिलिएसी कुल के हेनिआ तथा ऐनाकार्डिएसी कुल के ड्रेकॉन्टोमिलम् की वर्तमान काष्ठों से निकट तुलनीय हैं तथा मॉंडला क्षेत्र में प्रारम्भिक आदिनूतन युग में एक प्रचुर वन्य-वनस्पति की उपस्थिति इंगित करते हैं।

INTRODUCTION

ALTHOUGH the Deccan Traps cover an area not less than about 5,12,000 square kilometers, occupying about one-third of the Peninsular India (Krishnan, 1968), the palaeobotanical work on the Intertrappean flora has been confined mostly to the regions of Nagpur and Chhindwara. However, new areas have recently been explored in search of more fossiliferous exposures so as to have a better knowledge of this important flora of the Indian Palaeogene. One such area is Mandla District of Madhya Pradesh, which has turned out to be quite rich in fossil woods. All the dicot woods so far described from this area have been listed in Table 1 and the relative positions of these different localities have been shown in Map 1. The assemblage includes 19 species of fossil dicotyledonous woods besides two species of *Palmoxylon* described by Lakhanpal, Prakash and Ambwani (1979). Besides the three fossiliferous localities previously known from this area, a fourth one has recently been discovered near Shahpura, a township 86 km east of Jabalpur. The actual locality is situated between the villages Ghughua and Katangi at a distance of 13 km from Shahpura on

TABLE 1 — FOSSIL DICOTYLEDONOUS WOODS FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT

Fossil Species	Family	Living Comparable Species	Locality	Reference
1. *Vitexoxylon indicum*	?Verbenaceae	?*Vitex leucoxylon*	Mandla District	Ingle, 1972
2. *Polyalthioxylon parapaniense*	Anonaceae	*Polyalthia simiarum*	Parapani	Bande, 1973
3. *Syzygioxylon mandlaense*	Myrtaceae	*Syzigium cumini*	Mandla District	Ingle, 1973
4. *Homalioxylon mandlaense*	Flacourtiaceae	*Homalium tomentosum*	Parapani	Bande, 1974
5. *Bischofinium deccanii*	Euphorbiaceae	*Bischofia javanica*	Parapani	Bande, 1974
6. *Sterculioxylon deccanensis*	Sterculiaceae	*Sterculia foetida, S. angustifolia*	Mohgaon	Lakhanpal, Prakash & Bande, 1979
7. *Grewioxylon* sp.	Tiliaceae	*Grewia laevigata*	Mohgaon	Lakhanpal, Prakash & Bande, 1979
8. *Elaeocarpoxylon mandlaensis*	Elaeocarpaceae	*Elaeocarpus-Echinocarpus*	Mohgaon	Lakhanpal, Prakash & Bande, 1979
9. *Atalantioxylon indicum*	Rutaceae	*Atalantia monophylla-Limonia acidissima*	Mohgaon	Lakhanpal, Prakash & Bande, 1979
10. *Hydnocarpoxylon indicum*	Flacourtiaceae	*Hydnocarpus alpina* *Hydnocarpus wightiana*	Parapani	Bande & Khatri, 1980
11. *Garcinioxylon tertiarum*	Guttiferae	*Garcinia cowa & G. xanthochymus*	Parapani	Bande & Khatri, 1980
12. *Gomphandroxylon samnapurensis*	Icacinaceae	*Gomphandra tetrandra*	Samnapur	Bande & Khatri, 1980
13. *Dracontomelumoxylon mangiferumoides* syn. *Dracontomeloxylon palaeomangiferum*	Anacardiaceae	*Dracontomelum mangiferum*	Parapani & Ghughua near Shahpura	Bande & Khatri, 1980
14. *Barringtonioxylon mandlaensis*	Lecythidiaceae	*Barringtonia acutangula, B. pterocarpa*	Parapani	Bande & Khatri, 1980
15. *Sterculioxylon shahpurensis*	Sterculiaceae	*Sterculia foetida, S. guttata & S. campanulata*	Ghughua near Shahpura	Bande & Prakash, 1980
16. *Calophylloxylon dharmendrae*	Guttiferae	*Calophyllum spectabile* *C. tomentosum*	Ghughua near Shahpura	Bande & Prakash, 1980
17. *Burseroxylon preserratum*	Burseraceae	*Bursera serrata*	Ghughua near Shahpura	
18. *Heyneoxylon tertiarum*	Meliaceae	*Heynea trijuga*	Ghughua near Shahpura	Bande & Prakash, 1980
19. *Laurinoxylon deccanensis*	Lauraceae		Ghughua near Shahpura	Bande & Prakash, 1980

Shahpura-Niwas Road (Map 2). This road is not shown in the map as the map has been prepared from the Survey of India Topo Sheet no. 64A/12 of an old date. Four fossil woods collected from this locality are described here. These are comparable with the modern woods of *Sterculia* of Sterculiaceae, *Bursera* of Burseraceae, *Heynea* of Meliaceae, and *Dracontomelum* of Anacardiaceae respectively. Of these, the fossil woods of *Sterculia*, and *Heynea* have been recently recorded by us from this locality (Bande & Prakash, 1980).

DESCRIPTION

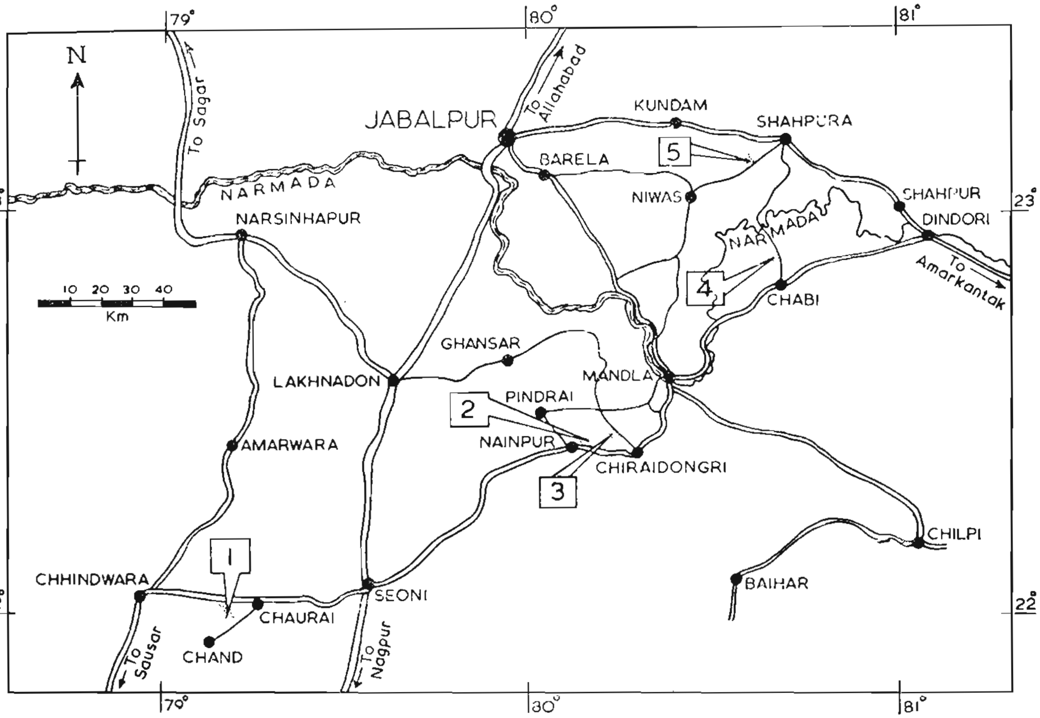
FAMILY — STERCULIACEAE

Genus — *Sterculioxylon* Kräusel, 1939

1. *Sterculioxylon shahpurensis* Bande & Prakash, 1980

Pl. 1, figs 1-5; Text-fig. 1

Material — A well-preserved piece of secondary xylem detached from a big petrified log.

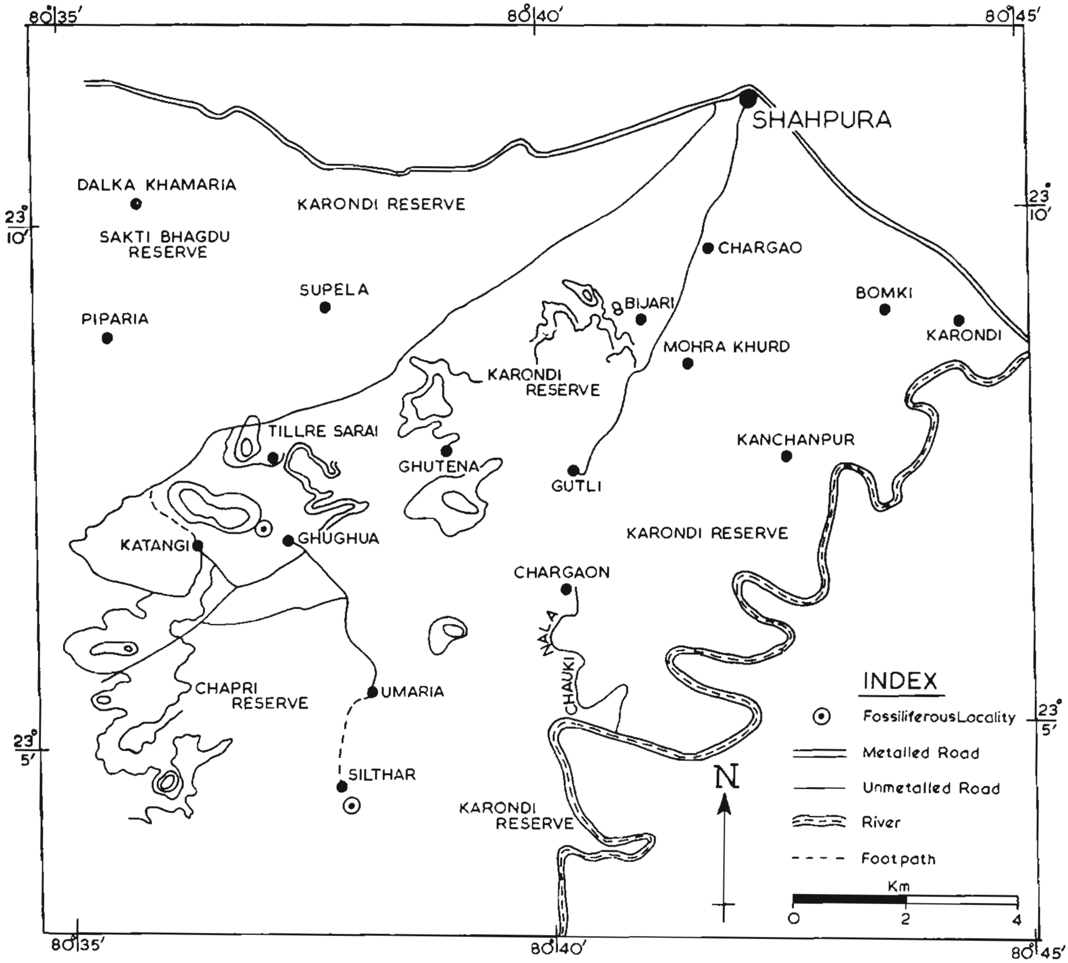


MAP 1 — Mandla and nearby areas showing various Deccan Intertrappean fossiliferous localities — (1) Mohgaon Kalan, (2) Samnapur, (3) Mohgaon, (4) Parapani, and (5) Ghughua.

Topography — *Wood* diffuse-porous (Pl. 1, fig. 1). *Growth rings* faintly demarcated by crowding of the vessels. *Vessels* small to large, mostly in radial multiples of 2-10, rarely solitary, frequently in clusters (Pl. 1, figs 1, 2; Text-fig. 1), uniformly distributed, 5-12 per sq mm. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming 1-2 seriate continuous or interrupted sheath around the vessels or vessel groups (Pl. 1, figs 1, 2; Text-fig. 1); apotracheal parenchyma abundant, diffuse-in-aggregate, forming 1-2 seriate, closely spaced, irregular, short tangential lines (Pl. 1, figs 1, 2; Text-fig. 1). *Xylem rays* evenly distributed, 4-5 per mm, homocellular to heterocellular, of two distinct types; uniseriate rays made up either of upright cells only or with some procumbent cells at places, 2-15 cells or 150-1000 μm in height (Pl. 1, fig. 3); multiseriate rays made up of procumbent cells in the central portion and with uniseriate extensions of upright cells at the ends, 4-22 cells or 90-450 μm in width and 15-200 cells or 600-8000 μm in height (Pl. 1, fig. 3); sheath cells present, ray tissue heterogeneous. *Fibres* aligned in radial rows in between the rays.

Elements — *Vessels* thick-walled, circular to oval when solitary, with flat contact walls when in groups, t.d. 45-255 μm, r.d. 60-360 μm (Pl. 1, figs 1, 2; Text-fig. 1), vessel-members 400-600 μm long with truncate ends; perforations simple, intervessel pit-pairs 4-6 μm in diameter, alternate, bordered, angular in shape with linear-lenticular apertures (Pl. 1, fig. 4). *Parenchyma cells* thin-walled, 15-30 μm in width and 60-120 μm in length, parenchyma strands as well as cells distinctly storied (Pl. 1, fig. 3). *Ray cells* thin-walled, procumbent cells 15-45 μm in tangential height and 30-120 μm in radial length; upright cells 60-120 μm in tangential height and 30-60 μm in radial length. *Fibres* libriform to semi-libriform (Pl. 1, fig. 2), non-septate, 30-40 μm in diameter and 450-1000 μm in length.

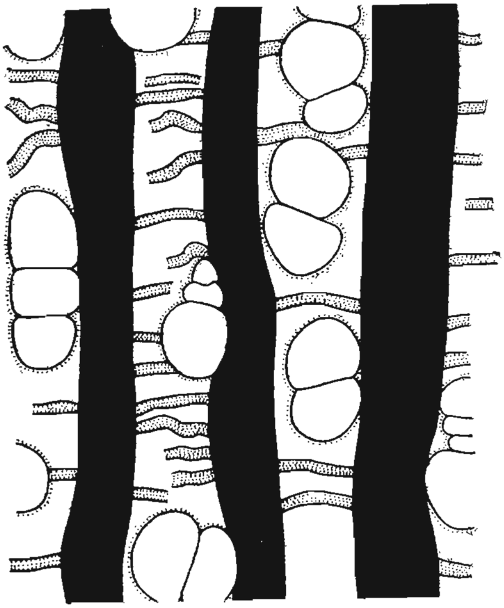
Affinities — Important anatomical characters of the present fossil such as small to large vessels with simple perforations, vasi-



MAP 2 — Locality map of Ghughua and nearby area.

centric and diffuse-in-aggregate parenchyma forming 1-2 seriate tangential lines with storied strands, 1-22 seriate, usually heterocellular, long xylem rays and libriform to semi-libriform, non-septate fibres clearly indicate its affinities with the extant genus *Sterculia* of the family Sterculiaceae. The fossil wood was compared with the modern woods of 13 species of *Sterculia* available to us besides the published descriptions and photographs of these and some other species (Lecomte, 1926, pl. 21; Pearson & Brown, 1932, pp. 146-152, figs 52-55; Chattaway, 1937, pl. 4, figs 1, 2; 1937, pls 29-31; Metcalfe & Chalk, 1950, pp. 243-251, fig. 61J; Henderson, 1953, pl. 68, fig. 362; pl. 69, fig. 364; Desch, 1954, pp. 581-583, pl. 114, fig. 2; Chowdhury & Ghosh, 1958, pp. 210-223, pls 27, 28, figs 160, 163, 164, 165; Brazier & Franklin, 1961, p. 79). The species which were studied from thin sections are *Sterculia alata* Roxb., *S. angustifolia* Roxb., *S. campanulata* Wallex Mast, *S. coccinia* Roxb., *S. colorata* Roxb., *S. foetida* L., *S. fulgens* Wall., *S. guttata* Roxb., *S. ornata* Wall., *S. populifolia* Roxb., *S. scaphigera* Wall., *S. urens* Roxb. and *S. villosa* Roxb.

Based on parenchyma distribution the species of *Sterculia* have been divided by Chattaway (1937) into two broad groups, viz., (i) in which apotracheal parenchyma



TEXT-FIG. 1 — *Sterculioxylon shahpurensis* sp. nov.— Cross section showing small to large vessels, broad xylem rays and tangential lines of parenchyma, × 55. Slide no. 6139/35368.

is predominantly in lines of one cell width, and (ii) those in which apotracheal parenchyma is predominantly in broad bands of 3-4 cells width. Consequently, as the apotracheal parenchyma in the present fossil wood is in the form of 1-2 seriate tangential lines, the fossil wood is comparable with only those species of *Sterculia* which exhibit this character. Out of a long list of *Sterculia* species included under this group by Chattaway (1937), the wood slides of only six species, viz., *Sterculia campanulata*, *S. foetida*, *S. guttata*, *S. ornata*, *S. urens* and *S. villosa* were studied for a detailed comparison. However, besides parenchyma when other anatomical characters of the present fossil are also taken into consideration, it becomes clear that it does not agree totally with any one species. Its anatomical characters are distributed in more than one species of *Sterculia*, viz., *S. foetida*, *S. guttata* and *S. campanulata*. Thus shape, size and the distribution of vessels in the fossil is quite similar to that in *Sterculia guttata* but in this species some tangential bands of apotracheal parenchyma are also present in addition to the uniseriate lines; these are, however, not seen in the present fossil. Apotracheal parenchyma very similar to that of the fossil wood is present in *S. foetida*, but in this species the xylem rays are much narrower than in the fossil, and the size and distribution pattern of the vessels also differ in the two. In its ray structure, the fossil is very closely comparable with *S. campanulata* in which up to 20 seriate, long, heterogeneous xylem rays are present. However, the vessels in this species are bigger than in the fossil and the parenchyma is also markedly different being vasicentric only.

Ten species of fossil woods said to be showing anatomical structures similar to those of extant genus *Sterculia* have so far been described from India and abroad under the generic name *Sterculioxylon* Kräusel (1939). Those described from outside the region of the Indian subcontinent are *Sterculioxylon aegyptiacum* (Unger) Kräusel (1939) from the Tertiary of Egypt and also from the Post Eocene of Tibesti in Sahara (Boureau, 1949), *S. giarabubense* (Chiarugi) Kräusel (1939) from the Lower Oligocene to Lower Miocene of North Africa, *S. rhenanum* Müller-Stoll (1949) from the Eocene of South West Germany and *S. freulonii* Boureau (1957) from the Post Eocene of Libya, Sahara. The species described from the various Tertiary localities of the Indian Subcontinent are *Sterculioxylon foetidense* Prakash (1973) from the Tertiary of Burma, *S. dattai* Prakash & Tripathi (1974) from the Tipam sandstones near Hailakandi, Assam, *S. kalagarhense* Trivedi and Ahuja (1978) from the Siwalik beds of Kalagarh, Uttar Pradesh, *S. deccanensis* Lakhanpal *et al.* (1978) from the Deccan Intertrappean beds near Mandla, Madhya Pradesh, *S. varmahii* Lakhanpal *et al.* (1981) from the Miocene-Pliocene of Deomali, Arunachal Pradesh and *S. pondicherriense* Awasthi (1981) from the Cuddalore Series near Pondicherry.

Of the four species described from outside the Indian subcontinent, the parenchyma is vasicentric to aliform, confluent and banded in *Sterculioxylon rhenanum*, while in *S. aegyptiacum*, *S. giarabubense* and *S. freulonii* it is present in broad apotracheal bands. Thus, these can easily be distinguished from our fossil wood where the parenchyma is in 1-2 seriate tangential lines. Similarly, in *S. varmahii*, *S. pondicheriense* and *S. kalagarhense* also broad apotracheal bands are present. Thus, in only three species, viz., *S. foetidense*, *S. dattai* and *S. deccanensis*, parenchyma similar to that of the present fossil is present. However, in the Burmese species, *Sterculioxylon foetidense*, the vessels are large to moderately large (t.d. 160-400 μm, r.d. 240-480 μm), solitary and in radial multiples of 2-4 and only 2-3 per sq mm, while in the present wood the vessels are small to large (t.d. 45-255 μm, r.d. 60-360 μm), rarely solitary, mostly in radial multiples of 2-10, frequently in clusters and with a frequency of 5-12 per sq mm. The xylem rays in *S. foetidense* are also quite different from those in the present fossil being only 1-8 seriate wide and 2700 μm high as against 1-22 seriate wide and up to 8000 μm high rays in the fossil wood under discussion. Similarly in *S. dattai* although the shape, size and the frequency of the vessels is somewhat similar as in the present fossil, but majority of the vessels are solitary, only occasionally in pairs. Also the xylem rays are only 1-10 seriate wide and up to 1500 μm high in this species. Lastly, *S. deccanensis*, the only species so far known from the Deccan Intertrappean beds, also differs distinctly from the present fossil in having smaller vessels (t.d. 50-120 μm, r.d. 70-180 μm), which are solitary and in radial multiples of 2-4 only. The xylem rays although somewhat similar to those of present fossil wood are only up to 4800 μm in height. As the fossil wood from near Shahpura is quite distinct from all the known species of *Sterculioxylon*, it has been placed under a new species, *Sterculioxylon shahpurensis*, the specific name indicating its occurrence near Shahpura.

The genus *Sterculia* Linn. consists of 300 species (Willis, 1973) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932, p. 145). Twenty species are known from India (Chowdhury & Ghosh, 1958). Of the three extant species resembling the fossil wood, *Sterculia foetida* is a large tree found on the west coast at low elevation from Konkan southwards, Ceylon and Martaban and Upper Tenasserim in Burma. *Sterculia guttata* is a medium sized to large tree occurring in the evergreen forests of the Western Ghats from Konkan to Travancore, ascending up to 600 m in Assam and also in Tenasserim in Burma. *Sterculia campanulata* is a large tree found in Lower Burma from Martaban to Mergui and Tenasserim and in the Andamans (Chowdhury & Ghosh, 1958, pp. 212-215).

SPECIFIC DIAGNOSIS

Sterculioxylon shahpurensis Bande & Prakash, 1980

Wood diffuse-porous. *Growth rings* faintly demarcated by crowding of vessels. *Vessels* small to large, t.d. 45-255 μm, r.d. 60-360 μm, rarely solitary, majority in radial multiples of 2-10, frequently in clusters, evenly distributed, 5-12 per sq mm; perforations simple; intervessel pit-pairs alternate, bordered, 4-6 μm in diameter with linear-lenticular apertures. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma vasicentric, forming 1-2 seriate sheath around vessels; apotracheal parenchyma diffuse-in-aggregate forming 1-2 seriate, tangential lines, cells storied. *Xylem rays* 4-5 per mm, heterogeneous, of two distinct types, 1-22 seriate, uniseriate rays made up of either upright cells only or both upright and procumbent cells, up to 15 cells or 1500 μm in height; multiseriate rays made up of procumbent cells in the middle part with uniseriate extensions of upright cells at the ends and sheath cells along the flanks, up to 22 seriate and 200 cells or 8000 μm in height. *Fibres* libriform to semi-libriform, non-septate, polygonal in cross section, 30-40 μm in diameter and 450-1000 μm in length.

Holotype — B.S.I.P. Museum specimen no. 35368.

Sterculioxylon sp. cf. *S. shahpurensis* Bande & Prakash, 1980

Pl. 1, fig. 6; Pl. 2, fig. 8

Material — A well-preserved piece of secondary wood taken out from a large log of the fossil wood.

Description — *Wood* diffuse - porous. *Vessels* medium to large, mostly in radial multiples of 2-8 or in clusters (Pl. 1, fig. 6); rarely solitary; perforations simple; intervessel pit-pairs alternate, bordered, 4-6 μm in diameter with linear-lenticular apertures. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric in 1-2 seriate sheath (Pl. 1, fig. 6); apotracheal parenchyma diffuse-in-aggregate forming 1-2 seriate tangential lines (Pl. 1, fig. 6); parenchyma cells storied (Pl. 2, fig. 8). *Xylem rays* heterogeneous, 1-40 seriate, of two distinct types; uniseriate rays made up of upright cells only or both upright and procumbent cells, up to 15 cells or 1500 μm in height, multiseriate rays made up of procumbent cells in the middle part with extensions of upright cells at the ends and sheath cells on the flanks, up to 40 seriate in width and more than 200 cells or 11,000 μm in height (Pl. 2, fig. 8). *Fibres* libriform, non-septate.

Specimen — B.S.I.P. Museum no. 35369.

Affinities — The structural features of the present fossil wood also indicate its closest affinities with the genus *Sterculia* although such broad rays have not been seen in the modern woods of *Sterculia* so far examined. Besides, during the present study some more fossil woods have been examined from the same locality which exhibit a wide range in the width and height of the xylem rays showing intermediate stages between this fossil wood and that of *Sterculioxylon shahpurensis*. In the fossil wood no. 35372 which exhibits similar structural features like that of *Sterculioxylon shahpurensis*, the xylem rays are much narrower, up to 7 cells in width and 225 cells or 11,000 μm in height and the solitary vessels are quite frequent (Pl. 2, figs 12, 13). In another specimen no. 35371, the xylem rays are more broad, up to 11 cells in width and 200 cells or 9000 μm in height (Pl. 2, figs 10, 11). Further, in specimen no. 35370, even broader, spindle-shaped xylem rays with 23 cells width and 150 cells or 4500 μm in height are seen which exhibit a stage nearer to this fossil wood (Pl. 2, fig. 9). Consequently, all this indicates that there is a series of anatomical structures exhibited by the specimens 35369, 35370, 35371 and 35372 which show variable stages of ray width ranging from narrow, 1-7 seriate to broad, 1-40 seriate condition. Somewhat similar variations in the width of the xylem rays have also been observed in different wood specimens of *Sterculia alata*, *S. campanulata* and *S. urens*. In wood specimen no. F.R.I. 43768/B 6441 of *Sterculia alata*, the xylem rays are 1-9 (mostly up to 6) seriate, while in wood specimen no. F.R.I. 462/06205 of this species the xylem rays are 1-15 seriate. In *Sterculia campanulata* the xylem rays, which are only 1-10 seriate in wood specimen no. F.R.I. A935/B6547, are 20 seriate in wood specimen no. F.R.I. A1825/B6083. Similarly, in *Sterculia urens* the xylem rays also show variation in their width. While in wood specimen no. F.R.I. A3057/C11027, the xylem rays are 1-13 seriate, they are 1-25 seriate in another wood specimen no. F.R.I. A3059/D64027. This suggests that the fossil wood specimens described above, exhibiting a wide range of variation in ray width, might belong to a single species of *Sterculia* and may represent different parts of the stem and the root; the broader rays being usually present in the root wood. The possibility of their belonging to one and the same species is strengthened by the fact that all these fossil woods have been collected from a small area of the same locality. However, in spite of all this, it would be better to refer them to *Sterculioxylon* sp. cf. *S. shahpurensis* till further evidences are forthcoming either to separate them or put them definitely under this species. It may be further said that this study also emphasizes the necessity of a cautious approach in creating new species of fossil woods based on variable characters.

FAMILY — BURSERACEAE

Genus — *Burseroxylon* Prakash & Tripathi emend. Lakhanpal, Prakash & Awasthi, 1981

2. *Burseroxylon preserratum* Prakash & Tripathi, 1975

Pl. 3, figs 14-17

Material — A single piece of well-preserved secondary wood 25 cm in length and 10 cm in diameter.

Description — *Wood* diffuse-porous. *Growth rings* indistinct, faintly demarcated by crowding of vessels. *Vessels* small to medium-sized, t.d. 30-150 μm, r.d. 30-200 μm (Pl. 3, fig. 14) solitary and in radial multiples of 2-4 (the multiples become longer in the region of the growth ring), almost uniformly distributed, 10-30 per sq mm (may be more near the region of the growth ring), tyloses present (Pl. 3, fig. 14); vessel members 200-450 μm long with truncate to tailed ends; perforations simple; intervessel pit-pairs alternate, bordered, polygonal with lenticular apertures, 8-10 μm in diameter (Pl. 3, fig. 17). *Parenchyma* scanty paratracheal vasicentric forming 1-2 seriate sheath around the vessels (Pl. 3, fig. 17). *Xylem rays* 8-12 per mm, 1-3 (mostly 2) seriate, uniseriate rays sparse, made up of upright cells only or both upright and procumbent cells, multiseriate rays made up of procumbent cells in the centre and 1-3 seriate extensions of upright cells at one or both the ends (Pl. 3, fig. 15), the end cell usually enlarged and crystalliferous, the rays 2-12 cells or 40-225 μm in height; ray tissue heterogeneous. *Fibres* moderately thick-walled with big lumen, angular in cross section, septate and 400-800 μm long.

The fossil is almost identical to the known fossil species *Burseroxylon preserratum* Prakash & Tripathi (1975) described from the Tipam sandstones near Hailakandi in Assam showing close resemblance with the modern wood of *Bursera serrata* Wall. ex Coleb. Consequently, it is assigned to it. The minor anatomical differences observed in the fossil wood from the Deccan and that from Assam are due to the absence of growth rings in the latter and in the size of the vessels which are somewhat smaller in the former. However, these differences have been found to occur in different modern wood specimens of *Bursera serrata* (Prakash & Tripathi, 1975, p. 59). In addition to the variations observed by these authors it was also observed that there is a variation in the frequency of enlarged crystalliferous cells in the rays of *Bursera serrata*. In some of the specimens of this species studied at the Forest Research Institute, Dehradun (slide nos. 355/E6013 & A264/B6438), the crystalliferous cells are not frequent, whereas in other specimens (slide nos. 289/05507 & 1983/E6073) the crystalliferous cells are abundant. Similar variations were also observed in different fossil wood specimens collected along with the fossil described above. Thus in the above specimen, the crystalliferous cells in the rays are not very frequent but in another specimen no. 35375 they are abundant (Pl. 3, fig. 16).

The genus *Bursera* Linn. consists of 80 species widely distributed in tropical America especially in the West Indies, northern South America, Central America and Mexico, and two species extend northward into the United States. *Bursera serrata* Wall. ex Coleb. with which the present fossil wood resembles closely is the sole Indian species extending from eastern moist zone of Bengal, Assam, Orissa, Chittagong to tropical forests of Upper and Lower Burma. It also occurs in Rajmahal hills, extending to eastern Ghats, especially in the valley and along water courses (Pearson & Brown, 1932, p. 224; Ghosh, Purkayastha & Rawat, 1963, p. 71; Willis, 1973). The present finding thus records *Bursera serrata* in the Deccan Plateau and extends the antiquity of this genus in the Palaeogene of India. The other fossil records of Burseraceae from the Deccan Intertrappean beds of India are *Boswellioxylon indicum* Dayal (1964, 1966) said to be similar to the modern genus *Boswellia* and one more fossil wood tentatively assigned to this family by Shallom (1958).

Specimen — B.S.I.P. Museum no. 35374.

FAMILY — ANACARDIACEAE

Genus — *Dracontomelumoxylon* Ghosh & Roy, 1979

3. *Dracontomelumoxylon mangiferumoides* Ghosh & Roy, 1979

Pl. 3, figs 18-20

Material — A silicified piece of mature secondary wood, 10 cm in length and 6 cm in diameter.

Description — *Wood* diffuse - porous. *Growth rings* absent. *Vessels* small to large, t.d. 60-225 μm, r.d. 60-300 μm, solitary and in radial multiples of 2-4, rarely in small clusters (Pl. 3, fig. 19), 9-12 per sq mm; tyloses present; perforations simple; intervessel pit-pairs alternate, bordered, 8-12 μm in diameter, polygonal in shape with lenticular apertures (Pl. 3, fig. 18). *Parenchyma* paratracheal vasicentric to aliform, sometimes aliform-confluent (Pl. 3, fig. 19). *Xylem rays* 1-4 seriate, up to 30 cells high and 5-7 per mm; uniseriate rays made up of upright cells only, multiseriate rays made up of procumbent cells in the centre with uniseriate extensions of upright cells at the ends (Pl. 3, fig. 20); ray tissue heterogeneous. *Fibres* moderately thick-walled, rarely septate, polygonal in cross section.

The fossil wood is almost identical to the known species *Dracontomelumoxylon mangiferumoides* Ghosh & Roy (1979) recently described from the Tertiary deposits of Labpur, District Birbhum, West Bengal and resembles the modern wood of *Dracontomelum mangiferum*. The only difference observed between the two fossil woods is that in the wood described from West Bengal the parenchyma is only 2-4 seriate vasicentric but in the present fossil wood from Deccan it is vasicentric to aliform, sometimes aliform confluent. However, similar variation in parenchyma distribution has also been observed in different modern wood samples of *Dracontomelum mangiferum*. Consequently, the present fossil wood has been referred to this species.

Besides, two more fossil woods resembling *Dracontomelum mangiferum* have recently been described under the name *Dracontomeloxylon palaeomangiferum* by Prakash (1979) and by Bande and Khatri (1980) from the Lower Siwalik beds of Himachal Pradesh and the Deccan Intertrappean beds of Parapani in Madhya Pradesh respectively. All these fossil woods are almost identical to each other except in possessing some minor variations. Under the circumstances, *Dracontomeloxylon palaeomangiferum* Prakash (1979) becomes synonym to *Dracontomelumoxylon mangiferumoides* Ghosh & Roy (1979) which has the priority.

Dracontomelum mangiferum Blume is a tree by habit growing wild in damp places along the streams in Andaman and Nicobar islands. In Burma, it is found in Myitkyiana, Katha and Mergui. It also occurs in Malaya Peninsula (Ghosh & Purkayastha, 1963, p. 275).

Specimen — B.S.I.P. Museum no. 35376.

FAMILY — MELIACEAE

Genus — *Heyneoxylon* Bande & Prakash, 1980

4. *Heyneoxylon tertiarum* Bande & Prakash, 1980

Pl. 4, figs 21-25; Text-fig. 2

Material — A piece of secondary wood 8 cm in length and 5 cm in diameter.

Topography — *Wood* diffuse - porous. *Growth rings* indistinct demarcated by fine bands of terminal parenchyma. *Vessels* mostly small, rarely medium-sized, solitary and in radial rows of 2-6, also in clusters (Pl. 4, figs 21, 22; Text-fig. 2), evenly distributed, 6-13 per sq mm. *Parenchyma* terminal and paratracheal forming 3-10 seriate continuous or interrupted tangential bands alternating with similar bands of the fibres. The bands bifurcating at places and joining similar bands on upper and lower side (Pl. 4, figs 21, 22; Text-fig. 2). *Xylem rays* fine to medium, 6-9 per mm, 1-6 (mostly 2-4) seriate or 15-90 μm in width and 1-42 cells or 30-900 μm in height; uniseriate rays either made up of upright cells only or both upright and procumbent cells, multiseriate rays made up of procumbent cells in the central portion with 1-5 cells high uniseriate extensions similar to uniseriate rays at one or both the ends, ray tissue heterogeneous. *Fibres* arranged in tangential bands alternating with similar bands of parenchyma (Pl. 4, figs 21, 22).

TEXT-FIG. 2 — *Heyneoxylon tertiarum* gen. et sp. nov.— Cross section showing small vessels, xylem rays and alternating bands of parenchyma and fibres, × 40. Slide no. 6158/35377.

Elements — *Vessels* circular to oval when solitary, with flat contact walls when in groups, t.d. 30-90 µm, r.d. 20-135 µm, vessel members 100-300 µm long with truncate to tailed ends; perforations simple; intervessel pit-pairs alternate to opposite, bordered, minute, about 4 µm in diameter with lenticular sometimes coalescent apertures (Pl. 4, fig. 25). *Parenchyma cells* very variable in size, thin-walled, 20-50 µm in diameter and 30-120 µm in length, sometimes fusiform and quite similar to the smaller vessels, vessel parenchyma pits similar to intervessel pits. *Ray cells* thin-walled, procumbent cells 15-20 µm in tangential height and 20-90 µm in radial length; upright cells 30-40 µm in tangential height and 20-25 µm in radial length (Pl. 4, fig. 24). *Fibres* moderately thick-walled to thick-walled, angular in cross-section, rarely septate, 15-30 µm in diameter and 400-600 µm in length

Affinities — The important anatomical characters of the fossil wood namely mostly small vessels with simple perforations, broad bands of paratracheal parenchyma, 1-6 seriate heterocellular xylem rays and thick-walled, mostly nonseptate fibres indicate its affinities with the modern woods of Meliaceae (Kribs, 1930; Panshin, 1933; Pearson & Brown, 1932, pp. 234-274; Metcalfe & Chalk, 1950, pp. 349-359; Ghosh, Purkayastha & Krishna Lal, 1963, pp. 81-159). Besides, a near resemblance was also observed with the wood of *Mappia foetida* Miers. of Icacinaceae. However, in *Mappia foetida* the percentage of uniseriate xylem rays is much more than in the present fossil, the multiseriate rays are usually separated by a number of uniseriate rays. Among the various genera of Meliaceae the present fossil is very closely comparable with the modern wood of *Heynea trijuga* Roxb., the only species of the genus *Heynea* Roxb. represented in India. This comparison included a detailed examination of a number of thin sections from wood samples of this species besides studying its photographs and description (Ghosh, Purkayastha & Krishna Lal, 1963, pp. 130-132, pl. 44, figs 259, 260). It indicates that both in *Heynea trijuga* as well as in the present fossil, the wood is diffuse-porous, growth rings indistinct, vessels small to very small, solitary and in radial multiples of 2-4 and in short clusters, perforations simple and the inter-vessel pit-pairs are bordered, alternate and minute. Parenchyma in *H. trijuga* is quite similar to that in the fossil wood. It is aliform to aliform-confluent and forms wavy, continuous tangential bands. The thickness of these bands also varies at different places and quite frequently they are as thick as the alternating fibre bands like those of the present fossil. The xylem rays of *H. trijuga* are also quite similar to those of the present fossil being 1-5 seriate, heterocellular, made up of both procumbent and upright cells and are up to 35 cells in height. Further, the fibres in both the extant species and the fossil wood are moderately thick-walled to thick-walled and rarely septate.

As the fossil is closely comparable to the modern wood of *Heynea trijuga* in its anatomical characters, it has been placed under the genus *Heyneoxylon* instituted to include the fossil woods of *Heynea* Roxb. of the family Meliaceae. The specific name *Heyneoxylon tertiarum* indicates its occurrence in the Tertiary period. Although this is the first record of a fossil wood of *Heynea* from the Deccan Intertrappean beds, a fossil wood showing similarity with the genus *Amoora* Roxb., also belonging to Meliaceae, has recently been described from the Deccan Intertrappean beds near Nawargaon in Wardha District of Maharashtra (Bande & Prakash, 1983).

The family Meliaceae consists of 50 genera and 1400 species of trees and shrubs growing in warm climate (Willis, 1973). In India, the family is represented by 19 genera. *Heynea* Roxb. is a small genus of trees or shrubs confined to the Indo-Malayan region. The only Indian species, *Heynea trijuga* Roxb., is a small tree, 6-12 m in height, widely distributed in India. It grows in the sub-Himalayan tract up to 1500 m elevation from Kumaon eastwards to North Bengal. It also occurs in the plain and hill forests of Assam ascending to 600 m, Chota Nagpur, in the Eastern Ghats up to 1400 m and in the Western Ghats where it is common from Mysore to Travancore up to 1800 m. In Burma, it occurs in the hill forests at an elevation of about 600-1200 m. It is also found in southern China, Thailand, the Malaya Peninsula and Sumatra (Ghosh, Purkayastha & Krishna Lal, 1963, p. 131).

GENERIC DIAGNOSIS

Heyneoxylon Bande & Prakash, 1980

Wood diffuse-porous. *Growth rings* faint, demarcated by fine bands of parenchyma. *Vessels* very small to medium, solitary and in short radial multiples; perforations simple; intervessel pit-pairs bordered, alternate to opposite, and minute. *Parenchyma* aliform confluent frequently forming wavy bands and also thin lines at the growth rings. *Xylem rays* fine to medium, ray tissue heterogeneous. *Fibres* moderately thick-walled to thick-walled, septate or nonseptate. *Gum canals* vertical, traumatic, present or absent.

Genotype — *Heyneoxylon tertiarum* Bande & Prakash, 1980.

SPECIFIC DIAGNOSIS

Heyneoxylon tertiarum Bande & Prakash, 1980

Wood diffuse-porous. *Growth rings* indistinct, demarcated by terminal parenchyma. *Vessels* mostly small, rarely medium-sized, t.d. 30-90 µm, r.d. 20-135 µm, solitary and in radial rows of 2-6, also in clusters, 6-13 per sq mm; vessel members 100-300 µm long with truncate to tailed ends; perforations simple; intervessel pit-pairs bordered, alternate to opposite, about 4 µm in diameter with lenticular, sometime coalescent apertures, *Parenchyma* terminal and paratracheal. forming 3-10 seriate, continuous or interrupted, tangential bands; cells very variable in length and width. *Xylem rays* 1-6 (mostly 2-4) seriate, homocellular to heterocellular, made up of both procumbent and upright cells, 1-42 cells or 30-900 µm in height and 6-9 per mm. *Fibres* moderately thick-walled to thick-walled, arranged in tangential bands alternating with similar bands of parenchyma, rarely septate, 15-30 µm in diameter and 400-600 µm in length.

Holotype — B.S.I.P. Museum no. 35377.

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REFERENCES

AWASTHI, N. (1981). Fossil woods belonging to Sterculiaceae and Lythraceae from the Cuddalore Series near Pondicherry. *Palaeobotanist*, **27** (2): 182-189.

BANDE, M. B. (1973). A petrified dicotyledonous wood from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh, *Botanique*, **4** (1): 41-47.

BANDE, M. B. (1974). Two fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Geophytology*, **4** (2): 189-195.

BANDE, M. B. & KHATRI, S. K. (1980). Some more fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeontographica*, **173B**: 147-165.

BANDE, M. B. & PRAKASH, U. (1980). Four new fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla Dist., M.P. *Geophytology*, **10** (1 & 2): 268-271.

BANDE, M. B. & PRAKASH, U. (1983). Occurrence of *Evodia, Amoora* and *Sonneratia* from the Palaeogene of India. *Prof. A. K. Ghosh Commemoration Volume* (in Press).

BOUREAU, E. (1949). Étude Palaeoxylalogique du Sahara (VI). Sur une forme nouvelle *Sterculioxylon* (*Nicolia*) *aegyptiacum* (Unger) Kräusel, des couches Post-Éocene du Tibesti. *Bull. Mus.*, 2e serie, **21** (6): 776-787.

BOUREAU, E. (1957). Étude Palaeoxylologique du Sahara (XXIII). Sur une nouvelle espéce de bois fossile de Sterculiaceae réoltee a Ouaou en Namous (Libya): *Sterculioxylon freulonii* n. sp. *Bull. Mus.*, **29** (1): 112-120.

BRANDIS, D. (1971). *Indian Trees.* 5th edn. Dehradun.

BRAZIER, J. D. & FRANKLIN G. L. (1961). Identification of hard woods. A microscopic key. *Bull. Forest. Prod. Res. Lond.*, **46**: 1-96.

CHHATTAWAY, M. M (1937). The wood anatomy of the family Sterculiaceae. *Phil. Trans. R. Soc.*, **228**: 313-366.

CHOWDHURY, K. A. & GHOSH, S. S. (1958). *Indian Woods, their Identifications, Properties and Uses.* Delhi.

DAYAL, R. (1964). Occurrence of *Boswellia* in the Deccan Intertrappean beds of Keria, Madhya Pradesh. *Curr. Sci.*, **33** (22): 683-684.

DAYAL, R. (1966). Occurrence of *Boswellia* in the Deccan Intertrappean beds of Keria, Madhya Pradesh. *Palaeobotanist*, **14** (1-3): 185-190.

DESCH, H. E. (1954). Manual of Malayan Timbers-2. *Malayan For. Rec.*, **15**: 329-762.

GHOSH, S. S. & PURKAYASTHA, S. K. (1963). Famliy Anacardiaceae in: *Indian woods, their Identification, Properties & Uses*-**2**. Dehradun.

GHOSH, S. S., PURKAYASTHA, S. K. & KRISHNA LAL (1963). Family Meliaceae, pp. 81-159 in: *Indian Woods, their Identification, Properties & Uses*-**2**. Dehradun.

GHOSH, S. S., PURKAYASTHA, S. K. & RAWAT, M.S. (1963). Family Burseraceae, pp. 68-80 in: *Indian Woods, their Identification, Properties & Uses*-2. Dehradun.

GHOSH, P. K. & ROY, S. K. (1979). Fossil wood of *Dracontomelum* from the Tertiary of West Bengal, India. *Curr. Sci.*, **48** (8): 362.

HENDERSON, F. Y. (1953). An Atlas of end-grain photographs for the identification of hard woods. *Forest Prod. Res. Bull.*, **26**.

INGLE, S. R. (1972). A new fossil dicotyledonous wood of Verbenaceae from Mandla District of Madhya Pradesh. *Botanique*, **3** (1): 7-12.

INGLE, S. R. (1973). *Syzygioxylon mandlaense* gen. et sp. nov. a fossil dicotyledonous wood from Mandla District of Madhya Pradesh, India. *Botanique*, **4** (1): 71-76.

KRAÜSEL, R. (1939). Ergebnisse der Forschungsreisen Prof. E. Stromers in den Wusten Agyptens. IV. Die Fossilen Floren Agyptens. *Abh. bayer Akad. Wiss. N.F.*, **47**: 5-140.

KRIBS, D. A. (1930). Comparative anatomy of the woods of the Meliaceae. *J. Am. bot. Soc.*, **17** (8): 724-738.

KRIBS, D. A. (1959). *Commercial foreign woods on the American market*. Pennsylvannia.

KRISHNAN, M. S. (1968). *Geology of India and Burma*. 5 edn. Madras.

LAKHANPAL, R. N., PRAKASH, U. & AMBWANI, K. (1979). Two petrified palm woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **26** (2): 119-129.

LAKHANPAL, R. N., PRAKASH, U. & AWASTHI, N. (1981). Some more dicotyledonous woods from Deomali, Arunachal Pradesh, India. *Palaeobotanist*, **27** (3): 232-251.

LAKHANPAL, R. N., PRAKASH, U. & BANDE, M. B. (1979). Fossil dicotyledonous woods from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist*, **25**: 190-204.

LECOMTE, H. (1926). *Les bois de L'Indochine*. Paris.

LEMOIGNE, Y. (1978). Flores Tertiaires de la Haute Vallee de L'omo (Ethiopie). *Palaeontographica*, **165B**: 89-157.

METCALFE, C. R. & CHALK, L. (1950). *Anatomy of Dicotyledons*. **1** & **2**. Oxford.

MÜLLER-STOLL, W. R. UND H. (1949). *Sterculioxylon rhenanum* nov. spec. ausden altertiar Sudwest Deutschlands (Studien uber Fossil Laub-Holzer 1). *Palaeontographica*, **89B**: 204-217.

PANSHIN, A. J. (1933). Comparative anatomy of the woods of the Meliaceae, sub-family Switenioideae. *American J. Bot.*, **20** (10): 638-668.

PEARSON, R. S. & BROWN, H. P. (1932). *Commercial Timbers of India*. **1** & **2**. Calcutta.

PRAKASH, U. (1966). Some fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist*, **14** (1-3): 223-235.

PRAKASH, U. (1973). Fossil woods from the Tertiary of Burma. *Palaeobotanist*, **20** (1): 48-70.

PRAKASH, U. (1979). Some more fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Himalayan Geology*, **8**: 61-81.

PRAKASH, U. & AWASTHI, N. (1971). Fossil woods from the Tertiary of eastern India-II. *Palaeobotanist*, **18** (3): 219-225.

PRAKASH, U. & TRIPATHI, P. P. (1974). Fossil woods from the Tertiary of Assam. *Palaeobotanist*, **21** (3): 305-316.

PRAKASH, U. & TRIPATHI, P. P. (1975). Fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist*, **22** (1): 51-62.

SHALLOM, L. J. (1958). A fossil docotyledonous wood from the Deccan Intertrappean beds of Mahurzari. *J. Indian bot. Soc.*, **37** (2): 492-498.

TRIVEDI, B. S. & AHUJA, M. (1978). *Sterculioxylon kalagarhense* sp. nov. from Kalagarh (Bijnor District), U.P., India. *Curr. Sci.*, **47** (1): 24-25.

WILLIS, J. C. (1973). *A Dictionary of Flowering Plants and Ferns*. (Eighth edn). Cambridge.

EXPLANATION OF PLATES

PLATE 1

1. *Sterculioxylon shahpurensis* — Cross section showing shape, size and distribution of vessels, broad xylem rays and parenchyma. × 35. Slide no. 6139/35368.
2. *S. shahpurensis* — Cross section enlarged to show vessels, broad xylem rays, tangential lines of parenchyma and thick-walled fibres. × 55. Slide no. 6139/35368.
3. *S. shahpurensis* — Tangential longitudinal section showing uniseriate and broad multiseriate xylem rays and storied parenchyma. × 30. Slide no. 6140/35368.
4. *S. shahpurensis* — Intervessel pit-pairs. × 110. Slide no. 6140/35368.
5. *S. shahpurensis* — Radial longitudinal section showing heterocellular xylem rays. × 110. Slide no. 6141/35368.
6. *Sterculioxylon* sp. cf. *S. shahpurensis* — Cross section showing vessels, broad xylem rays and parenchyma. × 25. Slide no. 6142/35369.
7. *Sterculioxylon* sp. cf. *S. shahpurensis* — Cross section showing vessels, xylem rays and tangential lines of parenchyma. × 25. Slide no. 6144/35370.

PLATE 2

8. *Sterculioxylon* sp. cf. *S. shahpurensis* — Tangential longitudinal section showing up to 40 seriate

xylem rays and storied parenchyma. × 30. Slide no. 6143/35369.

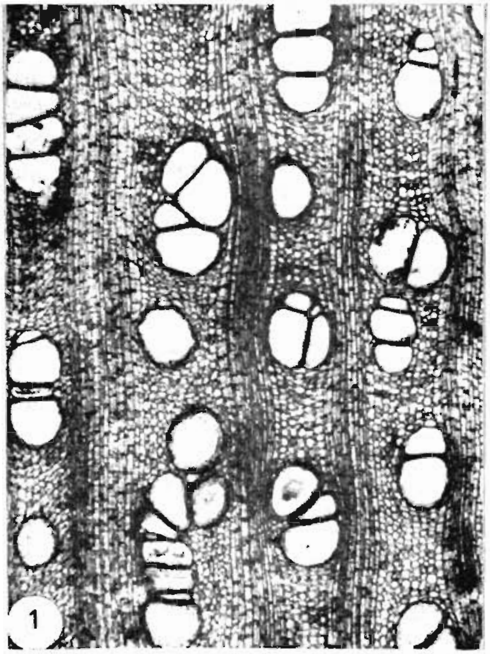
9. *Sterculioxylon* sp. cf. *S. shahpurensis* — Tangential longitudinal section showing spindle-shaped, up to 20 seriate xylem rays and storied parenchyma. × 30. Slide no. 6145/35370.
10. *Sterculioxylon* sp. cf. *S. shahpurensis* — Cross section showing vessels, xylem rays and parenchyma. × 25. Slide no. 6146/35371.
11. *Sterculioxylon* sp. cf. *S. shahpurensis* — Tangential longitudinal section showing up to 10 seriate heterocellular xylem rays and storied parenchyma. × 25. Slide no. 6147/35371.
12. *Sterculioxylon* sp. cf. *S. shahpurensis* — Cross section showing vessels, xylem rays and parenchyma. × 25. Slide no. 6148/35372.
13. *Sterculioxylon* sp. cf. *S. shahpurensis* — Tangential longitudinal section showing up to 6 seriate xylem rays and storied parenchyma. × 40. Slide no. 6149/35372.

PLATE 3

14. *Burseroxylon preserratum* — Cross section showing solitary and paired vessels with tyloses, vasicentric parenchyma and xylem rays. × 105. Slide no. 6153/35374.
15. *B. preserratum* — Tangential longitudinal section showing 1-2 seriate, xylem rays with enlarged crystalliferous cells in some of the rays and septate fibres. × 105. Slide no. 6154/35374.
16. *B. preserratum* — Tangential longitudinal section from another specimen showing xylem rays with abundant crystalliferous cells. × 135. Slide no. 6155/35375.
17. *B. preserratum* — Intervessel pit-pairs. × 250. Slide no. 6154/35374.
18. *Dracontomelumoxylon mangiferumoides* — Intervessel pit-pairs. × 250. Slide no. 6156/35376.
19. *D. mangiferumoides* — Cross section showing shape, size and distribution of vessels, paratracheal aliform to confluent parenchyma and xylem rays. × 30. Slide no. 6157/35376.
20. *D. mangiferumoides* — Tangential longitudinal section showing heterocellular xylem rays. × 55. Slide no. 6156/35376.

PLATE 4

21. *Heyneoxylon tertiarum* — Cross section showing shape, size and distribution of vessels, alternating bands of parenchyma and fibres and xylem rays. × 40. Slide no. 6158/35377.
22. *H. tertiarum* — Cross section enlarged to show alternating bands of parenchyma and fibres. × 65. Slide no. 6158/35377.
23. *H. tertiarum* — Tangential longitudinal section showing heterocellular xylem rays, parenchyma and fibres. × 100. Slide no. 6159/35377.
24. *H. tertiarum* — Radial longitudinal section showing heterocellular xylem rays. × 40. Slide no. 6160/35377.
25. *H. tertiarum* — Intervessel pit-pairs. × 250. Slide no. 6159/35377.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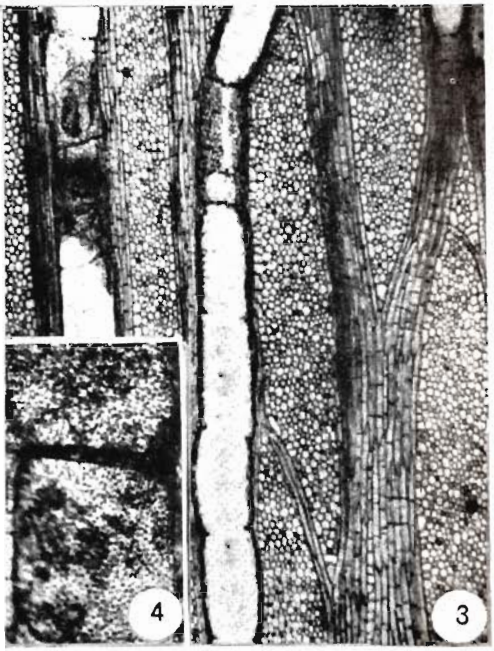
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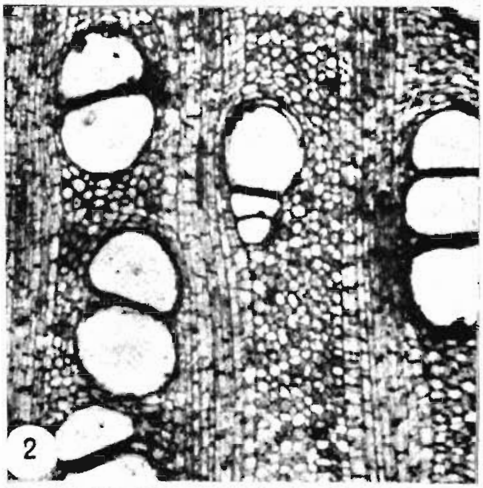
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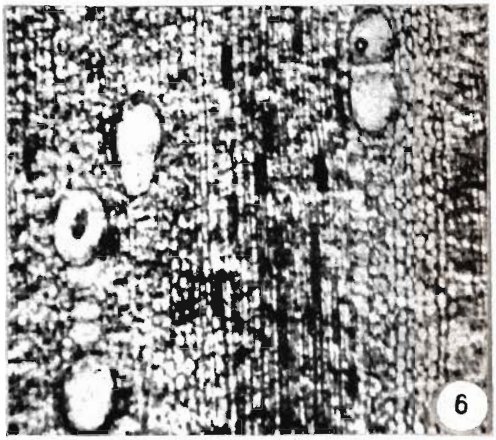
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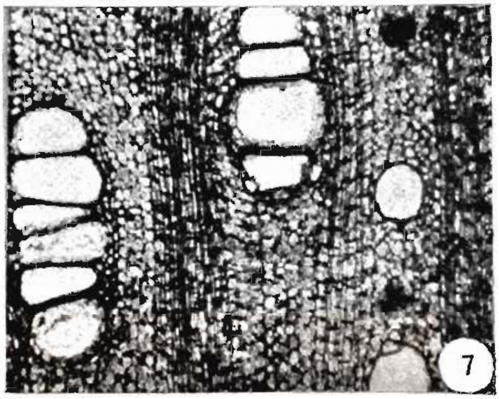
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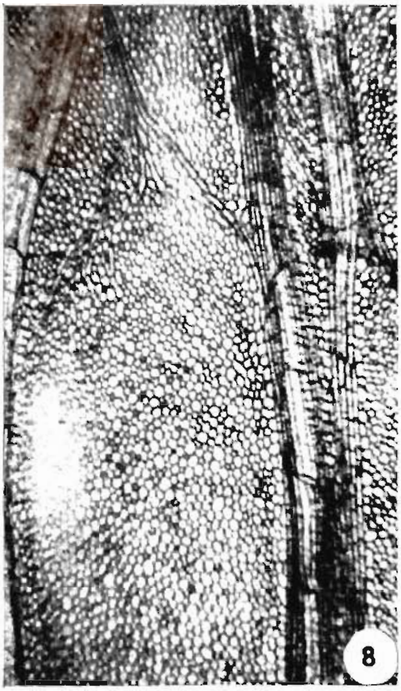

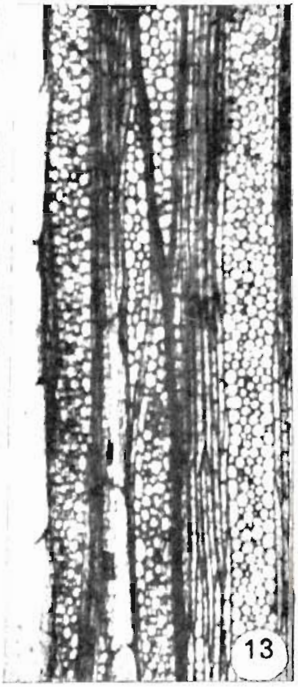

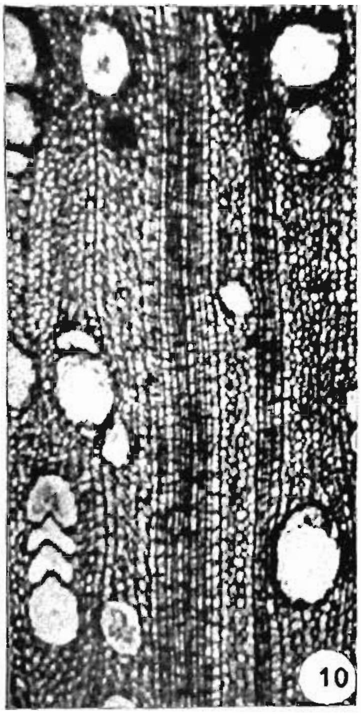

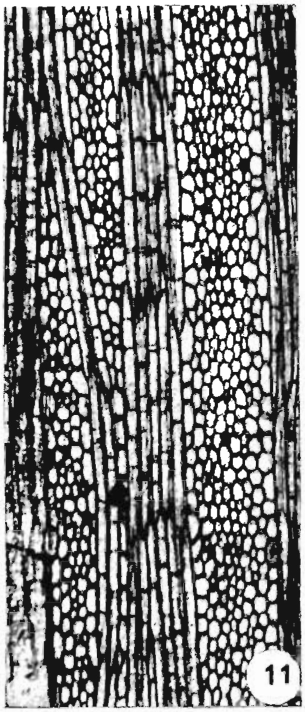

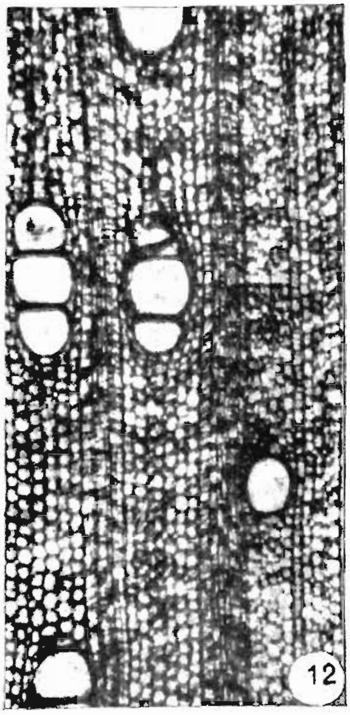

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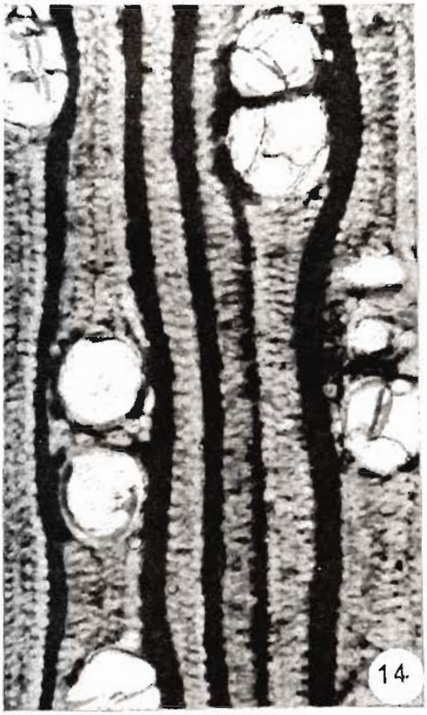

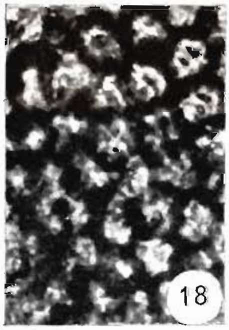

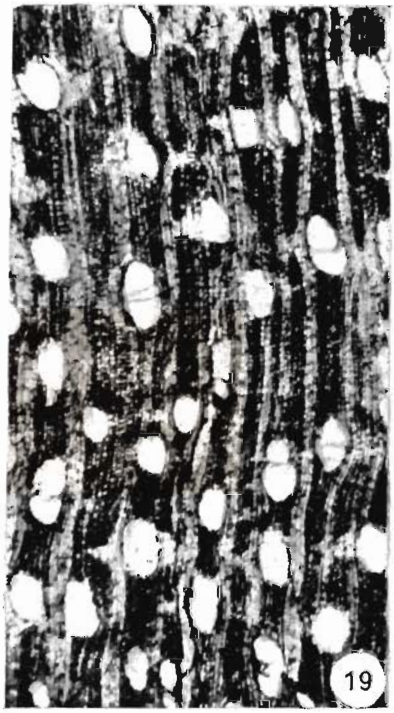

PLATE 3


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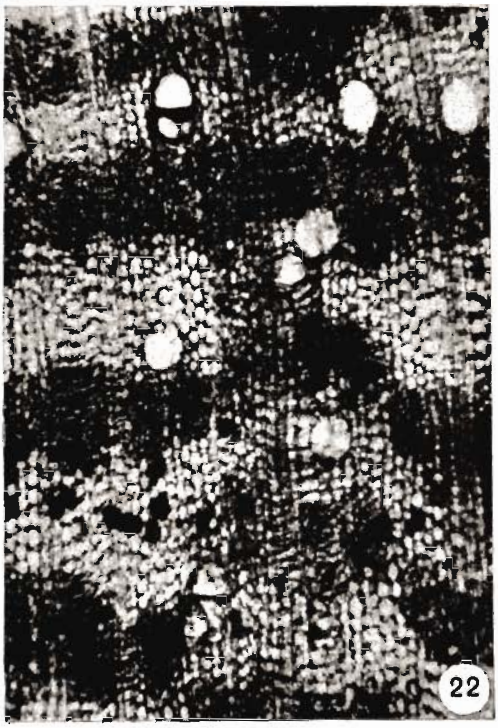
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PLATE 4

The Palaeobotanist, **31**(1): 30-44, 1983.

BIOMETRIC STUDY OF *PLICATIPOLLENITES* LELE AND *POTONIEISPORITES* BHARDWAJ IN THE LOWER GONDWANA FORMATIONS OF THE HUTAR COALFIELD, BIHAR, INDIA

K. M. LELE & MANOJ SHUKLA

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

ABSTRACT

The data on the morphological trends of the *Plicatipollenites/Potonieisporites* populations worked out from Talchir to Barakar in the Hutar Basin are investigated. These trends are compared with the average picture obtained earlier from the synthesis of five basins. This study reveals that there is a reasonable degree of similarity between the morphological evolutionary trends of the *Plicatipollenites/Potonieisporites* populations of the Hutar basin and those obtained in the synthesis from the five Lower Gondwana basins by Lele and Shukla.

Key-words — Biometry, Morphological variations, *Potonieisporites*, *Plicatipollenites*, Lower Gondwana (India).

सारांश

बिहार (भारत) में हुतार कोयला-क्षेत्र के अधर गोंडवन शैल-समूहों से उपलब्ध प्लिकेटिपोलिनाइटिस लेले एवं पोतोनियेस्पोराइटिस भारद्वाज का जीवसाँख्यिकीय अध्ययन – केशव मुकुन्द लेले एवं मनोज शुक्ला

हुतार द्रोणी में तालचिर से बाराकार तक अन्वेषित प्लिकेटिपोलिनाइटिस/पोतोनियेस्पोराइटिस समष्टियों की आकारिकीय प्रवृत्तियों के आँकड़े अन्वेषित किये गये हैं। इन प्रवृत्तियों की तुलना पाँच द्रोणीयों के संश्लेषण के पहले से प्राप्त औसत अनुमान से की गई है। इस अध्ययन से यह व्यक्त होता है कि लेले एवं शुक्ला द्वारा पाँच अधर गोंडवन द्रोणीयों के किये गये संश्लेषण से उपलब्ध तथा हुतार द्रोणी से प्राप्त प्लिकेटिपोलिनाइटिस-पोतोनियेस्पोराइटिस समष्टियों की आकारिकीय वैकासिक प्रवृत्तियों में आपस में बहुत कुछ समानता है।

MORPHOLOGICAL transitions between *Plicatipollenites* Lele and *Potonieisporites* Bhardwaj have been noted by several earlier workers (Potonié & Lele, 1961; Lele, 1964, 1974; Maheshwari, 1967). Recently a detailed biometric study on morphological variation of the two genera through the Talchir to the Lower Barakar times has been published by Lele and Shukla (1978). In this synthesis, five Lower Gondwana basins, viz., South Rewa, Jayanti, Giridih, North Karanpura and Hutar were investigated. Of these basins, the data worked out from the Hutar Basin has a particular significance because here a more or less complete stratal sequence from the Talchir to the Barakar is available for carrying out a successional study of morphological variations through time. It was, therefore, considered useful to work out in greater detail the morphological/evolutionary trends of the *Plicatipollenites-Potonieisporites* populations in the Hutar Basin and demonstrate their compatibility with the general picture synthesized earlier by Lele and Shukla (1978) from the five Lower Gondwana basins. The present paper deals with this objective in view.

The genera *Plicatipollenites* and *Potonieisporites* can be differentiated on the basis of a new criterion called " Distal saccus spread " (Lele & Shukla, 1978). According to this *Plicatipollenites* belongs to the " monosaccate group " characterized by " Uniform saccus spread " and *Potoniei-*

sporites to the monosaccoid group characterized by "Differential saccus spread". The study of Lele and Shukla (1978) further reveals that *Plicatipollenites* population shows a strong association of bilateral spores with monolete to monoletoid mark and bilateral infold system.

MATERIAL AND METHOD

In the present paper the methodology of Lele and Shukla (1978) has been adopted in order to bring out the individual trends of *Plicatipollenites* and *Potonieisporites* in the Hutar Coalfield and to check how far they agree with the overall trends found out earlier by Lele and Shukla (1978).

The samples from which the actual counts were done are as detailed below (Map 1):

SECTION	FORMATION	SAMPLE No.	LITHOLOGY
Deori Nala	Lower Karharbari	DK_5 DK_6	Shale & Carbonaceous Shale
	Talchir	DT_2	Needle shale
Koel River	Barakar	KB_7, KB_8	Carbonaceous sandy shale
	Lower Karharbari	KB_3	Coaly-shale
	Talchir	KT_1	Needle shale

Upper Karharbari beds of the Deori Nala Section do not possess well-preserved specimens of the genera *Plicatipollenites* and *Potonieisporites* and hence they have been excluded from the biometric study.

Norms — All the six basic morphological types or norms instituted earlier by Lele and Shukla (1978) have been used in the biometric study of the palynoflora in the Hutar Coalfield. For the sake of clarity these are re-stated below.

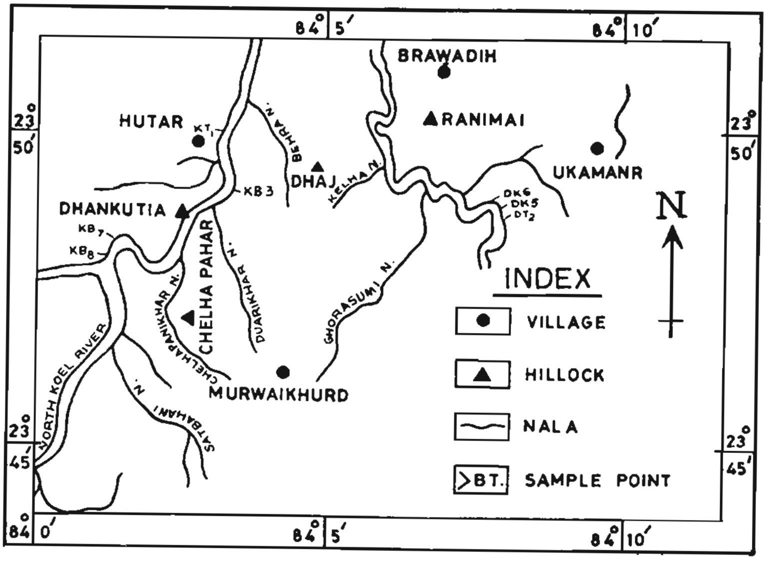
Plicatipollenites population:

Norm A_1 — Characterized by radial symmetry of miospore and uniform saccus spread (Pl. 1, figs 1-4).
Spore circularity ratio $= 1 \pm 0{\cdot}1$
Body infold circularity ratio $= 1 \pm 0.1$
Saccus spread value $= \pm 0.1$

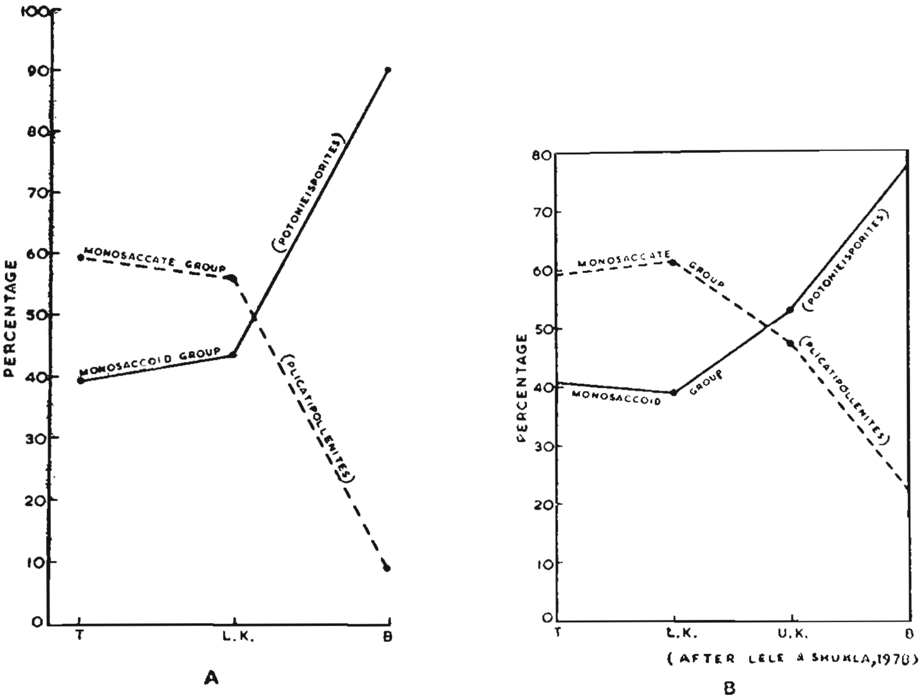
Norm A_2 — Characterized by bilateral symmetry of miospore and uniform saccus spread (Pl. 1, figs 5-7).
Spore circularity ratio $= > 1.1$
Body infold circularity ratio $= > 1.1$
Saccus spread value zero or less (negative value)

Potonieisporites population:

Norm B_1 — Characterized by bilateral symmetry of miospore and diffe-



MAP 1



TEXT-FIG. 1 — Distribution trend of monosaccate and monosaccoid groups through time — **A**, in the Hutar Coalfield, and **B**, in the Lower Gondwana (after Lele & Shukla). T=Talchir, L.K.=Lower Karharbari, U.K.= Upper Karharbari, B=Barakar.

rential saccus spread. Body infold bilateral and horizontally oriented, i.e. its longer axis (x) is parallel to longer axis of spore (X) (Pl. 1, fig. 8).

Spore circularity ratio = >1.1

Body infold circularity ratio = >1.1 but less than spore circularity ratio, hence the saccus spread value is always positive.

Norm B_2 — Characterized by bilateral symmetry of miospore radial symmetry of body infold and differential saccus spread (Pl. 1, figs 10, 11).

Spore circularity ratio = >1.1

Body circularity ratio = 1 ± 0.1

Saccus spread value = >0.1

Norm B_3 — Characterized by bilateral symmetry of miospore and differential saccus spread. Body infold bilateral and vertically oriented, i.e. its longer axis (x) is at right angle to longer axis (X) of miospore (Pl. 1, figs 12-14).

Spore circularity ratio >1.1

Body infold circularity ratio = <0·9

Saccus spread value = >0.1

Norm B_4 — Characterized by radial symmetry of miospore and differential saccus spread. Body infold bilateral and vertically oriented as in Norm B_3 (Pl. 1, figs 15, 16).

Spore circularity ratio = 1 ±0.1

Body infold circularity ratio = 0.9

Saccus spread value = 0.1

EVALUATION OF VARIABILITY TRENDS

1. *Miospore Symmetry* — An assessment of spore circularity parametral trend shows that mean spore circularity (Table 2) in the Talchir Formation is 1.16 (Deori Nala 1.14 & Koel River 1.19). It increases up to

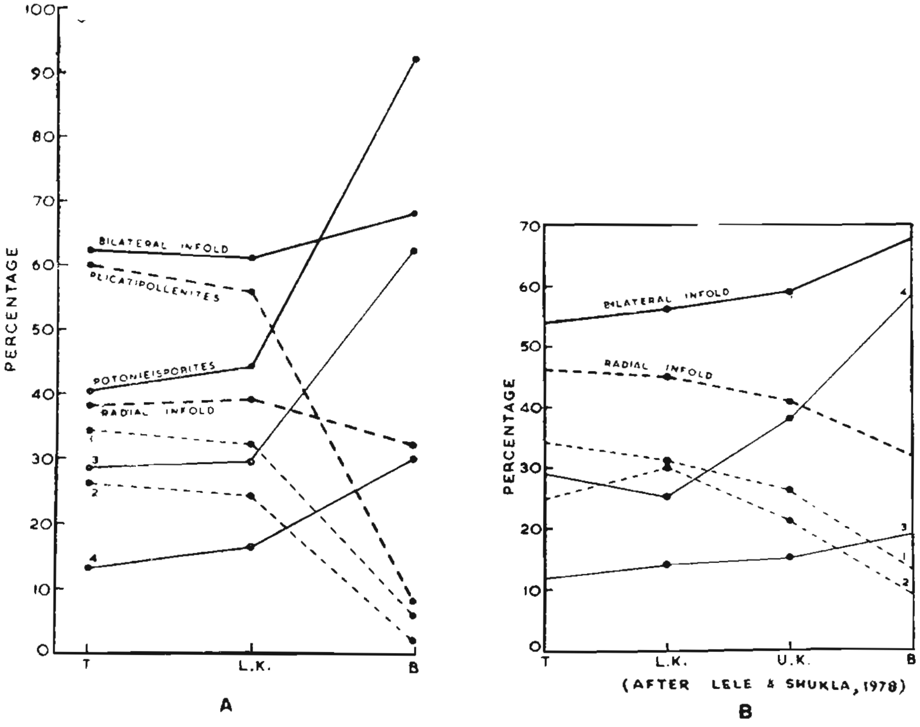
TABLE 1 — MEAN PERCENTAGE DISTRIBUTION OF RADIAL AND BILATERAL MIOSPORES OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* IN THE KOEL RIVER AND DEORI NALA SECTIONS AND MEAN OF BOTH SECTIONS

LOCALITY	MIOSPORES SYMMETRY	TALCHIR	LOWER KARHARBARI	BARAKAR
Deori Nala	Radial	35	32	×
	Bilateral	65	68	×
Koel River	Radial	30	25	6
	Bilateral	70	75	94
Mean	Radial	32	28	6
	Bilateral	68	72	94

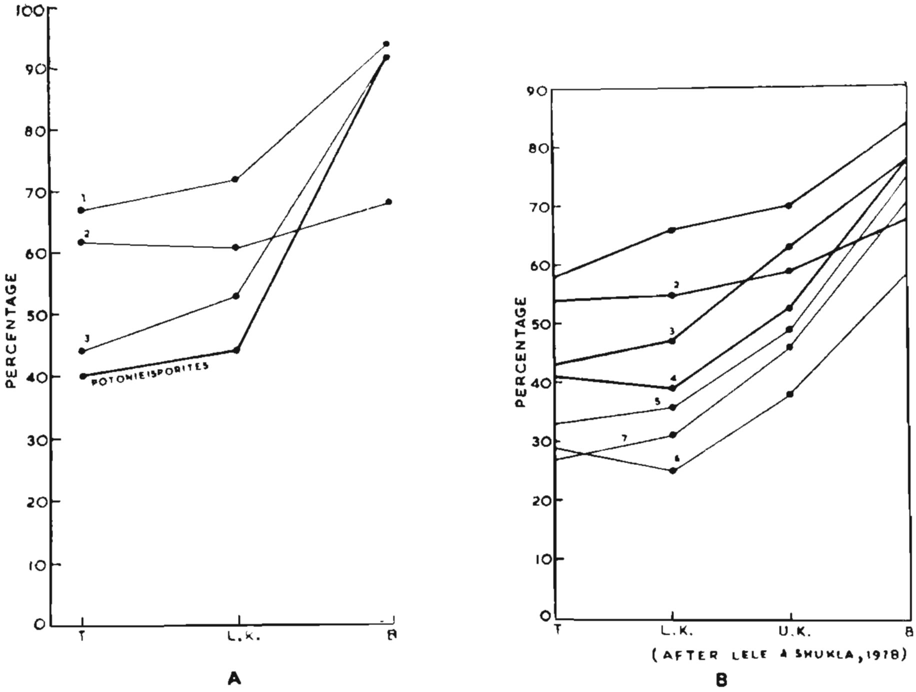
TABLE 2 — MEAN SPORE CIRCULARITY RATIO OF THE SPORES OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* FROM DEORI NALA AND KOEL RIVER SECTIONS AND MEAN OF BOTH SECTIONS

LOCALITY	TALCHIR	LOWER KARHARBARI	BARAKAR
Deori Nala Section	1.14	1.18	×
Koel River Section	1.19	1.3	1.29
Mean	1.16	1.24	1.29

1·24 (Deori Nala 1·2 & Koel River 1·28) in the Karharbari Formation and further rises to 1·29 in the Barakar Formation. These above mentioned figures agree with the results of Lele and Shukla (1978) except in the Barakar Formation where mean circularity is 1·3. It is, however, interesting to note that though in individual section the overall circularity ratio of spore increases



TEXT-FIG. 2 — A, distribution trends of the body infold symmetry through time and their correlation with *Plicatipollenites* and *Potonieisporites* trends in the Hutar Coalfield, (i) bilateral infold in *Plicatipollenites*, (ii) radial infold in *Plicatipollenites*, (iii) bilateral infold in *Potonieisporites*, and (iv) radial infold in *Potonieisporites*. **B**, distribution trends of the body infold symmetry through time and their correlation with *Plicatipollenites* and *Potonieisporites* trends (after Lele & Shukla)— (1) radial infold in *Plicatipollenites*, (2) bilateral infold in *Plicatipollenites*, (3) radial infold in *Potonieisporites*, and (4) bilateral infold in *Potonieisporites*.



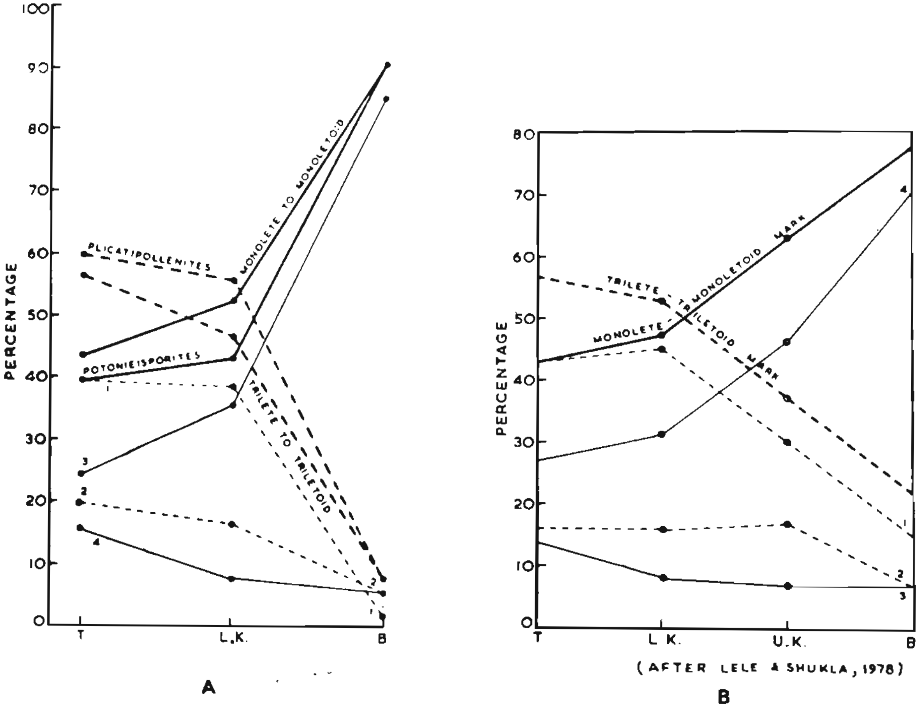
TEXT-FIG. 3 — A, composite correlation of variation trends in *Potonieisporites* in the Hutar Coalfield — (1) spores with bilateral form, (2) spores with bilateral body infold, and (3) spores with monolete to monoletoid mark. B, composite correlation of variation trends in *Potonieisporites* (after Lele & Shukla, 1978) parametral trends of bilateral spore symmetry — (1) bilateral body infold symmetry, (2) monolete-monoletoid mark, (3) *Potonieisporites* population, (4) *Potonieisporites* with bilateral spore symmetry, (5) bilateral body infold, and (6) monolete-monoletoid mark.

in time, the value of miospore circularity ratio is different from the mean value calculated. Therefore, bilateralism in spores at a particular time level may vary from field to field and from section to section but the general trend remains the same.

In the Hutar Coalfield trends of distribution of radial and bilateral spores in time show reverse tendency (Text-fig. 5) which agrees with distributional trends of *Plicatipollenites* (Text-fig. 7A) (Norm A_1 and A_2) and *Potonieisporites* (Text-fig. 3A) (Norms B_1 to B_4) respectively. Distributional trends of circular *Plicatipollenites* and *Potonieisporites* and bilateral *Plicatipollenites* and *Potonieisporites* clearly indicate that circular spore of both the genera showed a decline with the proliferation of bilateral forms (Text-fig. 5A). These trends of the Hutar Coalfield agree with the overall trends (Text-fig. 5B) given by Lele and Shukla (1978).

2. *Tetrad Mark* — The problem regarding the development of tetrad mark in spores and pollen and the type of tetrad found in these spores has already been discussed by various authors (Staplin *et al.*, 1967; Lele, 1974; Vischer, 1971) and summarized by Lele and Shukla (1978). Five types of marks: (i) trilete mark, (ii) triletoid mark, (iii) monoletoid mark, (iv) bilete mark, and (v) monolete mark — have been recognized by Lele and Shukla (1978) for biometric analysis.

Parametral variation trends of the tetrad mark reveal that the normal trilete is well-represented by 27% (Deori Nala — 29%, Koel River 25%) spores in the Talchir Formation, whereas it reduces to 24% (Deori Nala — 19%, Koel River — 29%) in the Lower Karharbari beds and finally



TEXT-FIG. 4 — A, distribution trends (parametral) of trilete-triletoid set and monolete-monoletoid set in time (thick lines) and their correlation with *Plicatipollenites* and *Potonieisporites* population — (1) trilete and triletoid mark in *Plicatipollenites*, (2) monolete and monoletoid mark in *Plicatipollenites*, (3) trilete to triletoid mark in *Potonieisporites*, and (4) monolete to monoletoid mark in *Potonieisporites*. **B**, distribution trends (parametral) of trilete-triletoid set and monolete and their correlation with *Plicatipollenites* and *Potonieisporites* trends (thin line) — (1) *Plicatipollenites* trilete-triletoid, (2) *Plicatipollenites* monolete-monoletoid, (3) *Potonieisporites* trilete-triletoid, and (4) *Potonieisporites* monolete-monoletoid (after Lele & Shukla, 1978).

no trilete mark is seen in the Barakar Formation (Table 3; Text-fig. 10A). In contrast to this, the incidence of monolete mark in the Talchir Formation is 5% (Deori Nala — 6%, Koel River — 4%), it further increases to 12% (Deori Nala — 13%, Koel River — 11%) in the Lower Karharbari beds and finally reaches 40% (Koel River) in the Barakar Formation (Text-fig. 10A). The asymmetrical trilete (Text-fig. 10A) in general shows a higher percentage at any time level but it shows a gradual decrease with time (Talchir — 68%, Karharbari — 54%, Barakar — 60%). These trends also agree with the trends shown by Lele and Shukla (1978) (Talchir — 69%, Karharbari — 62-56%, Barakar — 61%) (Text-fig. 10B).

Among the 3 categories of asymmetrical trilete, the triletoid mark registers a progressive decline (Text-fig. 10A) in number (Talchir — 29%, Karharbari — 23%, Barakar — 8%). The monoletoid mark (Text-fig. 10A) shows a stabilization tendency towards Karharbari and then a slight rise (Talchir — 38%, Karharbari — 38%, Barakar — 42%). The bilete mark (Text-fig. 10A) also shows a gradual increase in the Karharbari and Barakar formations (Talchir — 1%, Karharbari — 3%, Barakar — 10%).

It is also seen that the combined trend of trilete and triletoid mark shows a decrease in time, while of monolete, bilete and monoletoid marks shows an increase through time (Text-fig. 4A). These trends are compatible with *Plicatipollenites* and *Potonieisporites* respectively (Text-fig. 4A). It is also seen that *Plicatipollenites* is dominated by the trilete and triletoid marks

TABLE 3 — PERCENTAGE DISTRIBUTION OF VARIATION CHARACTERS OF THE NORMS OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* IN KOEL RIVER AND DEORI NALA SECTIONS OF THE HUTAR COALFIELD

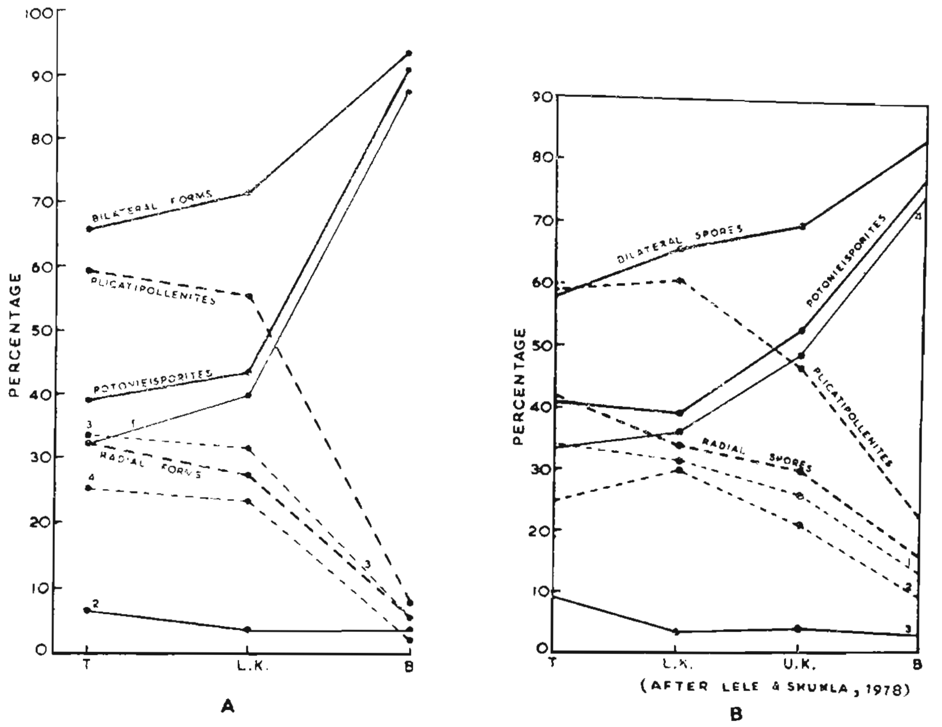
SECTION	FORMATION	NORM A_1				NORM A_2					NORM B_1					NORM B_2					NORM B_3					NORM B_4			
		T	T_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	B	M
KOEL RIVER	BARAKAR	×	2	×	×	×	×	6	×	×	×	×	8	×	2	×	2	10	4	14	×	×	18	6	24	×	4	×	×
	LOWER KARHARBARI	11	12	×	×	11	3	14	1	×	2	1	11	×	4	2	4	7	2	3	×	×	4	1	5	2	×	×	×
	TALCHIR	13	11	×	×	6	8	23	×	4	2	2	10	×	×	2	2	4	×	×	2	×	4	1	×	×	6	×	×
DEORI NALA	LOWER KARHARBARI	13	12	×	1	6	8	19	×	×	×	2	4	×	2	×	×	7	×	5	×	×	8	2	5	×	5	1	×
	TALCHIR	15	13	×	×	4	9	14	×	×	4	2	7	×	2	3	×	11	1	2	×	1	2	1	2	3	4	×	×

T = Trilete, T_1 = Triletoid, B = Bilete, M = Monolete, M_1 = Monoletoid.

TABLE 4 — PERCENTAGE DISTRIBUTION OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* NORMS AND THEIR VARIATION CHARACTERS THROUGH TIME IN THE HUTAR COALFIELD

NORMS	A_1				A_2					B_1					B_2					B_3					B_4			
BARAKAR	2				6					10					30					48					4			
KARHARBARI	24				32					13					15					12					4			
TALCHIR	26				34					15					12					6					67			
BARAKAR	×	2	×	×	×	×	6	×	×	×	×	8	×	2	×	2	10	4	14	×	×	18	6	24	×	4	×	×
LOWER KARHARBARI	12	12	×	×	9	6	17	×	×	1	1	8	×	3	1	2	7	1	4	×	×	6	1	5	1	2	1	×
TALCHIR	14	12	×	×	5	9	18	×	2	3	2	9	×	1	2	1	8	×	1	1	×	3	1	1	2	5	×	×
TETRAD MARK	T	T_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	M_1	B	M	T	T_1	B	M

T = Trilete, T_1 = Triletoid, B = Bilete, M = Monolete, M_1 = Monoletoid.



TEXT-FIG. 5 — A, distribution trends of miospore symmetry through time in the Hutar Coalfield — (1) *Potonieisporites* bilateral (Norms B_1, B_2, B_3), (2) *Potonieisporites* radial (Norm B_4), (3) *Plicatipollenites* bilateral (Norm A_2), and (4) *Plicatipollenites* radial (Norm A_1). **B**, distribution trends of miospore symmetry in time (after Lele & Shukla) — (1) *Plicatipollenites* radial (Norm A_1), (2) *Plicatipollenites* (Norm A_2), (3) *Potonieisporites* radial (Norm B_4), and (4) *Potonieisporites* bilatearl (Norms B_1, B_2, B_3).

and *Potonieisporites* by monolete to monoletoid marks (Text-fig. 4A). Further, *Plicatipollenites* with trilete and triletoid marks show a declining trend but *Plicatipollenites* with monolete and monoletoid marks registers an increase in Karharbari and then a fall in Barakar (Text-fig. 4A). *Potonieisporites* with monolete to monoletoid marks registers an increase in time while those with trilete and triletoid marks show a fall in time (Text-fig. 4A).

It is apparent that during course of evolution the trilete and triletoid marks dominate the genus *Plicatipollenites* (Norms A_1 & A_2) (Text-fig. 6A) and in *Potonieisporites* (Norms B_1, B_2, B_3) the trilete and triletoid marks have been gradually eliminated (Text-fig. 6A) and replaced by the monolete to monoletoid mark (Text-fig. 8A). Thus the present study confirms the results of Lele and Shukla (1978).

TABLE 5 — MEAN PERCENTAGE DISTRIBUTION OF CIRCULAR AND BILATERAL BODY INFOLD OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* IN KOEL RIVER AND DEORI NALA SECTIONS AND THEIR MEAN

LOCALITY	MIOSPORES SYMMETRY	TALCHIR	LOWER KARHARBARI	BARAKAR
Deori Nala Section	Radial	45	38	×
	Bilateral	55	62	×
Koel River Section	Radial	32	51	32
	Bilateral	68	49	68
Mean	Radial	38	48	32
	Bilateral	62	52	68

3. *Body Infold System* (Tables 5 and 6) — Body infold system marks the point of separation of saccus (sexine) from the body

TABLE 6 — MEAN INFOLD CIRCULARITY RATIO OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* FROM DEORI NALA AND KOEL RIVER SECTIONS AND THEIR MEAN

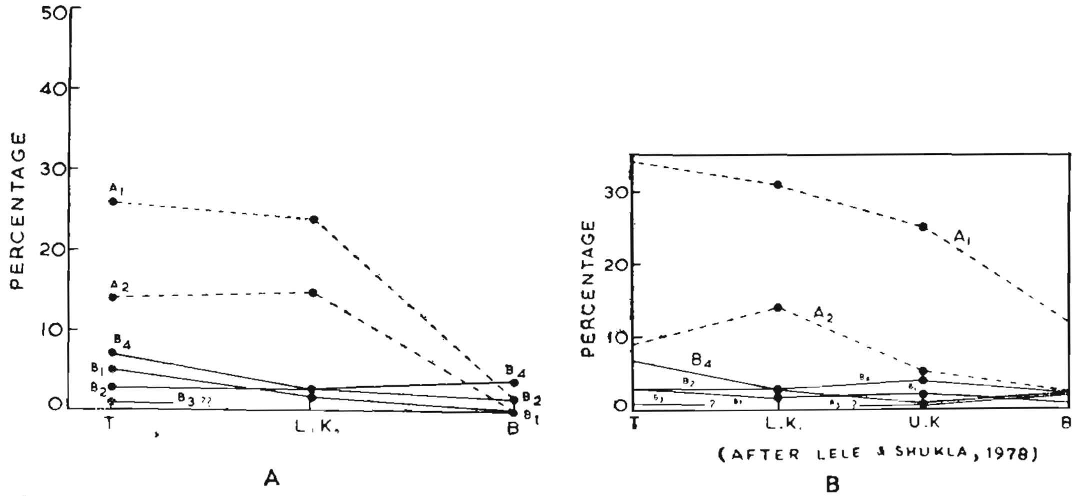
Locality/ Formations	Talchir	Lower Karharbari	Barakar
Deori Nala	1.06	1.05	×
Koel River	1.08	1.05	0.95
Mean	1.07	1.05	0.95

(nexine) in the genera *Plicatipollenites* and *Potonieisporites* (Lele, 1964). The area circumscribed by the infold is said to mark the germinal area of tenuitas (Potonié & Lele, 1961; Lele, 1964; Bharadwaj, 1964a, 1974a). The body infold is of various shapes (Text-fig. 11 of Lele & Shukla, 1978). They have been grouped into 3 major types on the basis of body infold circularity ratio.

	Body infold circularity ratio
1. Vertical bilateral body infold	< ×0.9
2. Circular body infold	± 1×0.1
3. Horizontal bilateral body infold	> ×1.1

An objective assessment of parametral variation trends shows that radial body infold system has a downward trend of distribution through time (Talchir = 38%, Lower Karharbari = 48%, Barakar = 32%) and bilateral fold shows an upward distribution in time (Talchir = 62%, Lower Karharbari = 52%, Barakar = 68%) (Table 5; Text-fig. 2A). These distributional trends are compatible with genera *Plicatipollenites* and *Potonieisporites*. *Plicatipollenites* is mostly associated with radial fold and *Potonieisporites* with bilateral fold (Text-fig. 2A). Norm A_2 (*Plicatipollenites*) has bilateral fold yet it meets the same fate as Norm A_1 which has radial folds. But Norm B_1, which is nearer to Norm A_2, shows somewhat stabilizing tendency and after that Norms B_2 and B_3 show step by step rise in the distribution and advancement of morphology (Text-fig. 9A). This suggests a time proportionate evolutionary relationship and gradual establishment of bilateral infold from horizontal to vertical position. The above results are in general agreement with the results of Lele and Shukla (1978).

Body symmetry — Central body of the genera *Plicatipollenites* and *Potonieisporites* shows considerable variation in shape patterns, which may be due to compressional factors, original curvatures of the body, saccus attachment and its thickness and the



(AFTER LELE & SHUKLA, 1978)

TEXT-FIG. 6 — Distribution trends of trilete-triletoid mark in the Norms of *Plicatipollenites* (A_1 A_2) and *Potonieisporites* (B_1, B_2, B_3, B_4)— **A**, in the Hutar Coalfield and **B**, in the Lower Gondwana beds (general) (after Lele & Shukla, 1978).

TABLE 7 — MEAN BODY CIRCULARITY RATIO OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* FROM DEORI NALA AND KOEL RIVER SECTIONS AND MEAN OF BOTH SECTIONS

LOCALITY/ FORMATION	TALCHIR	LOWER KARHARBARI	BARAKAR
Deori Nala	1.13	1.125	×
Koel River	1.2	1.16	1.02
Mean	1.16	1.14	1.02

TABLE 8 — MEAN PERCENTAGE DISTRIBUTION OF CIRCULAR AND BILATERAL BODY OF *PLICATIPOLLENITES* AND *POTONIEISPORITES* IN KOEL RIVER AND DEORI NALA SECTIONS AND MEAN OF BOTH SECTIONS

LOCALITY	MIOSPORE SYMMETRY	TALCHIR	LOWER KARHARBARI	BARAKAR
Deori Nala Section	Circular	34	59	×
	Bilateral	66	41	×
Koel River Section	Circular	26	42	56
	Bilateral	74	58	44
Mean	Circular	30	50	56
	Bilateral	70	50	44

flexibility of exine. Therefore to reconstruct the original shape of the body a study of all these factors is called for. But these factors do not appreciably affect the symmetry of the body which can be determined from the Body circularity ratio.

An assessment of body circularity ratio (Table 7) shows that the mean circularity for Talchir is 1.16 (Deori Nala — 1.13, Koel River — 1.2) and it gradually decreases to 1.14 (Deori Nala — 1.125, Koel River — 1.16) in Lower Karharbari and 1.02 (Koel River) in Barakar. Thus overall circularity of spore shows a decline trend indicating more and more circular bodies.

The parametral trends also show that circular bodies form 30% in Talchir (Deori Nala — 34%, Koel River — 26%), 50.5% in Karharbari (Deori Nala — 59%, Koel River — 42%) and 56% in Barakar (Koel River); against this the bilateral bodies show a downward trend — 70% in Talchir (Deori Nala — 66%, Koel River — 74%), 49.5% in Karharbari (Deori Nala — 41%, Koel — 50%) and 44% in Barakar (Koel River). Thus, though the two trends are opposite to each other but they do not coincide with other parametral trends and instead they show an inverse correlation (Table 8).

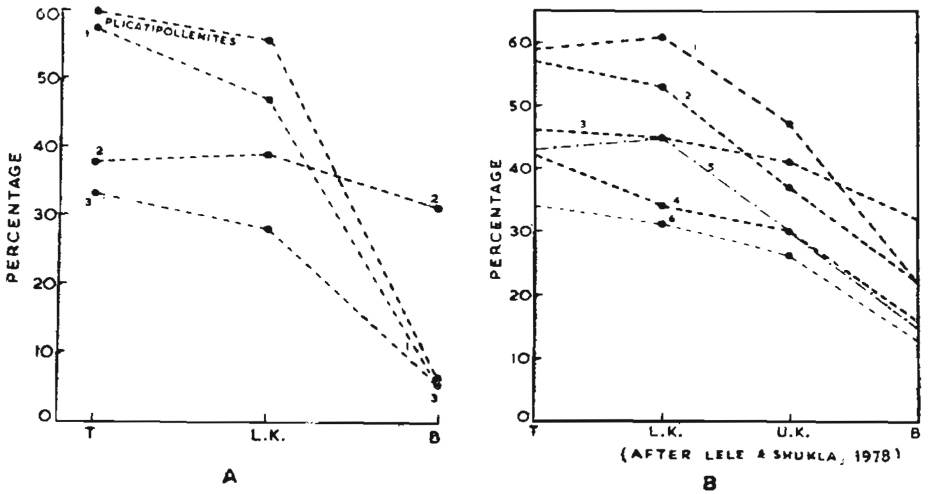
CONCLUSION

Considering the overall trend of *Plicatipollenites* and *Potonieisporites* and individual trends of parameters, *Plicatipollenites* population is marked by radial miospore symmetry, radial infold system and trilete to triletoid mark (Text-fig. 7), whereas *Potonieisporites* population is marked by bilateral spores, bilateral infold, and monolete to monoletoid mark (Text-fig. 3).

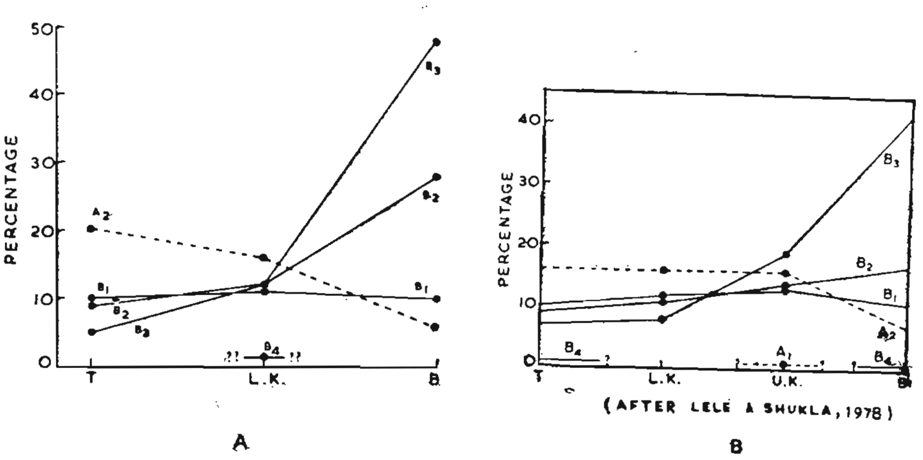
The body parameter shows an inverse correlation with both populations and rest of the parameters. It does not show enough change in symmetry to be of any use to demarcate the morphological criteria to differentiate the *Plicatipollenites* population from *Potonieisporites* population.

Plicatipollenites population is represented by Norms A_1 and A_2 which show a continuous downward trend through time (Text-fig. 9A). The *Potonieisporites* population is typically represented by Norms B_2 and B_3 which show an upward trend across time (Text-fig. 9A). Norms B_1 and B_4 of *Potonieisporites* population show superficial morphological resemblance with Norms A_2 and A_1 respectively. The Norms B_1 and B_4 also show a downward trend across time which is similar to *Plicatipollenites* population (Text-fig. 9A). Norms B_1 and B_4 could indeed be confused morphologically with *Plicatipollenites* but the biometric criteria help in separating these Norms. Biometrically B_1 and B_4 belong to *Potonieisporites* as they definitely show a step towards the advanced type of morphology defined for the *Potonieisporites* population.

The study thus demonstrates that there is a reasonable degree of similarity between the morphological evolutionary trends of the

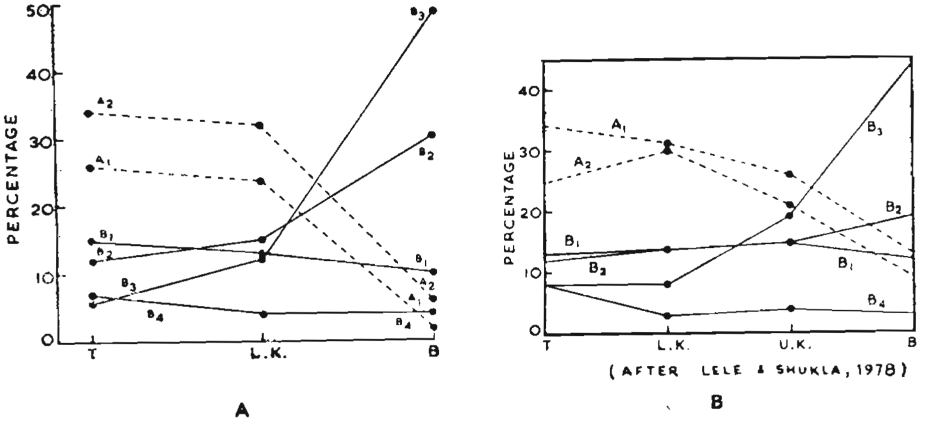


TEXT-FIG. 7 — A, composite correlation of variation trends in *Plicatipollenites* and parametral trends in the Hutar Coalfield — (1) Trilete to triletoid mark, (2) radial infold system, (3) radial miospore symmetry. B, composite correlation of variation trends (after Lele & Shukla, 1978) of *Plicatipollenites* population — (1) Parametral trends of *Plicatipollenites* population, (2) trilete-triletoid mark, (3) radial body infold symmetry, (4) radial spore symmetry, (5) *Plicatipollenites* with trilete-triletoid mark, and (6) radial spore symmetry.

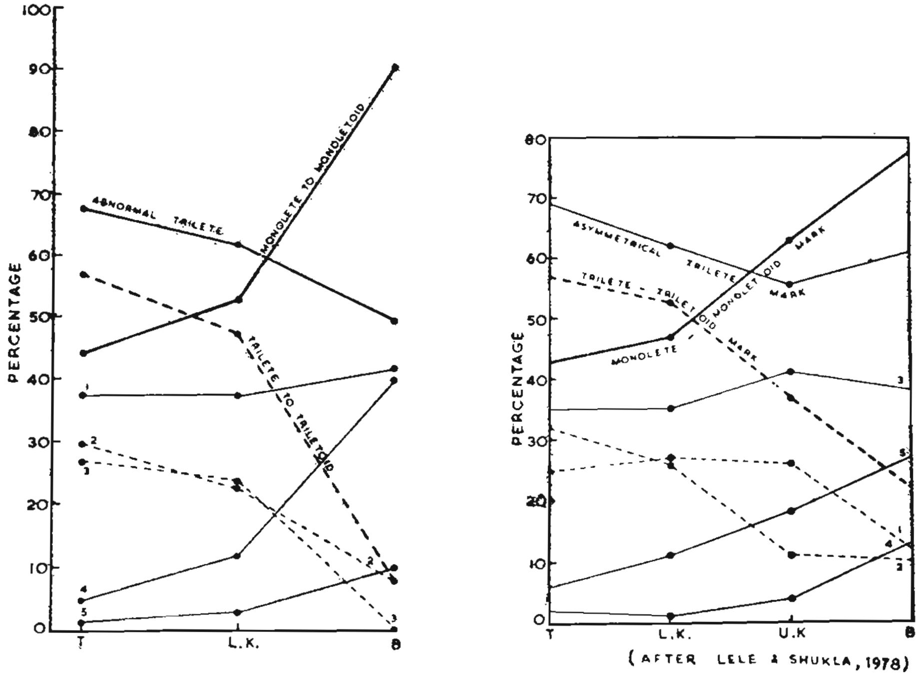


TEXT-FIG. 8 — Distribution trends of monolete-monoletoid mark in the Norms of *Plicatipollenites* (A_1, A_2) and *Potonieisporites* (B_1, B_2, B_3, B_4)— A, in the Hutar Coalfield and B, in the Lower Gondwana beds (after Lele & Shukla, 1978).

Plicatipollenites/Potonieisporites populations of the Hutar Basin and those obtained in the synthesis from the five Lower Gondwana basins by Lele and Shukla (1978) (Text-figs 3, 7). However, the differences of individualistic nature are reflected in the analysis of Hutar Coalfield. For example, in general trend (Lele & Shukla, 1978) Norms A_1 and A_2 of *Plicatipollenites* characterize the Talchir and Lower Karharbari respectively. In Hutar Coalfield, however, the values of Norm A_2 are not so distinctive

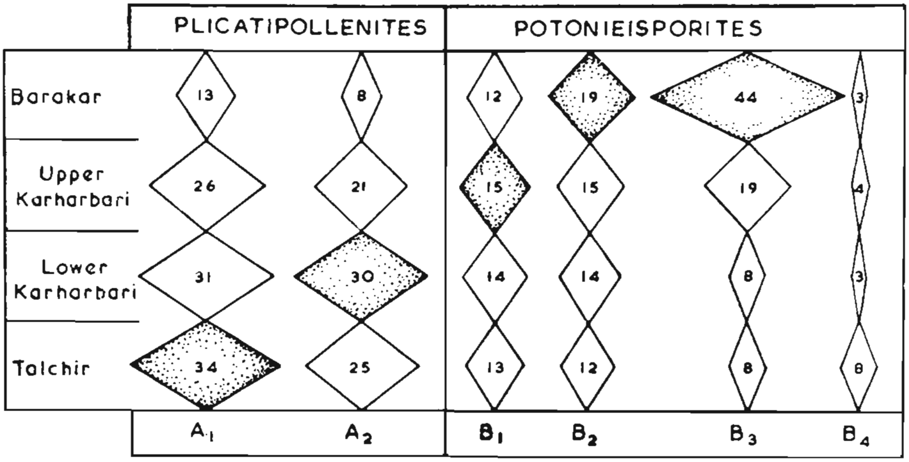


TEXT-FIG. 9 — Distribution trends of various norms of *Plicatipollenites* (A_1, A_2) and *Potonieisporites* (B_1, B_2, B_3, B_4) — **A**, in the Hutar Coalfield and **B**, in the Lower Gondwana beds (after Lele & Shukla, 1978).

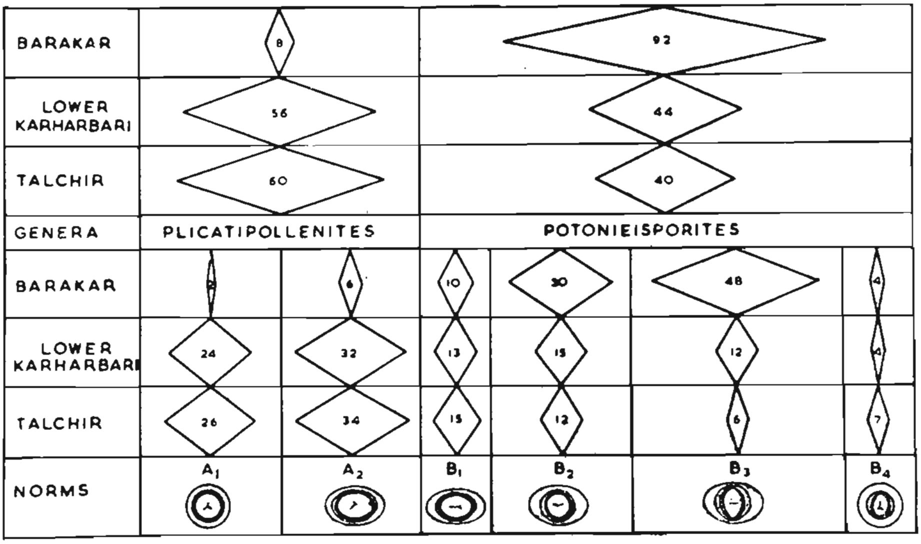


TEXT-FIG. 10 — **A**, distribution trends of tetrad mark categories through time in the Hutar Coalfield — (1) monoletoid, (2) triletoid, (3) trilete, (4) monolete, and (5) bilete. **B**, distribution trends of tetrad mark categories in time — (1) trilete, (2) triletoid, (3) monoletoid, (4) bilete, and (5) monolete (after Lele & Shukla, 1978).

for the Lower Karharbari (Text-fig. 11). Similarly the distributional values of Norm B_1 (*Potonieisporites*) are not at all well-marked in stratigraphical time even in the general synthesis. Perhaps the best of the *Potonieisporites* Norms is B_3, followed by



A (AFTER LELE & SHUKLA, 1978)



B

TEXT-FIG. 11 — **A**, percentage frequency distribution of the norms of *Plicatipollenites* and *Potonieisporites* (after Lele & Shukla). **B**, percentage frequency distribution of *Plicatipollenites* and *Potonieisporites* and their respective norms through time in the Hutar Coalfield.

B_3, both of which show continuous rise in frequencies across time. In this respect the Hutar data fully agree with the general synthesis of Lele and Shukla (1978). Therefore, we are of the opinion that Norms B_2 and B_3 are more trustworthy forms for the biostratigraphical determinations than B_1 or B_4.

REFERENCES

BHARDWAJ, D. C. (1954). An approach to the problem of taxonomy and classification in the study of *sporae dispersae*. *Palaeobotanist*, **4**: 3-9.

BHARDWAJ, D. C. (1964). *Potonieisporites* Bhard. ihre Morphologie, systematik und stratigraphie. *Fortscher., Geol. Rheild. Westf.*, **12**: 45-54.

LELE, K. M. (1964). Studies in the Talchir flora of India-2. Resolution of the spore genus *Nuskoisporites* Pot. & Kl. *Palaeobotanist*, **12** (2): 147-168.

LELE, K. M. (1974). Palaeozoic monosaccate miospores, pp. 232-252 in K. R. Surange *et al.* (eds)—*Aspects & Appraisal of Indian Palaeobotany*. Birbal Sahni Institute of Palaeobotany, Lucknow.

LELE, K. M. & SHUKLA, M. (1978). Biometric resolution of *Plicatipollenites* and *Potonieisporites* in Lower Gondwana succession of India. *Palaeobotanist*, **25**: 217-237.

MAHESHWARI, H. K. (1967). Studies in the Glossopteris flora of India-29. Miospore assemblage from the Lower Gondwana exposures along Bansloi River in Rajmahal Hills, Bihar. *Palaeobotanist*, **15** (3): 258-280.

POTONIÉ, R. & LELE, K. M. (1961). Studies in the Talchir flora of India-1. *Sporae dispersae* from the Talchir beds of the South Rewa Gondwana Basin. *Palaeobotanist*, **8** (1-2): 22-37.

STAPLIN, F. L., POCOCK, S. J. & JANSONIUS, J. (1967). Relationship among gymnospermous pollen. *Rev. Palaeobot. Palynol.*, **3**: 297-310.

VISSCHER, H. (1971). The Permian and Triassic of Kingscourt outlier, Ireland. *Geol. Surv. Ireland. Spl. Publ.*, **1**: 1-114.

EXPLANATION OF PLATE

(All figures are × 250 unless otherwise mentioned)

PLATE 1

1. *Plicatipollenites*, Norm A_1 (Deori Nala Section, Talchir Formation). Spore circularity ratio—(1·04). Body infold circularity ratio (1·04). Saccus spread value — Zero. Slide no. 6377.
2. *Plicatipollenites*, Norm A_1 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·1). Body infold circularity ratio (1·1). Saccus spread value (Zero). Slide no. 6394.
3. *Plicatipollenites* Norm A_1 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·1). Body infold circularity ratio (1·1). Saccus spread value (Zero). Slide no. 6394.
4. *Plicatipollenites* Norm A_1 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·05). Body infold circularity ratio (0·95). Saccus spread value (0·1). Slide no. 6390.
5. *Plicatipollenites* Norm A_2 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·45). Body infold circularity ratio (1·45). Saccus spread value (Zero). Slide no. 6394.
6. *Plicatipollenites* Norm A_2 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·34). Body infold circularity ratio (1·54). Saccus spread value (−0·2). Slide no. 6388.
7. *Plicatipollenites*, Norm A_2 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·14). Body infold circularity ratio (1·29). Saccus spread value (−0·15). Slide no. 6377.
8. *Potonieisporites* Norm B_1 (Deori Nala Section, Talchir Formation). Spore circularity ratio (1·21). Body infold circularity ratio (1·15). Saccus spread value (0·06). Slide no. 6377.
9. *Potonieisporites* Norm B_2 (Barakar Formation, Koel River Section). Spore circularity ratio (1·57); Infold circularity ratio (0·95); saccus spread value (0·62). Slide no. 6284.
10. *Potonieisporites* Norm B_2 (Barakar Formation, Koel River Section). Spore circularity ratio (1·46); Infold circularity ratio (1·04); Saccus spread value (0·42). × 500. Slide no. 6284.
11. *Potonieisporites* Norm B_3 (Barakar Formation; Koel River Section). Spore circularity ratio (1·2); infold circularity ratio (0·8); saccus spread value (0·4). Slide no. 6284.
12. *Potonieisporites* Norm B_3 (Barakar Formation, Koel River Section). Spore circularity ratio (1·44); infold circularity ratio (0·47); saccus spread value (0·97). ×500. Slide no. 6284.
13. *Potonieisporites* Norm B_3 (Karharbari Formation, Deori Nala Section). Spore circularity ratio (1·14); body infold circularity ratio (0.8); saccus spread value (0.34). Slide no. 6285.
14. *Potonieisporites* Norm B_3 (Karharbari Formation, Deori Nala Section). Spore circularity ratio (1·28); body infold circularity ratio (0·65); saccus spread value (0.63). ×500. Slide no. 6284.
15. *Potonieisporites* Norm B_4 (Barakar Formation, Koel River Section). Spore circularity ratio (1·05); body infold circularity ratio (0·6); saccus spread value (0·45). × 500. Slide no. 6286.
16. *Potonieisporites* Norm B_4 (Barakar Formation, Koel River Section). Spore circularity ratio (1·05); body infold circularity ratio (0·44); saccus spread value (0·61). × 500. Slide no. 6284.

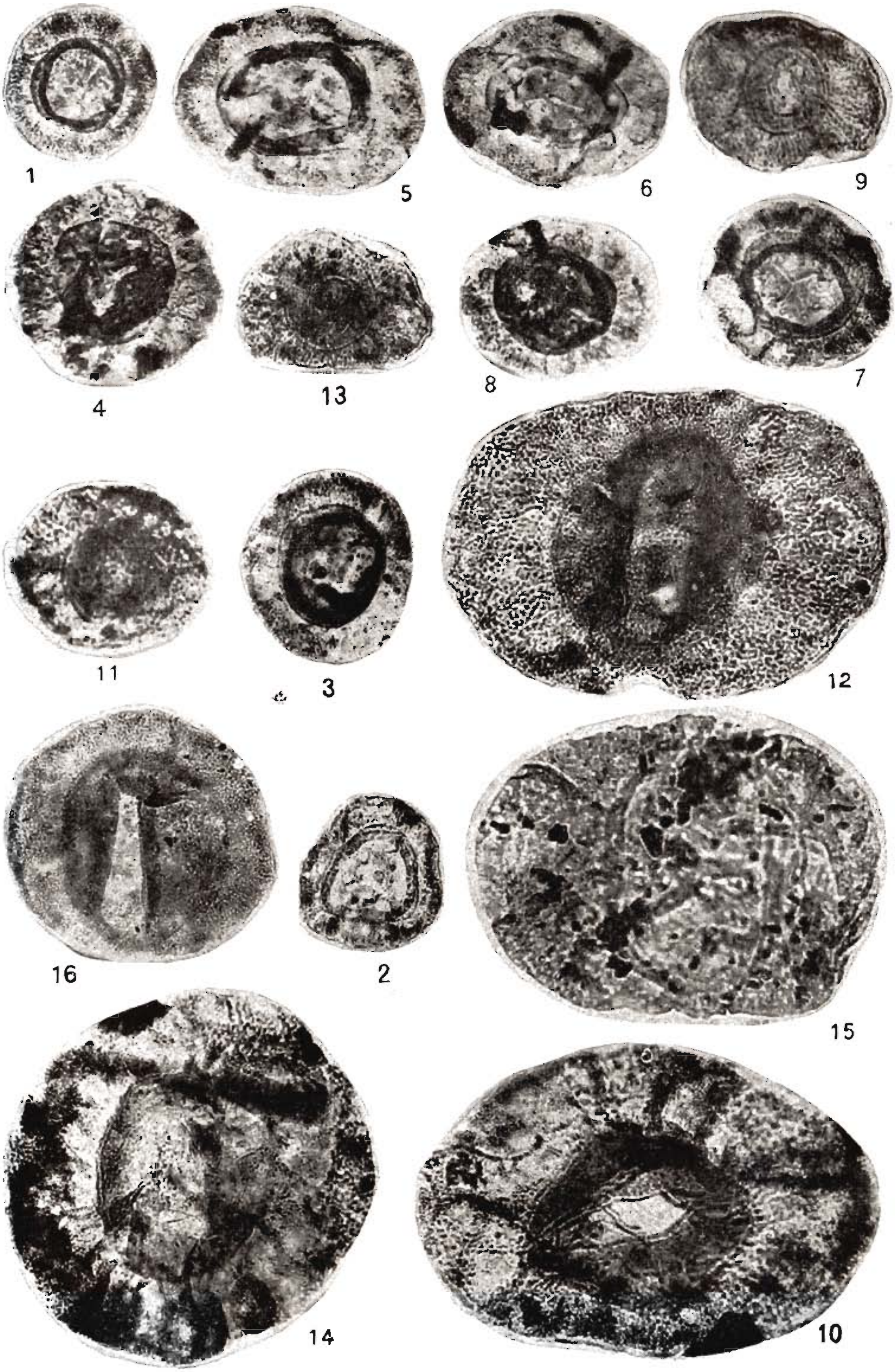


PLATE 1

The Palaeobotanist, **31**(1): 45-51, 1983.

A NEW SPECIES OF PTERIDIACEAE — *PTERIDIUM DACHINGSHANENSE*

WANG ZIQIANG

Tianjin Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, Tianjin, 300170,
People's Republic of China

ABSTRACT

A new fossil species, *Pteridium dachingshanense*, is described from the Early Cretaceous strata in Dachingshan Range of Neimonggol Autonomous Region (Inner Mongol), China.

The species shows some characteristics of *Pteridium*, such as the continuous marginal sorus and a true scarious indusium. It differs from the living bracken fern *Pteridium aquilinum* in its overall smaller size, more or less reduced pinnules, smaller combined terminal pinnules, and obscure venation. The secondary veins arising from the midvein near the base of the pinnules seem to form a little fan-like pattern.

New species traces the history of Pteridiaceae back to the Cretaceous period.

Key-words — Pteridiaceae, *Pteridium*, Dachingshan Range, Early Cretaceous, China.

साराँश

टेरीडिएसी की एक नव जाति – टेरीडियम् दैकिंगशानेन्से – वाँग ज़िकियाँग

चीन के नीमंगोल आटोनोमस क्षेत्र (आन्तरिक मंगोल) की दैकिंगशान श्रेणी में स्थित प्रारम्भिक क्रीटेशस स्तरों से एक नवीन पादपाश्मीय जाति, टेरीडियम् दैकिंगशानेन्से, का वर्णन किया गया है।

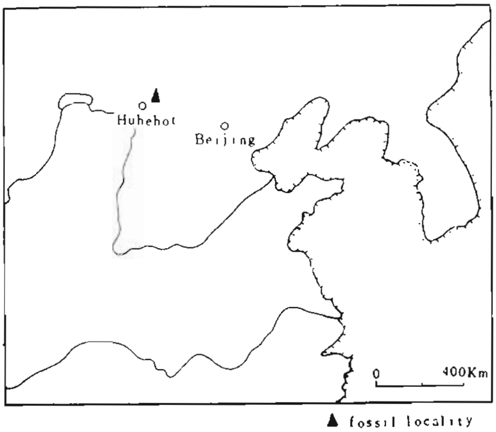
यह जाति टेरीडियम् के कुछ विशिष्ट लक्षण प्रदर्शित करती है जैसे कि अविच्छिन्न उपांतीय बीजाणुधानी एवं तद्रूप झिल्लीदार सोरसछद। वर्तमान ब्रेकन फ़र्न टेरीडियम् ऐक्वीलाइनम् से यह अपने छोटे आकार, प्रायः संकुचित पिच्छिकाओं, कुछ छोटी अग्रस्थ संयोजित पिच्छिकाओं तथा अस्पष्ट शिरा विन्यास के कारण भिन्न है। पिच्छिकाओं के आधार के पास मध्यशिरा से उत्पन्न द्वितीयक शिरायें छोटे पंखे की तरह का रूप धारण कर लेती हैं।

इस नवीन जाति से क्रीटेशस युग में टेरीडिएसी कुल की उपस्थिति का आभास होता है।

THE fern family Pteridiaceae was separated by Ching (1975) from the family Pteridiaceae. Its striking character is the double indusium, formed by the modified reflexed margin of pinnules (so-called false indusium) and the true indusium developing from the epidermal cells of pinnules. Initially the family was monotypic and included only one genus, i.e. *Pteridium* having a single cosmopolitan species *P. aquilinum* (L.) Kuhn (commonly called the bracken fern) with some geographical variants. Not long ago, these variants were raised to specific ranks. In 1978, Ching assigned the genus *Paesia* of Taiwan Province of China to the family.

So far the fossil records of the family are too few to learn its geological range and phylogenetic history accurately. Although a few specimens were referred to the genus *Pteridium* from the Cenozoic beds of Northern Hemisphere, none of them shows a sorus or indusium and hence their assignment to the genus is rather suspect.

During my travels to Dachingshan Range (Text-fig. 1) in Neimonggol Autonomous Region for geological survey in 1965, a number of well-preserved fossil plants, though fragmentary, were collected and examined. One of them while showing many important features of living bracken fern also shows several remarkable differences from the latter. After accurate observation and sufficient comparison the writer decides to attribute it to a new species of *Pteridium*.



TEXT-FIG. 1 — Map showing the locality.

The new species occurs in the sediments of the Early Cretaceous period dated on many important index fossil plants associated with it. From this the present writer concludes that the history of the family Pteridiaceae should be carried back to remote a past as Cretaceous. In the same way as few other ferns, the present day world-wide distribution of *Pteridium* also is relative to its rather antiquity.

DESCRIPTION

FAMILY — PTERIDIACEAE

Genus — *Pteridium* Scopoli, 1760

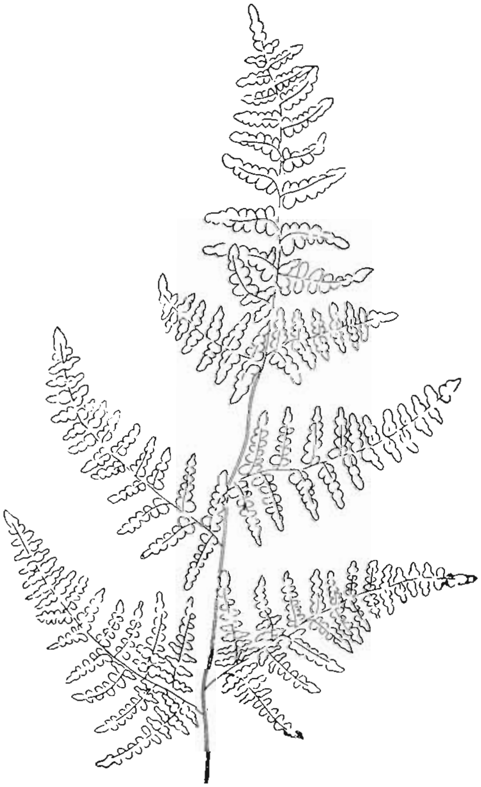
Pteridium dachingshanense sp. nov.

Pl. 1, figs 1-9; Pl. 2, figs 14-22; Text-figs 2, 3

Syntypes — D6-4663, D6-4829, D6-4895, D6-4888b, D6-4898, D6-4891.

Material — All the fossil specimens consist of impression and counter impression. The former (Pl. 1, figs 2, 7, 9; Pl. 2, figs 17, 20, 22, etc.) shows the ventral surface of pinnules with concave veins and their margin reflexed downwards. On the contrary, the latter (Pl. 1, figs 3, 5, 8; Pl. 2, figs 13a, b, 15, 16, etc.) shows the dorsal surface of pinnules including a continuous scarious band round a central elevation where the dorsal surface of pinnules is placed and between them, a dark-coloured, tubercular ridge which should be considered as a sorus along the margin of pinnules though the tubercles are faint in outline. Occasionally, there are few traces like the thickened cells of annulus (Pl. 2, fig. 14). Pl. 1, fig. 2 probably shows the apical region of a frond; Pl. 1, fig. 1 probably shows a basal bi-pinna of a frond with reducing pinnules; Pl. 1, figs 7, 9 may be the middle part of a frond and Pl. 2, fig. 22 shows the rachis with hairs on its dorsal surface. All these specimens, therefore, are listed as the syntypes for *Pteridium dachingshanense* sp. nov. and the reconstruction (Text-fig. 2) is made on them.

Description — Frond tripinnate at least. Apical pinnae in general, alternate to opposite, elongate to lanceolate in outline; basal pinnae often bipinnate, oval or oblong in outline, nearly 8 cm in length by 4 cm in width. All the pinnae attached to rachis at nearly right angle. Rachis delicate, slightly flexed with a smooth, grooved ventral surface and prominent dorsal surface with some hairs. Pinnules ovate to triangular with obtuse or rounded, opposite

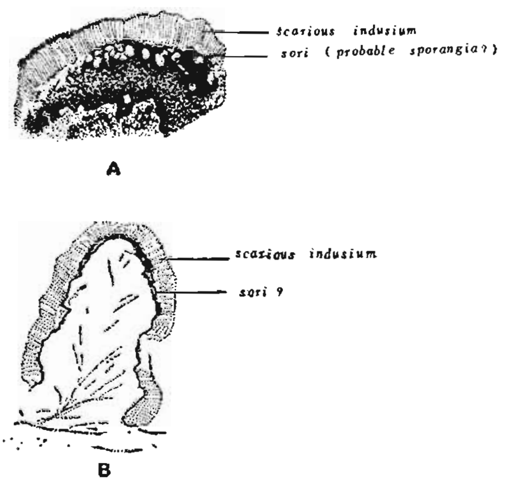


TEXT-FIG. 2 — *Pteridium dachingshanense* sp. nov.— Reconstruction of a frond, × 1.

to alternate, closely set, gradually contiguous each other with their base toward the distal end of pinnae and eventually passing into a remarkable terminal pinnule. The margin of pinnules reflexed downward. A number of parallel, fine strips present all over surface of pinnules (in high magnifier). Mid-vein obscure, lateral veins fine, often once-formed near the base of pinnules. Sorus clearly continuous along the margin of pinnules. The more developed the sorus, the stronger the reduction of pinnules. Indusium double: a true scarious indusium covered regularly with dense fine strips in correspondence with the surface of pinnules and a false indusium (reflexed margin of pinnules). Sporangia and spores unknown.

Comparison & Discussion — Among the living ferns, a few genera, e.g. *Pteris*, *Histiopteris*, etc. of Pteridiaceae and *Aleuropteris*, *Sinopteris*, etc. of Sinopteridaceae also have continuous marginal sorus with a sorus having a scarious indusium and their sporangia as well as spores are more or less similar to *Pteridium*. But their " scarious indusium " is formed by the reflexed margin of pinnules (so-called false indusium) and differs from the true scarious indusium developing from the epidermal cells of pinnules as in *Pteridium*. The former lacks the regular microscopic sculptures of epidermal cells as latter. Pl. 2, fig. 10a shows the dorsal surface of a *Pteris* pinnule: the upper half showing veins extending onto the reflexed margin of pinnule where sorus is undeveloped; the lower half showing the scarious false indusium where the sorus develops. Certainly the rest of pinnule is no longer reflex.

In the fossil materials, it is difficult to identify the double indusium because of the poor preservation. However, on the impression a distinct scarious band may be clearly seen when the slightly reflexed margin of pinnule has been taken off (Pl. 2, fig. 16). On counter-impression, the band always occurs near the outside of marginal sorus and has no traces of veins on it (Text-fig. 3). Its surface is sculptured with many regular fine strips, not wrinkles, unlike the sinuous outline of cells in living bracken fern and in correspondence with those on the epidermal surface of pinnule itself (Pl. 2, fig. 17). Therefore, based on the features and its position in the pinnule, this kind of scarious band should be considered as a true indusium for the fossil plant rather than false scarious indusium as in *Pteris*.



TEXT-FIG. 3 — *Pteridium dachingshanense* sp. nov. showing the true scarious indusium and continuous sori; **a**, × 30 from the same specimen as Pl. 2, fig. 5; **b**, × 8 from the same specimen as Pl. 2, fig. 4.

In addition, there are some another features depending on which the present specimens may not be identified with *Pteris*. In marginal sorus being discontinuous near the apex of pinnules they differ from *Pteris*; in the opposite pinnae having stipule-like basal pinnules and anastomosing veins from *Histiopteris*; in the larger bipinnatifid basal pinnae and the ceraceous dorsal surface of pinnules from *Aleuritopteris*; in the smaller size, the digittate tri- or quinquefoliate frond, the ceraceous covering instead of hair and the dichotomous veins from *Sinopteris* and so on. So far as we know, this kind of scarious indusium does not occur in the members with synangiate sporangia of the Eusporangiatae.

In the light of the above-mentioned features, it is suitable to attribute the present specimens to the genus *Pteridium*, though the sporangia and spores are not known.

In the general features of pinnae, pinnules, rachis, sorus and indusium *Pteridium dachingshanense* is certainly like the living bracken fern, but there are some important distinctions between them. Firstly, the new species is much less than the bracken in size and has smaller terminal pinnules. Secondly, the new species often has strongly reduced pinnules than the bracken, its fan-like venation is more obscure while the bracken fern has pinnate venation. Finally, in the new species the parallel strips on the scarious indusium also differentiate it from the sinous lines of cells in living one.

As we know, only a few specimens have been assigned to the genus *Pteridium* for example: by Straus (1952, p. 17, pl. 2, fig. 14) from the Pliocene of Germany; by Takhtajan (1963, p. 194, pl. 1, figs 6-12) from the Neogene of USSR; by Axelrod (1966, p. 61, pl. 5, figs 1-3) and by Weber (1851, p. 154, pl. 18, figs 3, 3b) as *Pteris crenata* from the Tertiary of Germany and so on. But all the specimens are fragmentary, many only an individual pinnule with neither a sorus nor an indusium. In fact, their assignation should be in doubt. From the Early Cretaceous of Siberia, a specimen described as the fertile pinna of *Arctopteris kolymensis* Samylina (1964, p. 51, pl. 4, fig. 2) and a specimen described as fertile pinna of *Tchucotopteris* (Vassilevskaya, 1977, p. 126, pl. 12, fig. 3) are somewhat similar to the new species in the more or less marginal sorus. But they clearly differ from the latter in discontinuous sorus and nothing is known about their indusium. Some specimens described by Fontaine (1889, p. 68, pl. 3, fig. 2; pl. 6, figs 10, 11a) as sterile pinnae of his *Cladophlebis constricta* from the Early Cretaceous Potomac Group are also similar to *Pteridium* in their terminal pinnules. However, without fertile pinnules it is impossible to accurately classify the American specimens.

Living bracken fern has rather wide adaptability to environment; from wetter shelter under the forest to arid grassland in the sun. In the beginning of the century, some experiments concerning the subject were conducted (Boodle, 1904). With the change in environment most of the fronds features such as size, hairs, texture, midvein, the reduced pinnules and sorus, etc. show remarkable variation, even in the same frond; the upper part exposed to the sun also appears more reduced than the lower part buried in dense grassmass. In accordance with the result of Boodle's experiments, it may be concluded that the new species lived in a rather arid environment than the living bracken fern.

Occurrence & Age — Zishaying Village, Zhuozixien District, Dachingshan Range in Neimonggol Autonomous Region, People's Republic of China (located to the east of the famous Huhehot, not far from the city).

The strata containing fossils mainly consist of yellowish-green coarse-grained continental sediments such as sandstones, conglomerates and a few mudstones, etc.

The age of the strata should be dated as the second half of Early Cretaceous based on the other fossil plants associated with the new species, such as: *Acanthopteris onychioides* (Vassil. & K.-M.), *Otozamites denticulatus* K. & P. (i.e. " Neozamites "), *Cephalotaxopsis asiatica* HBDYS, *Vitmia oblongifolia* (Zhang), and *Celatrophyllum* sp., etc.

ACKNOWLEDGEMENT

The author expresses his sincere thanks to Dr G. X. King of the Beijin Institute of Botany, Academia Sinica for his kind help in my work.

REFERENCES

Axelrod, D. I. (1966). The Pleistocene Soboba Flora of S. California. *Univ. Calif. Publ. Geol. Soc.*, p. 61.

Boodle, L. A. (1904). The structure of the leaves of the Bracken (*Pteris aquilina* L.) in relation to environment. *Linn. Soc. Lond.* (*Bot.*), **35**: 659.

Ching, R. C. (1975). The two new fern families. *Acta phytotax. sin.*, **13** (1): 96.

Ching, R. C. (1978). The Chinese fern families and genera: Systematic arrangement and historical origin. *Acta phytotax. sin,*: **16** (3): 1.

Copeland, E. B. (1947). Genera Filicum. *Annales Cryptogamia at Phytopathologia*, **5**.

Fontaine, W. M. (1889). The Potomac or Younger Mesozoic flora. *U.S. geol. Surv. Monogr.*, **15**: 68.

Samylina, V. A. (1964). The Mesozoic flora of the area to the west of the Kolyma River (the Zyrianka Basin)— I. Equisetales, Filicales, Cycadales, Bennettitales. *Acta Inst. Bot. Komarov, Acad. Sci. USSR.*, Ser. 8, **5**: 41.

Seward, A. C. (1910). *Fossil Plants.* II. Cambridge, p. 304.

Straus, A. (1952). Pliozanflora Willershausen III. *Paleontographica*, B **XCIII**: 17.

Takhtajan, A. L. (1963). Neogene flora of Golerdsk Perevela. I. *Acta Inst. Bot. Komarov Acad. Sci. USSR.*, Ser. 8, **4**: 194.

Vassilevskaya, N. D. (1977). New Cretaceous ferns from Chukotka and the Koryak Range. *Palaeont. Jour.*, **2**: 122.

Weber, O. O. (1851). Tertiarflora der Niederreinischen Braunkohlenformation. *Palaeontographica*, **II**: 154.

EXPLANATION OF PLATES

All figures. × 1 unless otherwise indicated. All specimens are deposited in Tianjin Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences.

Plate 1

1-9. *Pteridium dachingshanense* sp. nov.
1. Probable basal bi-pinna with the reducing pinnules (counter-impression), D6-4829. 1a. × 2.
2. Probable summit of a frond (impression), D6-4663. 2a. × 2.
3-6, 8. Pinnae, showing the continuous sorus along the marginal pinnules (counter-impression), D6-4896b, 4926, 4888, 4898c, 4861. 3 & 5. × 2; 6. × 4.
7, 9. The pinnae of mid-part of a frond (impression), D6-4902, 4895. All. × 2.

Plate 2

10. A part of a pinnule from living *Pteris*.
10a. Dorsal surface, the upper half showing the unmodified reflexed margin with the branches of veins; the lower half showing many sporangia. × 8.
10b. Ventral surface, the lower half showing the scarious false indusium. × 8.
11, 12. Living *Pteridium* (bracken fern).
11a. Dorsal surface. × 2.
11b. Ventral surface.
12. Apex of a pinnule, dorsal surface, showing the outer false indusium and the inner true indusium. × 8.
13-22. *Pteridium dachingshanense* sp. nov.
13-15. Pinnules (counter-impression) showing the continuous sorus and the true scarious indusium. × 4.
13a. Showing the trace of thickened cells of annulus (under the sagittate sign). × 15.
14. Showing the regular fine strips in scarious indusium. × 30. D6-4888b, 4898, 4961.
16-18. Pinnules (impression), right showing the reflexed margin of pinnules and left exposing the true scarious indusium where the reflexed margin of pinnule has exploited, D6-4904. × 4.
17. Upper right exposing the true scarious indusium, D6-4666. × 8.
18. Unmature pinnule with a narrow scarious indusium beneath its margin, D6-4666. × 8.
19-21. The part of bi-pinnae, D6-4891, 4888d, 4888a, all × 2.
22. The dorsal surface of rachis showing hairs on it. D6-4891. × 8.

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1a

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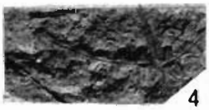

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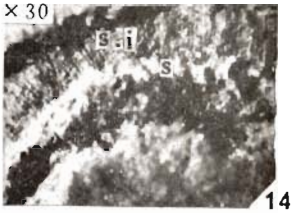
PLATE 1

10a

11a



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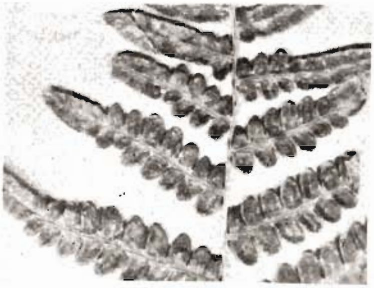
13a

10b



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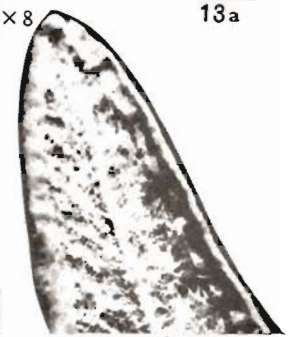

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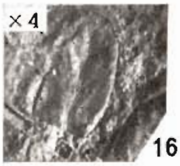

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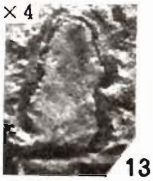

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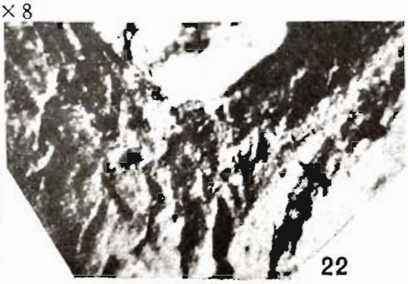

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PLATE 2

The Palaeobotanist, **31**(1): 52-59, 1983.

PALMOXYLON SHAHPURAENSIS SP. NOV., A FOSSIL PALM RESEMBLING *LICUALA* FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT, MADHYA PRADESH

K. AMBWANI

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

ABSTRACT

Palmoxylon shahpuraensis sp. nov., a petrified palm wood showing close resemblance with the extant *Licuala* belonging to sabaloid group of Palmae, has been described here. The specimen was collected from the Deccan Intertrappean beds near the village Ghugua in Mandla District. It shows compact to spongy nature of the ground tissue with usually one to two metaxylem vessels in dermal, two in subdermal and central zones and the absence of the fibrous bundles in the stem.

Key-words — Xylotomy, *Palmoxylon*, *Licuala*, Deccan Intertrappean Series, Early Eocene, India.

सारॉश

मध्य प्रदेश में माँडला जनपद की दक्खिन अन्तर्ट्रैपी संस्तरों से लिकुआला से मिलता-जुलता एक
ताड़-काष्ठाश्म: पालमॉक्सीलॉन शाहपुरायेन्सिस नव जाति – कृष्ण अम्बवानी

पाल्मी कुल के सैबॅलॉयड समूह से सम्बन्धित एवं वर्तमान लिकुआला से घनिष्ठ सजातीयता व्यक्त करने वाला एक अश्मीभूत ताड़ काष्ठाश्म – पालमॉक्सीलॉन शाहपुरायेन्सिस नव जाति – का वर्णन किया गया है। यह प्रादर्श माँडला जनपद में घुगुआ गाँव के समीपस्थ दक्खिन अन्तर्ट्रैपी संस्तरों से एकत्र किया गया था। यह काष्ठाश्म तने में रेशेदार बंडलों की अनुपस्थिति तथा त्वचीय, उपत्वचीय एवं केन्द्रीय खंड़ों में प्राय: एक से दो तक अनुदारू वाहिनीयों के साथ-साथ संहत से स्पंजी भरण ऊतक प्रदर्शित करता है।

INTRODUCTION

ONLY a few fossil dicotyledonous woods (Ingle, 1972, 1973; Bande, 1973, 1974; Lakhanpal, Prakash & Bande, 1978; Lakhanpal, Prakash & Ambwani, 1980; Bande & Khatri, 1980; Bande & Prakash, 1981) and a petrified palm fruit resembling the modern genus *Hyphaene* (Bande, Prakash & Ambwani, 1981) as well as a fossil palm wood resembling the extant genus *Chrysalidocarpus* Ambwani & Prakash (1983) have so far been described from the Mandla District.

SYSTEMATIC DESCRIPTION

Family — Palmae

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon shahpuraensis sp. nov.

The present specimen is well-preserved to reveal all the structural details. It is a triangular piece measuring 10×18×4.5 cm in size with a radius of 9 cm, having well preserved dermal, subdermal and central zones.

Dermal Zone — The fibrovascular bundles in this zone are not conjested but regularly oriented (Pl. 1, fig. 1). They are generally oval in shape with their xylem facing towards the centre. The frequency of the fibrovascular bundles in this zone ranges from 140-150 per cm^2 and the size of the bundles varies from 720×400-1000×720 μm. The f/v ratio is 4/1-6/1. The dorsal sclerenchymatous sheath is prominent and is usually reniform to cordate and the cells of this sheath are thick-walled with very narrow lumen (Pl. 1, fig. 1). The median sinus is concave to angular and the auricular lobes are round while the auricular sinus is indistinct. Generally one to two excluded metaxylem vessels are present in each fibrovascular bundle (Pl. 1, fig. 1). Tabular parenchyma is indistinct and the radiating parenchyma is absent. Stegmata are present around the fibrous part of the fibrovascular bundles. Phloem is not preserved and is represented by a cavity. The diminutive fibrovascular bundles are sometimes seen in this zone. The leaf-trace bundles are frequently visible but the fibrous bundles are absent.

Subdermal Zone — The fibrovascular bundles in this zone are sparsely placed and regularly oriented; sometimes a few deflected bundles may also be seen among the regularly oriented ones (Pl. 1, fig. 2). They are comparatively bigger in size than those of the dermal zone. Their frequency varies from 65-70 per cm². The shape of the bundles varies from round to oval. They vary from 800×800-1200×800 μm in size. The f/v ratio varies from 2/1-4/1. The dorsal sclerenchymatous sheath is reniform to cordate and the cells of this sheath are thick-walled having small lumen (Pl. 1, fig. 2). Median sinus is concave to angular and the auricular sinus is indistinct while the auricular lobes are round (Pl. 1, fig. 2). One to three excluded metaxylem vessels may be seen in each fibrovascular bundle but the vessels in pairs are frequently seen (Pl. 1, fig. 2). Tabular parenchyma generally indistinct, sometimes a layer may be observed around the fibrous part of the fibrovascular bundles. Stegmata are present in the fibrous part of the fibrovascular bundles. Phloem is badly preserved to indicate cellular details and is generally represented by a lacuna.

Central Zone — The fibrovascular bundles are sparsely placed and irregularly oriented in the ground mass (Pl. 1, fig. 3). They are usually round to oval in shape. Their frequency ranges from 40-50 per cm². They vary from 800×800-1000×800 μm and the f/v ratio ranges from 1/1 to 2/1. The dorsal sclerenchymatous sheath is prominent and usually reniform to cordate in shape. Cells of this sheath are thick-walled with comparatively larger lumen than those of the dermal and subdermal zones. Generally two sometimes three, rarely four excluded metaxylem vessels may be seen in each fibrovascular bundle (Pl. 1, fig. 3). Tabular and radiating parenchyma are absent. Stegmata are present in the fibrous portion of the fibrovascular bundles. Phloem is mostly represented by a lacuna. The diminutive fibrovascular bundles are absent and the leaf-trace bundles are frequent in this zone.

Diminutive Fibrovascular Bundles — These bundles are restricted only to the dermal and the subdermal zones of the present specimen. They measure about 320×400 μm in size and exhibit similar structure to that of the larger bundles. They are irregularly oriented in the ground tissue but less frequent.

Leaf-trace Bundles — These are frequently present throughout the stem and can be easily distinguished by their protruded tongue-like vascular part with a number of smaller vessels (Pl. 1, figs 1, 2).

Ground Tissue — The ground tissue in the dermal zone is compact in nature while in subdermal and central zones, it becomes spongy having small intercellular spaces. Thus showing a gradual change from compact to spongy texture. The parenchymatous cells in the dermal zone vary from round, oval to sometimes slightly elongated in shape (Pl. 1, fig. 1). In the subdermal zone also these cells are round to oval as well as elongated in shape with very small intercellular spaces having spongy nature while in the central zone the cells are more or less similar in nature to those in subdermal zone but the intercellular spaces are slightly larger (Pl. 1, figs 2, 3).

Vessel Elements — Metaxylem vessels of the fibrovascular bundles measure 100-120 μm in diameter and 1.5-2 mm long. Their perforation plates are oblique with 3-8 perforation bars and usually with scalariform thickenings on their walls. Whereas the protoxylem vessels are 60-80 μm in diameter and are usually longer, measuring 2-2.5 mm. Their perforation plates are oblique with 2-4 perforation bars and they have annular to spiral thickenings.

SPECIFIC DIAGNOSIS

Palmoxylon shahpuraensis sp. nov.

The fossil palm stem shows well preserved dermal, subdermal and central zones. Fibrovascular bundles of dermal zone regularly oriented, 720×400-1000×720 μm size; frequency 140-150 per cm²; f/v ratio 4/1-6/1. Shape of fibrovascular bundles round, oval to elongated; metaxylem vessels one to two, excluded. Dorsal sclerenchymatous sheath reniform to cordate; median sinus concave to angular, auricular sinus indistinct, auricular lobes round. Tabular and radiating parenchyma absent. Stegmata present, fibrous bundles absent. Diminutive fibrovascular bundles scanty, leaf-trace bundles present.

Fibrovascular bundles of subdermal zone mostly regularly oriented, 800×800-1200×800 μm in size. Frequency varies from 65-70 per cm²; f/v ratio 2/1-4/1. Shape of fibrovascular bundles usually round to oval; generally with two excluded metaxylem vessels, some times three may be seen. Dorsal sclerenchymatous sheath reniform to cordate; median sinus usually concave to angular, auricular sinus indistinct to absent, auricular lobes round. Tabular and radiating parenchyma absent. Stegmata present, fibrous bundles absent, diminutive fibrovascular bundles present.

Fibrovascular bundles of central zone irregularly oriented, 800×800-1000×800 μm size; frequency 40-45 per cm²; f/v ratio 1/1-2/1. Shape of bundles round to oval; usually two sometimes three to four metaxylem vessels in each bundle; dorsal sclerenchymatous sheath reniform to cordate, median sinus concave to angular, auricular sinus absent, auricular lobes round. Tabular and radiating parenchyma absent, stegmata present. Fibrous and diminutive fibrovascular bundles absent.

Metaxylem vessels 100-120 μm in diameter, 1.5-2.0 mm long; perforation plates oblique, 3-8 bars; scalariform thickenings. Protoxylem vessels 60-80 μm in diameter, 2.0-2.5 mm long; perforation plates oblique, 2-4 bars; annular to spiral thickenings.

Ground tissue shows gradual transformation from compact in dermal to spongy towards central zone. The cells are round, oval to slightly elongated with prominent intercellular spaces in the central zone.

Holotype — B.S.I.P. Museum no. 35980.

Locality — Ghugua Village near Shahpura, Mandla District, Madhya Pradesh.

Horizon — Deccan Intertrappean Series.

Age — Probably Early Eocene.

Affinities — The anatomical features of the present fossil palm wood closely resemble the modern sabaloid palm wood of *Licuala* Thunb., especially with *Licuala peltata* Roxb. (Tomlinson, 1961). The species of *Licuala* examined for comparison include the stem sections of *L. Peltata* Roxb., *L. rumphiana* Bl., *L. grandis* H. Wendl. and *L. spinosa* Roxb. The dermal zone, both in the present fossil and in the stem of *Licuala peltata*, is very narrow and fibrovascular bundles in this zone are not very densely arranged and show regular orientation (Pl. 1, figs 1, 4). They are more or less similar in shape and size and measure 380×250-880×800 μm in the living species. The shape of the dorsal sclerenchymatous sheath is usually reniform to cordate having thick-walled cells with narrow lumen both in the fossil as well as living specimens. Median sinus is concave to angular and the auricular lobes are rounded in both. However, the frequency of the fibrovascular bundles in the dermal zone of *Licuala peltata* is 150-180 per cm². The f/v ratio is also closely comparable both in the fossil as well as in living species up to 4/1-61 in the dermal zone of living species and slightly greater in the fossil. The number of metaxylem vessels in each fibrovascular bundle of fossil as well as living species is one to two (Pl. 1, figs 1, 4) though vessels in *L. peltata* are slightly smaller. Stegmata are present around the fibrous portion of the fibrovascular bundles while tabular and radiating parenchyma are absent in both. The ground tissue in the dermal zone of fossil and living species is compact and the cells are generally round, oval to slightly elongated in shape but the tangential pattern of arrangement of cells seen in *L. peltata* is not evident in the fossil specimen.

The subdermal zone of the present fossil species also resembles that of the living species. The fibrovascular bundles of this zone also show similar shape and size, measuring 900×400-1000×600 μm in the living species. They are more or less regularly oriented. The dorsal sclerenchymatous sheath is usually reniform to cordate and the cells of this sheath are less thickened in the outer part in the fossil and living species. Median sinus is concave to angular, the auricular sinus is indistinct and auricular lobes are rounded in both. The frequency of the fibrovascular bundles both in the fossil and living species is nearly same, being 50-60 per cm² in the living species. F/v ratio is similar in both the species, being 2/1-4/1 (Table 1). The number of metaxylem vessels in each fibrovascular bundle is two to three, usually two and they are excluded in both (Pl. 1, figs 2, 5). Stegmata are present around the fibrous part of the fibrovascular bundles while tabular

TABLE 1

Genus/Species	Stenzel's Classification	Fibrous Bundles and Stegmata	Size of Fibrovascular Bundles in μm	F/V Ratio	Distribution of Fibrovascular Bundles/cm²	Median Sinus	Auricular Sinus/Auricular Lobes	Vascular Part of Fibrovascular Bundles with Number of Metaxylem Vessels in each Fibrovascular Bundle	Ground Tissue			Nature of the Cells of Fibrous Sheath of Fibrovascular Bundles
									General Parenchyma	Tabular Parenchyma	Radiating Parenchyma	
Licuala peltata	Cordata to Reniformia	Fibrous bundles absent; stegmata present	D=380×250–880×800	D=3/1-4/1	D=150–180	Angular to concave	D=Auricular sinus indistinct, auricular lobes rounded	D=Excluded; usually one to two vessels in each fibrovascular bundle	D=Compact, cells round, oval and horizontally elongated	Indistinct Indistinct or absent	Absent	D= Thick-walled with narrow lumen
			SD=900×480–1000×600	SD=2/1-4/1	SD=50-60		SD=Auricular sinus indistinct, auricular lobes rounded	SD=Excluded; two to three vessels in each fibrovascular bundle	SD=Compact, cells round, oval to slightly elongated with small intercellular spaces	Indistinct or absent	Absent	SD=Lignified, more lignification towards inner side, outer cells with larger lumen, inner cells with narrow lumen
			C=400×600–1000×800	C=1/1-2/1	C=40-50		C=Auricular sinus indistinct, auricular lobes rounded	C=Excluded; two to three vessels in each fibrovascular bundle	C=Slightly lacunar, cells round, oval to angular	Indistinct or absent	Absent	C=Outer cells with larger lumen, inner cells with narrow lumen
L. rumphiana	Cordata to Reniformia	Fibrous bundles absent; stegmata present	D=200×200–320×560	D=1/1-6/1	D=250–280	Concave to angular	D=Auricular sinus present, auricular lobes rounded	D=Excluded; usually one sometimes two vessels	D=Compact	Absent	Absent	D=Thick-walled with narrow lumen
			SD=480×400–800×400	D=1/1-3/1	SD=140–150		SD=Auricular sinus present, lobes rounded	SD=Excluded; one to two sometimes three small vessels	SD=Slightly lacunar	Absent	Absent	SD=Less thickened with wider lumen
			C=720×600–800×480	C=1/1-2/1	C=60-65		C=Auricular sinus present, lobes rounded	C=Excluded, one to two small vessels	C=Lacunar with bigger intercellular spaces	Absent	Absent	C=Less thick with wider lumen
L. spinosa	Cordata to Reniformia	Fibrous bundles absent; stegmata present	D=320×200–800×600	D=3/1-5/1	D=200–215	Concave to angular	D=Auricular sinus indistinct or absent, auricular lobes round	D=Excluded; usually one sometimes two vessels	D=Compact, cells usually round to oval	Indistinct or absent	Absent	D=Thick-walled with narrow lumen
			SD=480×400–800×480	SD=2/1-3/1	SD=60–70		SD=Auricular sinus indistinct or absent, auricular lobes round	SD=Excluded; usually two sometimes three rarely four vessels	SD=Compact with tiny air spaces cells round, oval to elongated	Indistinct or absent	Absent	SD=Thick-walled with narrow lumen
			C=600×480–800×600	C=usually 1/1	C=30–40		C=Auricular sinus indistinct or absent, auricular lobes round	C=Excluded; usually two sometimes three to four	C=Lacunar, cells elongated to variously shaped	Indistinct or absent	Absent	C=Thick-walled with narrow lumen
L. grandis	Cordata to Reniformia	Fibrous bundles absent; stegmata present	D=200×200–600×520	D=4/1-6/1	D=200-150	Concave to angular	D=Auricular sinus indistinct; auricular lobes round	D=Excluded; one to two vessels	D=Compact, cells round, oval to angular	Indistinct or absent	Absent	D=Thick-walled with narrow lumen
			SD=600×480–800×480	SD=2/1-4/1	SD=65–70		SD=Auricular sinus indistinct, auricular lobes round	SD=Excluded; usually two vessels	SD=Spongy with small air spaces, cells variously shaped	Indistinct or absent	Absent	SD=Thick-walled with narrow lumen
			C=600×800–600×480	C=1/1-2/1	C=40-45		C=Auricular sinus indistinct auricular lobes round	C=Excluded; usually two vessels	C=Lacunar cells variously shaped	Indistinct or absent	Absent	C=Thick-walled with narrow lumen
Palmoxylon shahpuraensis sp. nov	Cordata to Reniformia	Fibrous bundles absent; stegmata present	D=720×400–1000×720	D=4/1-6/1	D=140-–150	Concave to angular	D=Auricular sinus indistinct; auricular lobes rounded	D=Excluded; one to two vessels, usually two	D=Compact, cells usually round oval to elongated	Indistinct	Absent	D=Usually all the cells thick-walled with narrow lumen
			SD=800×800–1200×800	SD=2/1-4/1	SD=65–70		SD=Auricular sinus indistinct; auricular lobes rounded	SD=Excluded; usually two sometimes three vessels	SD=Compact, cells usually round oval to slightly elongated with small air spaces	Indistinct	Absent	SD=Cells thick-walled with narrow lumen
			C=800×800–1000×800	C=1/1-2/1	C=40–45		C=Auricular sinus indistinct, auricular lobes rounded	C=Excluded, usually two sometimes three, rarely four vessels	C=Cells loosely placed with slightly bigger intercellular spaces	Indistinct	Absent	C=Cells thick-walled with narrow lumen towards the inner side

and the radiating parenchyma are absent in both. Ground tissue has small intercellular spaces in the fossil and living species and the cells are round, oval to slightly elongated in shape.

Similarly the central zone of both the fossil and living specimens is also closely comparable. The fibrovascular bundles of fossil and living species are almost of similar size and shape. They range 400 × 600-1000 × 800 μm in *Licuala peltata* (Table 1), usually irregularly oriented. The dorsal sclerenchymatous sheath is generally reniform to cordate and the cells of outer portion of the sheath have larger lumen as compared to those of inner ones, both in the fossil as well as living specimens (Pl. 1, figs 3, 6). Median sinus is concave to angular and the auricular sinus is indistinct whereas the auricular lobes are round in both. The frequency of the fibrovascular bundles in the central zone of fossil as well as *Licuala peltata* is 40-50 cm^2 while the f/v ratio is 1/1-2/1 in both (Table 1). The number of the metaxylem vessels in each fibrovascular bundles is usually two sometimes three and they are excluded in both. Stegmata are present around the fibrous part of the fibrovascular bundles and the tabular parenchyma is indistinct whereas radiating parenchyma is absent both in the fossil and the living species. Ground tissue has slightly larger intercellular spaces in both (Pl. 1, figs 3, 6), the cells are round to oval sometimes angular.

Although the present fossil specimen also shows similarities with other species of *Licuala*, viz., *Licuala rumphiana*, *L. spinosa* and *L. grandis* (amongst wood specimens available for comparison), it differs from them in size, frequency of the fibrovascular bundles, f/v ratio as well as in the nature of parenchymatous cells of the ground tissue. The ground tissue is much lacunar in *L. rumphiana*, *L. spinosa* and *L. grandis*. Also the cells of the dorsal sclerenchymatous sheath are thicker-walled with narrow lumen throughout the stem (Table 1).

Among the different species of *Licuala*, *L. peltata* attains a height of 8-15 ft (Blatter, 1926, pl. 23) and it also appears from the photograph that the mature stem of this species attains a girth of about 20-25 cm, which agrees with the present fossil palm stem being 18 cm in diameter.

The species of the genus *Licuala* are distributed in tropical Asia, Australia and Pacific islands (Blatter, 1926, p. 88; Brandis, 1971, p. 656; Willis, 1973, p. 651). At present *L. peltata* occurs in Sikkim, deep hot valleys near the Teesta River, Assam, Khasia Hills, Cachar, woody mountainous country to the coast and near Chitagong, Burma in damp ravines of the Pegu Yoma and Andaman islands. Present finding of fossil stem resembling *Licuala* suggests that the sabaloid palms similar to *Licuala* were also existing during the Early Eocene time in central India. Further, occurrence of sabaloid palm petiole, *Palmocaulon costapalmatum* Kulkarni & Patil (1977) from Wardha District and a fossil palm wood, *Palmoxylon livistonoides* Prakash & Ambwani (1980) also support the presence of sabaloid palms during the Early Eocene in the Deccan Intertrappean beds of India.

REFERENCES

AMBWANI, K. & PRAKASH, U. (1983). *Palmoxylon ghuguensis* sp. nov. resembling *Chrysalidocarpus* from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist*, **31** (1): 76-81.

BANDE, M. B. (1973). A petrified dicotyledonous wood from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Botanique*, **4** (1): 41.

BANDE, M. B. (1974). Two fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Geophytology*, **4** (2): 189-193.

BANDE, M. B. & KHATRI, S. K. (1980). Some more fossil woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh, India. *Palaeontographica*, **173**: 147-165.

BANDE, M. B. & PRAKASH, U. (1980). Four new fossil dicotyledonous woods from the Deccan Intertrappean beds near Mandla District, Madhya Pradesh. *Geophytology*, **10**: 248-251.

BANDE, M. B., PRAKASH, U. & AMBWANI, K. (1981). A fossil palm fruit *Hyphaeneocarpon indicum* gen. et sp. nov. from the Deccan Intertrappean Series, India. *Palaeobotanist*, **30** (3): 303-309.

BLATTER, E. (1926). *Palms of British India and Ceylon*. Oxford Univ. Press, Oxford.

BRANDIS, D. (1971). *Indian Trees*. 5th edition. Dehradun.

INGLE, S. R. (1972). A new fossil dicotyledonous wood of Verbenaceae from Mandla District of Madhya Pradesh. *Botanique*, **3** (1): 7.

INGLE, S. R. (1973). *Syzygioxylon mandlaense* gen. et sp. nov., a fossil dicotyledonous wood from

Mandla District of Madhya Pradesh, India. *Botanique*, **4** (1): 71.

KULKARNI, A. R. & PATIL, K. S. (1977). *Palmocaulon costapalmatum*, a petrified palm leaf-axis from the Deccan Intertrappean beds of Wardha District, Maharashtra. *Geophytology*, 7 (2): 208-213.

LAKHANPAL, R. N., PRAKASH, U. & AMBWANI, K. (1980). Two petrified palm woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **26** (2): 119-129.

LAKHANPAL, R. N., PRAKASH, U. & BANDE, M. B. (1978). Fossil dicotyledonous woods from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist*, **25**: 190-204.

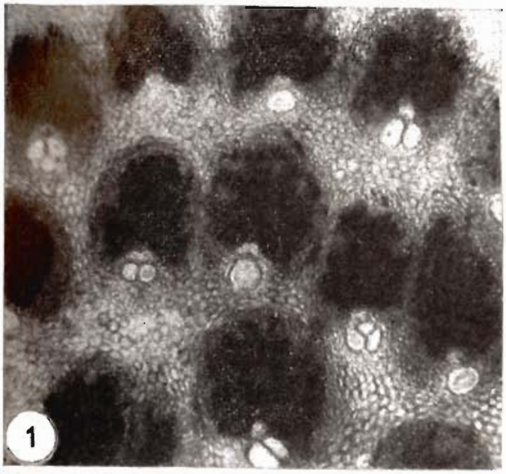
PRAKASH, U. & AMBWANI, K. (1980). A petrified *Livistona*-like palm stem, *Palmoxylon livistonoides* sp. nov. from the Deccan Intertrappean beds of India. *Palaeobotanist*, **26**: 297-306.

WILLIS, J. C. (1973). *A Dictionary of the Flowering Plants and Ferns*. 8th edition. Cambridge Univ. Press, pp. 1-1245.

EXPLANATION OF PLATE

Palmoxylon shahpuraensis sp. nov.

1. Cross section of the dermal zone of the fossil showing regular orientation of the fibrovascular bundles. × 25. Slide no. 6617.
2. Cross section of the subdermal zone of the fossil showing regular orientation of the fibrovascular bundles with usually two metaxylem vessels. × 25. Slide no. 6617.
3. Cross section of the central zone of the fossil showing irregular orientation of the bundles and spongy ground tissue. × 25. Slide no. 6618.
4. Cross section of the stem of *Licuala peltata* showing regularly oriented fibrovascular bundles with compact ground tissue. × 25. B.S.I.P. Herbarium slide no. 48.
5. Cross section of subdermal zone of *L. peltata* showing fibrovascular bundles usually with two metaxylem vessels. × 25. B.S.I.P. Herbarium slide no. 48.
6. Cross section of *L. peltata* showing irregularly oriented fibrovascular bundles and spongy nature of the ground tissue in the central zone. × 25. B.S.I.P. Herbarium slide no. 48.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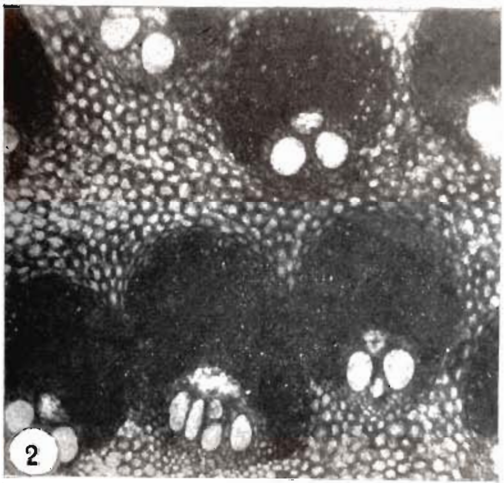
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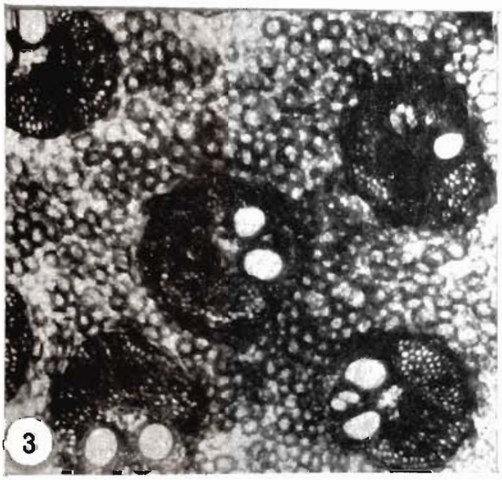
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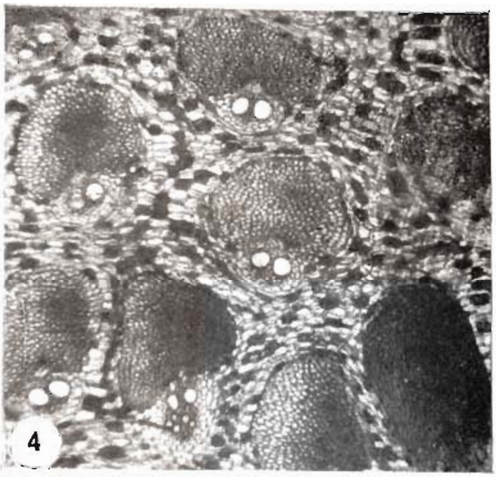
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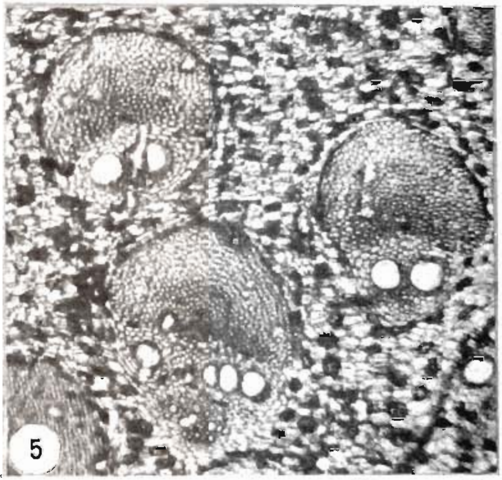
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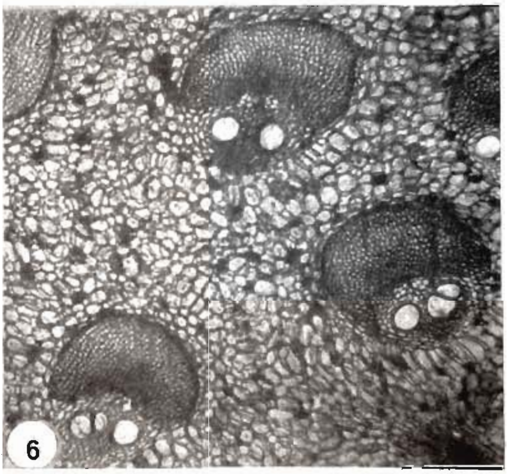
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PLATE 1

The Palaeobotanist, **31**(1): 60-68, 1983.

ORGANOSEDIMENTARY STRUCTURES AND BIOTA FROM UPPER PROTEROZOIC OF EQUATORIAL AFRICA

P. K. MAITHY

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

ABSTRACT

Organosedimentary structures and biota from the Upper Proterozoic of Lower Zaire, Kasai, Shaba, North-east Zaire and South-east Burundi are recorded. These structures belong to oncolites, viz., *Ambigolamellatus*, *Asterosphaeroides*, *Polysphaerula*, *Babetosphaera* and *Burundiocyathus* f. nov. and catagraphs — *Conferta* and *Vesicularites*. The stratigraphical significance of the organosedimentary structures in the Upper Proterozoic of Equatorial Africa has also been given.

Key-words — Organosedimentary structures, Oncolites, Catagraphs, Upper Proterozoic, Equatorial Africa.

सारांश

भूमध्यरेखीय अफ्रीका के उपरि प्राजीवी कल्प से कार्बनिक-अवसादीय संरचनायें एवं जीवितायें – प्रभात कुमार माइती

प्रस्तुत शोध-पत्र में अधरि ज़ायर, कसाई, शाबा, उत्तर-पूर्व ज़ायर एवं दक्षिण-पूर्व बुरुन्डी के उपरि प्राजीवी कल्प से जीवितायें एवं कार्बनिक-अवसादीय संरचनायें अभिलिखित की गई हैं। ये संरचनायें ऑन्कोलाइटों अर्थात् ऍम्बीगोलामैलेटस, ऍस्टॅरोस्फ़ेयरोइड्स, पोलिस्फ़ेयरुला, बाबेटोस्फ़ेयरा एवं बुरुन्डीस्यैथस नव जाति तथा कैटाग्राफों – कनफर्टा एवं वैसिकुलाराइटिस – से सम्बन्धित हैं। ह्यूरोनिस्पोरा, ऍफ़ेनोकैप्सिऑप्सिस एवं कोरिम्बोकोक्कस अभि-निर्धारित की गई जीवितायें हैं। मूमध्यरेखीय अफ्रीका के उपरि प्राजीवी कल्प में कार्बनिक-अवसादीय संरचनाओं का स्तरिकीय महत्व भी दिया गया है।

INTRODUCTION

CAYEUX (1930, 1931) reported the presence of algal structure from the System " Schisto-Calcaire " of Zaire. Choubert (1931, 1932) reported the presence of algae, viz., *Sycidium panderi* f. *minor* Karpinoy, *Sycidium dubosi* sp. nov. and *Robertia katangae* sp. nov. from the " Calcaire rose Oolithique " and the Kundelungu Superior of Zaire. Hacquaert (1931a, 1931b) also reported the algal remains from the ' Calcaire Rose ' and limestone of the Kundelungu System of Katanga with a discussion on their distribution in the Kundelungu System. Later in 1933, he reported the existence of algae in " Oolithe de Kisantu ". Hacquaert (1943) reported *Girvanella* from the " Mwaysha Oolite " of Katanga.

Betrand-Sarfati (1972) reported several forms of stromatolites from the Precambrian of Zaire. Along with these remains of Catagraphs, viz., *Vesicularites* were also reported. Maithy (1979) recorded Oncolite — *Volvatella*, *Ambigolamellatus*, *Asterosphaeroides* and *Osagia* and Catagraphs — *Vesicularites* from the Upper Proterozoic of Lower Zaire, Shaba and eastern Kasai.

In 1972, Binda described a preliminary account of biota from Katanga. Maithy (1975) recorded microbiota from the Bushimay System of Kanshi, Zaire. The biota has rich assemblage of algae and acritarchs. Edhorn (1978) reported the microbiota from the Mwashya Group from N'Guba, Mulungwishi and Shituru localities of Shaba. The important records are *Cumulosphaera*, *Girvanella* tubes, *Chlamydomonopsis*, spherical coccoid algae and spiralled inner structure of filament.

The present paper deals with the organosedimentary structures and biota previously not known from the Upper Proterozoic of

Bas Zaire, Kasai, Shaba, North and north-east Zaire and South-east Burundi.

MATERIAL

A. Bas Zaire — West Congolian Supergroup

All the specimens from Bas Zaire belong to West Congolian Supergroup (see Cahen, 1978). Those specimens, that proved to be positive, some from four of the five groups of this supergroup have been marked with asterisk in the following enumeration from youngest to oldest.

Inkisi
*Mpioka
*Schisto-Calcaire
*Haut-Shiloango
*Sansikwa

Mpioka Group

16608 — Fine grained grey blue rock with pyrite, Bangu Plateau; river Nkela; coll. M. C. Brades (B. 372).
16551 — Blue grey slate, Bangu Plateau, river Bidi; coll. M. C. Brandes (B. 281).

Schisto-Calcaire Group

Lukunga Subgroup (C-II)
11615 — Oolithic limestone, Kinganga, point 1133; coll. J. Lepersonne (n°E 2100).

Kwilu Subgroup (C-I)
11619 — Limestone (" calcaire a structure en betonnets ") lovo, point 1139. coll. J. Lepersonne (n°E 2108).

Haut Shiloanga Group

Sekelolo Subgroup
18061 — Black finely laminated argillaceous Sekelolo limestone, Safricans Quarry, near Kimpese, coll. L. Cahen (n° 33/10).

B. Eastern Kasai — Mbuji Mayi Supergroup

The remains from eastern Kasai are all from the uppermost B-II group of the Mbuji Mayi Supergroup (Raucq, 1957, 1970). Only one specimen from the topmost formation of this group is described here, i.e, from the B-IIe formation.

31784 — B-IIe formation, dark grey limestone with discontinuous, lighter laminations; small quarry near Miya, 3 km NE of Lomuele, coll. P. Raucq (n° 194c/15).

C. Shaba — Katangan

From Shaba (formerly Katanga) all specimens studied belong to the Katangan. From top to bottom it is subdivided in three supergroups, viz. upper Kundelungu, Lower Kundelungu and Roan (Francois, 1974). Several specimens belong to the " Calcaire oolithique des cimenteries de Lubudi " (oolithic limestone of the Lubudi cement works) which is a distinctive formation of the lower part of the Upper Kundelungu, and one specimen comes from the " Kakontwe Limestone ", the lowest formation of the Lower Kundelungu.

Upper Kundelungu

7314 — Oolithic limestone of the above horizon, Lukafu region, coll. C.S.K.
7339 — d° from NE of Degree Sheet Mokabe Kasari, coll. L. Cahen (n° 1642).
74016 — Sedimentary breccia from NE of Degree Sheet Mokabe Kasari, coll. L. Cahen (n° 1639).
74017 — d° from Lubudi cement Quarry, as in previous paper (1979).

Lower Kundelungu

12884 — Kakontwe limestone, Kakontwe Quarry, coll. M. Sluys (SK 23).

D. North-East Zaire

The Liddian Supergroup is situated in the north-east of Zaire. From top to bottom it is subdivided into three groups — Aruwimi, Lokomo and Ituri (Verbeek, 1970). Following four specimens are described from the Mamungi Formation of the Bombua Subgroup which belongs to the ' Lokoma Group '.

12958 — Grey oolitic limestone, Wanie Rukula, coll. M. Sluys (1496).
12959 — Red oolitic limestone, Wanie Rukula, coll. M. Sluys (1497).
12960 — Red oolitic limestone, Wanie Rukula, coll. M. Sluys (1498).

41000 — d° bore hole, depth between 9-13·50 m, near Wanie Rukula, coll. CICO n° 6/42.

E. South Burundi — Malagarasian Supergroup

The Malagarasian Supergroup of South Burundi corresponds to the Bukoba of Tanzania. It is more or less connected with the Katangan of Shaba. The present state of knowledge is given by Cahen and Snelling (1974). In this Supergroup several superposed groups are known in which the four youngest in Burundi are Kibago, Mosso, Nkoma, and Musindozi. The Kibago and the Mosso groups correspond to Uha Group of Tanzania. Nkoma is only known in Burundi. The Musindozi Group is correlated with the Kingonero Flags of Tanzania. Two specimens from the Bugono silicified Limestone of the Mosso Group and three from the Kusasa Dolomitic Limestone at the top of the Musindozi Group proved productive.

Mosso Group

69119 — Silicified oolith, right bank of Ndekwe River, coll. A. Waleffe (n° 108).

69131 — d° (rolled pebble), Makamba-Songa road, coll. A. Waleffe (127/1).

Musindozi Group

69365 — Finely laminated dark grey argillaceous limestone, Bukamba Hill, coll. A. Waleffe (n° 103/2).

69371 — Fine grained dark grey limestone, coll. A. Waleffe (n° 103/8).

The material was studied in thin sections of 30 μm thickness. All the figured slides are preserved at the Museum of Museé Royal de la Afrique, Tervuren, Belgium.

DESCRIPTION

Oncolites

Ambigolamellatus **Zhuravleva, 1968**

Ambigolamellatus horridus Zhuravleva, 1968

Pl. 1, fig. 1; Text-fig. 1B

Description — Tumour circular or circular-oval in outline measuring 1-3.5 mm common 3-2.5 mm, distinct lamellate zones present around central nucleus, commonly 5-10 lamellate zones present.

Comparison — *Ambigolamellatus horridus* Zhuravleva (1968) is morphologically similar with the present specimens. This species has also been reported earlier by Maithy (1979) from Shaba.

Asterosphaeroides **Zhuravleva, 1968**

Asterosphaeroides serratus Zhuravleva, 1968

Pl. 1, fig. 1; Text-fig. 1E

Description — Tumour circular in outline, measuring 0.5-1 mm (common 0.5 mm), several radial thickenings radiating from the central point to margin, thickenings narrow near centre and broader towards margin.

Comparison — *Asterosphaeroides serratus* Zhuravleva (1968) agrees morphologically with this form.

Babetosphaera **Boureau & Monod, 1958**

Babetosphaera africana Boureau & Monod, 1958

Pl. 1, fig. 2; Text-fig. 1C

Description — Tumour circular in outline, measuring 300-500 μm; entire area with polygonal, reticulate thickenings; central region occasionally distorted by iron pyrites.

Comparison — The form compares with *Babetosphaera africana* reported by Boureau (1975) from Mauritinae, Africa.

Polysphaerula **Boureau, 1975**

Polysphaerula globosa Boureau, 1975

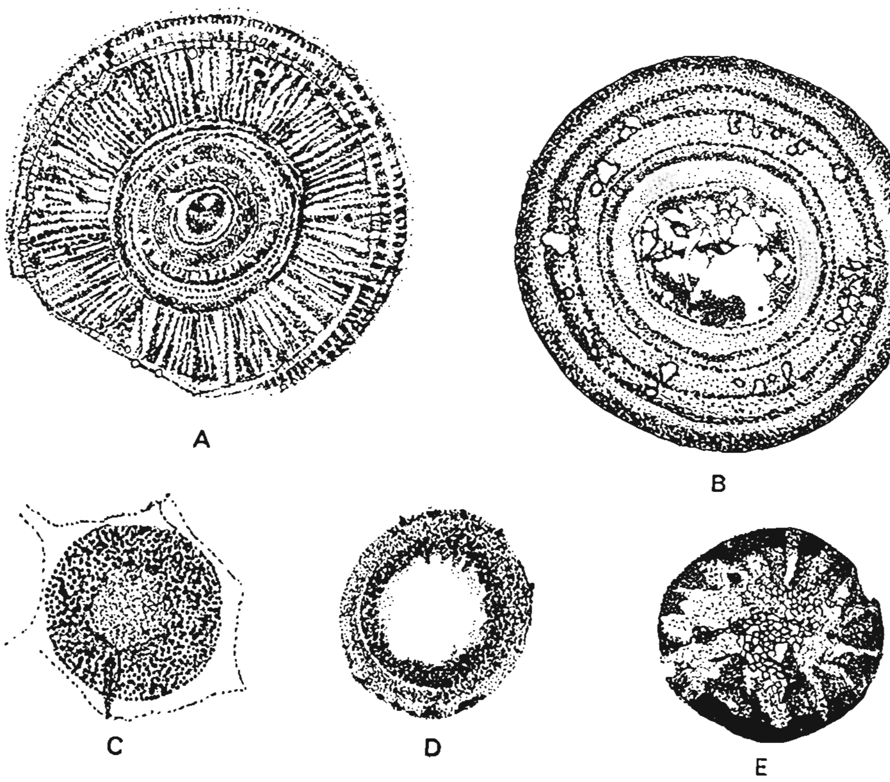
Pl. 1, fig. 3; Text-fig. 1D

Description — Tumour circular, 1-2 mm, central zone circular surrounded by a wide outer zone; outer margin with irregular thickenings.

Comparison — The present form compares with *Polysphaerula globosa* Boureau (1975) from Mauritinae, Africa.

Burundia **f. nov.**

Generic Diagnosis — Tumour circular, distinctly demarcated into two zones; central zone with consecutive circular concentric



TEXT-FIG. 1 — **A**, *Ambigolamellatus horridus*, × 10; **B**, *Asterosphaeroides serratus*, × 10; **C**, *Babetosphaera africana*, × 100; D. *Polysphaerula globosa*, × 20; and **E**, *Burundia malagarsianse*, × 20.

thickenings, outer zone with several transverse thickenings.

Genotype — *B. malagarsianense* sp. nov.

Comparison — The present form differs from the known oncolites in having two distinct zones with different type of thickenings. In *Osagia*, only circular concentric thickening are present all over the tumour; the transverse thickenings are absent.

Etymology — The generic name has been derived after the country ' Burundi '.

Burundia malagarsianense sp. nov.

Pl. 1, fig. 4; Text-fig. 1A

Diagnosis — Tumour ± circular in configuration in cut sections; central zone with concentric ring-like structure, divisible into two distinct areas, in the inner area the concentric rings are more compactly arranged than in the outer area; outer zone with simple, branched, closely arranged radial thickening.

Holotype — Specimen no. 69119, Museé Royal de la Afrique Centrale, Tervuren, Belgium.

Horizon — Mosso Group, Bugongo Silicified Limestone.

CATAGRAPHS

Vesicularites Retlinger, 1959

Vesicularites renatus sp. nov.

Pl. 1, fig. 5

Diagnosis — Several small ± circular or circular-oval structures, grouped in kidney-shaped areas; each structure surrounded by narrow margin composed of small rectangular areas.

Holotype — 12884, Museé Royal de la Afrique Centrale, Tervuren, Belgium.

Horizon — Kakontwe Limestone.

Comparison — *Vesicularites renatus* sp. nov. differs from *V. flexuosus* Retlinger

(1959), *V. parvus* Zabrodin (1968), *V. ovatus* Zhuravleva (1968) and *V. textus* Klinger (1968), in its characteristic kidney-shape.

Conferta **Klinger, 1968**

Conferta rara Klinger, 1968

Pl. 1, fig. 6

Description — Vertical canal-like structures formed due to biological activities. The canals are variously shaped. Occasionally they are branched irregularly.

Comparison — Similar sedimentary gaps formed by the activities of biological organisms were earlier recorded by Klinger (1968) from the Precambrian of Karakhatan, Siberia.

MICROBIOTA

Aphanocapsiopsis **Maithy & Shukla, 1977**

Aphanocapsiopsis musindoziense sp. nov.

Pl. 1, fig. 7

Diagnosis — Cells circular, loosely arranged in an irregular elongate colony of 8-20 cells, measuring 8-12 μm; cells with thickenings on the margin, encompassing sheath absent.

Holotype — Specimen no. 69365, Museé Royal de la Afrique Centrale, Tervuren, Belgium.

Locality & Horizon — Bukamba Hill; Musindozi Group, Malagarasian Supergroup.

Comparison — *Aphanocapsiopsis sitholeyi* Maithy & Shukla (1977) differs from *A. musindoziense* sp. nov. in the absence of wall thickenings. A similar form has also been figured by Binda (1972, fig. 3) from the Lower Roan of Zambia.

Corymbococcus **Awarmik & Barghoorn, 1977**

Corymbococcus minutus sp. nov.

Pl. 1, fig. 8

Diagnosis — Small spheroidal cells, 0.5-2 μm, arranged in irregular chains, smooth surface, all cells enclosed in a large thick amorphous sheath.

Holotype — Specimen no. 69371, Museé Royal de la Afrique Centrale, Tervuren, Belgium.

Locality & Horizon — Bukamba Hill; Musindozi Group.

Comparison — *Corymbococcus hodgkissi* Awarmik & Barghoorn (1977) differs due to large size cells and ornamented surface.

Huronispora **Barghoorn, 1965**

Huronispora psilata Barghoorn, 1965

Pl. 1, fig. 9

Description — Spherical cells, psilate or sculptured. They are solitary or rarely arranged in groups. The size range varies from 10 to 20 μm.

Comparison — *Huronispora psilata* recorded from the Gunflint Iron Formation by Barghoorn (1965) and from Amelia Dolomite by Muir (1967) compares well with the African form.

CONCLUDING REMARKS

Oncolites are small spheroidal, concentrically laminated calcareous sedimentary structures resembling an oolith and formed by the accretion of successive layered masses of gelatinous sheaths of blue green algae and bacteria. They are smaller than stromatolites and generally do not exceed 10 cm in diameter. It is possible that oncolites, though looking alike in morphology, may have been deposited by different forms of bacteria and cyanophytes. Therefore they should be used with utmost caution for stratigraphic zonation. They may work very well in stratigraphic correlation within one basin for instance in the Siberian platform (Klinger, 1968; Zabrodin, 1968; Zhuravleva, 1968). Earlier an attempt was made by Maithy (1979) to use these sedimentary structures for stratigraphic zonation. In the present paper this is elaborated further (see Table 1). It appears that oncolites with simple organization (*Osagia*) occur in rocks older than 950 m.y. whereas the oncolites with complex organization (*Ambigolamellatus*, *Asterosphaeroides* & *Polysphaerula*) occur in younger sequence of equatorial Africa.

Catagraph is a complex structure made up of traces of canals and cavities formed due to the activity of Cyanophytes and bacteria in the Late Precambrian and the Lower Cambrian. The role of catagraphs in stratigraphy is well established in the Russian platform. Their significance in the African succession is still not known and their

TABLE 1 — DISTRIBUTION OF UPPER PROTEROZOIC BIOTA AND ORGANOSEDIMENTARY STRUCTURES FROM EQUATORIAL AFRICA

(1) Ma	BAS ZAIRE WEST CONGO SUPERGROUP	KASAI & W. SHABA MBUJI MAJI SUPERGROUP	SHABA KATANGAN	N & NE ZAIRE LINDIAN SUPERGROUP	S. BURUNDI MALAGARASIAN SUPERGROUP
600	Inkisi Gp.		Upper III	Aru Banalia arkoses	Kibago Gp.
C. 715					
	Mpioka Gp. *Huronispora psilata*		Kunde II	Wimi Gp. Alolo Shales Galamboge quartzites	Mosso Gp. *Burundia malagarsianense* *Babetosphaera africana*
C. 800					
	Schisto-calcaire Gp. CIV CIII Bangu Subgp. *Volvatella vadosa* *Volvatella marginatus* *Ambigolamellatus ovatus* *Ambigolamellatus zonatus* *Asterosphaeroides asymmetricus* *Vesicularites parvus* CII Lukunga Subgp. *Ambigolamellatus horridus* *Vesicularites* aff. *parvus* *Vesicularites bothridioformis* *Vermiculites* cf. *tortuosus* CI Kwilu Subgp. *Polysphaerula globosa*		lungu I lubudi cement works limestone *Ambigolamellatus horridus* *Asterosphaeroides serratus*	Lokoma Gp. Wanie Rukula limestone *Ambigolamellatus horridus* *Asterosphaeroides serratus*	Nkoma Gp.
	Haut Shiloango Gp. Sekelolo Limestone *Huronispora psilata*		Lower Kundelungu Gp. Kakontwe Limestone *Vesicularites renatus*		
C. 950					
	Sansikwa Gp. *Osagia* sp.	Mbuji Maji Supergroup BIIe *Conferta rara* BIId *Osagia tenuilamellata* BIIc Rich microbiota algae acritarchs & others BI	Roan Mwashya *Osagia nucleata* Upper Roan Lower Roan	Ituri Gp.	Musindozi Gp. *Aphanocapsiopsis musindoziense* *Corymbococcus minutus* Kavumwe Gp.
C. 1100					

(1) The geochronological framework of this table is schematic and adopted from L. Cahen in final Report IGCP PROJECT-99

importance will only be assessed when they are recorded from other localities.

ACKNOWLEDGEMENTS

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REFERENCES

Awarmik, S. M. & Barghoorn, E. S. (1977). The Gunflint microbiota. *Precambrian Res.*, **5**: 121-142.

Barghoorn, E. S. & Tyler, S. A. (1965). Microorganisms from the Gunflint chert. *Science*, **147**: 563-577.

Bertrand-Sarfati, J. (1972). Stromatolites columnaires de certaines formations carbonatee's du Precambrian Superieur du Bassin congolais (Bushimay, Lindien, Ouest-Congolien). *Annals Mus. r. Afr. Cent.* ser. 8°, *Sci. geol.*, **74**.

Binda, P. L. (1972). Preliminary observations on the palynology of Precambrian Katanga sequence, Zambia. *Geologie Mijnbow*, **51** (3): 315-319.

Boureau, M. E. (1975). Les Babetosphaere Precambrien representent une structure intermediare an cours de un enrichissement exogene des Celluler procaryotes. *C.R. Acad. Sci. Paris*, **280**: 1669-1672.

Cahen, L. (1978). La stratigraphie et la tectonique du Supergroupe ouest-congolien dans les zones mediane et externe de l'orogene sines. *Annals Mus. r. Afr. cent.*, ser. 8°, *Sci. geol.*, **83**: 1-150.

Cahen, L. & Snelling, N. J. (1974). Potassium-Argon ages and additions to the stratigraphy of the Malagarasian Bukoban System. *J. geol. Soc. Lond.*, **130**: 461-470.

Cayeux, L. (1930). Existence de deux groupes d'algues a' structure conservee dans systeme Schisto-calcaire du Congo Francais. *C.R. Acad. Sci.*, **190**: 231-235.

Cayeux, L. (1931). Existence de restes organiques et notament d'algues siphonees verticillee dans le systeme schistocalcaire du Congo Belge. *C.R. Acad. Sci.*, **193**: 11-13.

Choubert, B. (1931). Sur la presence d'algues devoniennes dans le niveau du " Calcaire rose" du systeme du Kundelungu du Katanga. *Bull. Oil Sci.*, Ser. 5, **17** (12): 1421-1431.

Choubert, B. (1932). Nouvelles recherches sur les algues du niveau du " Calcaire rose oolithique" du Kundelungu Superieur du Congo Belge (Province Orientale et Katanga). *Bull. Soc. Belg. geol. Palaeont. Hydro.*, **62**: 63-70.

Edhorn, A., S. (1978). Microorganisms preserved in cherty stromatolitic dolomite of the Mwashya Group from N'guba, Mulungwishi and Shistru localities, Shaba, Zaire, Central Africa. *Comparative Palaeontology*, pp. 257-268. Academic Press.

Francois, A. (1974). Stratigraphie, tectonique et mineralisations dans l'arc aurifere du Shaba (Republique du Zaire). Gisements stratiformes et provinces auriferes. *Cent. Soc. geol. Belg., Liege*, **1964**: 79-101.

Hacquaert, A. L. (1931a). Ont de king van Fossile Groenwieren in het " Calcaire Rose" (Kundelungu System) can Katanga. *Natuurw. Tijdschr.*, **13** (3-5): 131-136.

Hacquaert, A. L. (1931b). Neiuwe fossilen uiteen Kalksteen van het Kundelungu system van Katanga (Belg. Congo). *Natuurw. Tijdschr.*, **13** (8): 281-284.

Hacquaert, A. L. (1933). Voorkomen van fossilen in een oolitisch gesteente van Kisantu (Belgisch-Congo). *Natuurw. Tijdschr.*, **15** (6-7): 173-176.

Hacquaert, A. L. (1943). Over het Voortkomen van *Girvanella* in een oolitisch Gesteene van de serie van Mwashya uit Katanga. *Natuurw. Tijdschr.*, **25**: 33-38.

Klinger, B. Sh. (1968). Oncolites and catagraphs of the central and southern eastern parts of Erementan-Niyaz anticlimorium (Central Kazakhstan). Problematics Urals and Karakhatan — *Acad. Sci. USSR*, **188**: 101-107 (in Russian).

Maithy, P. K. (1975). Microorganisms from the Bushimay System (Late Precambrian) of Kasai, Zaire. *Palaeobotanist*, **22** (2): 133-149.

Maithy, P. K. (1979). Oncolites and catagraphs from the Precambrian of Zaire (Lower Zaire, Shaba and eastern Kasai). *Ann. Soc. geol. Belg.*, **101**: 193-207.

Maithy, P. K. & Shukla, M. (1977). Microbiota from Suket shales, Ramapura, Vindhyan System (Late Precambrian), Madhya Pradesh. *Palaeobotanist*, **23** (3): 176-188.

Raucq, P. (1957). Contribution a la connaissance du systeme de la Bushimay (Congo belge). *Ann. Mus. r. Congo belge.*, ser. 8°, *Sci. geol.*, **18**: 1-427.

Raucq, P. (1970). Nouvelles acquisitions sur le Systeme de la Bushimay (Republique democratique du Congo). *Ann. Mus. r. Afr. Cent.*, ser. 8°, *Sci. geol.*, **69**: 1-156.

Reitlinger, A. (1959). Atlas des restes microscopiques et des Problematica des couches ancienes de Siberie. *Trudy Geol. Atlas, Nauk. SSR.*, **25**.

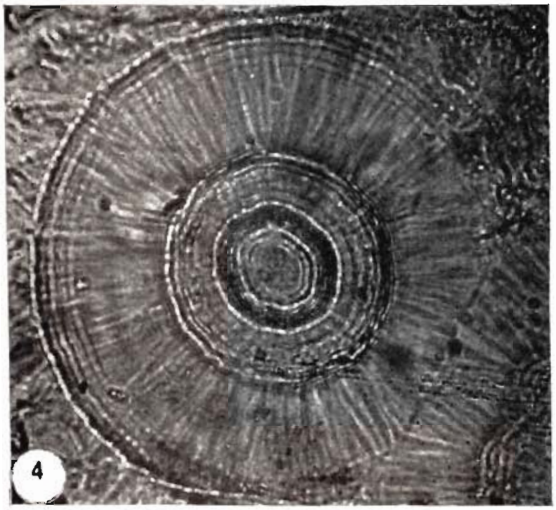
Verbeek, Th., (1970). Geologie et lithologie du Lindien (Precambrian superieur du Nord de la Republique democratique du Congo). *Ann. Mus. r. Afr. cent.*, ser. 8°, *Sci. geol.*, **66**: 1-311.

Zabrodin, V. E. (1968). Catagraphs of *Vesicularites* Reitlinger group, their diagnostic features and research methods, in: *Problematics of Riphean and Cambrian layers of the Russian platform urals and Kazakhstan. Acad. Sci. USSR.*, **188**: 37-82 (in Russian).

ZHURAVLEVA, Z. A. (1968). Diagnostic features of Oncolites and Catagraphs and their distribution in a Riphean section of South Urals, in: *Problematics of Riphean and Cambrian layers of the Russian platform, Urals and Kazakhstan. Acad. Sci. U.S.S.R.*, **188**: 83-100 (in Russian).

EXPLANATION OF PLATE

1. *Ambigolamellatus horridus* and *Asterosphaeroides serratus*; specimen no. 74016. × 4.
2. *Babetosphaera africana*; specimen no. 69131. × 100
3. *Polysphaerula globosa*; specimen no. 11615. × 20.
4. *Burundia malagarsianense* gen. et sp. nov., specimen no. 69119. × 20.
5. *Vesicularites renatus*; specimen no. 74016. × 4.
6. *Conferta rara*; specimen no. 31784. × 20.
7. *Aphanocapsiopsis musindoziense* sp. nov., specimen no. 69365. × 2000.
8. *Corymbococcus minutus* sp. nov., specimen no. 69371. × 500.
9. *Huronispora psilata*; specimen no. 18061. × 2000.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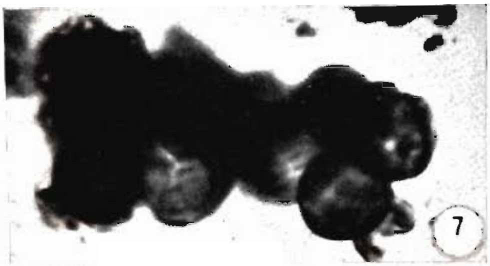
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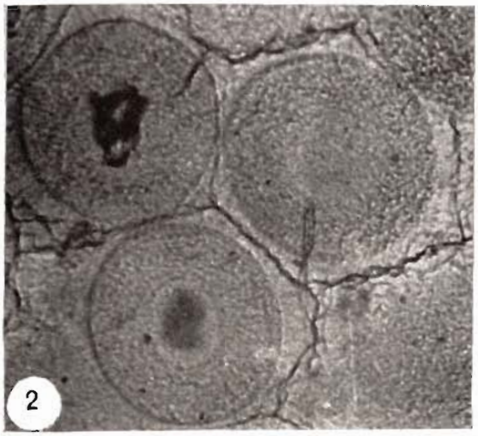
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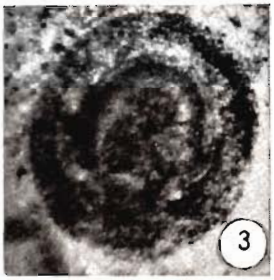
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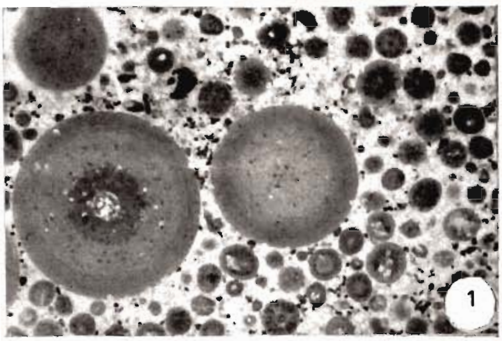
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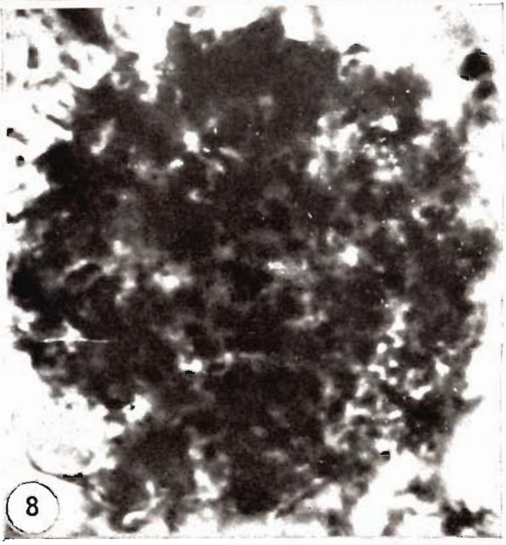
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PLATE 1

The Palaeobotanist, 31(1): 69-75, 1983.

UPPER PALAEOCENE CALCAREOUS NANNOPLANKTON FROM VRIDDHACHALAM AREA, CAUVERY BASIN, SOUTHERN INDIA*

K. P. JAIN, RAHUL GARG & D. C. JOSHI

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

ABSTRACT

Phytoplankton analysis of a 240 meter deep bore hole, located in the Gopurapuram Village north-east of Vriddhachalam in Cauvery basin, revealed the presence of calcareous nannofossils and dinoflagellate cysts in the basal sample, whereas the samples higher up in the sequence yielded only dinocysts.

The nannofossil assemblage includes eight genera containing 16 recognizable species. Out of these, *Discoaster multiradiatus* is discussed to mark the Standard Nannoplankton Zone NP 9 of Upper Palaeocene. The equivalent zone marker taxa of dinocysts, foraminifera and mega-algae also support an Upper Palaeocene age for these sediments.

Key-words — Calcareous nannoplankton, Cauvery basin, Upper Palaeocene, Southern India.

सारांश

दक्षिणी भारत में कावेरी द्रोणी के वृद्धाचलम् क्षेत्र से उपरि पुरानूतन युगीन चूनामय परासूक्ष्म-जीवाश्म – कृष्ण प्रसाद जैन, राहुल गर्ग एवं दिनेश चन्द्र जोशी

कावेरी द्रोणी में वृद्धाचलम् के उत्तर-पूर्व में गोपुरापुरम गाँव में स्थित एक 240 मीटर गहरे वेध-छिद्र के आधारीय नमूनों के पादप-प्लवकीय विश्लेषण से चूनामय परासूक्ष्म-जीवाश्म एवं घूर्णीकशाभ पुटीयाँ उपलब्ध हुई हैं, जबकि इसी अनुक्रम के ऊपरी नमूनों से केवल घूर्णीकशाभ पुटीयाँ प्राप्त हुई हैं।

इस परासूक्ष्म समुच्चय में आठ प्रजातियों की 16 अभिनिर्धारणीय जातियाँ मिलती हैं। इनमें से डिस्कोएस्टर मल्टीरेडिएटस का उपयोग उपरि पुरानूतन के परासूक्ष्म-जीवाश्मीय मानक मंडल ऍन-पी० 9 को प्रदर्शित करने के लिए किया गया है। घूर्णीकशाभ पुटीयों, फोरेमिनीफ़ॅरों एवं गुरु-शैवालों के समतुल्य मंडलीय-चिन्हक वर्गकों से भी इन अवसादों की उपरि पुरानूतन आयु का पुष्टीकरण होता है।

INTRODUCTION

THE marine fossiliferous rocks of Vriddhachalam area in South Arcot District, Tamil Nadu (Southern India) were described by Blanford (1862). He assigned Cretaceous age to these sediments, equivalent to the Ariyalur group of rocks of the neighbouring Trichinopoly area. The Palaeocene rocks in Vriddhachalam area were first recognized by Rajagopalan (1966-67). He found the lithology, microfauna and flora comparable with that of the Palaeocene, Upper Marl Unit of the Pondicherry Formation developed in Pondicherry area (Rajagopalan, 1965). The surface exposures of Palaeocene rocks in Vriddhachalam area are scanty and recorded mainly from the subcrops. The Palaeocene biostratigraphy of the area is, thus, largely based on the subsurface data obtained from shallow dug wells and shallow bore holes.

During three field trips to the area undertaken between 1977 and 79, two of us (KPJ & RG) encountered a few Cretaceous-Tertiary

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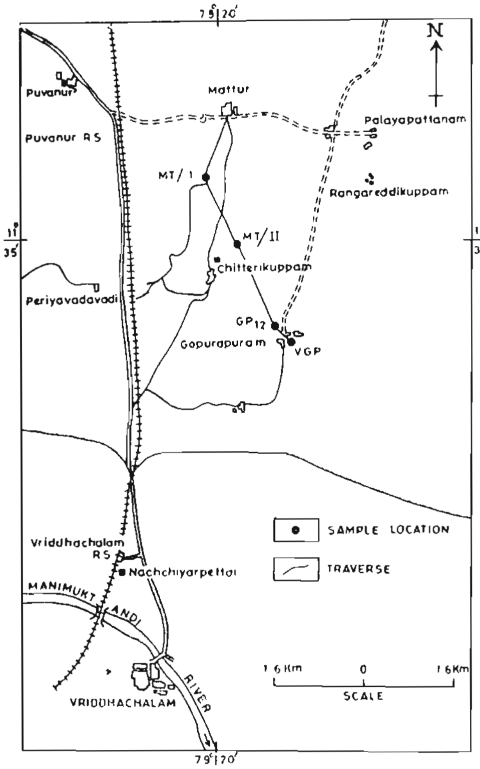
*The paper was presented at the IX Indian Colloquium on Micropalaeontology and Stratigraphy held at Udaipur, 1981.

sequences in shallow irrigation dug wells between Mattur and Gopurapuram, northeast of Vriddhachalam (Text-fig. 1). Dinoflagellate cysts from these sequences have recently been published by Jain (1978) and Jain and Garg (1979). In the present paper calcareous nannofossils are recorded.

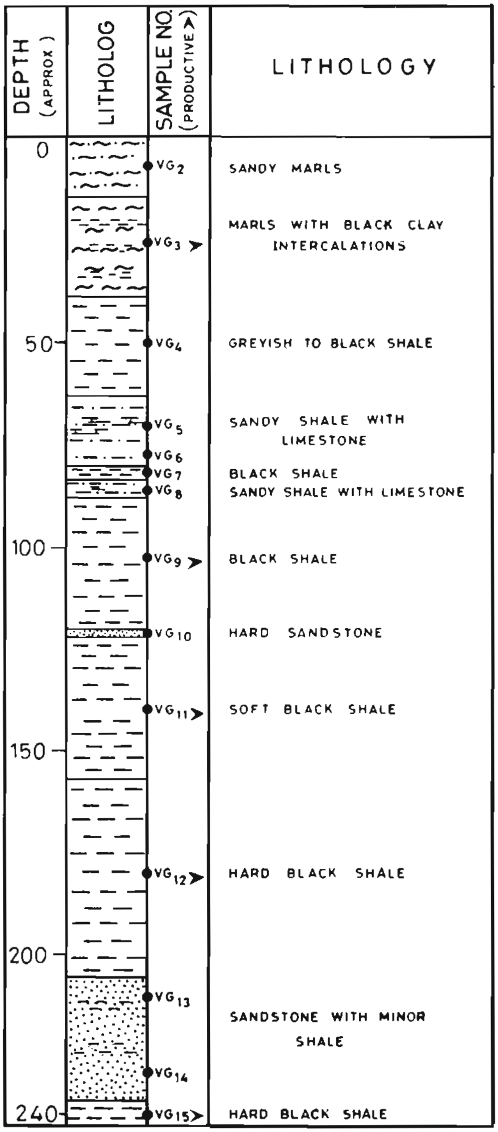
MATERIAL

The material for the present study is from a bore hole no. VGP (Text-fig. 1) sunk a few meters east of the Gopurapuram-Pallakolai road in the Gopurapuram Village, where a thick sedimentary sequence has been encountered. The drilling has penetrated through nearly 240 m strata. The succession consists dominantly of sandy marl and greyish to black shale with minor sandstone and limestone (Text-fig. 2).

The black shales have yielded a rich dinocyst assemblage at various levels in the sequence but calcareous nannofossils are recovered only from the basal sample VG 15 (Text-fig. 2). The dinoflagellate cysts, characterized by the presence of *Wetzeliella* (*Apectodinium*) *homomorpha* plexus, occur throughout the sequence. The dinocyst assemblage will be dealt in detail elsewhere.



TEXT-FIG. 1 — Map of Vriddhachalam area showing location of samples.



TEXT-FIG. 2 — Lithological sequence of the Gopurapuram borehole (VGP).

All the figured slides are housed at the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow.

CALCAREOUS NANNOFOSSIL ASSEMBLAGE

The calcareous nannofossil assemblage is quite rich though the individual specimens are fewer in number. The dominant and important coccolith and discoaster taxa present in the assemblage are listed below. The assemblage as a whole is characterized by the predominance of *Braarudosphaera* and *Micrantholithus* species.

SYSTEMATIC DESCRIPTION

Family — Zygodiscaceae Hay & Mohler, 1967

Genus — *Zygolithus* Matthews, 1956

Zygolithus concinnus Martini, 1961

Pl. 1, figs 5, 6

Family — Coccolithaceae Kamptner, 1928

Genus — *Markalius* Bramlette & Martini, 1964

Markalius inversus (Deflandre) Bramlette & Martini, 1964

Pl. 1, fig. 9

Genus — *Coccolithus* Schwarz, 1894

Coccolithus pelagicus (Wallich) Schiller, 1930

Pl. 1, figs 12, 13

Genus — *Chiasmolithus* Hay & Mohler, 1967

Chiasmolithus consuetus (Bramlette & Sullivan) Hay & Mohler, 1967

Pl. 1, figs 10, 11

Chiasmolithus solitus (Bramlette & Sullivan) Hay & Mohler, 1967

Pl. 1, fig. 3

Chiasmolithus sp. 1

Pl. 1, fig. 4

Remarks — These forms exhibit much smaller central area (5 μm along major axis) and sharply curved ends of the bars, thus could not be compared with the known species of the genus *Chiasmolithus*.

Genus — *Cyclolithella* Loeblich & Tappan, 1963

Cyclolithella ?robusta (Bramlette & Sullivan) Radomski, 1968

Pl. 1, figs 7, 8

Family — Thoracosphaeraceae Deflandre, 1952

Genus — *Thoracosphaera* Kamptner, 1927

Thoracosphaera operculata Bramlette & Martini, 1964

Pl. 1, figs 1, 2

Family — Braarudosphaeraceae Deflandre, 1947

Genus — *Braarudosphaera* Deflandre, 1947

Braarudosphaera bigelowii (Gran & Braarud) Deflandre, 1947

Pl. 1, figs 31, 32

Braarudosphaera discula Bramlette & Riedel, 1954

Pl. 1, figs 29, 30

Braarudosphaera africana Stradner, 1961

Pl. 1, fig. 27

Braarudosphaera sp. 1

Pl. 1, fig. 28

Remarks — But for its much smaller size, this tiny form about 6-7 μm in diameter, closely resembles *B. discula*.

Genus — *Micrantholithus* Deflandre, 1950

Micrantholithus flos Deflandre, 1950

Pl. 1, fig. 33

Micrantholithus vesper Deflandre, 1950

Pl. 1, figs 18-21

Micrantholithus attenuatus Bramlette & Sullivan, 1961

Pl. 1, figs 34, 35

Micrantholithus pinguis Bramlette & Sullivan, 1961

Pl. 1, figs 22, 23

Micrantholithus sp. 1

Pl. 1, fig. 17

Remarks — This form is comparable with *Micrantholithus vesper* but differs in its much smaller size (6-8 μm) and acutely pointed rays.

Micrantholithus sp. 2

Pl. 1, fig. 24

Remarks — These forms appear closest to *Micrantholithus pinguis* but are distinguished due to their small size (5-7 μm) and broadly rounded tips of the rays.

Micrantholithus sp. 3

Pl. 1, fig. 25

Remarks — This form compares best with *Micrantholithus flos* but for its smaller size and deeply incised margins of the pentaliths.

Micrantholithus sp. 4

Pl. 1, fig. 26

Remarks — These forms are almost identical with *Micrantholithus flos* but for their much smaller size (7-8 μm).

Family — Discoasteraceae Vekshina, 1959

Genus — *Discoaster* Tan, 1927

Discoaster helianthus Bramlette & Sullivan, 1961

Pl. 1, fig. 15

Discoaster mediosus Bramlette & Sullivan, 1961

Pl. 1, fig. 16

Discoaster multiradiatus Bramlette & Riedel, 1954

Pl. 1, fig. 14

Discussion — The nannofossil assemblage contains several long ranging species like *Coccolithus pelagicus*, *Markalius inversus*, *Micrantholithus pinguis*, *Braarudosphaera bigelowii* and *B. discula*. However, the presence of *Discoaster multiradiatus* is very significant. This species appears for the first time in the NP9 Zone of Martini (1971) and CP8 Zone of Okada and Bukry (1980), indicating uppermost Palaeocene age for the sediments. The NP9 zone of Martini is defined as the interval from the first occurrence of *D. multiradiatus* to the first occurrence of *Marthasterites bramlettei*.

The age derivations based on nannoplankton are in conformity with the distribution of planktonic foraminifera recorded by Mehrotra and Banerji (1972) from another borehole (210 m deep) drilled in the Gopurapuram Village. They recorded the occurrence of *Globorotalia velascoensis* up to the depth of ca. 190 m only, the underlying ca. 20 m claystone unit did not yield any foraminifera. The drilled sequence has been dated by them as Upper Sparnacian (uppermost Palaeocene), equivalent to the Standard Planktonic Foraminiferal Zone, *Globorotalia velascoensis* Zone (Zone P5; Berggren, 1969). Martini (1971) has also shown his NP9 Zone to be equivalent to Zone P5, the *Globorotalia velascoensis* Zone. The present find of nannofossils, therefore, suggests that the uppermost Palaeocene (Sparnacian) sediments in Gopurapuram extend further down to a depth of ca. 240 m.

The Upper Palaeocene rocks have also been recently encountered in another shallow well No. GP12 about 2.5 km further SSE of Mattur and north-west of Gopurapuram Village (Text-fig. 1). The well was dug about 200 m westward of milestone 14 on the Gopurapuram-Pallakolai Road. The sequence, in the 6 m deep dug well, comprises 5 m thick sandy marls interbedded with 0.5-0.6 m thick, 2-3 bands of bluish grey calcareous sandstone. This sandstone does not form a persistent bed but occurs as large, oval to round concretions at different levels within the sandy marls. Both sandy marls and calcareous sandstone concretions are fossiliferous.

Calcareous sandstone in thin section is made up of poorly sorted, angular to occasionally subangular quartz held in a micritic (lime mud) matrix. Quartz constitutes more than 90% of the terrigenous material.

The overall aspect of the rock in thin section suggests that the concretions are *in situ*, formed during diagenesis subsequent to the deposition of the sandy marls.

Presence of rare larger foraminifera (*Nummulites* and *Discocylina* species), planktonic foraminifera and several smaller benthonic foraminifera (Rotaliids, Miliolids, etc.) and frequent algae (including *Distichoplax biserialis*) have also been noticed in thin sections. The conventional acid/alkali treatment of this sandstone has further revealed a rich dinoflagellate flora containing *Wetzeliella* (*Apectodinium*) *homomorpha* plexus (sensu stricto, Harland, 1979). The sandy marls have not yielded any palynoflora. Jain and Garg (1979, p. 20) mentioned the presence of *Wetzeliella homomorpha quinquelata* from this material but the subsequent detailed study showed the presence of *Wetzeliella homomorpha* plexus. The biostratigraphic significance of *Wetzeliella* (*Apectodinium*) *homomorpha* plexus has recently been discussed by Harland (1979). It marks the Palaeocene/Eocene boundary or top of Sparnacian. Dutta and Jain (1980) also reported the presence of *Wetzeliella homomorpha* plexus at the contact of Lakadong Sandstone and Umlatdoh Limestone members of the Sylhet Formation, Meghalaya, suggesting Palaeocene/Eocene boundary at this contact.

The Palaeocene sequence recorded by Rajagopalan (1967) from a dug well near Gopurapuram, may possibly be equivalent to the above sequence (Well GP12). In a 5 m thick sequence of marlstone, Rajagopalan (1967, p. 94, figs 1-3) mentioned the presence of two thin beds of hard limestone containing *Discocyclina* species and *Distichoplax biserialis* and compared them with the fossiliferous limestone of the Pondicherry area. The limestone beds of Rajagopalan appear to be the extension of the same calcareous sandstone concretions recorded by Jain and Garg (1979). From marlstones, Rajagopalan (1967) recorded a rich microfauna consisting of foraminifera (including *G. velascoensis*) and ostracoda indicating a Middle-Late Palaeocene age, and further correlated this sequence with the Upper Marlstone Unit of the Pondicherry Formation, from which he (1965) recorded nannoplankton, *Heliolithus riedelii*. This coccolith species is now considered to be the zone marker (NP7 extending up to NP9).

The significance of *Globorotalia velascoensis*, *Discoaster multiradiatus*, *Wetzeliella* (*Apectodinium*) *homomorpha* plexus and to some extent *Distichoplax biserialis* at the top of Palaeocene or Palaeocene/Eocene boundary is thus recognized. Therefore, from the above discussion it is clear that a multidisciplinary approach in marine biostratigraphy would be of much help.

The dominance of tiny braarudosphaerids in the sample is significant favouring low salinity and near shore environment of deposition (Bukry, 1974; Bramlette & Martini, 1964; Martini, 1965).

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REFERENCES

BLANFORD, H. F. (1862). On the Cretaceous and other rocks of the South Arcot and Trichinopoly districts. *Mem. geol. Surv. India*, **4** (1): 1-217.

BERGGREN, W. A. (1969). Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time scale. *Nature*, **224** (5224): 1072-1075.

BRAMLETTE, M. N. & MARTINI, E. (1964). The great change in calcareous nannoplankton fossils between the Maestrichtian and Danian. *Micropaleontology*, **10**: 291-322.

BUKRY, D. (1974). Coccoliths as palaeosalinity indicators. Evidence from the Black sea, in Degens, E. T. & Ross, D. A. (Eds)— *The Black Sea, its geology, chemistry & biology. Am. Assoc. Petr. Geol. Mem.*, **20**: 353-363.

DUTTA, S. K. & JAIN, K. P. (1980). Geology and palynology of the area around Lumshnong, Jaintia Hills, Meghalaya, India. *Biol. Mem.*, **5** (1): 56-81.

HARLAND, R. (1979). *Wetzeliella* (*Apectodinium*) *homomorpha* plexus from the Palaeocene/earliest Eocene of north-west Europe. *Proc. IV int. palynol. Conf., Lucknow (1976-77)*, **2**: 59-70.

JAIN, K. P. (1978). An Upper Cretaceous dinoflagellate assemblage from Vriddhachalam area, Cauvery Basin, South India. *Palaeobotanist*, **25**: 146-160.

JAIN, K. P. & GARG, R. (1979). Palaeocene dinoflagellate cysts from Vriddhachalam area, Cauvery Basin, South India. *Abstract : Symp. Evol. Botany Biostratigr., Calcutta*: 20.

Martini, E. (1965). Mid-Tertiary calcareous nannoplankton from Pacific deep-sea cores, in W. F. Whittard & R. B. Bradshaw (Eds)— *Submarine Geology and Geophysics. Colston. Res. Soc. 17th Symp., London*: 393-422.

Martini, E. (1971). Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proc. II Plankt. Conf., Roma*, **2**: 739-777.

Mehrotra, K. K. & Banerji, R. K. (1972). Foraminiferal biostratigraphy and correlation of the Palaeocene sequence of Vriddhachalam, Cauvery Basin. *J. Palaeont. Soc. India*, **15**: 55-63.

Okada, H. & Bukry, David (1980). Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Marine Micropalaeontology*, **5** (3): 321-325.

Rajagopalan, N. (1965). Late Cretaceous and Early Tertiary stratigraphy of Pondicherry, South India. *J. geol. Soc. India*, 6: 108-121.

Rajagopalan, N. (1966). Occurrence of marine Palaeocene sediments in the Vriddhachalam area, South India. *Bull. geol. Soc. India, Spec. No.* **1**: 22-23 (Abst.).

Rajagopalan, N. (1967). The Palaeocene of Vriddhachalam, South India. *Bull. geol. Soc. India*, **4** (3): 94-96.

EXPLANATION OF PLATE

(*All magnified.* × 2000; *the coordinates refer to the Amplival Jena Microscope*)

1, 2. *Thoracosphaera operculata* Bramlette & Martini; slide no. 6576; Coordinates: 120·0 × 11·4.

3. *Chiasmolithus solitus* (Bramlette & Sullivan) Hay & Mohler; slide no. 6579; Coordinates: 11·0 × 15·0.

4. *Chiasmolithus* sp. 1; slide no. 6577; Coordinates: 120·5 × 15·0.

5, 6. *Zygolithus concinnus* Martini; slide no. 6576; Coordinates: 11·4 × 14·1.

7, 8. *Cyclolithella ?robusta* (Bramlette & Sullivan); Radomski; slide no. 6577; Coordinates 81·2 × 13·8.

9. *Markalius inversus* (Deflandre) Bramlette & Martini; slide no. 6579; Coordinates: 111·1 × 15·0.

10, 11. *Chiasmolithus consuetus* (Bramlette & Sullivan) Hay & Mohler; slide no 6576; Coordinates: 127·4 × 13·5.

12, 13. *Coccolithus pelagicus* (Wallich) Schiller; slide no. 6576; Coordinates: 127·4 × 13·5.

14. *Discoaster multiradiatus* Bramlette & Riedel; slide no. 6578; Coordinates: 124·2 × 7·6.

15. *D. helianthus* Bramlette & Sullivan; slide no. 6579; Coordinates: 118·0 × 14·1.

16. *D. mediosus* Bramlette & Sullivan; slide no. 6579; Coordinates: 115·5 × 15·2.

17. *Micrantholithus* sp. 1; slide no. 6578; Coordinates: 126·7 × 16·1.

18-21. *Micrantholithus vesper* Deflandre; slide no. 6577; Coordinates: 119·6 × 11·3 & 119·6 × 11·3 respectively.

22, 23. *Micrantholithus pinguis* Bramlette & Sullivan; slide no 6576; Coordinates: 113·0 × 12·3.

24. *Micrantholithus* sp. 2; slide no. 6579; Coordinates; 79·5 × 21·6.

25. *Micrantholithus* sp. 3; slide no. 6580; Coordinates: 116·5 × 13·0.

26. *Micrantholithus* sp. 4; slide no. 6582; Coordinates: 124·8 × 17·5.

27. *Braarudosphaera africana* Stradner; slide no. 6576; Coordinates: 121·9 × 16·6.

28. *Braarudosphaera* sp. 1; slide no. 6581; Coordinates: 119·0 × 13·3.

29, 30. *B. discula* Bramlette & Riedel; slide nos. 6576 & 6579; Coordinates: 126·5 × 14·3 & 116·9 × 13·8 respectively.

31, 32. *B. bigelowi* (Graan & Braarud) Deflandre; slide no. 6577; Coordinates: 118·0 × 15·3 & 119·8 × 11·2 respectively.

33. *Micrantholithus flos* Deflandre; slide no. 6579; Coordinates: 114·6 × 14·8.

34, 35. *M. attenuatus* Bramlette & Sullivan; slide nos. 6576 & 6582; Coordinates: 122·1 × 15·6 & 84·0 × 40·0 respectively.

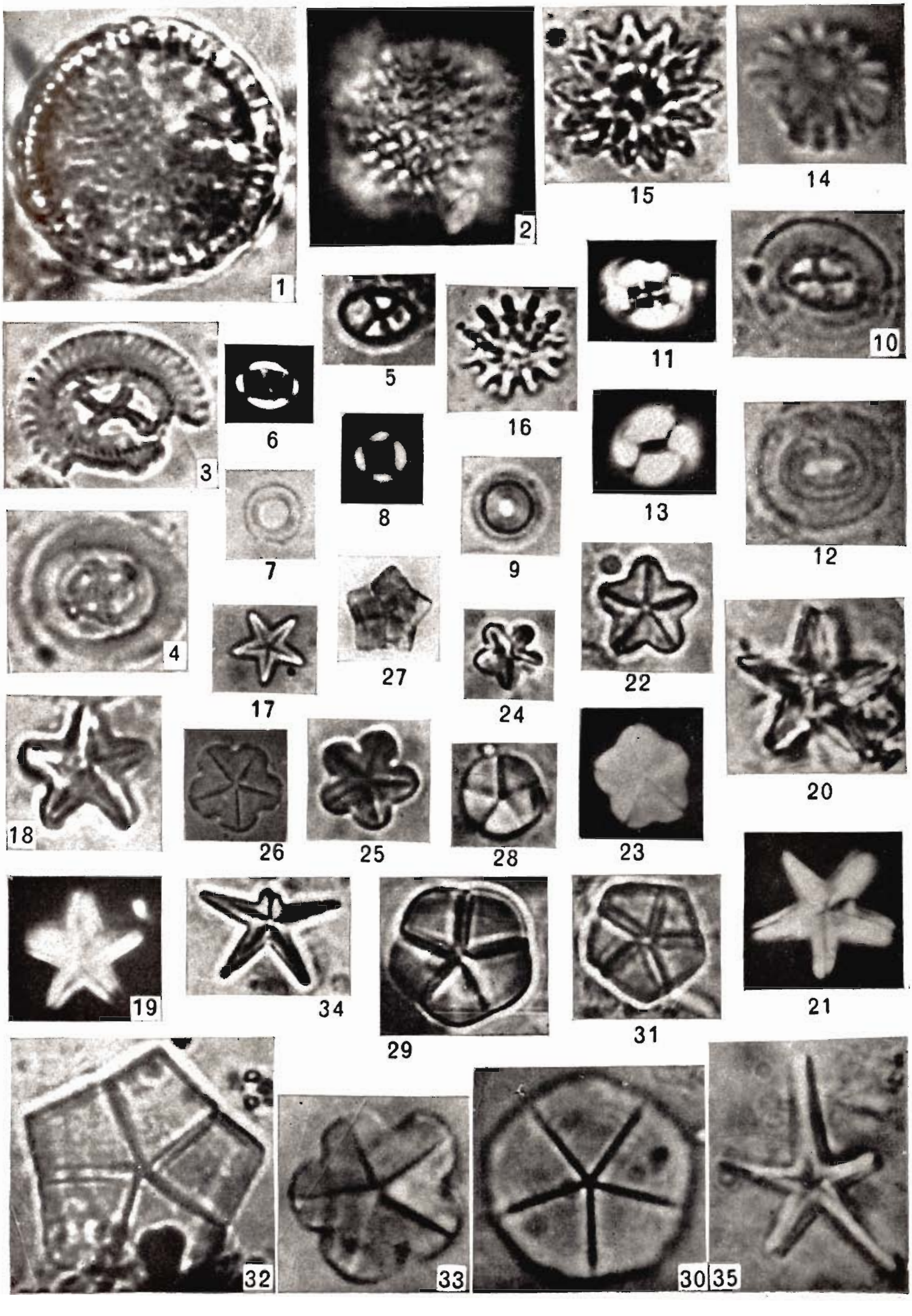
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PLATE 1

The Palaeobotanist, 31(1): 76-81, 1983.

PALMOXYLON GHUGUENSIS SP. NOV. RESEMBLING *CHRYSALIDOCARPUS* FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT IN MADHYA PRADESH

K. AMBWANI & U. PRAKASH

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

ABSTRACT

Palmoxylon ghuguensis sp. nov. showing close resemblance with the extant *Chrysalidocarpus lutescens* has been described from the Deccan Intertrappean beds near the village Ghugua. It shows characteristic divided phloem placed above the metaxylem in the fibrovascular bundles.

Key-words — Xylotomy, *Palmoxylon*, *Chrysalidocarpus*, Deccan Intertrappean beds.

सारॉंश

मध्य प्रदेश में मॉंडला जनपद की दक्खिन अन्तर्ट्रैपी संस्तरों से क्राइसेलिडोकार्पस से मिलती-जुलती पामॉक्सीलॉन घुगुयेन्सिस नव जाति – कृष्ण अम्बवानी एवं उत्तम प्रकाश

घुगुआ गॉंव के समीपस्थ दक्खिन अन्तर्ट्रैपी संस्नरों से पाल्मॉक्सीलॉन घुगुयेन्सिस नव जाति वर्णित की गई है जो कि वर्तमान क्राइसेलिडोकार्पस ल्यूटिसेन्स से घनिष्ठ सजातीयता प्रदर्शित करती है। इसमें वाहिनी बंडलों में अनुदारू के ऊपर लाक्षणिक विभक्त पोषवाह विद्यमान है।

INTRODUCTION

A NEW species of a petrified palm stem is described here from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. The fossiliferous locality is situated between the villages Ghugua and Katangi at a distance of 13 km from Shahpura on Shahpura-Niwas road (80°45′E: 23°10′N). The present fossil palm wood shows well preserved structural details with compact ground tissue throughout the stem alongwith divided phloem in the fibrovascular bundles.

So far only a few fossil plants are known from this locality consisting mainly of petrified palms and dicotyledonous woods. These are *Sterculioxylon shahpurensis*, *Calophylloxylon dharmendrai*, *Burseroxylon preserratum*, *Heyneoxylon tertiarum*, *Dracontomelumoxylon mangiferumoides* and *Laurinoxylon deccanensis* (Bande & Prakash, 1980, 1981). Recently a fossil palm fruit resembling *Hyphaene* Bande, Prakash & Ambwani (1982) as well as a fossil palm wood resembling *Licuala* (Ambwani, 1983) has been reported from these beds.

SYSTEMATIC DESCRIPTION

MONOCOTYLEDONAE

FAMILY — PALMAE

Palmoxylon ghuguensis sp. nov.

Pl. 1, figs 1-6; Pl. 2, figs 7-10

Material — The fossil wood is almost complete in cross section consisting of outer and inner regions of the stem devoid of cortex (Pl. 1, fig. 2). It is well preserved and measures about 20 cm in length and 9 cm in diameter (Pl. 1, fig. 1).

Outer Zone — This zone is about 2 cm in thickness. The fibrovascular bundles are closely placed and usually regularly oriented. They are variously shaped, mostly round, oval to slightly elongated with their xylem facing towards the centre. Their frequency varies from 200-250 per cm^2 and the bundles measure 600×400-1000×450 µm. The f/v ratio is 1/1-3/1. The dorsal sclerenchymatous sheath is prominently developed and is generally reniform. The median sinus is concave and the auricular lobes are more or less rounded. Generally one rarely two large excluded metaxylem vessels are present in each fibrovascular bundles (Pl. 1, fig. 3). A layer of tabular parenchyma is present around the fibrous part of the fibrovascular bundles (Pl. 1, fig. 4), but radiating parenchyma are absent. The stegmata are present around the fibrous part of the fibrovascular bundles (Pl. 1, fig. 6). Phloem is usually divided into two patches and is represented by two lacunae just above the metaxylem; these are separated by a patch of sclerenchymatous tissue. However, sometimes a few phloem cells may be observed. The diminutive fibrovascular bundles are also sometimes present in this zone (Pl. 1, fig. 3). The leaf-trace bundles are frequently observed throughout this zone but the fibrous bundles are absent (Pl. 1, figs 3, 4).

Inter Zone — This zone is about 3 cm in radius and the fibrovascular bundles are sparsely placed, irregularly oriented and round to oval in shape. The frequency of the fibrovascular bundles is 120-140 per cm^2 and they measure 800×500-1200×800 µm in size. The f/v ratio varies from 1/1-1/2. The dorsal sclerenchymatous sheath is rather poorly developed and is generally reniform in shape. The median sinus is concave and the auricular sinus is absent. The auricular lobes are rounded. Generally one sometimes two large and very rarely three (one large and two small) excluded metaxylem vessels are present in each fibrovascular bundle (Pl. 2, fig. 7). Tabular parenchyma is not clearly observed and the radiating parenchyma is absent in this zone. Stegmata are present in the fibrous part of the fibrovascular bundles. Here the phloem is usually divided into two patches (Pl. 2, fig. 9) and is represented by two lacunae due to bad preservation. These lacunae are separated by a patch of thick-walled cells. These phloem lacunae are clearly observed just above the metaxylem vessels in the fibrovascular bundles. The diminutive fibrovascular bundles are frequently seen in this zone (Pl. 2, fig. 7). The larger leaf-trace bundles are sometimes fused together (Pl. 2, fig. 7) and the fibrous bundles are also absent in this zone.

Ground Tissue — The ground tissue is compact throughout the stem of the present species. Outer part, generally composed of round to oval parenchymatous cells (Pl. 1, fig. 3) while in the inner part, though not well preserved, usually exhibits the same type of parenchymatous cells as in the outer part of the stem. Here, the parenchymatous cells are slightly larger in size and their shape is usually round to oval (Pl. 2, fig. 10). At some places a layer of tangentially elongated cells can be seen between the two adjacent fibrovascular bundles.

Diminutive Fibrovascular Bundles — These bundles are present both in the outer as well as in inner zone of the stem but they are not many in number. They are smaller in size and vary from 400-500 µm. They reveal similar structural details as seen in larger fibrovascular bundles. Generally the diminutive fibrovascular bundles possess one metaxylem vessel.

Leaf-Trace Bundles — These are present throughout the stem but are more frequent in the inner part. They are recognized by their protruded tongue-like vascular part. Sometimes two leaf-trace bundles are fused together. Each leaf-trace bundle has many small protoxylem vessels, alongwith one to two large metaxylem vessels (Pl. 1, figs 3, 4; Pl. 2, figs 7, 10). The metaxylem vessels have scalariform while protoxylem vessels possess annular to spiral thickenings.

DIAGNOSIS

Stem large brownish stump, complete in cross section, about 20 cm in length and 9 cm in diameter. *Outer zone* with regularly oriented, round to oval sometimes slightly elongated fibrovascular bundles, 600×400-1000×450 µm in size, 200-250 per cm^2, mostly with one large excluded metaxylem vessel; f/v ratio 1/1-3/1; dorsal sclerenchymatous sheath generally reniform with median sinus concave and auricular lobes rounded; tabular parenchyma present but radiating parenchyma absent; stegmata present; phloem usually divided into two patches; diminutive fibrovascular bundles evenly distributed; leaf-trace bundles frequent and the fibrous bundles absent. *Inner zone* with irregularly oriented, sparsely placed, round to oval fibrovascular bundles 800 × 500-1200 × 800 μm in size, 120-140 per cm^2, with generally one large sometimes two excluded metaxylem vessels; f/v ratio 1/1-1/2; dorsal sclerenchymatous sheath poorly developed and reniform with median sinus concave; auricular lobes round, auricular sinus absent; stegmata present; tabular parenchyma not clearly seen, radiating parenchyma absent; phloem usually divided into two patches; diminutive fibrovascular bundles evenly present; leaf-trace bundles frequent and fibrous bundles absent. *Ground tissue* compact, composed of round to oval parenchymatous cells.

Holotype — B.S.I.P. Museum no. 35447.

Locality — Ghugua Village near Shahpura, Mandla District, Madhya Pradesh.

Horizon — Deccan Intertrappean Series.

Age — Early Eocene.

Affinities — The structural features of the present fossil wood with characteristic divided condition of the phloem are closely comparable with the modern arecoid palm, *Chrysalidocarpus* especially with *Chrysalidocarpus lutescens* H. Wendl. (Tomlinson, 1961, p. 90).

Apart from *Chrysalidocarpus*, three other genera of lepidocaryoid palms, viz., *Calamus*, *Daemonorops* and *Korthalsia* also show divided condition of the phloem and mostly one wide vessel in the fibrovascular bundles. However, *Calamus* and *Daemonorops* differ from *Chrysalidocarpus* in having lateral postion of the divided phloem with respect to the metaxylem vessels. Besides, all these three genera also differ from *Chrysalidocarpus* in possessing lacunar ground tissue (Tomlinson, 1961, pp. 224, 232, 238) as against compact ground tissue in *Chrysalidocarpus* (Tomlinson, 1961, p. 90).

Both in *Chrysalidocarpus lutescens* and the fossil species the stem can be demarcated into outer and inner zones. The fibrovascular bundles in the outer zone of both the living and fossil species are closely placed and usually round to oval in shape. They are almost similar in size and range from 1000 × 400 to 1000 × 800 μm and 600 × 400 to 1000 × 450 μm respectively. The frequency of the fibrovascular bundles in the outer zone of living species is 200-230 per cm^2 which is almost similar to the outer zone of our fossil being 200-250 per cm^2. The f/v ratio is also closely comparable in both the living (1/1 to 2/1) as well as fossil species (1/1 to 3/1). The number of metaxylem vessels in fibrovascular bundles is generally one both in living and fossil species, which is large and excluded. Rarely two smaller vessels may also be seen. Stegmata are present around the fibrous part of the fibrovascular bundles, both in the living as well as fossil species. Tabular parenchyma is present while the radiating parenchyma is absent in both.

The inner zone of living as well as fossil species also resembles closely. The fibrovascular bundles show almost similar shape and size (Pl. 2, figs 7, 8). They are usually oval in shape and measure 1000 × 800-1600 × 1000 μm in the living, whereas they are 800 × 500-1200 × 800 μm in the fossil. The fibrovascular bundles are irregularly oriented and the dorsal sclerenchymatous sheath is reniform in both. The frequency of the fibrovascular bundles is more or less similar in living and the fossil species, i.e. 120-130 per cm^2 and 120-140 per cm^2 respectively. The f/v ratio of the fibrovascular bundles in the living species is 1/1 whereas it varies from 1/1-1/2 in the fossil species. Both show the presence of stegmata around the fibrous part of the fibrovascular bundles.

The ground tissue is compact, composed of round to oval parenchymatous cells (Pl. 2, fig. 10) in both and the cells are slightly bigger in the inner than the outer zone. Phloem is divided into two parts by a narrow sclerenchymatous patch of cells; it is usually indicated by two separate lacunae above the metaxylem vessels (Pl. 2, fig. 9) in the present fossil.

Presence of diminutive fibrovascular bundles as well as leaf-trace bundles have been recorded both in the living and fossil species whereas the fibrous bundles are absent throughout the stem in both. Further, the stem *Chrysalidocarpus lutescens* attains a diameter about 8 cm (Blatter, 1926) which is quite comparable with the diameter of the fossil species.

Because of a close resemblance of the fossil palm wood with the structural features of the stem wood of *Chrysalidocarpus lutescens* H. Wendl. which is indigenous to Madagascar (Blatter, 1926), it seems quite likely that *Chrysalidocarpus* might have been growing in the Deccan Trap country during the Late Cretaceous/Early Eocene times.

It has now been proved that the peninsular Indian Plate was close to Madagascar 40° south of the equator about 180-200 million years ago during the Triassic period (Dietz & Holden, 1970, 2 maps on pp. 824, 825; Schuster, 1972, pp. 3-86) and as it gradually migrated northward, it most probably carried with it a large and complex flora of austral origin including those from the Madagascar (Schuster, 1972, pp. 3-86). The presence of *Chrysalidocarpus* in the Deccan Intertrappean beds would explain this. However, this genus became extinct from the Trap country after the Palaeogene and is presently found only in Madagascar (Willis, 1973). This is because drier climatic conditions prevailed in peninsular India specially in the Deccan Trap country due to its migration at about 40° north of the equator where there is less of atmospheric precipitation. Besides, there are certain modern species of angiosperms, viz., *Flacourtia indica* and *Eriocaulon seiboldianum* which are still found in the flora of Madagascar and the Indo-Malayan region (Meher-Homji, 1974).

REFERENCES

AMBWANI, K. (1983). *Palmoxylon shahpurensis* sp. nov., a fossil palm resembling *Licuala* from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **31**(1): 52-59.

BANDE, M. B. & PRAKASH, U. (1980). Four new fossil dicotyledonous woods from the Deccan Intertrappean beds near Mandla District, Madhya Pradesh. *Geophytology*, **10**: 248-251.

BANDE, M. B. & PRAKASH, U. (1983). Fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla District, Madhya Pradesh. *Palaeobotanist*, **31**.

BANDE, M. B., PRAKASH, U. & AMBWANI, K. (1982). A fossil palm fruit *Hyphaeneocarpon indicum* gen. et sp. nov. from the Deccan Intertrappean Series, India. *Palaeobotanist*, **30**(3): 303-309.

BLATTER, E. (1926). *Palms of British India and Ceylon*. Oxford Univ. Press, Oxford.

DIETZ, R. S. & HOLDEN, J. C. (1970). The break up of Pangaea. *Scient. Am.*, **223** (4): 30-41.

MEHER-HOMJI, V. M. (1974). On the origin of the tropical dry evergreen forest of South India. *Int. J. Ecol. Environ., Sci.*, **1**: 19-39.

SCHUSTER, R. M. (1972). Continental movements "Wallace's Line" and Indo Malayan-Australasian dispersal of land plants. Some electric concepts. *Bot. Rev.*, **38** (1): 3-86.

TOMLINSON, P. B. (1961). *Anatomy of the Monocotyledons*. Part III. Oxford Clarendon Press: 1-453.

WILLIS, J. C. (1973). *A dictionary of the flowering plants and ferns*. 8th edition. Cambridge Univ. Press: 1-1245.

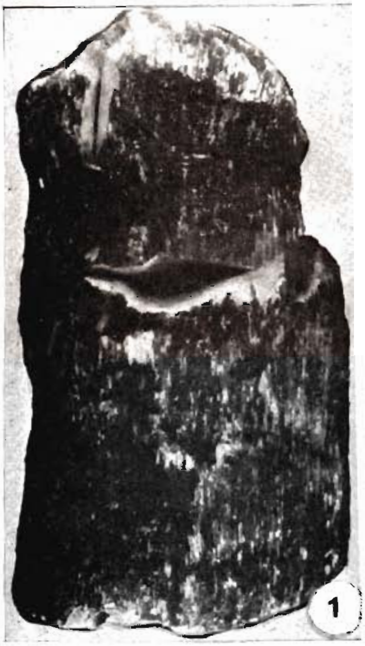
EXPLANATION OF PLATES

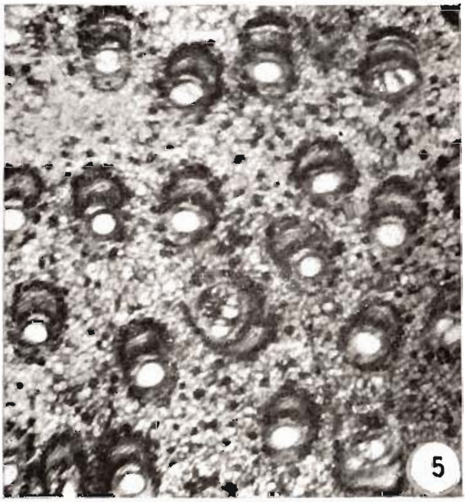
PLATE 1

1. A specimen of *Palmoxylon ghuguensis* sp. nov. × 1/2. Specimen no. 35447.
2. A sector of the same in cross section under low power showing orientation of the fibrovascular bundles. × 8. Slide no. 6557.
3. Cross section of outer portion of outer zone showing fibrovascular bundles with usually one large metaxylem vessel and leaf-traces. × 15. Slide no. 6557.
4. Cross section of inner portion of outer zone showing fibrovascular bundles with one to two large vessels and leaf-traces. × 15. Slide no. 6557.
5. Cross section of the portion of outer zone of *Chrysalidocarpus lutescens* (younger stem) showing fibrovascular bundles with usually single metaxylem vessels. × 15. B.S.I.P. Herbarium slide no. 2648.
6. Longitudinal section showing stegmata in the fibrous portion of fibrovascular bundle. × 60. Slide no. 6558.

PLATE 2

7. Cross section of inner part of inner zone of *Palmoxylon ghuguensis* sp. nov. showing irregular orientation of the fibrovascular bundles. × 15. Slide no. 6557.
8. Cross section of the inner portion of inner zone of *Chrysalidocarpus lutescens* showing irregular orientation of the fibrovascular bundles with usually one metaxylem vessel and divided phloem. × 15. B.S.I.P. Herbarium slide no. 2677.
9. Enlarged fibrovascular bundles of *Palmoxylon ghuguensis* sp. nov. from the inner zone to show divided condition of the phloem. × 60. Slide no. 6557.
10. Enlarged inner portion of inner zone of the same to show compact ground tissue. × 60. Slide no. 6557.





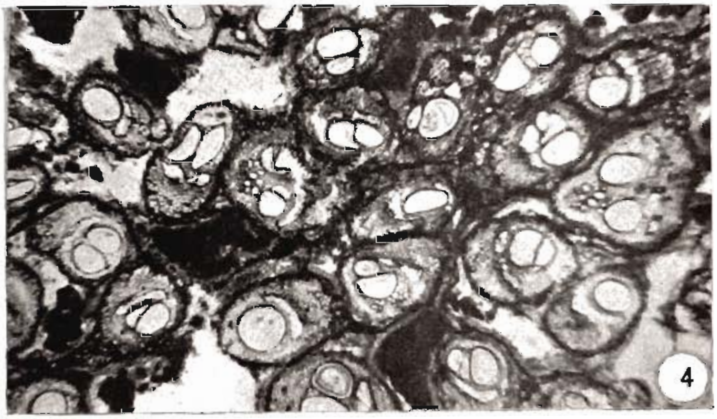
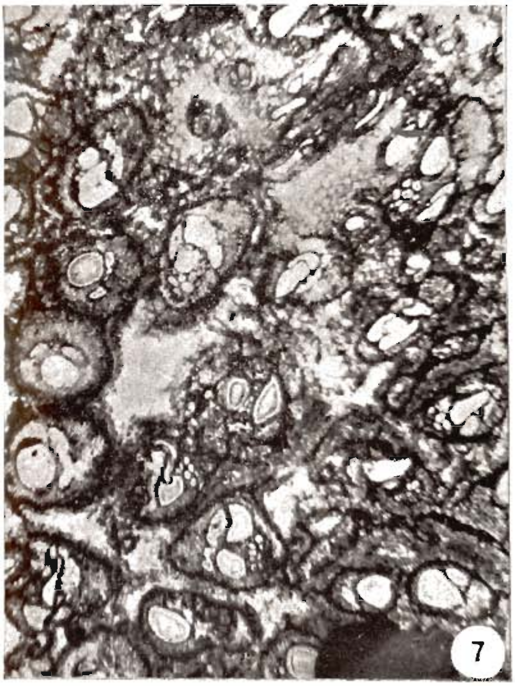


PLATE 1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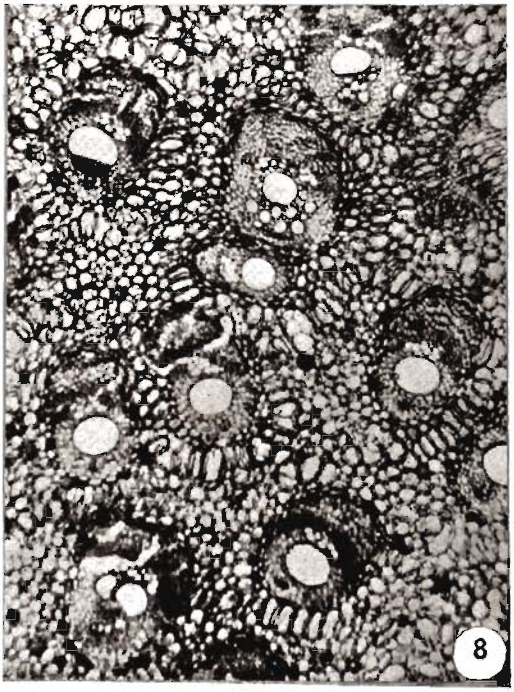
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PLATE 2

The Palaeobotanist, 31(1): 82-99, 1983.

ELEVENTH BIRBAL SAHNI MEMORIAL LECTURE

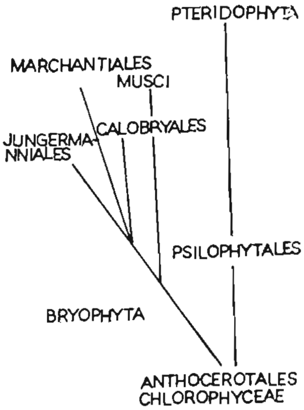
STATUS AND POSITION OF HORNWORTS

R. S. CHOPRA
(Retd) Reader, Botany Department, Punjab University, Chandigarh 160 015, India

SINCE 1879, when Leitgeb pointed out some anomalies in hornworts (or anthocerotes), a small natural group of bryophytes, their status and position have been a subject of lively discussion.

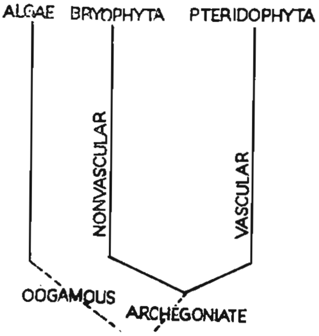
Fulford (1965, p. 3) wrote, " The Anthocerotales or Anthocerotae if you will, is a taxon with very many gametophyte and sporophyte characters unique to itself. Whether it is very closely or more distantly related to other Hepaticae remains to be proved".

Campbell (1895) derived pteridophytes from anthocerotes. Later (1925, 1940) he derived the Psilophytales from the Anthocerotales (Text-fig. 1) which in turn were derived from the Chlorophyceae.

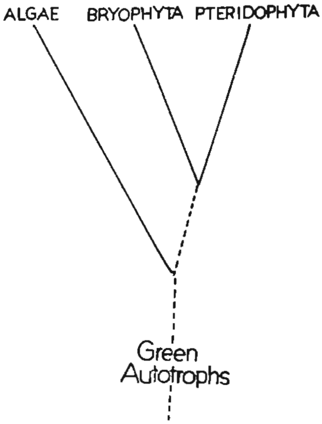


TEXT-FIG. 1 — Phylogeny (after Campbell, 1940).

Goebel (1898, 1905) refuted Campbell and considered the Bryophyta and the Pteridochyta as two independent lines. Later (1930) he concluded that the Bryophyta are not connected with any taxon either upwards or downwards. Bower (1935) supported Goebel (Text-fig. 2). Steere (1969) rejected a direct algal origin of bryophytes, or that they present an evolutionary way station between algae and higher plants, and concluded that they are an offshoot of the Archegoniatae, a " dead end ". An adaptation of the phylogenetic scheme by Zimmermann (1932) expresses these relationships better (Text-fig. 3).



TEXT-FIG. 2 — Relationships (ideas of Bower, Goebel & Steere).



TEXT-FIG. 3 — Phylogeny (adapted from Zimmermann, 1932).

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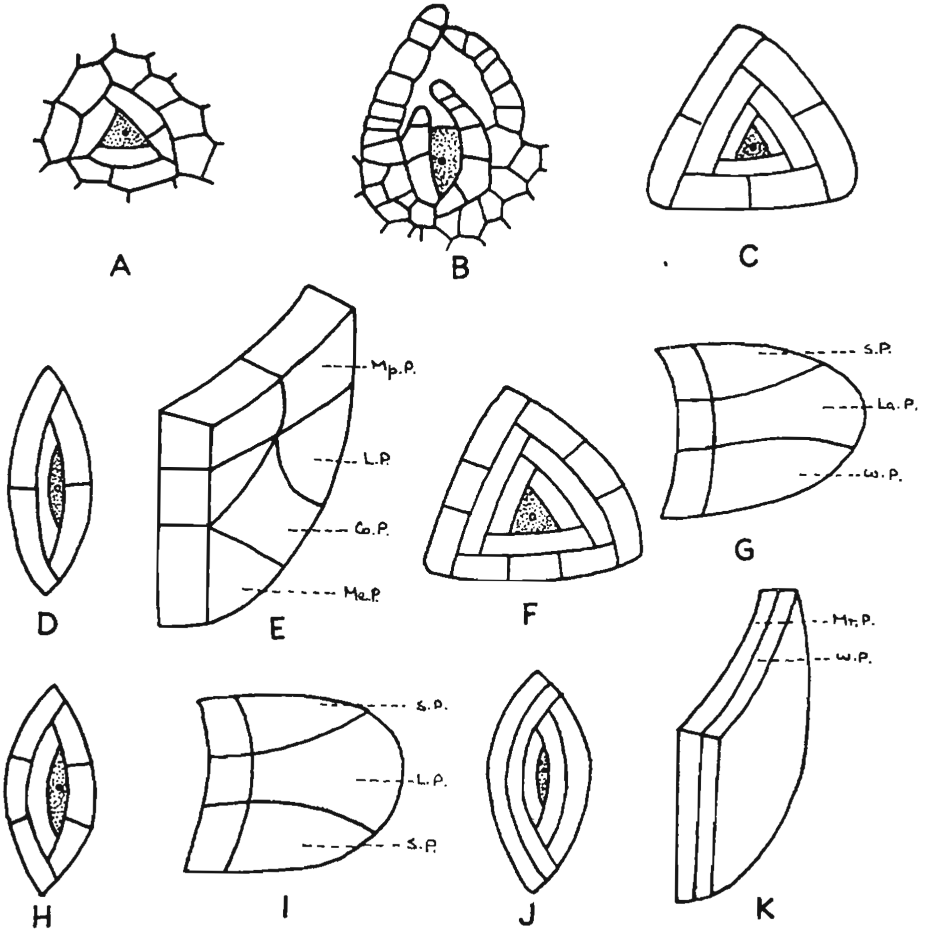
To decide as to the ideas of which school of thought are more tenable than those of the other and to incorporate the comments of various authors, where necessary, it is desirable to cover the entire gamut, considering and evaluating all features, rather than dwell upon a limited number of features (*cf.* Howe, 1898: peculiar chloroplasts, sunken sexual organs, meristematic seta, sterile columella and stomata on the capsule wall).

DATA AND DISCUSSION

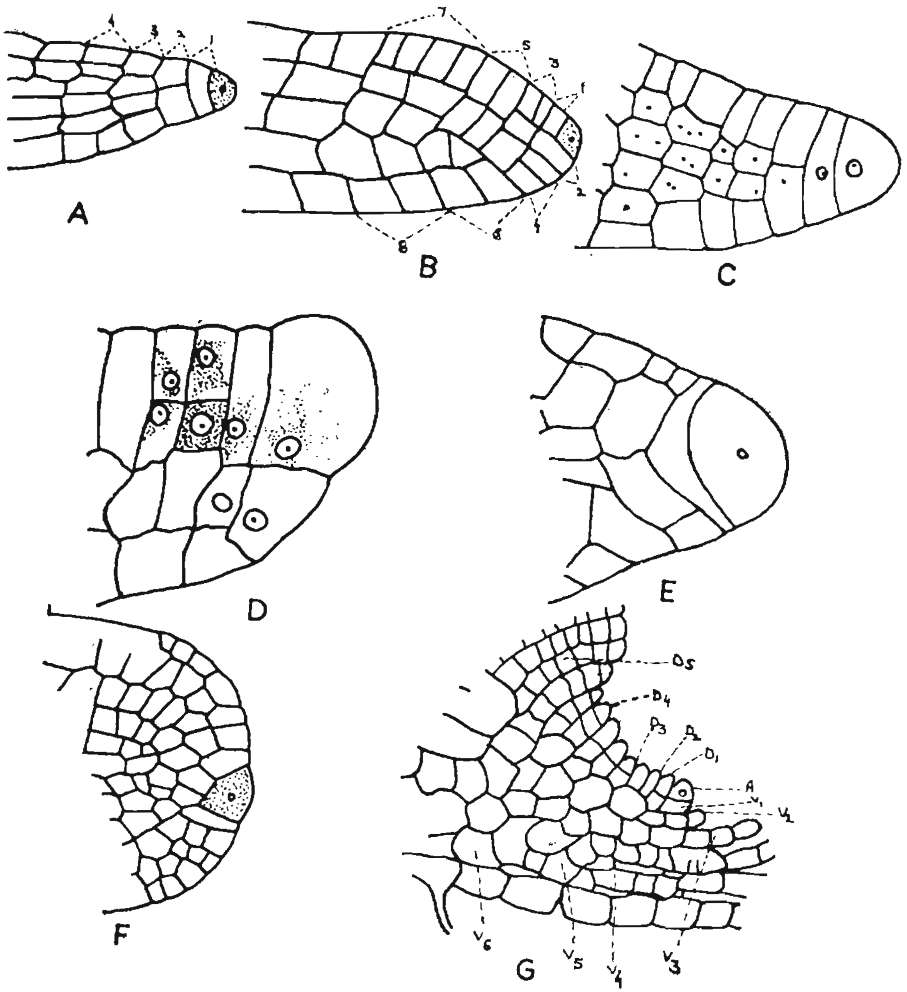
HAPLOPHASE

The habit of growth, but for the presence of colonies of *Nostoc* in the thallus, resembles that of the thalloid Metzgeriales.

Cavers (1911, pp. 90, 91) wrote, " The mode of apical growth is of interest and even of value in helping to understand the morphology of the plant body with special



TEXT-FIG. 4 — Showing sections of apical cell and divisions in segments. **A**, **B**, diagramatic transverse and longitudinal sections respectively. *Haplomitrium gibbsiae* (after Campbell)— **C**, **D**, transverse sections of *Porella* and *Plagiochila* respectively; **E**, a segment of either C or D; **F**, transverse section; **G**, a segment. *Petalophyllum* — **H**, transverse section; **I**, a segment. *Fossombronia* — **K**, a segment. *Metzgeria*. Abbreviations — CoP, cortex stem primordial; LP, leaf primordial; McP, mucilage primordium; SP, stem primordium; LaP, lamella primordium; MrP, midrib primordium.

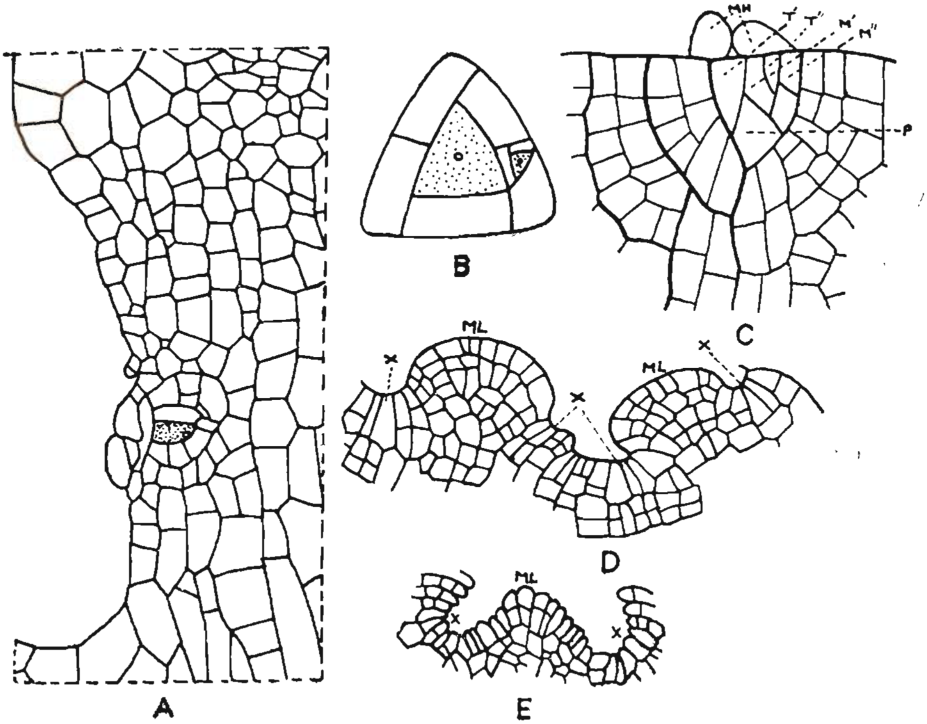


TEXT-FIG. 5 — Vertical longitudinal sections — A, *Dendroceros*; B, *Anthoceros* (schematic after Leitgeb); C, *Notothylas breuteii*, × 600 (after Campbell); D, *Anthoceros* (*Phaeoceros*), × 390 (after Bharadwaj); E, *Pellia epiphylla*, × 450; F, *Pallavicinius cylindricus*, × 225 (both after Campbell); G, *Riccia glauca*, × 325 (after Smith). The numerals indicate the position of apical cell, while D and V stand for dorsal segments. The cells between two epidermis in fig. C are dotted.

reference to the origin of the differentiation into stem and leaves". This is an apt description with regard to the Calobryales, Jungermanniales and such Metzgeriales as they have two- or three-sided apical cells. Different types (Text-fig. 4) are: Calobryales, Jungermanniales, *Petalophyllum - Fossombronia* and *Metzgeria*.

In taxa where the apical cell, as a rule, cuts off four sets of segments (Text-fig. 5) development of the plant body, subject to the interpolation of air-chambers in the Marchantiales, follows more or less the same pattern.

In Calobryales (Text-fig. 6) a cortical cell is transformed into an apical cell of a branch. Several types of branching have been recognized in the Jungermanniales. However, for our limited comparison (Text-fig. 6) we may note intercalary and apical branching. In the former case a branch arises endogenously on the lower side of the stem and in the latter case a branch primordium is developed in one cell either



TEXT-FIG. 6 — Branching. A, vertical section of part of a stem of *Haplomitrium*, × 175 (after Campbell); B, origin (diagrammatic) of a branch primordium in a member of the Jungermanniales; C, horizontal longitudinal section of *Metzgeria furcata*, × 540 (after Strassburger through Goebel); D, horizontal longitudinal sections of *Anthoceros* (after Goebel); E, horizontal longitudinal section of *Riccia glauca* (after Campbell). Abbreviations — mh, mucilage hairs; m' m', first and second grade marginal cells; ML, middle lobe; p, surface cell of the first grade; t' t', old and new apical cells.

of a leaf or an amphigastrium primordium. In the Metzgeriales, where there is always a single apical cell, ventral branching is exogenous and branching in the horizontal plane of the thallus is pseudodichotomous and similar branching in *Sphaerocarpus*, *Monoclea*; in Marchantiales and the Anthocerotales where there is a single apical cell or a group of such cells, is truely dichotomous and is accompanied by the development of ' middle lobe '.

If diverse types like the Calobryales, Jungermanniales, Metzgeriales with three- or two-sided apical cells, and those with four-sided apical cells, *Sphaerocarpus*, *Monoclea* and the Marchantiales (subject to interpolation of air-chambers) can be retained in one taxon by those who segregate the Anthocerotales from the Hepaticae, why should the anthocerotes alone be segregated?

Bower (1935, p. 10) wrote, " A peculiar structural feature, of occasional but not constant occurrence, is the presence of stomata-like clefts on the lower side of the thallus " (Text-fig. 7). Leitgeb (1879) gave the same name to both these structures (Spaltöffung). Goebel (1930) considered these clefts to be homologous with the stomata (Text-fig. 8). Mucilage slits (Text-fig. 7E) have been recorded on the upper surface of the thallus. Bower (1935, p. 23) after due consideration concluded, " A picture would thus be suggested of the original haplophase of the Anthocerotales as a fully equipped photosynthetic structure, probably terete like the present diplophase ". It is of interest to note the presence of stomata on the gametophyte of *Rhynia gwynne-vaughani* (*cf.* Pant, 1962).

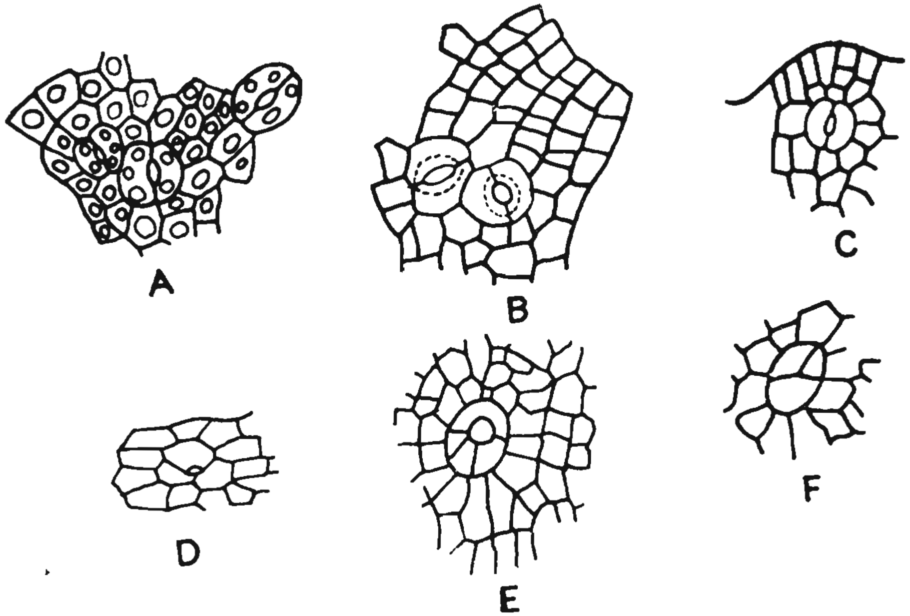
Proskauer (1960) writing on his " common ancestral denominator " speculated the presence of stomata in this hypothetical taxon. It is conceivable that the early archegoniates had stomata on both phases. In the later taxa, this expression was governed by ecological or habit of growth considerations.

In *Cythodium* (Lang, 1905; Kashyap, 1929) pores are present on the lower side of the thallus in small plants (those on the upper side are seen only in large plants) as an adaptation — not to reduce photosynthetic surface in small plants, growing in reduced light.

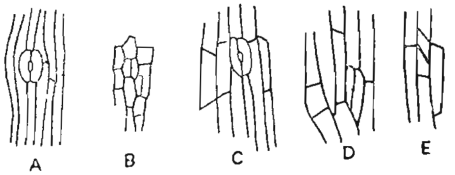
Regression of the mucilage clefts and stomata (to be taken up later) has made a beginning in this taxon, i.e. a trend towards their total elimination, a feature characteristic of other liverworts, has set in.

Combination of this primitive feature with the advanced features of the Marchantiales (shape of the apical cell, development of the thallus and branching in the horizontal plane of the thallus) suggests that the anthocerotes, in their evolutionary march, have travelled longer than any other corresponding group of liverworts. Kashyap (1929), Goebel (1930), Bower (1935) and Campbell (1940) have rightly placed the anthocerotes in a position preceding other taxa.

Cavers (1911, p. 141) wrote, " In every cell there is, in most species of *Anthoceros* a single large chloroplast, with a conspicuous pyrenoid" and on p. 143 he wrote on the chloroplasts in the capsule wall, " each cell contains two chloroplasts ". A part of this concept is considered here and part will be taken up with the sporogonium. Campbell (1905) had expressed the same view in respect of the haplophase chloroplasts and noted the presence of two chloroplasts in a species of *Anthoceros*. Again (1925, 1940) he compared the Anthocerotales with the Ulotrichales. In the later year he noted that: *A. pearsoni* has two chloroplasts, *A. howelli* has four and *Megaceros* as many as twelve in the inner cells of the thallus. A species of *Dendroceros* (Text-fig. 7) has on the lower side of the thallus a single large chloroplast in each cell of the epidermis; but two or three chloroplasts in each guard cell. *A. husnotii*, *A. punctatus* and *Megaceros* have no pyrenoids. Further



TEXT-FIG. 7 — Mucilage clefts on the thallus (all after Goebel). A, *Dendroceros* sp. (epidermal cells have one chloroplast, guard cells have two or three chloroplasts each); B, *Anthoceros* sp.; C, *Anthoceros*; D, *Anthoceros* sp.,— a stoma with a divided guard cell; E, *Megaceros* wih a cleft (from the upper surface); F, *Anthoceros*, a cleft without opening.



TEXT-FIG. 8 — Stomata on the capsule wall. **A**, *Anthoceros*; **B**, *Dendroceros crispulus* (rudimentary); **C**, *Megaceros* (functional); **D**, *Megaceros* (rudimentary); **E**, *Megaceros* stoma-mother cell with oblique division.

studies are likely to add to these examples of more than one chloroplast per cell of the haplophase. This feature is not universal either in the anthocerotes or in the green algae.

Bower (1935, p. 23) wrote, " The Anthocerotales show in this detail of chloroplast-number a scale of variation towards the state habitual in the higher plants, viz., that with numerous small chloroplasts ". This feature does not warrant the segregation of the Anthocerotales, nor their derivation from the green algae, because this resemblance cannot overrule the limitations imposed by oogamous reproduction.

5. Oil-bodies have so far not been recorded in this taxon.

6. Initials of the sexual organ in bryophytes other than the Anthocerotales become papillate and project above the general surface of the haplophase (Text-figs 9, 10). Similar is the case in the antheridium initials in Leptosporangiate ferns. Sometimes (*cf.* Bower, 1935, p. 510, fig. 397) the archegonia too are not sunken in this taxon. In the Anthocerotales, Psilotales, Lycopodiales and Eusporangiate ferns the initials are flush with the general surface of the haplophase. According to Bower (1935, p. 516) this is the simplest method of protection of the archegonium and the young sporogonium. In mosses, except the secondary archegonia of *Sphagnum*, these initials develop apical cells. Howe (1898), Campbell (1905, 1925, 1940) and Mehra (1967, 1968) have over emphasized this feature to segregate the anthocerotes from the Hepaticae.

The antheridium initial (Text-fig. 9) by transverse divisions produces some discs, each of which undergoes two vertical intersecting divisions in the Sphaerocarpales and the Marchantiales. This is followed by periclinal walls in each of the four cells to produce primary wall and primary androgonial cells.

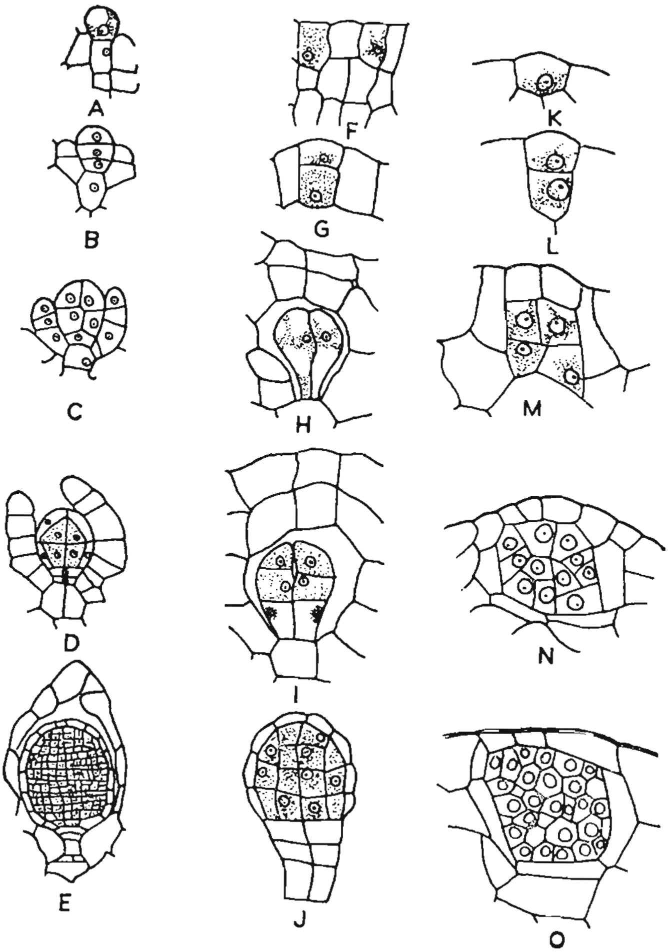
In the Anthocerotales the initial divides transversely into an outer and an inner cell. The outer produces two-cell thick roof of the antheridial chamber. The inner cell produces either one or more antheridia in each chamber. In either case the body of the antheridium develops as in Sphaerocarpales and the Marchantiales.

In *Marattia* the flush initial, as in *Anthoceros*, divides in the same manner. The outer cell produces the roof of the antheridial chamber. Here ends the resemblance with *Anthoceros*. The inner cell develops into spermatogenous tissue, without a stalk and antheridial wall, in the antheridial chamber.

Campbell (1925) noted a developmental similarity between the antheridium of *Notothylas* and *Marattia*. He had done so in 1895 (see Goebel, 1905, pp. 185, 186). Goebel (1905) wrote, " The mature antheridia are constructed like those of other Hepaticae with a wall-layer, stalk, and other parts, and its cellular construction is like what occurs elsewhere amongst Hepaticae, *but is known in none of the Pteridophyta* .... The endogenetic origin is evidently a secondary phenomenon... .... When Campbell endeavours to find an analogy between the antheridium of *Marattia* and an embedded antheridium of *Anthoceros*, which is covered on the outside by a double cell-layer, and to do so has to imagine the wall-layer and the stalk to be absent, the comparison seems to me to be bred of the wish to discover points of relationship between the Bryophyta and Pteridophyta, and not to be founded on facts ".

The spermatozoids in anthocerotes are bicilliate and according to Bower (1953, p. 11) they resemble those of other Hepaticae. In the Marattiaceae the spermatozoids are multicilliate.

Subject to minor details in the sequence of walls and sunken nature in anthocerotes, the development of the archegonium (except the Calobryales, see Campbell, 1920, Campbell, 1959) follows the pattern of *Riccia*, i.e. an axial row of cells is cut off by three peripheral or jacket cells, transverse walls make the archegonium double



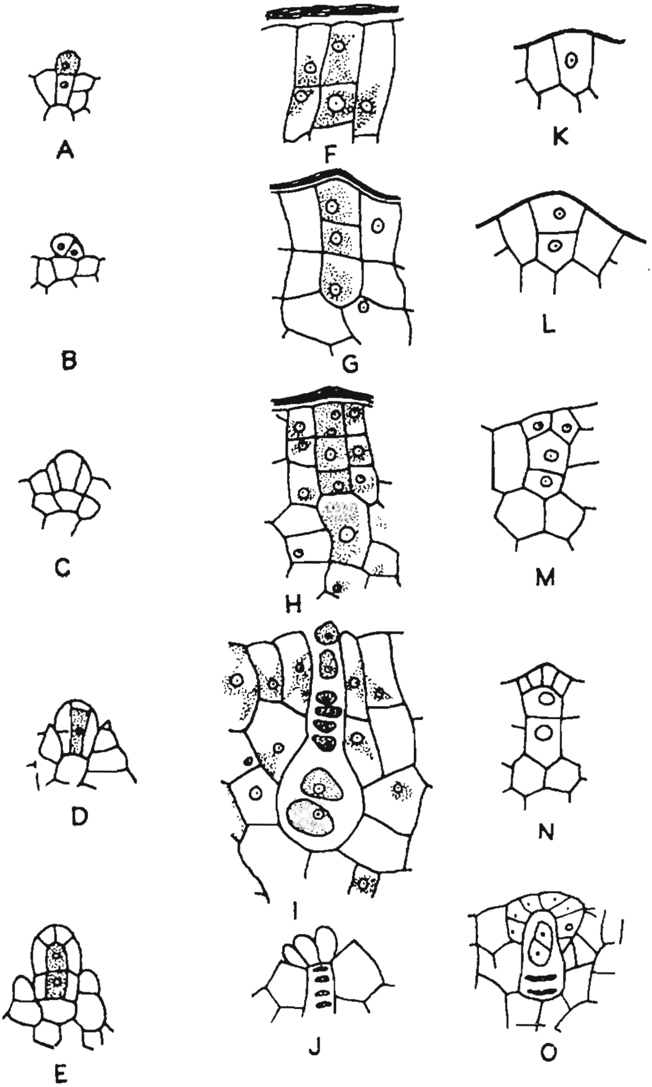
TEXT-FIG. 9 — Vertical sections showing antheridium development (diagrammatic). **A-E**, Sphaerocarpales (after Campbell); **F-J**, Anthocerotales (after Bharadwaj); **K-O**, Marattiaceae (after Campbell).

storied, another transverse wall cuts off the cover cell and this cell takes no part in the development of the neck (Text-fig. 10). Campbell (1940, p. 60) wrote, " The axial cells is next divided by a transverse wall into an outer and an inner cell. From the first by a similar division a terminal, or cap cell, is separated from the primary neck canal cell. The inner cell is later divided into two nearly equal cells — egg cell and venter canal cell. The primary neck canal cell divides into four or five neck canal cells ". In spite of this difference the development remains hepatic.

In *Marattia* the initial divides into two or three cells (the lowermost when three take no further part). The top cell undergoes two intersecting vertical divisions. The four cells thus produced divide transversely to produce four rows of neck cells (four rows of neck cells in *Haplomitrium* are due to vertical division in one of the jacket cells instead of being laid in two or three jacket cells). The middle cell divides to produce the axial row of cells.

Campbell (1925) compared the archegonium of *Notothylas* with that of *Marattia* to indicate a close similarity, ignoring the differences in the development of the neck and neck canal cells in the two genera.

Bower (1935, p. 12) rightly remarked, " The sexual organs of the Anthocerotales,



TEXT-FIG. 10 — Vertical sections showing archegonium development (diagrammatic). **A-E**, *Riccia glauca* (after Campbell); **F-I**, *Anthoceros* (after Bharadwaj); **J**, showing cap cells (after Campbell); **K-O**, Marattiaceae (after Campbell).

though differing in certain details from other Hepaticae, are clearly of the Hepatic-type and this is so notwithstanding that they alone are deeply sunk in the fleshy thallus and that the antheridia are even endogenous in origin". (Leitgeb, 1879; Lampa, 1903 noted exogenous antheridia).

Goebel (1905, p. 186) on this topic wrote, "in Anthoceros we have to deal with a derived type which at any rate shows no near relationship to the Pteridophyta. The kinship of Anthoceros to the Pteridophyta is then, so far as the sexual organs are concerned, a mistaken one".

Foregoing comparison and opinions expressed do not warrant:

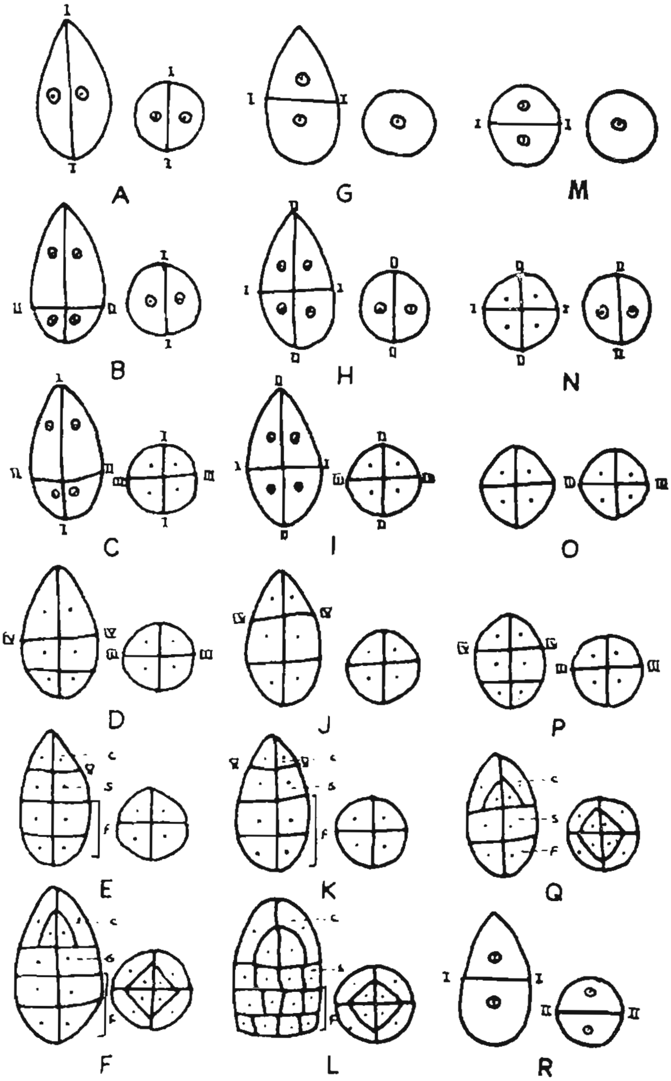
1. Derivation of the Archegoniatae from ancestors like the modern green algae with unicellular gametangia (Bold & Wyne,

1977), not even from *Chara* where growth of pericentral cells encloses the oogonium.

2. Derivation of psilophytes with pteridophytic archegonium (see Pant, 1962) from anthocerotes with hepatic archegonium and *vice versa*.

DIPLOPHASE

The zygote in the Archegoniatae, except most species of the Anthocerotales is more or less spherical and the first wall, except the Anthocerotales and pteridophytes with quadripolar embryo where it is vertical, is transverse. In most of the Anthocerotales (Text-fig. 11) the embryo is spindle-shaped and the first wall is vertical. In mosses and pteridophytes with bipolar, exoscopic embryo the hypobasal half forms the foot and the epibasal half develops an apical cell. In no liverwort does an embryo develop an apical cell and apical growth.



TEXT-FIG. 11 — Embryology of some anthocerotes (diagramatic) in longitudinal and transverse sections. **A-F**, *Anthoceros fusciformis* (after Campbell); **G-L**, *A. crispulus* (after Bharadwaj); **H-Q**; *A. erectus* (after Mehra & Handoo); **R**, *Notothylas orbicularis* four-celled embryo (after Campbell). Roman figures indicate the sequence of walls.

Mehra and Handoo (1953) noted a spherical zygote in *Anthoceros erectus* (Text-fig. 11M-O). Transverse first wall has been recorded by Campbell (1905) in *Notothylas orbicularis* (Text-fig. 11R), Pande in *N. indica*, Bhardwaj (1950) in *A. crispulus* and Mehra and Handoo (1953) in *A. erectus*. According to Bhardwaj (1958) Hofmeister found an oblique septum in *A. laevis*. Leitgeb (1875) mentioned first division in the hypobasal half to be vertical in *Frullania dilatata*.

Campbell (1940, p. 267) wrote, " There is a good deal of variation in the early development of the embryo in *Equisetum arvense* and *E. maximum* the basal wall is transverse and this may be the case in *E. debile*; but in the latter case there is a good deal of variation and the basal wall may be vertical". The spindle-shaped zygote, and the first wall being vertical are derived conditions.

The embryology of the Calobryales is not sufficiently known. According to Campbell (1959) the first transverse wall is not equatorial, the epibasal cell is larger of the two cells. The second wall in each cell is vertical. According to Campbell (1940) the embryo comes to be of four tiers. In most of the Jungermanniales and the Metzgeriales, the hypobasal half produces a haustorium and a filamentous embryo is developed from the epibasal half. However, in *Frullania dilatata* (Leitgeb, 1875; Cavers, 1911) and *Fossombronia* (Campbell, 1940) the hypobasal half produces the foot. In these two taxa the embryo consists of three tiers of four cells each, i.e. foot, seta and capsule tiers. Campbell (1940, p. 136) noted similarity with the embryo of *Anthoceros* in this respect.

According to Campbell (1940, p. 39), " In *Anthoceros*, following the octant division, a second transverse division occurs and the embryo consists of three tiers, each consisting of four equal cells (compare *Frullania* and *Fossombronia*). The two lower tiers develop into the large foot. The upper tier by further transverse divisions, is separated into a terminal segment in which the archesporium arises, and an intermediate zone between this and the foot ". Thus at this stage the embryo is a filament of four tiers of four cells each. *Anthoceros fusciformis* (Campbell, 1905, fig. 69) (Text-fig. 11A-E) shows this type of development.

Bhardwaj (1950, pp. 152-155, figs 19-23) (Text-fig. 11F-L) described the embryology of *Anthoceros crispulus*. In this species the first wall in the zygote is transverse and not vertical. Octant development follows the same pattern as in the Marchantiales and *Anthoceros erectus* (Mehra & Handoo, 1953). Transverse walls are laid both in the hypobasal and epibasal halves to produce a filament of four tiers of four cells each. The lowermost two tiers, as in *A. fusciformis*, develop into the foot, and the upper two tiers give rise to the seta and the capsule as in *A. erectus* and other species where the embryo consists of only three tiers of cells. Elimination of transverse walls in the epibasal half too can result in an octant only. The embryo of *A. crispulus* in having, before periclinal walls are laid, four tiers of four cells each, resembles the filamentous embryo of the Calobryales, Jungermanniales, etc. Growth, following the laying down of periclinal walls, makes it anthocerotalean embryo. This embryology suggests how the octant embryo of the Marchantiales may have arisen. In mosses and pteridophytes the embryo has apical growth at least in the epibasal half; while the Anthocerotaceae like other liverworts lack in apical growth. The embryo is nearest to that of the Hepaticae.

Foot tier is the first to become active and grow into a foot to establish a close contact with the thallus to draw nutrients from the latter. The top tier of four cells, cut off by the first transverse divisions in the epibasal half, differentiates into the ' primary capsule ' (where the seta adds to it from below) or the capsule (where the seta does not add to it). Former is the method of Anthocerotales and a few of the Jungermanniales and latter is the method of rest of the Jungermanniales and the Metzgeriales, etc.

In anthocerotes periclinal walls are laid in the top or terminal four cells. This is followed by differentiation into: columella, archesporium and the capsule wall. The seta tier becomes active and begins to add to the tissues of the primary capsule from below.

Cavers (1911, p. 119, fig. 82G, H, p. 120) enlarged the observations by Leitgeb (1875) on *Frullania dilatata*. Campbell (1940, pp. 136-138) described this and some more cases where the seta does contribute to the basal part of the capsule. He (p. 136) found resemblance among *F. dilatata*, *Fossombronia* and *Sphaerocarpus* on one hand and with *Anthoceros* on the other (i.e. in all these cases the embryo consists of three tiers of four cells each). In these cases the foot develops from the hypobasal half for close contact with the thallus. Other cases described by him are: *Lejeunea serpifolia*, *Radula* and *Cephalozia bidentata*. In these cases the hypobasal half develops into a haustorium and the whole sporogonium is developed from the epibasal half and the seta does add to the basal part of the capsule. In *Radula* (p. 137), " In the terminal segment the first periclinals define the primary archesporial cells, but similar divisions in the segments below the apex also contribute to the archesporium, which is much more extensive than in *Frullania* ".

Meristematic activity of the seta in the Anthocerotales as compared with the Jungermanniales and Metzgeriales is a question of degree and not of kind. Cavers (1911, p. 149) rightly wrote, " meristematic tissue above the haustorium of the sporogonium of the Anthocerotales evidently results from the persistence of a stage which is quickly passed through in the development of the sporogonium in other Hepaticae ".

Campbell (1925, p. 68) correctly expressed the fate of a normal sporogonium of the Anthocerotales. However, as a result of his observations on *Anthoceros fusciformis*, growing under exceptionally favourable circumstances, he (p. 74) concluded that a close resemblance between this sporogonium and the Devonian Rhyniaceae warrants the assumption of a real relationship between the latter and the Anthocerotaceae. He overlooked the fact that this is the only archegoniate taxon with a basal meristem in the sporogonium and the Rhyniaceae had apical growth.

Bower (1935, p. 109) rightly indicated that, " before basal intercalary growth alone no morphological future seems to be open ". Yet Campbell (1940) derived the psilophytes or the Rhyniaceae from the Anthocerotaceae (Text-fig. 1). This had the effect of catapulating this taxon to an unwarranted position. Many authors continue to follow him.

Anthocerotes and sphagna are the only bryophytes where the entire endothecium produces a sterile columella and the archesporium arising from the inner layer of the amphithecium is inverted over it. The condition in *Horneophyton* (see Bower, 1935, p. 120) is similar, though the columella is phloem part of the central stele. In all the three cases the archesporium is essentially axial in contrast with that of living pteridophytes, where it is hypodermal, or superficial in origin. In *Sphagnum* the archesporium is enclosed in a spore-sac and a tapetum surrounds the sporogenous tissue in *Horneophyton*.

On the basis of a survey of the relative extent of the columella and the archesporium, various genera of anthocerotes can be arranged in a series. At one end of this series are types with a well developed columella and a thin archesporium. The latter progressively becomes more massive and the former regresses. At the other end are non-columellate species of *Notothylas*. This genus is reduced and is no closer to other hepatics than is *Anthoceros*. In spite of the difference in the origin of the archesporium, it is nearer to that of other hepactics than any other taxon because of the absence of a spore-sac and a tapetum.

In the primitive taxa of hepatics other than anthocerotes, spore-mother cells and elater-mother cells belong to the same generation. As a result of sporogenesis there come to be four spores for each elater. In the higher taxa divisions are interpolated between the original spore-mother cell and the one that produces four spores. The result is presence of several spores to each elater.

In the anthocerotes converse is the case. In *Dendroceros*, the most primitive genus, the elater mother cells do not divide (see Schuster, 1966), and the ratio remains: four spores to one elater. In other genera the elater-mother cells divide mitotically; the cells generally remain united and the result is: four spores to one compound elater or pseudo-elater. Often the pseudo-elaters break, or undergo extra divisions, or some cells branch.

In *Dendroceros* and *Megaceros* (where the cells remain placed end to end) the elaters/

pseudo-elaters develop spiral thickenings, as in other hepatics. Hepaticae is the only taxon, where elaters/pseudo-elaters are present, no other archegoniate has these. This feature indicates that in spite of a difference in the origin of the archesporium, the anthocerotes are nearer to Hepaticae than to any other taxon.

Cavers (1911, p. 143) and Bower (1935, p. 15) indicated that each cell of the capsule wall contains two large chloroplasts. Campbell (1905, 1940) showed that each guard cell of stomata on the capsule wall of *Anthoceros pearsonii* has a single chloroplast. Bharadwaj (1965) noted that each cell in either phase of *A. communis* contains a single chloroplast. Bower (1935, p. 16), on the authority of Schimper, noted that most of the cells of the sporogonium contain two chloroplasts, but those of the epidermis contain several chloroplasts. A male gamete has no chloroplast, so doubling or increase in the number of chloroplasts in cells of the sporogonium is not due to syngamy but due to fission — a condition that is normal in the Archegoniatae. It was the absence of this clear understanding that lead some early authors to over emphasize a partial truth and suggest a derivation of this taxon from green algae.

Most species of *Anthoceros* and *Phaeoceros* (Text-fig. 8) are stomatose (*A. halli* has a few large stomata on the upper part of the capsule); some species of *Folioceros* are stomatose; while others (*F. fusciformis* and *F. incurvans*) are non-stomatose (see Bharadwaj, 1972); some species of *Megaceros* have poorly developed or no stomata; species of *Dendroceros* either have regressed stomata or none and *Notothylas* in non-stomatose.

Proskauer (1948) indicated that a cross section of *Anthoceros* capsule shows four lines of dehiscence of which only two are functional. This resembles the Calobryales and Monocleales (with one of the lines being functional), the Jungermanniales and the Metzgeriales. However, according to Proskauer (1948) the capsule does not open by two valves in the beginning (*cf.* the Blyttiaceae). Openings appear along two lines and they coalesce. External agencies cause the opening by two valves.

CYTOLOGY

Mehra and Handoo (1953) on the basis of persistent occurrence of *m*-chromosome in Anthocerotales, Jungermanniales, Sphaerocarpales and Marchantiales suggested a monophyletic origin of these taxa. In no pteridophyte do we find the presence of *m*-chromosome.

Proskauer (1960, p. 17) wrote, "I do not wish at this stage, to go beyond my recent presentation (Proskauer, 1958a) of the cytological evidence suggesting the derivation of the typical karyotype of liverworts from a kayrotype similar to that of typical hornworts. I do not concur with Tautno's (1959) opinion on this point". Do these features not conflict with the "Anthorhyniaceae" concept ?

RELATIONS HIPS

The Anthocerotaceae are considered to be a synthetic taxon and conclusions that are not warranted have been drawn on the basis of these resemblances. It seems desirable to discuss some of these relationships before arriving at a conclusion. Those to be evaluated are: (i) between anthocerotes and other Hepaticae,(ii) between the Anthocerotaceae and mosses through *Sphagnum*, (iii) between anthocerotes and the Rhyniaceae, and (iv) between the last taxon and mosses.

To determine the relationship of the hornworts with rest of the Hepaticeae, matter under data and discussion can be considered under three heads: (i) features that are hepatic, (ii) those that appear to be different, but show a trend towards what is normal in other liverworts, and (iii) those that are anthocerotalean, or nearly so.

Habit of growth, shape and segmentation of the apical cell, further divisions in the segments or merophytes and development of the plant body resemble those of the Metzgeriales, *Monoclea*, *Sphaerocarpus* and the Marchantiales; branching in the horizontal plane of the thallus agrees with the last three taxa. Development and structure of the sexual organs are hepatic and not pteridophytic. It is not fair to ignore these features and over emphasize their sunken nature — the simplest protective device. But for the absence of oil bodies, the haplophase is hepatic. Absence of apical growth recalls hepatic and *Sphagnum* sporogonia. Presence of a *m*-chromosome suggests lack of relationship with pteridophytes and the karyotype is hepatic.

That the meristematic seta is the retention of a stage which is quickly passed through in the Calobryales, Jungermanniales and the Metzgeriales is proved by the embryology of *Frullania dilatata*, *Cephalozia bidentata* and *Rudula*. A single large chloroplast per cell of the thallus and two such chloroplasts per cell of the sporogonium concept is at best a partial statement and a single large chloroplast per cell is not universal in green algae. Increase in number of chloroplasts in the cells of sporogonium is not due to syngammy but due to fission — a condition normal in the Archegoniatae. Elimination of mucilage clefts and stomata is a trend towards what is normal in other liverworts.

Absence of oil bodies and presence of a tierd embryo (though longitudinal cleavage disguise the underlying filamentous nature) and by comparison with mosses and pteridophytes it is nearest to the filamentous type and is actually filamentous in *Anthoceros crispulus*). Entire endothecium producing a columella; the archesporium of amphithecial origin inverted over the columella (remaining essentially axial in contrast to the peripheral or superficial archesporium of pteridophytes); compound elaters in five out of six genera (although the presence of elaters, and those of *Dendroceros* and *Megaceros* with spiral thickenings are features of hepatics); and fully photosynthetic sporogonia, in combination, are features that are not shared with any other group of liverworts in combination.

Bower (1935, p. 19) wrote, " The conclusion from such considerations would be that the place of Anthocerotales is with the liverworts, but not closely with any section of them ". The question does not remain, whether the Anthocerotales are closely or more distantly related to other Hepaticae ? It becomes, what are the status and position of the Anthocerotales in the Hepaticophytina?

Cavers (1911, p. 196) on the relationship between Sphagnales and the Anthocerotales wrote, " These two aberrant groups show a striking resemblance to each other. If Anthocerotales are to be made a separate class from the Hepaticae, either Sphagnales should be considered a separate class apart from the Musci, thus making four primary divisions of Bryophyta or the Anthocerotales and Sphagnales might be united to form a class ". However, he retained the customary two-fold division of the Bryophyta.

Bower (1935, p. 65) wrote, " *Sphagnum* has always been ranked as a Moss on general grounds of habit. But now not only does the evidence from the sexual organs point to an intermediate position between the mosses and liverworts, but also the primary segmentation and absence of apical growth in the sporogonium and the amphithecial origin and complete dome-shaped archesporium, are all features which point rather to the Anthocerotales than to the true Mosses ". Campbell (1940, p. 185) wrote, " There are some significant points of structure between *Sphagnum* and *Anthoceros*, indicating a possible remote relationship".

Leaving aside ecological adaptations, vegetative development and structure of the haplophase of *Sphagnum* resemble those of other mosses*. *Sphagnum* has no elaters or pseudo-elaters, spores are enclosed in a spore-sac, multistratose capsule wall lacks in intercellular spaces, the capsule has an operculum and opens by an annulus.

Resemblances with mosses outweigh the differences between them, so the sphagna cannot be separated from true mosses. Besides the differences between the sporogonia of *Anthoceros* and *Sphagnum*, the gametophytes are so different that a close relationship between the two taxa is not warranted. Campbell (1940, p. 69) wrote, " It is possible, however, that the highly specialized sporophytes of the higher mosse is a case of parallel development rather than an indication of any close relationships with *Anthoceros*." Bower (1908) and Chopra (1967) considered the Hepaticae and Musci to be diphyletic. Steere (1969) suggested that the bryophytes are polyphyletic. Presumably the Bryophyta are triphyletic, Takakiophytina constituting the third line.

It may be of interest to note that all stages through which the extant fauna and

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**Andreaea* is unique in that the apical cell of the leaf does not cut off two sets of segments. A single segment is cut off by a wall parallel to the posterior face of the apical cell.

flora have passed are not lost. Some of them are retained either as fossils or in some living taxa. A few examples of the latter are: *Takakia*, in having parenchymatous apices of the subterranean axes, and genetically unfixed apical cells in aerial axes, represents a stage between the ancestors without apical cells (green autotrophs) and those with them (Archegoniatae). Liverworts, which have apical cells in the haplophase but lack in them in the diplophase, show an early stage in the evolution of the archegoniate diplophase. Anthocerotes, with peculiar chloroplasts, enable some authors to connect this taxon with green algae. Basal meristem of Anthocerotales, which has no morphological future open to it, is retention of a stage, which is quickly passed through in other orders of the Hepaticae. Presence of mucilage clefts on the thallus and stomata on the capsule wall are retention of a feature of early archegoniates. Sphagna, in retaining hepatic features and the psilophytes, in lacking lignin, are other examples. Cytological and physiological resemblances between the green algae and Embryobionta are the best examples of the retention of features from the pre-archegoniate green ancestors with the same cytological and physiological features. I (1981) named these early ancestors as " green autotrophs ".

Diametrically opposite views have been expressed on the relationship between the Anthocerotales and the Psilophytales. Various authors have suggested the derivation of bryophytes or anthocerotes from pteridophytes or the Rhyniaceae through regressive evolution (for references see Takhtajan, 1953). Miller (1974, p. 166) wrote " Bryophytes in the broadest sense are vascular plants from stocks which arose in the early to middle Devonian from Rhyniophytina and Zosterophyllophytina". I do not propose to add to what I have already written (1981) on this topic.

Campbell (1895), on the basis of what he considered to be similarities between the sexual organs of the two taxa found kinship between *Anthoceros* and pteridophytes. Goebel (1898, 1905, p. 186) wrote, " The kinship of Anthoceros to the pteridophytes is then, so far as the sexual organs are concerned, a mistaken one ". Bower (1935, p. 109) wrote, " Before basal intercalary growth alone no morphological future seems to be open ". According to Proskauer (1960) Kidston and Lang (1920) astutely forebore to consider the point of view that the psilophytes had an origin from Anthocerotes.

Campbell (1925) ignored others' point of view, made a comparison between the sexual organs of *Notothylas* and *Marattia*, noted a close similarity (though wrongly) between the sporogonium of *Anthoceros* and the sporangium of the Rhyniaceae and concluded that a real relationship between the two taxa is warranted. Goebel (1930), Bower (1935) and Zimmermann (1952) did not accept this point of view.

Campbell (1940, p. 72) wrote, " The ancestors of vascular plants, if not actually anthocerotes at any rate closely resembled them ". He (p. 190, fig. 1) did not remove the Anthocerotaceae from its position with the Bryophyta and lump it with vascular plants, as was done by Mehra (1968, p. 24, fig. 9). Zimmermann (1952, p. 464) wrote, " Parallel to the Rhyniaceae the Bryophytes developed from thalassiophytic forms by relative dominance of the gametophyte".

Mehra and Handoo (1953) developed the 'Antho-rhyniaceae' concept. Howe (1898, vide Cavers, 1911, p. 148) enumerated five peculiarities to distinguish anthocerotes from rest of the Hepaticae. Of the features enumerated by Mehra and Handoo four are more or less the same as those of Howe. Instead of the stomata on the capsule wall they added the low number of chromosomes in Anthocerotes. Goebel (1905, p. 185) noted the deviations from the Hepaticae shown by *Anthoceros* and wrote, " But a careful examination does not show a resemblance with peculiarities found in the Pteridophyta".

Mehra and Handoo compared the sporangium of *Horneophyton* with sporogonium of *Anthoceros* and did not derive the latter from the former taxon and rightly so. They derived this stock from the Chlorophyceae.

Proskauer (1960, pp. 15, 16) wrote, " I suspect that the anthocerotalean sporophyte is derived by reduction and specialization from a sporophyte such as that of *Horneophyton*...... In the case of *Horneophyton* itself the occurrence of forked sporangia represents indirect counter evidence...... I do not wish to expostulate at length on the Psilophytic ancestory of Anthocerotales. At present no firm proof can be brought...... I have no quarrel with the postulated "Anthorhyniaceae" of Mehra and Handoo (1953)". He also presented a pen picture of "common ancestral denominator" for these groups.

Mehra (1967, p. 50), on "common ancestral denominator", quoted Proskauer as: "A green parenchymatous land plant; with stomata, single laminate plastids with 'pyrenoid', presumably archegoniate, and with alternation of generations".

According to Zimmermann (1952) origin of an apical cell capable of continuously cutting off segments in a spiral manner, was followed by internal differentiation into a central or medullary and a peripheral or cortical regions. This was an important step in the evolution of the Embryobionta. It made possible the divergence between oogamous and archegoniate plants as well as the internal differentiation of the stem, its branches and the sexual organs of the Archegoniatae.

In the passage quoted above by Mehra no mention is made of an apical cell. It is assumed that Proskauer's "common ancestral denomator", in the absence of an apical cell, was not archegoniate.

Proskauer, continuing (pp. 15, 16) wrote, "It is quite possible that the archegoniate plants arose from a member of the Ulotrichales which not only possessed isomorphic alternation of generations but was itself subaerial and parenchymatous..... Adding stomata, sex organs with sterile outer tissue, etc. we arrive at the "Anthorhyniaceae, but as a group with at maturity free alternating phases, and thus by minimum definition a pteridophytic group". Again no mention is made of an apical cell.

Mehra (1968, p. 23) on Anthorhyniaceae concept wrote, "...... the haploid and diploid phases were morphologically, more or less similar, independent and photosynthetic. Both of them had apical cell segmentation and were radial in organization...... The haploid phase possessed antheridia and archegonia......" The Antho-rhyniaceae of Mehra and Handoo were archegoniate. It is difficult to accept that the diploid phase in all the early archegoniates had apical growth. If so, why such an important feature was lost in the Hepaticae and was replaced by basal growth in the Anthocerotaceae ?

Steere (1969, pp. 137, 138) wrote, "It has been proposed by Zimmermann (1932) and others who promulgate the analogy between isomorphic algae and bryophytes or protobryophytes were identical but separate, and that the present-day epiphytic habit of the sporophyte is derived or secondary, and relatively recent. Although space does not permit a full discussion of the merits of the case, in my opinion the idea is fallacious and should be discarded".

Recently, I have re-confirmed that bryophytes are collaterals of green algae and pteridophytes, offered an explanation of the origin of archegonium and concluded that the advent of archegonium brought about changes, which were not possible in the oogamous green algae. Meiosis was deferred and the zygote continued to develop into a new, hitherto unknown, entity — the embryo. Origin and evolution of an interphase became possible, the function of nourishing the developing sporophyte, was passed on, mainly to the gametophyte.

Bower (1935, pp. 142, 143) after discussing the embryos of *Tmesipteris* and *Anthoceros* (a consideration which can include the embryos of *Sphagnum* and *Rhynia* (cf. Pant, 1962) wrote, "It will be more instructive to enquire what follows in each, as it passes to the adult state...... The alternatives open to the epibasal half are either (i) direct spore-formation without branching or other marked morphological features than intercalary growth, or apical growth soon arrested; or (ii) morphological elaboration with continued apical growth and branching, while spore-formation is deferred. The former is the method of the Bryophyta, with their capsules dependent on the gametophyte; the latter is the method of vascular plants with their independent* sporophyte".

In the light of these remarks is it fair to remove the Anthocerotales from the Bryophyta and lump them with the Pteridophyta ? The place of the Anthocerotales,

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*It should not imply that Bower considered that two phases in the Pteridophyta were free from the very beginning (see Bower, 1935, p. 139, fig. 103A), with hepatic sexual organs, and the sporogonium lacking in branching and apical growth, is with the Hepaticae. The place of Rhyniaceae, with branched axes bearing terminal sporangia and the archesporium with a tapetum, as well as, the pteridophytic archegonium of *Rhynia* is with the Pteridophyta.

Takhtajan (1953) compared the branching axes of *Horneophyton* with branched sporogonia (teratologies) of mosses. According to Mehra (1968, p. 9), " Merker (1959) interprets the creeping part in *Rhynia* and *Horneophyton* is the gametophyte and not the rhizome.... He considers that a circumvellation is present at the region of the junction of the aerial part with the prostrate one which is not the case in a dichotomously branched stem ". Miller (1974, p. 162) credited to Lemoigne (of course with a note that his interpretations are not fully accepted by palaeobotanists) on *Rhynia* as: " He has unquestionably discovered both archegonium-like and antheridium-like structures, which are consistent generally with Merker's observations ". This confirms the discovery of archegonia in *Rhynia gwynne-vaughani* (Pant, 1962).

Hebant (1977, pp. 108, 109, pl. 80) wrote, " It may be noted that the earliest known tracheophytes were more similar in general appearance to certain present day bryophytes than to most contemporary vascular plants. This concerns more particularly certain Rhynophytina such as *Steganotheca* or *Cooksonia.* Their tiny dichotomously branched axes with terminal sporangia are somewhat reminiscent of moss sporogonia. (The latter are unbranched, but some examples of teratological branching are known; in these cases, they are frequently dichotomous)...... As pointed out earlier, the internal organization of these early tracheophytes, with a ring of outer supportive cells and a ' simple ' central strand, is also more or less comparable to that of moss stems".

" With particular reference to *Rhynia*, it must be noted that Kidston and Lang (1920) failed to identify lignified secondary thickenings in the tracheids of *R. major.* Similar observations were made on *Nothia aphylla* by A. G. Lyons...... Similarly, Proskauer (1960) suggested that the water-conducting cells of *R. major* may have been unlignified. These elements in *R. major* and *Nothia* would then be very similar to the hydroids of mosses. Indeed the stele of *Rhynia* as a whole may show an extraordinary resemblance to certain moss steles (figs 339-341). "

It is clear that Rhyniaceae resemble the mosses more than they do with the Anthocerotes and that a moss type sporogonium is not handicaped by a basal meristem as apical growth of the sporophyte is the rule in mosses. I am not tempted to suggest a " Musco-rhyniaceous " stock, nor I suggest an " Antho-sphagno-rhyniaceous " stock because I am fully aware of the limitations inherent in the diplophase of bryophytes. The position of the anthocerotes vis-a-vis other hepatics is the same as that of *Sphagnum* vis-a-vis other mosses and the Rhyneophytina vis-a-vis other sub-divisions of pteridophytes. The resemblances between the Anthocerotales, Sphagnales and the Psilophytales do not warrant any phyletic affinity between these three taxa closer than what exists between the Hepaticae, Musci and the Pteridophyta. Each one of the first three taxa is an early blind offshoot from its respective stock.

CONCLUSION

Bold (1956-57) modified the classical concept of the Bryophyta by raising the rank of anthocerotes, other hepatics and mosses to that of three divisions. Steere (1958) did not concur with him and remarked, " As a professional bryologist, on the other hand, I can go much further than Bold has and with equal justice raise other highly distinctive groups of Bryophytes to divisional rank ". I fully agree with him. I (1975) treated mosses as subdivision Muscophytina, and I still maintain the rank of a division for the Bryophyta. A lot of information is needed to do justice to splitting up of Bryophyta. In my opinion a start should be made by defining the subdivisions and classes before the creation of more divisions.

In 1967, I considered the Bryophyta to be diphyletic and Steere (1969) considered them to be polyphyletic. I (1975) treated Musci as a subdivision. They are at least triphyletic, Takakiophytina being the third suborder.

*Subdivision Takakiophytina** — Prostrate or subterranean axes, lacking in leaves and rhizoids, with parenchymatous apices, bear erect leafy shoots with pyramidal or tetrahedral apical cells; mucilage pads on the lower portions of shoots are composed of crowded, numerous, multicellular and branched hairs, which may possibly be homologous to moss rhizoids (though the functions of the two are different); leaf development from a segment, besides unparalleled form, is unique; oil-bodies are present; antheridia are unknown; pedastaled and spirally twisted archegonium recalls moss archegonium and sporogonium is unknown. Under humid cultural conditions apices of erect shoots become parenchymatous and often the oil-bodies are lost. The chromosomal compliment, as a rule, is $K(n) = 4 = V(H) + V + J + J(h)$, or $K(n) = 5 = V(H) + J + V_1 + V_2 + J(h)$, though sometimes in *T. lepidozoides* an additional " F-derivate " is present.

Subdivision Hepaticophytina — The shoots whether erect or prostrate are with flat leaves, with genetically fixed apical cells in both cases and so are the oil-bodies (except the Anthocerotales); all growth other than that of the plant body is intercalary; elaters or pseudoelaters are almost invariably present.

Subdivision Muscophytina — Leaves are flat, apical cells and oil-bodies are genetically fixed; and growth (except some organs in *Sphagnum*) is apical; and elaters or pseudoelaters are always absent.

Diagnostic features of the three subdivisions of the Bryophyta indicate that the Anthocerotales belong to the Hepaticophytina. This is in conformity with the conclusion arrived at while discussing the relationship of the Anthocerotales with rest of the Hepaticae on the basis of data and discussion (*cf.* Bower, 1935, p. 19: " the place of the Anthocerotales is with the liverworts ").

A combination of features seen in the Anthocerotales is not shared by it with any other section of liverworts. This warrants the status of a class coordinate with other classes into which the Hepaticophytina is to be split up sooner or later.

Resemblances between the two phases coupled with 5 or 6 chromosomes against 8-9-10 chromosome in other hepatics indicate for this class a position at the very bottom of the heirarchy of the Hepaticophytina.

It seems reasonable to presume that the ancestors of modern Anthocerotae or Anthoceropsida parted company from the stock/stocks that gave rise to other modern orders of the Hepaticophytina earlier than did the latter stock/stocks diverge to be the ancestors of modern orders other than the Anthocerotales or classes other than the Anthocerotae or Anthoceropsida.

To sum up, Anthoceropsida or the Anthocerotae, a class of Hepaticophytina, have been considered a synthetic taxon and much, that is unwarranted, has been read in the resemblances between this and other taxa. This class like the other Bryophyta is a collateral of green algae and the Pteridophyta. Ancestors of Anthoceropsida, presumably, were the first to part company or diverge from the stock/stocks that later diverged into other sections of the Hepaticophytina. Modern hornworts, at the very bottom of the heirarchy of the Hepatophytina, are a blind evolutionary line.

I thank all authors whose contributions have provided material for this lecture, particularly Prof. Kashyap, a pioneer botanist and father of bryology in India; Professors Goebel, Bower, Campbell, Zimmermann and Dr Cavers. I am indebted to the Chairman and members of the Governing Body of Birbal Sahni Institute of Palaeobotany for the honour they have conferred on me by inviting me to deliver this lecture on the birthday of the late Professor Birbal Sahni.

Scion of a family of intellectuals, by his qualities of head and heart, care for the progress of juniors, and courage to fight for upholding the right causes, he inspired many persons and endeared himself in their hearts. I consider him a model to be emulated.

REFERENCES

BHARDWAJ, D. C. (1950). Studies in Indian Anthocerotaceae. I. The morphology of *Anthoceros crispuius*. *J. Indian bot. Soc.*, **29** (3): 145-163.

BHARDWAJ, D. C. (1958). Studies in Indian Anthocerotaceae. II. The morphology of *Anthoceros cf. gemoulosus*. *J. Indian bot. Soc.*, 37 (1): 75-92.

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*This diagnosis is based upon the contributions of Hattari *et àl.* (1968, 1974) and Schuster (1966a).

Bhardwaj, D. C. (1965b). Studies in the Indian Anthocerotaceae. VI. Some aspects of morphology of *Phaeoceros*. *Phytomorphology*, **15** (2): 140-150.

Bharadwaj, D. C. (1972). On some Asian and African species of *Folioceros*. *Geophytology*, **2** (1): 74-87.

Bold, H. C. (1957). *Morphology of Plant*. New York.

Bold, H. C. & Wyne, W. I. (1978). *Introduction to Algae*. Prentice Hall Inc. Englewood Cliff, New Jersey.

Bower, F. O. (1908). *The Origin of a Land Flora*. Macmillan and Co., London.

Bower, F. O. (1935). *Primitive Land Plants*. Macmillan and Co., London.

*Campbell, D. H. (1895). *Structure and Development of Mosses and Ferns*. Macmillan & Co., London.

Campbell, D. H. (1905). *Structure and Development of Mosses and Ferns*. Macmillan & Co., London.

Campbell, D. H. (1920). Studies on some East Indian Hepaticae, *Calobrium blumei*. *Ann. Bot.*, **34**: 1-12, pl. 1.

Campbell, D. H. (1925). Relationships of the Anthocerotaceae. *Flora. Neve Folge*, **18-19**: 62-74.

Campbell, D. H. (1940). *The Evolution of Land Plants* (*Embryophyta*). pp. 1-731.

Campbell, E. O. (1959). The structure and development of *Calobrium gibbsiae*. *Trans. R. Soc. New Zealand*, **87** (3, 4): 243-254.

Cavers, F. (1911). Interrelationships of the Bryophyta. *New Phytologist*, Reprint no. 4, Oxford.

Chopra, R. S. (1967). Relationship between liverworts and mosses. *Phytomorphology*, **17** (1-4): 70-78.

Chopra, R. S. (1975). *Taxonomy of Indian Mosses* (*An Introduction*). Publications and information Directorate, C.S.I.R., New Delhi. pp. 1-631.

Chopra, R. S. (1981). Origin of Bryophyta. *Misc. Bryol. Lich.*, 9 (1): 1-7.

Fulford, M. (1965). Evolutionary trends and convergence in the Hepaticae. *Bryologist*, **68** (1): 1-31.

*Goebel, K. (1898). *Organographie der Pflanzen*.

Goebel, K. (1898). *Organography of Plants*, translated by Balfour, I. B. Reprint 1969. Hafner Publishing Company, New York and London. pp. 1-707.

Goebel, K. (1930). *Organographie der Pflanzen*. Zweiter Teil. Bryophyten-Pteridophyten. Verlag Von Gustav. Fisher. Jenna.

Hattari, S., Sharp, A. J., Mizutani, M. & Iwatsuki Z. (1968). *Takakia ceratophylla* and *T. lepidozoides* of Pacific North America and a short history of the genus. *Misc. Bryol. Lichen.*, **4** (9): 137-149.

Hattari, S., Iwatsuki, Z., Mizutani, M. & Inoue, S. (1974). Speciation in *Takakia*. *J. Hattari bot. Lab.*, **38**: 115-121.

Hebant, C. (1977). *Conducting Tissues of Bryophyta*. J. Cramer. Fl. 9490 Vaduz, i-xi, and: 1-157, pl. 1-180.

*Howe, M. A. (1898). The Anthoceroteae of North America. *Bull. Torrey bot. Club*, **25**.

Kashyap, S. R. (1929). *Liverworts of the Western Himalayas and the Punjab Plain*, Part I. Panjab Univ., Lahore, reprint by The Chronica Botanica, New Delhi, 1-121, pls. 25.

*Kidston, R. & Lang, W. H. (1920). On old red sandstone plants showing structure from the Rhynie Chert Bed, Aberdeenshire II. *Trans. R. Soc. Edinb.*, **52**: 603-627, pls. 1-10.

*Lampa, Emma (1903). Sex organs of *Anthoceros*. *Oester. bot. Zeitschr.*, **1903**: 436-438, 5 figs.

Lang, W. (1905). On the morphology of *Cyathodium*. *Ann. Bot.*, **19**: 411-426.

Leitgeb, H. (1875). *Untersuchungen uber die Lebermoose*. Heft. II. die Foliosen Jungermannieen. Jena. Reprint J. Cramer, 3301 Lehre.

Leitgeb, H. (1879). *Untersuchungen uber die Lebermoore*. Heft V. die Anthoceroteen Craz. Reprint J. Cramer, 3301, Lehre.

Mehra, P. N. (1967). Phyletic evolution in the Hepaticae. *Phytomorphology*, **17** (1-4): 47-58.

Mehra, P. N. (1968). Conquest of land and evolutionary patterns in early land plants. *15th Sir Albert Charles Seward Memorial Lecture*. Birbal Sahni Institute of Palaeobotany, Lucknow.

Mehra, P. N. & Handoo, O. N. (1953). Morphology of *Anthoceros erectus* and *A. himalayensis* and the phylogeny of the Anthocerotales. *Bot. Gaz.*, **114**: 371-382.

*Merker, H. (1959). Analyse der Rhynien-Bases Und Nachweis des Gametophyten. *Bot. Notiser*, **112** (4): 441-452.

Miller, H. A. (1974). Rhyniophytina, alternation of generations and evolution of bryophytes. *J. Hattari bot. Lab.*, **38**: 161-168.

Pande, S. K. (1932). On the morphology of *Notothylas indica*. *J. Indian bot. Soc.*, **11** (2): 160.

Pant, D. D. (1962). The gametophyte of the Psilophytales, pp. 276-301 in P. Maheshwari, B. M. Johri & I. K. Vasil (eds)— *Proc. Summer School Bot. Darjeeling*. Min. Sci. Cult. Affairs, New Delhi.

Proskauer, J. (1948). Studies on the morphology of *Anthoceros*. II. *Ann. Bot.* (*Lond.*), **12**: 427-439.

*Proskauer, J. (1958a). Studies on Anthocerotales. *Phytomorphology*, **7**: 113-135.

Proskauer, J. (1960). Studies on Anthocerotales. On spiral thickenings in the columella and its bearing on phylogeny. *Phytomorphology*, **10**: 1-19.

Schuster, R. M. (1966). *The Hipaticae and Anthocerotae of North America*. Vol. I. Columbia Univ. Press, New York and London.

Smith, G. M. (1955). *Cryptogamic Botany*, Vol. **2**. *Bryophytes* and *Pteridophytes*. 2nd ed. McGraw-Hill, New York and London, 1-399 pp.

Steere, W. C. (1958). Evolution and speciation in mosses. *Amer. Nat.*, **42**: 5-20.

Steere, W. C. (1969). A new look at evolution and phylogeny in bryophytes, pp. 134-143 in J. E. Gunkel (ed)— *Current Topics in Plant Sciences*. Academic Press, New York & London.

*Tatuno, S. (1959). Chromosomen von *Takakia lepidozoides* und eine studie Zur Evolution der Bryophyten. *Cytologia*, **24**: 138-147.

Zimmermann, W. (1932). Phylogenie in E. Verdoorn (Ed.)— *Manual of Bryology*. Reprint by A. Asher & Co., Amsterdam, 1967.

Zimmermann, W. (1952). Main results of the "Telome Theory". *Palaeobotanist*, **1**: 456-470.

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*Not seen in original.

The Palaeobotanist, **31**(1): 100-107, 1983.

THIRTIETH SIR ALBERT CHARLES SEWARD MEMORIAL LECTURE

PALYNOLOGY, ORGANIC PETROLOGY AND PETROLEUM — A PALAEOBOTANISTS VIEW

SVEIN B. MANUM
Institute of Geology, University of Oslo, P.O. Box 1047, Blindern, Oslo 3, Norway

It is not my intention to present here new and exciting results of palaeobotanical research. Indeed, the topics named in the title may appear to be departures from palaeobotany in the sense most people like to think of that subject, with the exception of palynology which has become a respectable branch of palaeobotany. Still, what I shall be dealing with has with fossil plant material to do.

One aspect of my presentation, at least, appears to bring something new to this lecture series: as far as I can see, the word petroleum has not before appeared in any title. I hope to show that there are aspects of petroleum geology which can be of interest in a wider palaeobotanical sense.

For the last two-three decades, petroleum exploration has been a major driving force behind geological activities throughout the world. It is my view that palaeobotany, taken in a broad sense, has been, and will continue to be, affected by this development. Palynology and organic petrology are key words in this connection.

Petroleum geology is a complex subject, embracing many fields of study. One of these is the study of dispersed organic matter in sediments, the acknowledged source of petroleum. This organic matter is almost entirely derived from the plant kingdom. Therefore, teaching and research in this field has to be based to a considerable extent on biological and not least botanical knowledge, hence it also enters the palaeobotanist's sphere of interest, and particularly that section of palaeobotany which is known as palynology. Organic petrology is merely a further development of palynology.

I shall first comment on developments in palynology. The 4th Seward Memorial Lecture was given by Gunnar Erdtman, who spoke on the development and growth of palynology. That was in 1956. Since then, and especially during the last 15 years, there has been a more dramatic development than any palynologist could possibly have foreseen. This expansion has taken place particularly within the field which we may call non-spore-pollen palynology. The force behind the expansion is application in petroleum geology. Palynology has become the most commercialized branch of palaeobotany. However, if we take a look at the situation from an academic point of view, I think it is a perfectly defendable statement that research and teaching in palynology has not kept pace with the applied aspects of the subject.

This is not the place for a comprehensive updating of Erdtman's review of palynology in 1956. I shall only point out two major areas of development:

1. Dinoflagellate studies played only a minor role in palynology in 1956. Since then, the volume of dinoflagellate studies has been growing steadily. As an aid in correlation and age determination of marine sediments, particularly in oil well studies, dinoflagellates have moved from a position of being resorted to when other fossils fail to becoming the first microfossil group to be studied in many instances. The stratigraphic resolution of dinoflagellates is in no way inferior to other microfossil groups. Furthermore, they have the advantage of producing adequate assemblages from samples of only a few grams. Dinoflagellate biostratigraphy is clearly going to be a significant growth field for some time to come, and as palaeoenvironmental indicators dinoflagellates have a considerable potential. However, the challenges presented by fossil dinoflagellates and their biostratigraphic application are not at the moment adequately met by teaching and research in universities.

2. Studies of dispersed organic matter in sediments started in the 1960's and since the early 70's they have been rapidly growing in volume and diversity. Prominent key words here are kerogen and organic maturation. It is this area of development in palynology for which the term organic petrology is now being applied. Previously, dispersed organic matter was only considered a nuisance in palynological preparations.

A brief review of programmes of some past international palynological conferences serves to illustrate the development of studies on dispersed organic matter. Titles and abstracts for the 2nd I.P.C. in Utrecht in 1966 contained no such topics as kerogen and organic maturation. Although industry palynologists were present, petroleum aspects of palynology hardly made a noticeable impact on the programme in Utrecht.

However, there was one remarkable exception: An invited paper entitled " Palynology and the oil industry ". The author was originally a palaeobotanist, Charles Hopping, a former student of John Walton in Glasgow who had become one of the early palynologists in the oil industry. The emphasis of Hopping's paper was on pollen/spore stratigraphy and environmental interpretations, particularly of deltas (Hopping, 1967). Kerogen and maturation were not mentioned in his paper.

If we move one decade and two conferences ahead to the memorable conference in Lucknow six years ago, we find that the programme had some ten papers devoted to kerogen studies. Finally, at the last I.P.C. in Cambridge 1980, not only was an entire section devoted to kerogen and maturation studies, but this section was one of the largest and most active during the conference. The position of this field is further illustrated by the fact that the proceedings of the section were the only to become published from that meeting (Brooks, 1981). The proceedings also give an indication of where the greater part of the activity in this field takes place. The addresses of the contributors show as many as 2/3 of them affiliated with oil companies or commercial and applied research institutions.

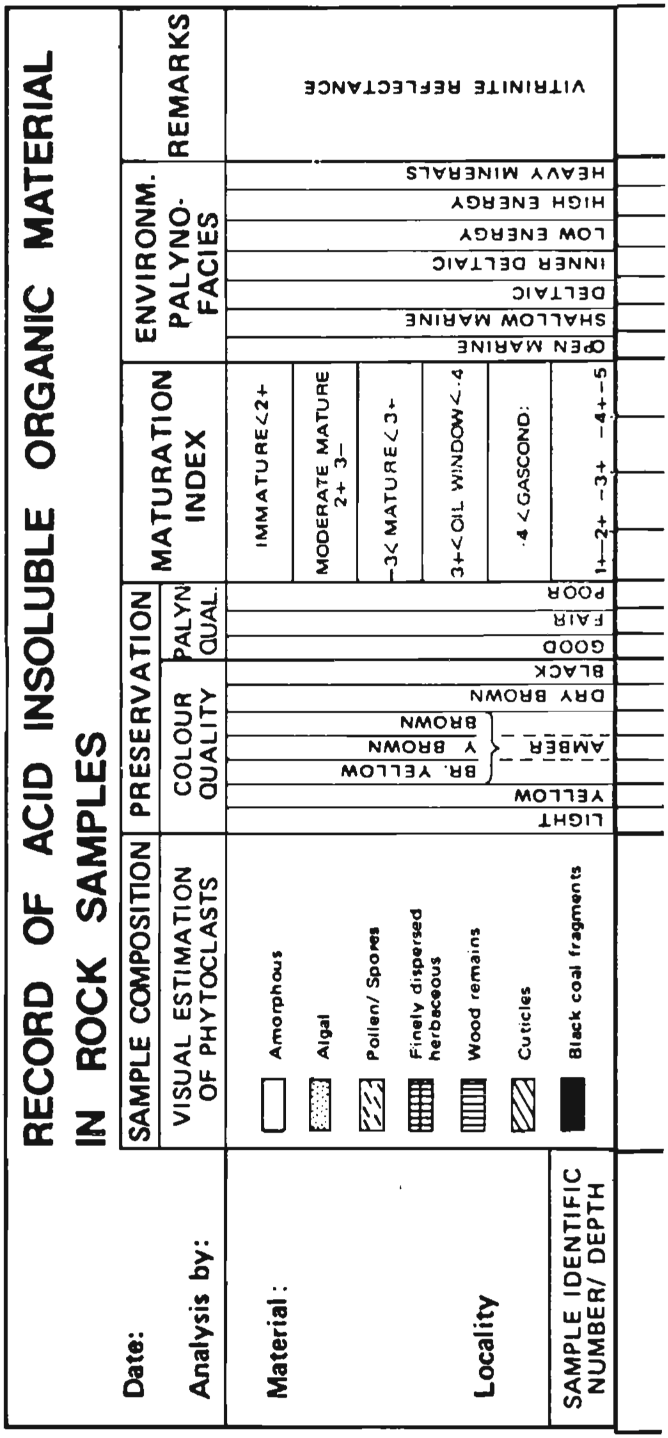
Organic petrology is the second key word in the title of this paper. By this I understand the study of solid organic constituents in rocks by microscopical methods. The term itself is easily associated to coal petrology to which it is in many ways related and owes certain basic principles.

Many palaeobotanists have contributed to the knowledge of coal and coal formation, and palaeobotanical thought and knowledge have had a significant impact on concepts and advances in coal petrology. The relations between organic petrology and palaeobotany are perhaps less evident at first view.

In order to illustrate what the organic petrologist is doing and what it is for, we may look at a log-sheet used in an applied research institution (Text-fig. 1). The design of the log-sheet will vary from one laboratory to another, but the kind of data recorded will be essentially the same. Most of the data entered in the log are from observations on palynological preparations.

Entries in the first column denote some structures which are familiar also to a palaeobotanist. The purpose of collecting the data, however, is not at all palaeobotanical. The two main purposes are seen from other columns: evaluation of the maturation level, which is an essential parameter in the assessment of a petroleum source rock; and interpretation of sedimentary environments.

The sample composition data recorded in the first column represent the bulk of organic matter which may be extracted from the sediments by means of acid solution of the mineral matrix. This is a medley which has been given many different names: acid insoluble organic material immediately conveys the right information, but is obviously too long for general use. Phytoclasts, meaning broken pieces of plant origin, is a good term, also descriptive in its concept. The term was proposed by Bostick (1971) but is used less than it deserves. The most widely used term is kerogen, hence visual kerogen analysis for the observations recorded. However, kerogen is an old term, older than the palynological method of acid digestion of sediments. It was proposed in 1912 by Crum Brown to designate the solid, in organic solvents insoluble residue of Scottish oil shales, which produced hydrocarbon distillates when heated (for ref. and further discussion, see Brooks, 1981, pp. 1-3). In palynology and organic petrology the term kerogen is used for the organic residue left after palynological methods of extraction,



RECORD OF ACID INSOLUBLE ORGANIC MATERIAL IN ROCK SAMPLES

Date:

Analysis by:

Material:

Locality

SAMPLE IDENTIFIC NUMBER/ DEPTH

SAMPLE COMPOSITION

VISUAL ESTIMATION OF PHYTOCLASTS

☐ Amorphous

▒ Algal

▨ Pollen/ Spores

▦ Finely dispersed herbaceous

▥ Wood remains

▧ Cuticles

■ Black coal fragments

PRESERVATION

COLOUR QUALITY

LIGHT

YELLOW

BR. YELLOW

Y BROWN

BROWN

AMBER

DRY BROWN

BLACK

PALYN QUAL.

GOOD

FAIR

POOR

MATURATION INDEX

IMMATURE<2+

MODERATE MATURE 2+ 3−

−3< MATURE <3+

3+< OIL WINDOW <·4

·4 < GASCOND:

1+ —2+ −3+ −4+ −5

ENVIRONM. PALYNO-FACIES

OPEN MARINE

SHALLOW MARINE

DELTAIC

INNER DELTAIC

LOW ENERGY

HIGH ENERGY

HEAVY MINERALS

REMARKS

VITRINITE REFLECTANCE

TEXT-FIG. 1 — Head of log-sheet for visual kerogen analysis (Continental Shelf Institute, Norway).

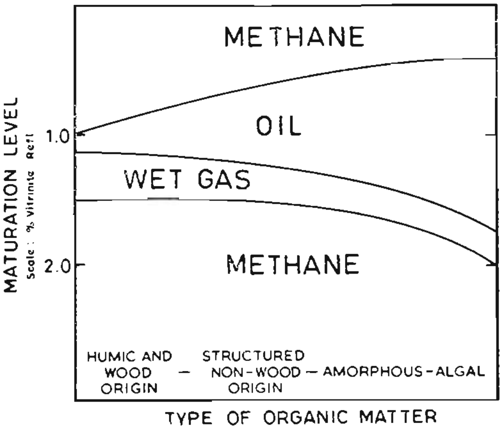
i.e. HCl nad HF treatment of sediments. This is the most widely used meaning and the one adopted here. We do well, however, to be aware that organic geochemists tend to prefer a definition more in line with the original.

So far I have been dealing with the more familiar palynological methods to study dispersed organic matter. But organic petrology includes a variety of other methods, all microscopical. The last column in Text-fig. 1 indicates one of these methods: vitrinite reflectance. This means the study of polished organic particles by incident light with the application of a photometer to measure their reflectivity. By still other methods, the fluorescence of organic particles on UV and blue light excitation is studied, both qualitatively and quantitatively. In all these various methods we can observe a rapid development towards higher level of technical sophistication with the objective of obtaining more quantitative data and reliable interpretations.

For the assessment of the hydrocarbon source quality of a sediment, three sets of observations on the organic particles are essential:

1. The total amount of organic matter in the sediment.
2. The composition of the organic matter; often called the " organic type " or " kerogen type ".
3. The maturation level. This means the degree to which chemical transformations have taken place in the organic matter; these transformations are controlled by temperature as a result of deep burial of the sediments, hence the terms thermal alteration and thermal maturation are widely used.

Organic matter of marine or algal origin and so-called amorphous material are the best petroleum sources over a broad range of maturation. Organic matter of wood origin, on the other hand, mainly produces gas and only little oil (Text-fig. 2). If the organic matter of wood origin is not the most interesting from a petroleum point of view, it is interesting in our context for other reasons. It is this material which demonstrates most clearly the relationship between organic petrology and coal petrology, and it offers the best microscopical basis for determination of the maturation level.



TEXT-FIG. 2 — General relationships between type of organic matter, maturation and hydrocarbon potential.

In humic coals, degradation products of wood are the major constituents. The coal petrologists recognize several types of such coalified wood material, and one of these is vitrinite. Vitrinite is further subdivided into many finer categories, based among other criteria on the degree to which wood structures can be recognized, but these subdivisions are not essential to us here. A polished vitrinite surface reflects light with a low grey intensity. Another wood constituent in coals, the so-called mineral charcoal, or fusinite in the coal petrology terminology, reflects light much brighter than vitrinite.

A most significant point about the reflectivity of vitrinite is that it shows a steady increase with increasing coal rank. This is the basis for the use of vitrinite reflectance as the most reliable and widely used parameter of coal rank. While measurement of vitrinite reflectance has a long history in coal petrology, it is not much more than ten years ago that it was realized that particles of wood origin, equivalent to vitrinite, are widespread in sediments and that the method of reflectance measurements may be applied also to these particles (Bostick, 1971). Since the mid-70's, this method has become the most widely used for assessing the maturation level of dispersed organic matter in sediments. Previously, spore colour had been the most commonly used maturation parameter. It is still a quick and much used method, however, less objective than vitrinite reflectance measurements.

I have mentioned mineral charcoal, or fusinite, as another example of wood material in coal. Particles equivalent to fusinite also commonly occur dispersed in sediments. That is not surprising, since it is one of the most inert organic materials which exists.

Coal petrologists recognize a number of other coal constituents besides vitrinite and fusinite. Coal maceral is the general term for such constituents of coal which can be distinguished on morphological structures and other physical characters under the microscope. Macerals are therefore analogous to the minerals of the non-coal petrology.

Many palaeobotanists have contributed to the understanding of coal and coal formation. Thus, the concept of coal macerals is attributed to a well known palaeobotanist — Mary (1935). Her ideas and proposals some 50 years ago provided the basis for maceral differentiation, classification and terminology of modern coal petrology. The maceral concept and methods used in coal petrology can be profitably applied in organic petrology as we have seen from the example of vitrinite. However, it is not possible to make a general transfer of coal maceral classification and concepts to the field of organic petrology. The main reason for this is the differences in depositional environments of coal and clastic organic particles. Coal is an autochthonous deposit, the material is produced and fossilized in place. Clastic organic particles, on the other hand, have a different history of transportation, deposition and fossilization compared to their equivalents in coal; and indeed, many have no equivalents in coal.

Coal maceral classification has long ago reached the level of international standardization. The classification and definitions in organic petrology, on the other hand, are still rather unsettled. This is not only because the subject is still in its infancy, there are also great problems inherent in the material itself.

Let us consider a palynological preparation of a marginal marine sediment, say from the Early Tertiary. We will most probably find terrestrial plant fragments, wood and cuticles, to be dominating, besides conifer and angiosperm pollen and some dinoflagellate cysts. All the particles of terrestrial origin have had a complex history before they became extracted by the palynologist. They travelled a long distance, most likely in the order of hundreds of kilometers from their sites of origin. As palaeobotanists, we would certainly like to know something about their mother plants. The wood is taxonomically problematic, even if we have sizeable fossils for study, so here it does not offer a clue. The cuticle fragments are not much more helpful, small as they are. Still, I believe the cuticles have some potential of differentiation, but not much has been done in this direction. Differences in cuticle diversity might be a useful parameter in the palaeoenvironmental analysis in addition to others obtained from the kerogen analysis, even though it will not tell us much about the plant groups represented.

The question of the mother plants is only one of many which may be asked. Here are some others — What is the history of the fragmentation of the material ? Did it take place on the ground, or in the soil, or by abrasion during transport, or on a lake bottom or in the sediment ? These are only parts of the more general question: What were the agents and the environments involved in the formation of these particles ? Can we learn anything from these particles and their preservation regarding predepositional history and the depositional environments ? These are questions of why, rather than where from, about processes rather than origins. In our context again, we shall remember that part of these processes are biological in nature.

Organic petrology has one major aim: to obtain as much information as possible from the assemblages of plant debris and palynomorphs. Usually, data from a single sample are not of much use. Data are collected from series of samples through stratigraphic sections and attention is paid to the stratigraphic changes in the assemblages. It goes without saying that the quality of interpretations depends entirely on the level of understanding of origins and processes involved in formation of the kerogen. However, it must be admitted that a great deal is lacking in basic knowledge in order to give correct answers to the questions that were just asked. This field is probably the most neglected in organic petrology today. Advances in this field can only be made through interdisciplinary approaches, which will involve botany, invertebrate zoology, microbiology, organic chemistry, and aspects of palynology, palaeobotany and sedimentology.

We have an example of this kind of research in studies on plant litter decomposition in soils. Since this is of interest to pedology and agriculture, it has been studied extensively and a large body of knowledge exists. Major agents in the fragmentation process in soils are various invertebrate groups which are feeding, not on the plant litter itself, but on the saprophytic microflora thriving on it. Large quantities of plant fragments from soils are washed into the aquatic environment by rain storms and inundations.

The degradation processes in the aquatic environment are less well documented. Something has been learnt from cultures and experiments in the laboratory, but the natural environment is a far more difficult one to work in. To slove the problems of sampling and in situ experiments require technical skill and resources not commonly associated with palaeobotanists. It requires also combined biological and sedimentological insight at a level which is probably also unusual.

A recent study (Spicer, 1981) describes the degradation of tree leaves in stream and lake environments from the point of view of a palaeobotanist who is trying to relate a deposited leaf flora to its originating vegetation. The study illuminates the engineering problems of making sampling devices and experimental set-ups. Comprehensive studies with the scope of Spicer's are very much wanted on the microscopic fragments. The technical problem involved is probably one reason why such studies are so rare.

At the ultimate end of the degradation scale we face the amorphous issue. The clouds of finely dispersed particles have always casued some trouble to the palynologist, since it can be difficult to remove and impedes microscopical work. It is also troublesome to the organic petrologist because of its unstructured, nondescript nature which escapes all attempts at morphological classification and identification of its origins.

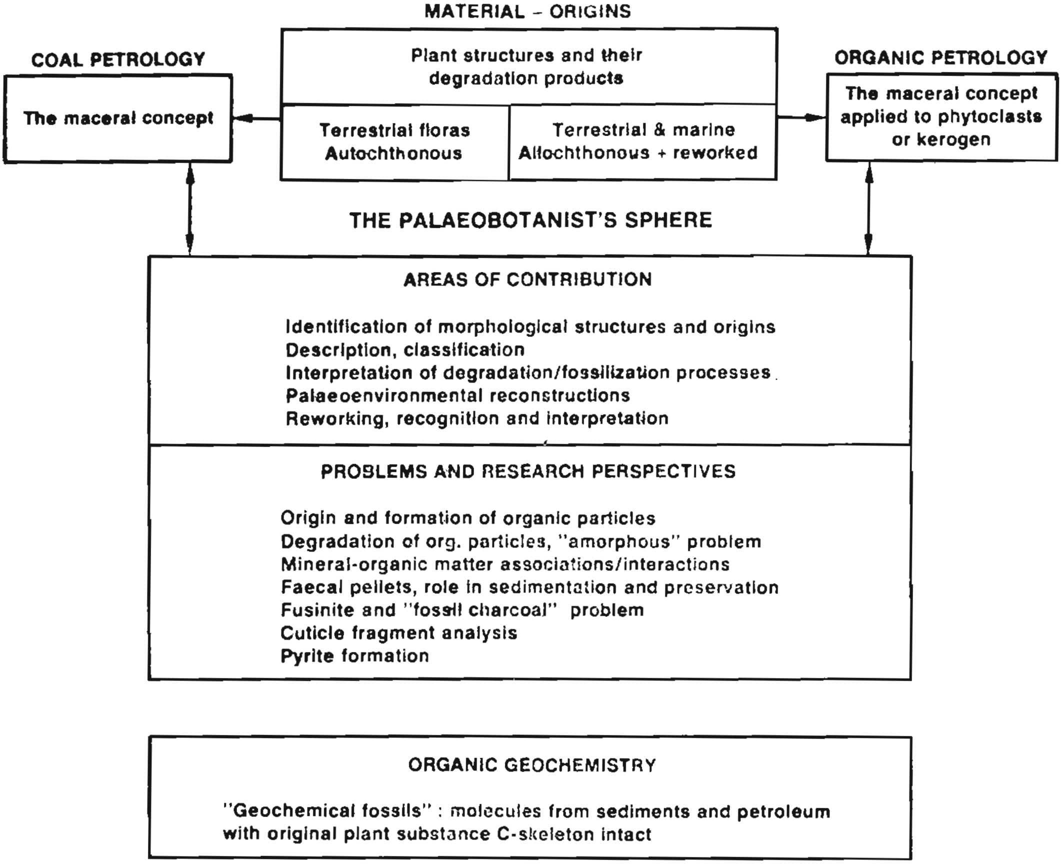
The coherence and lumping, quite often observed in the amorphous material, suggest that invertebrate ingestion and faecal pelletization play an essential role in its formation.

The kerogen in many organic rich marine sediments is dominated by amorphous material. It has a high H/C ratio and various chemical parameters point to algal origin. Because of the relatively high hydrogen content, it is reckoned to be a good hydrocarbon source. However, amorphous material in marine sediments may apparently also derive from land plants. Land plant membranes (cuticles, exines) are composed of relatively H-rich substances. Wood and associated tissues, on the other hand, are composed of substances of carbohydrate nature with less hydrogen and more oxygen. These two different origins of substances would produce amorphous material of markedly different petroleum source potential.

Laboratory experiments of microbial degradation of various terrestrial and marine plant materials indicate that all is eventually broken down to instructured matter whose origins cannot be distinguished under the ordinary light microscope (Masran & Pocock in Brooks, 1981). Bacteria are important agents in degradation processes, particularly in the aquatic environment. Much amorphous matter is probably derived from bacterial cell materials, which would explain its seemingly homogeneous nature irrespective of differences in origin.

There is a further kind of unstructured material which contributes to the amorphous category: the mineral-organic associations of a gel-like nature which can have the property of resisting HF digestion.

A great deal has yet to be learnt before we can claim to understand the processes and original materials involved in the formation of the diverse amorphous category, which is so important in the petroleum context. Recent advances in fluorescence microscopy appear to be promising for differentiation of amorphous material under the microscope (Robert, 1981). But this is a chapter of its own which shall not be further pursued here. However, palynologists and palaeobotanists should be aware of the potential advantages of fluorescence in morphological studies. Fluorescence can reveal structures which are otherwise imperceptible.



TEXT-FIG. 3 — Synthesis of relationships between organic petrology, coal petrology and palaeobotany.

I have attempted to present an overview of recent developments in palynology and particularly some palaeobotanical aspects of the dispersed organic matter in sediments. Text-fig. 3 is a synthesis of some of the diverse topics which I have touched upon with regard to organic petrology. The study of dispersed organic matter and of coal shares with palaeobotany the aspiration of building knowledge about past plants, floras and environments from bits and pieces of plants preserved in sediments. A palaeobotanical sphere of interest therefore clearly exists in both coal and organic petrology. Within this sphere there has been contributions of various kinds from palaeobotanical and other biological ideas and knowledge. One of these contributions not mentioned earlier in the text is the recognition of reworking and the potential which reworked palynomorphs and some of the debris have of indicating the provenance of sediments. There are not many systematic studies in this field, however, they can offer considerable contribution to geological interpretations.

The list of problems named in Text-fig. 3 is not meant to be exhaustive. The last item, pyrite formation, is included because it appears that pyrite varies so much in form that I wonder if there would not be environmental information to be gained from studying it more carefully.

I have entered organic geochemistry in the synthesis for a few reasons. The field is primarily concerned with studying the formation of petroleum from the sedimentary organic matter. It does also have its " fossils ", molecules which have retained their carbon-skeleton from the original plant substances. Organic geochemical research is for a great part directed at plant substances and their derivatives in sediments. This field should have our attention as palaeobotanists since methods and results are of potential value to us.

Plant fragments dealt with in organic petrology are smaller by some orders of magnitude than those which a macropalaeobotanist would normally want to look at. At the same time, however, they occur in numbers which are many orders of magnitude higher than macrofossils. There is a great challenge in the large volume of data on this plant material which is accumulated, particularly through applied studies, from many parts of the world.

REFERENCES

Bostick, N. H. (1971). Thermal alteration of clastic organic particles as an indicator of contact and burial metamorphism in sedimentary rocks. *Geosci. Man.*, **3**: 83-92.

Brooks, J. (ed.) (1981). *Organic maturation studies and fossil fuel exploration.* Academic Press, London, 441 pp.

Hopping, C. A. (1967). Palynology and the oil industry. *Rev. Palaeobot. Palynol.*, **2**: 23-48.

Robert, P. (1981). Classification of organic matter by means of fluorescence, application to hydrocarbon source rock. *Int. J. Coal. Geol.*, **1**: 101-137.

Spicer, R. A. (1981). The sorting and deposition of allochthonous plant material in a modern environment at Silwood Lake, Silwood Park, Berkshire, England. *G.S.U.S. Prof. Pap.*, 1143, 77 pp.

Stopes, M. C. (1935). On the petrology of banded bituminous coals. *Fuel*, **14**: 4-13.

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SOME FOSSIL WOODS FROM THE TERTIARY OF KACHCHH, WESTERN INDIA

J. S. GULERIA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

Fossil woods resembling the modern genera *Dipterocarpus* Gaertn. f., *Sterculia* Linn., *Terminalia* Linn. and a species of *Palmoxylon* Schenk are described from the probable Pliocene (Kankawati Series) beds of district Kachchh, Gujarat. They represent the families Dipterocarpaceae, Sterculiaceae, Combretaceae and Palmae respectively. The modern comparable forms of the fossil species indicate a more humid climate at the time of deposition contrary to the present day arid conditions in Kachchh.

Key-words — Xylotomy, *Dipterocarpoxylon*, *Sterculinium*, *Terminalioxylon*, *Palmoxylon*, Pliocene?, Kachchh (India).

साराँश

पश्चिमी भारत में कच्छ के तृतीयक कल्प से कुछ और काष्ठाश्म – जसवन्तसिंह गुलेरिया

गुजरात में कच्छ जनपद के सम्भवत: अतिनूतन युगीन (कन्कावती श्रेणी) संस्तरों से वर्तमान वंशों – डिप्टेरोकार्पस गेयर्टन० ऐंफ०, स्टरकुलिआ लिन्नियस, टर्मिनेलिया लिन्नियस तथा पाल्मॉक्सीलॉन् शैंक की एक जाति से मिलते-जुलते काष्ठाश्मों का वर्णन किया गया है। ये क्रमश: डिप्टेरोकार्पेसी, स्टरकुलिएसी, कॉम्ब्रीटेसी एवं पाल्मी कुलों का निरूपण करते हैं। इन काष्ठाश्मों के वर्तमान तुलनीय प्रारूप कच्छ की वर्तमान शुष्क परिस्थितियों के विपरीत निक्षेपण के समय अधिक आर्द्र जलवायु का होना इंगित करते हैं।

INTRODUCTION

LAKHANPAL and Guleria (1981) have recently summarized the work done till then onthe Tertiary flora of Kachchh. The present paper is a further addition to the knowledge of the megaflora of this area. The material of this paper comes from two localities — Dhaneti and Mothala. The former is situated about 24 km east of Bhuj and the latter about 66 km WWS of Bhuj (Map 1). Both the localities are easily accessible by road from Bhuj. The woods are found buried in the soil as well as strewn in a considerable area in both the localities. The preservation of material is fairly good. These fossil woods have been derived from the base of the Kankawati Series, the age of which is considered to be probable Pliocene (Biswas & Raju, 1973).

SYSTEMATIC DESCRIPTION

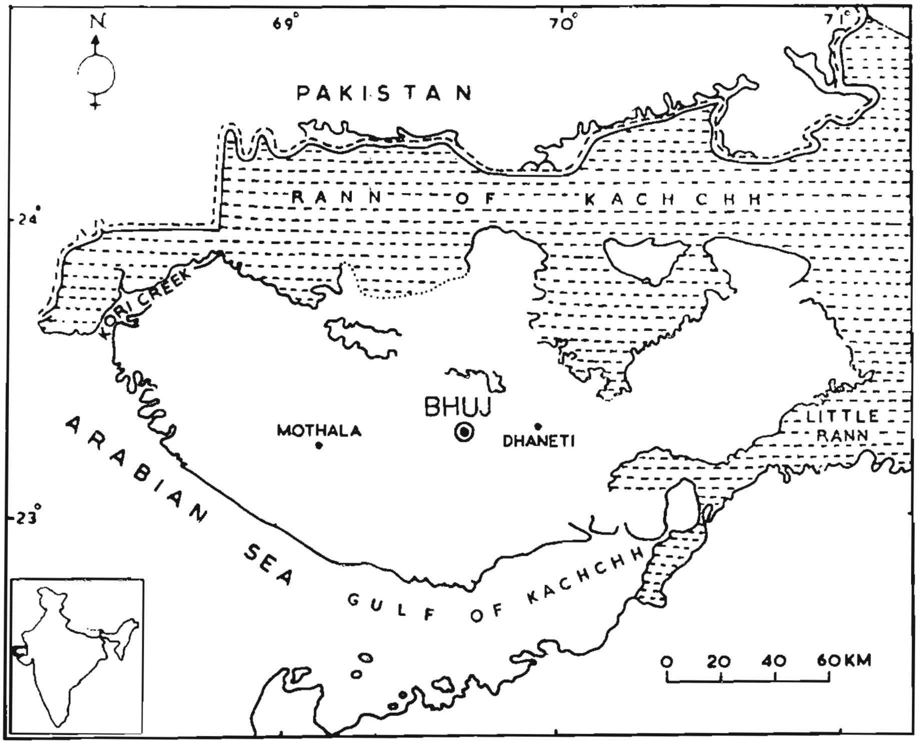
FAMILY — DIPTEROCARPACEAE

Genus — *Dipterocarpoxylon* Holden emend. Den Berger, 1927

Dipterocarpoxylon malavii Ghosh & Ghosh, 1959

Pl. 1, figs 1-4

In 1959, Ghosh and Ghosh briefly described a fossil dipterocarpaceous wood, *Dipterocarpoxylon malavii*, from the Pliocene beds of Mothala, district Kachchh. However, no attempt was made by them to find out the nearest modern equivalent of the fossil and also did not give any diagnosis for this species. In the present investigation a few woods were recognized as belonging to the genus *Dipterocarpus*. On critical exami-



MAP 1 — Map of Kachchh showing the fossil localities.

nation of their thin sections, two of them have been identified as *Dipterocarpoxylon malavii*. They exhibit more anatomical details and variations which were not mentioned earlier by Ghosh and Ghosh (1959). Therefore, it is considered necessary to give a detailed account of *D. malavii* before comparing it with the modern species of *Dipterocarpus*.

Topography — Wood diffuse - porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary, evenly distributed, 5-7 vessels per sq mm; tyloses abundant, completely plugging the vessels together with gummy material (Pl. 1, figs 1, 2). *Tracheids* sparse, intermingled with paratracheal parenchyma round the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, intermingled with vasicentric tracheids, forming 1-2 cells wide sheath round the vessels, sometimes aliform; apotracheal parenchyma diffuse or diffuse-in-aggregate and also associated with vertical gum canals (Pl. 1, fig. 2) frequently extending laterally, uniting with those of neighbouring gum canals, forming 3-8 (mostly 3-4) seriate bands. *Xylem rays* fine to moderately broad, 1-7 seriate (frequently 3-5), about 6-8 rays per mm; ray tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells, 3-13 cells or 30-400 μm high, 16-32 μm wide; multiseriate rays heterocellular, consisting of procumbent cells in the median portion and 1- several uniseriate marginal rows of upright cells (Pl. 1, figs 3, 4), 10-60 cells or 120-1600 μm high (most of the rays less than 1000 μm high), up to 208 μm wide; sheath cells occasionally present. *Fibre tracheids* aligned in radial rows between two consecutive rays. *Gum canals* frequent, vertical, diffuse, mostly solitary or in pairs, often up to 4, rarely 5, enclosed by parenchyma (Pl. 1, fig. 2); 3-4 gum canals per sq mm.

Elements — Vessels oval to elliptical in cross section, t.d. 80-240 μm (average 190 μm), r.d. 112-350 μm, thin-walled; vessel-members 180-440 μm with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, vestured. *Tracheidal cells* oval or flattened, 20-40 μm in diameter. *Parenchyma cells* circular, oval, elliptic to polygonal in cross section, 8-36 μm in diameter. Upright *ray cells* 32-60 μm in tangential height, 20-40 μm in radial length; procumbent cells 4-20 μm in tangential height, 40-60 μm in radial length. *Fibre tracheids* circular, oval to polygonal in cross section, 4-12 μm in diameter, non-septate, thick-walled, wall thickness 4-6 μm; pits about 4 μm in diameter, bordered. *Gum canals* circular to oval, t.d. 40-120 μm, r.d. 40-140 μm.

AFFINITIES

A large number of thin sections of the woods of *Dipterocarpus* were examined and published description and figures of many other species were also consulted (Chowdhury & Ghosh, 1958; Desch, 1941, 1957; Kribs, 1959; Lecomte, 1926; Moll & Janssonius, 1906; Pearson & Brown, 1932; Reyes, 1938). From this survey it was found that the present wood shows close similarity with that of *Dipterocarpus dyeri* Pierre ex De Laness.

Dipterocarpus is rather a large genus with 76 species, distributed in Sri Lanka and India to W. Malaysia and Bali (Willis, 1973, p. 376). *D. dyeri* Pierre ex De Laness is a large tree and occurs in Burma, Indo-China, Thailand and Malay Peninsula (Chowdhury & Ghosh, 1958, p. 115).

SPECIFIC DIAGNOSIS

Dipterocarpoxylon malavii Ghosh & Ghosh, 1959

Topography — *Wood* diffuse - porous. *Growth rings* absent. *Vessels* small to large (mostly medium), t.d. 80-240 μm (average 190 μm), r.d. 112-350 μm, exclusively solitary, 5-7 vessels per sq mm; perforations simple; pits leading to contiguous tracheids vestured; tyloses abundant. *Tracheids* intermingled with paratracheal parenchyma forming sheath round the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, intermingled with vasicentric tracheids forming 1-2 cells wide sheaths round the vessels, sometimes aliform; apotracheal parenchyma diffuse or diffuse-in-aggregate, and also associated with vertical gum canals forming 3-8 (usually 3-4) seriate bands. *Xylem rays* 1-7 (frequently 3-5) seriate or 16-208 μm wide, 10-60 cells or 120-1600 μm high (most of the rays less than 1000 μm); ray tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright and procumbent cells, 3-13 cells or 30-400 μm high; multiseriate rays heterocellular, consisting of procumbent cells and 1- several uniseriate marginal rows of upright cells at both the ends; sheath cells occasionally present. *Fibre tracheids* non-septate, 4-12 μm in diameter, thick-walled, wall thickness 4-6 μm; pits small, bordered. *Gum canals* frequent, diffuse, solitary or in pairs and often in tangential groups of 4-5; t.d. 40-120 μm, r.d. 40-140 μm.

Specimen — B.S.I.P. Museum no. 36003.

Localities — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road and Mothala about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Dipterocarpoxylon pondicherriense Awasthi, 1974a

Pl. 1, fig. 5; Pl. 2, fig. 8

This species is represented by two pieces of well-preserved secondary wood measuring 6-8 cm in length and 2.5-4.0 cm in diameter.

Topography — *Wood* diffuse - porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary (Pl. 1, fig. 5), evenly distributed, t.d. 96-240 μm (average 160 μm), r.d. 160-360 μm, 6-7 vessels per sq mm; tyloses not seen, gummy material occasionally filled in the vessels; vessel-members 240-440 μm in length with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, vestured. *Tracheids* sparse, intermingled with paratracheal parenchyma forming narrow sheath round the vessels; tracheidal cells oval or slightly flattened, 16-40 μm in diameter, *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma relatively sparse, intermingled with vasicentric tracheids forming narrow sheath round the vessels; apotracheal parenchyma associated with vertical gum canals (Pl. 1, fig. 5), frequently extending laterally uniting with those of neighbouring gum canals, forming short bands of 3-6 cells wide; diffuse cells occasionally present; parenchyma cells oval to polygonal in cross section, 15-28 μm in diameter. *Xylem rays* fine to moderately broad, 1-6 (mostly 4-5) seriate, 12-75 cells or 325-1920 μm high, up to 120 μm wide, 5-7 rays per mm; rays tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells, 3-12 cells or 128-320 μm high, 20-28 μm wide; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1- several marginal rows of upright cells at one or both the ends (Pl. 2, fig. 8), sheath cells occasionally present. *Fibre tracheids* aligned in radial rows, circular or oval to polygonal in cross section, 8-16 μm in diameter, non-septate, thick-walled, wall thickness 4-6 μm; pits about 4 μm, bordered. *Gum canals* abundant, diffuse, enclosed by parenchyma, rarely solitary, sometimes in pairs and usually in tangential rows of 3-11 canals; t.d. 64-144 μm, r.d. 96-160 μm; about 4-7 per sq mm (Pl. 1, fig. 5).

AFFINITIES

The above mentioned characters of the fossil indicate that it is a *Dipterocarpus* Gaertn. f. wood. Out of 23 species of *Dipterocarpoxylon* known so far from India and abroad (Awasthi, 1974a, b, 1980; Prakash, 1975, 1978, 1981; Lemoigne, 1978; Ghosh & Roy, 1979; Trivedi & Ahuja, 1980) the present fossil shows closest similarity in all its anatomical characters with *Dipterocarpoxylon pondicherriense* Awasthi (1974a) described from the Cuddalore Series near Pondicherry. The only difference between the two is that the frequency of gum canals seems to be relatively more in the present fossil than in *D. pondicherriense*. However, seeing the range of variation of this character in the living *Dipterocarpus indicus* Bedd. (with which *Dipterocarpoxylon pondicherriense* has been compared) the present fossil is being placed under *Dipterocarpoxylon pondicherriense*.

Dipterocarpus indicus Bedd. is a lofty tree up to 40 m high, distributed in the evergreen forests of Western Ghats from North Kanara southwards, Malabar and Travancore. It is common in South Kanara at the foot-hills and at an elevation up to 900 m especially in South Travancore.

Specimen — B.S.I.P. Museum no. 36004.

Locality — Mothala, about 66 km WWS of Bhuj, on the Bhuj Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

FAMILY — STERCULIACEAE

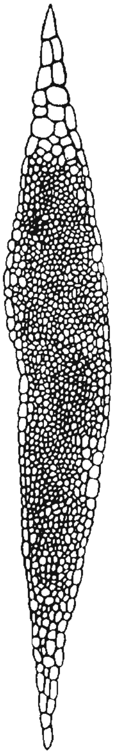
Genus — *Sterculinium* gen. nov.

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

Pl. 2, figs 6, 7, 9, 10; Text-fig. 1

This species is represented by half a dozen pieces of petrified wood. The biggest is 23 cm long and 13.5 cm in diameter. The preservation is fairly good.

Topography — *Wood* diffuse-porous (Pl. 2, figs 6, 7). *Growth rings* not clearly seen, delimited by somewhat denser and narrow late wood fibres. *Vessels* visible to naked eye in cross section as dots, medium to large, solitary or in multiples of 2, rarely 3-4, evenly distributed, about 1-2 vessels per sq mm; tyloses not seen, vessels often filled with gummy material. *Parenchyma* abundant, both paratracheal and apotracheal; paratracheal parenchyma sparse, forming narrow sheath of 1-3 cells round the vessels; apotracheal parenchyma forming regular tangential bands, about 4-6 bands per mm, each 4-7 cells in width (Pl. 2, fig. 7). *Xylem rays* of two sizes, broad and narrow (Pl. 2, fig. 9); narrow rays few, 1-4 (mostly 1-2) seriate or 20-60 μm broad, short, 5-14 cells or 100-400 μm in height, homocellular to heterocellular, consisting of upright and procumbent cells; broad rays mostly spindle-shaped, up to 25 seriate or 560 μm in width and 25-90 cells or 800-3420 μm (average 1280 μm) in height, cells in the median portion of broad rays sometimes disorganized; ray tissue heterogeneous, rays heterocellular, consisting of upright cells at one



TEXT-FIG. 1 — *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov. Tangential longitudinal view of a ray showing procumbent, upright and sheath cells, × 100.

or both the ends and procumbent cells in the median portion; sheath cells present (Text-fig. 1). *Fibres* poorly preserved, in broad conspicuous alternating bands, almost as broad as parenchyma bands (Pl. 2, figs 6, 7). *Gum canals* present at some places, aligned in regular tangential rows (Pl. 2, fig. 6), often confluent, 1-2 rows per cm.

Elements — *Vessels* mostly oval or flattened due to compression, walls 4-13 μm thick, t.d. 132-286 μm (average 250 μm), r.d. 118-308 μm; vessel members 200-400 μm in height with horizontal to slightly oblique ends; perforations simple, intervessel pits medium, hexagonal or polygonal in outline, 4-8 μm in diameter, crowded, alternate, bordered, aperture round-elliptical to linear (Pl. 2, fig. 10). *Parenchyma cells* four per strand, thin-walled, 20-30 μm in diameter, 40-90 μm in height, strands storied; crystals present. Procumbent *rays cells* variable in shape, vertical height 8-20 μm, radial length could not be measured, vertical height of upright cells 24-44 μm, radial length could not be measured. *Fibres* rectangular to polygonal in cross section, 12-20 μm in diameter, non-libriform to libriform. thin to thick-walled, wall 3-6 μm thick, non-septate; interfibre pits not seen. *Gum canals* r.d. 208-400 μm, t.d. variable and more than r.d. due to flattening.

AFFINITIES

The important characters of the fossil are: wood diffuse porous; vessels medium to large; parenchyma banded, bands alternating regularly with the fibre bands, parenchyma strands storied; rays of two types, narrow and broad, narrow rays 1-4 (mostly 1-2) seriate, broad rays up to 25 cells wide with sheath cells, ray tissue heterogeneous; fibres non-libriform to libriform, non-septate; gum canals at some places or in tangential rows.

Among these, the presence of banded parenchyma and broad and tall rays with sheath cells are the most important features of the present fossil. From a general survey of the dicotyledonous woods it has been found that similar type of parenchyma and rays are found in the following genera:

1. Bombacaceae — *Catostemma*
2. Boraginaceae — *Cordia*
3. Leguminosae — *Butea*, *Erythrina*
4. Moraceae — *Ficus*
5. Sterculiaceae — *Argyrodendron*, *Cola*, *Eriobroma*, *Firmiana* (inclusive *Erythropsis*), *Pterygota*, *Sterculia*

The genus *Catostemma* of Bombacaceae shows general similarity with the fossil. However, it differs in the vessels arrangement and paratracheal nature of the parenchyma bands (Chattaway, 1937, p. 361). Further, the rays are 4-10 cells wide as compared to much broad rays in the fossil. Fibres are commonly storied and extremely thick in *Catostemma* (Metcalfe & Chalk, 1950, pp. 238-240). Similarly some of the species of *Cordia*, *Butea*, *Erythrina* and *Ficus* show resemblance with the fossil. However, sheath cells are rare in the comparable species of these genera. *Butea* and *Erythrina* further differ in having vestured pits. In addition, gum canals are absent in *Butea*, *Erythrina* and *Ficus*. Of the family Sterculiaceae *Argyrodendron*, *Firmiana* (inclusive

Erythropsis) and *Pterygota* which are very close to the fossil, also differ from it in having storied fibres (Metcalfe & Chalk, 1950, p. 248). The gum canals are absent in *Cola* and *Eriobroma*. Evidently the fossil resembles in all its anatomical characters with the wood of *Sterculia*.

On the basis of wood anatomy Chattaway (1937, p. 358) divided the species of *Sterculia* into two groups, viz., *Sterculia* A and *Sterculia* B. The *Sterculia* A group comprises Sterculias with metatracheal parenchyma predominantly in lines of one cell width and *Sterculia* B group includes Sterculias with metatracheal parenchyma and paratracheal parenchyma often indistinguishable, predominantly in broad bands of 3-4 cells wide. Thus, the present fossil belongs to *Sterculia* B group of Chattaway.

Out of a large number of species of *Sterculia* having banded parenchyma, *Sterculia alata* Roxb., *S. coccinea* Roxb., *S. colorata* Roxb., *S. fulgens* Wall., *S. oblonga* Mast., *S. populifolia* Roxb., and *S. rhinopetala* K. Schum show apparently similar anatomical characters as present in the fossil. Among these, the rays are much narrower, 1-6 cells wide in *S. populifolia* while in *S. alata* the rays are comparatively shorter and not as broad as in the fossil. Fibres as well as parenchyma bands are relatively wider in *S. colorata*. Further, the gum canals are absent in these three species. However, they are present in *S. coccinea* and *S. fulgens* in tangential rows. *S. fulgens* shows close similarity with the fossil in most of the characters, but differs in having diffuse-aggregate parenchyma. Further, the fibre bands are occasionally double the width of parenchyma bands. Thus, *S. coccinea*, *S. oblonga* and *S. rhinopetala* shows nearest possible similarity with the fossil.

Some of the fossil woods which were earlier identified as *Nicolia aegyptiaca* (Unger, 1859; Chiarugi, 1933), *Nicolia giarabubensis* (Chiarugi, 1929) and *Nicolia oweni* (Schenk, 1883; Schuster, 1910) were reinvestigated by Kräusel (1939). He thought that they belong to *Sterculia* and accordingly constituted a new genus *Sterculioxylon* to accommodate these fossil woods which were placed by him under two new species, viz., *Sterculioxylon aegyptiacum* (Unger) and *Sterculioxylon giarabubense* (Chiarugi). From the work of Chattaway (1937), Metcalfe and Chalk (1950), Pearson and Brown (1932) and the study of thin sections of the modern woods of *Sterculia*, it is apparent that the genus *Sterculioxylon* of Kräusel does not show the characters of *Sterculia* wood. The most important differences are in the parenchyma and rays. The paratracheal parenchyma in the type species (*Sterculioxylon aegyptiacum*) is aliform to confluent and the apotracheal bands are irregular and distantly placed (see Kräusel, 1939, pl. 18, figs 3-6; pl. 19, figs 1-7; text-fig. 23), whereas in the modern wood of *Sterculia* paratracheal parenchyma is vasicentric and not distinctly aliform or confluent. Besides, the banded parenchyma is more or less regular and is relatively closely spaced. The rays in *Sterculioxylon aegyptiacum* are homogeneous and 1-7 seriate wide as compared to distinctly heterogeneous and much broader rays in *Sterculia*. Boureau (1949) and Boureau and Louvet (1975) have pointed out the resemblance of *Sterculioxylon aegyptiacum* with the wood of *Detarium* of Leguminosae. Lalitha and Prakash (1980) have also endorsed this view as it shows strong resemblance with the wood of *Copaifera-Detarium-Sindora*, which are anatomically inseparable.

Interestingly, Sheikh and Kolhe (1980) also instituted the genus *Sterculioxylon* while describing a fossil wood (*Sterculioxylon baradense* gen. et sp. nov.) from the Deccan Intertrappean beds of Mahurzari, near Nagpur. They have not mentioned about any earlier known species of *Sterculioxylon*. This, unfortunately, indicates their complete ignorance about the previous records of *Sterculioxylon*. They emphasized that their fossil shows close similarity with the family Sterculiaceae showing very close resemblance with the genus *Sterculia* of Chattaway's Subgroup B. A careful examination of the photographs and the accompanied description as given by the authors rules out the possibility of *Sterculioxylon baradense* being a wood belonging to *Sterculia* of Subgroup B of Chattaway for the following reasons: (i) though the author's claim the regular formation of parenchyma bands, they are not visible in the photographs, (ii) rays are homogeneous and 1-6 seriate broad in the fossil in contrast to markedly heterogeneous and much broader rays with sheath cells in *Sterculia*, (iii) there is no mention of the parenchyma strands whether storied or

TABLE 1 — *STERCULIOXYLON* SPECIES

NO.	NAME	VESSEL SIZE	PARENCHYMA	XYLEM RAYS	GUM CANALS	AGE AND DISTRIBUTION
1.	*Sterculioxylon aegyptiacum* (Ung.) Kräusel (1939), Boureau (149)	T.D. 100-240 μm R.D. 100-430 μm	Paratracheal and metatracheal; aliform, confluent and banded	1-7 seriate, homogeneous	Present	Tertiary of Egypt; Post Eocene of Tibesti in Sahara; Tertiary of Ethiopia
2.	*S. giarabubense* (Chiarugi) Kräusel (1939)	—	Paratracheal and metatracheal; aliform, confluent and banded	1-5 seriate, homogeneous	Present	Lower Oligocene to Lower Miocene of North Africa
3.	*S. rhenanum* Müller-Stoll & H. (1949)	T.D. 100-200 μm R.D. 150-300 μm	Paratracheal and metatracheal; vasicentric to aliform, confluent and banded	1-15 seriate, at best weakly heterogeneous	—	Eocene, South-west Germany
4.	*Sterculioxylon* sp. Hofmann (1952)	—	Paratracheal abundant aliform; apotracheal parenchyma forming tangential bands at considerable distance and 6-7 (14) cells wide	4-9 seriate, heterogeneous	—	Upper Miocene to Lower Pliocene, Austria
5.	*S. freulonii* Boureau (1957)	T.D. 120-200 μm R.D. 200-300 μm	Concentric bands of parenchyma sometimes with aliform types	1-6 seriate, heterogeneous	Present	Post Eocene, Libya
6.	*Sterculioxylon* sp.? Greguss (1969)	Diameter 60-90 μm	Vasicentric and terminal	1-2 seriate, homogeneous	—	Oligocene, Dorog, Hungary
7.	*S. foetidense* Prakash (1973)	T.D. 160-400 μm R.D. 240-480 μm	Paratracheal in narrow sheaths around vessels; apotracheal predominantly diffuse to diffuse-in-aggregate, irregular broken or in continuous uniseriate lines	1-8 seriate, heterogeneous	—	Tertiary, Burma
8.	*S. dattai* Prakash & Tripathi (1974)	T.D. 72-310 μm R.D. 96-348 μm	Paratracheal parenchyma vasicentric, 1-4 (mostly 1-2) cells thick around the vessels; apotracheal parenchyma abundant in fine, 1-2 cells thick lines, sometimes occurring as solitary cells, also around the gum ducts, sometimes forming tangential bands 1-6 (mostly 3-4) cells thick	1-10 seriate, heterogeneous	Present	Upper Miocene, Assam, India

— *Contd.*

TABLE 1 — *STERCULIOXYLON* SPECIES — *Contd.*

NO.	NAME	VESSEL SIZE	PARENCHYMA	XYLEM RAYS	GUM CANALS	AGE AND DISTRIBUTION
9.	*S. kalagarhense* Trivedi & Ahuja (1978)	T.D. 132-286 µm R.D. 118-308 µm	Paratracheal parenchyma vasicentric forming narrow to thick sheath around some of the vessels; apotracheal parenchyma in the form of regular bands	1-16 seriate, heterogeneous	Present	Mio-Pliocene, Kalagarh, Uttar Pradesh, India
10.	*S. deccanensis* Lakhanpal *et al.* (1978)	T.D. 60-120 µm R.D. 70-180 µm	As in *S. foetidense*	1-10 seriate, heterogeneous	—	? Early Eocene, Mandla District, Madhya Pradesh, India
11.	*S. shahpurensis* Bande & Prakash (1980, 1983)	T.D. 45-255 µm R.D. 60-360 µm	Paratracheal parenchyma 1-2 seriate, vasicentric; apotracheal parenchyma diffuse-in-aggregate forming 1-2 seriate, tangential lines	1-22 seriate, heterocellular	—	Early Tertiary, Shahpura, Mandla District, Madhya Pradesh, India
12.	*S. pondicherriense* Awasthi (1981)	T.D. 100-280 µm R.D. 50-250 µm	Paratracheal, banded, bands broad, 3-12 cells wide	Up to 25 seriate, heterogeneous	—	Mio-Pliocene, Pondicherry, India
13.	*S. baradense* gen. et sp. nov. Sheikh & Kolhe (1980)	T.D. 135 µm	Paratracheal vasicentric forming 2-3 layers around each vessel, and confluent forming regular bands between adjacent vessels	1-6 seriate, homogeneous	—	? Uppermost Cretaceous, Mahurzari (Barad), Nagpur District, Maharashtra, India
14.	*S. varmahii* Lakhanpal *et al.* (1981)	T.D. 120-225 µm R.D. 210-345 µm	Aliform, confluent to mostly banded; bands completely or incompletely enclosing the vessels, regular or irregular, 5-16 cells wide	1-11 seriate, homo-heterocellular	—	Mio-Pliocene, Arunachal Pradesh, India
15.	*Sterculioxylon* sp. cf. *S. shahpurensis* Bande & Prakash (1983)	—	As in *S. shahpurensis*	1-40 seriate, heterogeneous	—	Early Tertiary, Shahpura, Mandla District, Madhya Pradesh, India

non-storied which in the case of *Sterculia* are distinctly storied, and (iv) the fibres are storied in the fossil which are, however, non-storied in the Subgroup B of *Sterculia*.

From the foregoing discussion it is clear that both the *Sterculioxylon* (Kräusel, 1939; Sheikh & Kolhe, 1980) fail to represent the wood characters of *Sterculia*. Therefore, the fossil woods showing the characters of *Sterculia* cannot be placed under them. Hence, a new generic name *Sterculinium* is proposed for *Sterculia* and *Sterculia*-like fossil woods (which includes *Brachychiton*, *Cola*, *Eriobroma & Pterocymbium*; *Firmiana*, *Erythropsis*, *Pterygota* in part*, etc). The genus *Sterculinium* consists of two types of woods. The first type includes *Pterocymbium* and those species of *Sterculia* and *Brachychiton* which possess parenchyma predominantly in lines one cell wide. The second type includes *Cola*, *Eriobroma* *Firmiana*, *Erythropsis*, *Pterygota* and those species of *Sterculia* which possess predominantly broad bands of parenchyma. So far 15 species of *Sterculioxylon* have been described (see Table 1). Out of them, the following belong to *Sterculia* and they are now named as *Sterculinium freulonii* (Boureau) comb. nov., *Sterculinium foetidense* (Prakash) comb. nov., *Sterculinium dattai* (Prakash & Tripathi, comb. nov., *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov., *Sterculinium deccanensis* (Lakhanpal *et al.*) comb. nov., *Sterculinium shahpurensis* (Bande & Prakash) comb. nov., *Sterculinium pondicherriense* (Awasthi) comb. nov., *Sterculinium varmahii* (Lakhanpal *et al.*) comb. nov. and *Sterculinium* sp. cf. *S. shahpuraensis* (Bande & Prakash) comb. nov. The remaining species need reinvestigation for their true affinities.

The genus *Sterculia* Linn. consists of 300 species (Willis, 1973, p. 1103) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932, p. 145). Of the three comparable species, *Sterculia coccinea* is found in the eastern Himalayas ascending up to 900 m in Bhutan, Sikkim and Assam Hills and in Burma extending southwards to Tennasserim (Chowdhury & Ghosh, 1958, p. 214). The other two, *S. oblonga* and *S. rhinopetala* are confined to tropical forests of Africa.

GENERIC DIAGNOSIS

Sterculinium **gen. nov.**

Wood diffuse-porous. *Growth rings* indistinct, sometimes demarcated by thin bands of terminal parenchyma. *Vessels* mostly medium to large, solitary and in small radial multiples; perforations simple; intervessel pits alternate, bordered; tyloses sometimes present. *Parenchyma* abundant; apotracheal, paratracheal and terminal; paratracheal in narrow sheaths around the vessels and apotracheal predominantly in lines one cell wide or apotracheal and paratracheal parenchyma often indistinguishable, predominantly in broad bands, three to four cells wide; strands usually of two cells in the scattered cells and uniseriate bands, usually of four, sometimes eight cells in the broad bands; distinctly storied. *Xylem rays* often of two distinct sizes, larger one usually more than 10 cells wide; markedly heterogeneous with two to several marginal rows of upright cells and sheath cells; small rays storied when sufficiently numerous; crystals usually present in rays or parenchyma or both. *Fibres* non-libriform to libriform, non-septate; storied (*Sterculia* A) as well as non-storied (*Sterculia* B). *Intercellular canals* may or may not present.

Genotype — *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov.

SPECIFIC DIAGNOSIS

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

Growth rings not clearly seen. *Vessels* medium to large, t.d. 132-286 μm (average 250 μm), r.d. 118-308 μm, solitary or in multiples of 2, rarely up to 3-4, 1-2 per sq mm; tyloses absent; perforations simple; intervessel pits medium, 4-8 μm in diameter, alternate, bordered, hexagonal to polygonal in outline, aperture round-elliptic to linear. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma forming narrow sheaths of 1-3 cells round the vessels; apotracheal parenchyma in regular bands,

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*As some of the species of *Sterculia* have been transferred to *Firmiana* and *Pterygota* (Chowdhury & Ghosh, 1958, pp. 211, 212, 214, 275).

bands 4-7 cells wide; parenchyma strand storied. *Xylem rays* narrow and broad, narrow rays 1-4 (mostly 1-2) seriate or 20-60 μm broad, short, 5-14 cells or 100-400 μm in height, homocellular to heterocellular, sparse; broad rays mostly spindle-shaped, up to 25 seriate or 560 μm wide, 25-90 cells or 800 to 3420 μm (average 1280 μm) in height, consisting of procumbent and upright cells at one or both ends; sheath cells present. *Fibres* in regular alternating bands of almost same width as of parenchyma bands, non-libriform to libriform, non-septate. *Gum canals* present at some places; in tangential rows; r.d. 208-400 μm, t.d. variable and more than r.d. due to flattening.

Holotype — S-23, Botany Department, Lucknow University, Lucknow.

Specimen — B.S.I.P. Museum no. 36005.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

FAMILY — COMBRETACEAE

Genus — *Terminalioxylon* Schönfeld, 1947

Terminalioxylon felixii Ramanujam, 1956

Pl. 3, figs 11, 12

This species is represented by a well-preserved piece of silicified wood 8 cm long and 4 cm in diameter.

Topography — *Wood* diffuse-porous (Pl. 3, fig. 11). *Growth rings* distinct, demarcated by narrow lines of parenchyma and small vessels (Pl. 3, fig. 11). *Vessels* small to large (mostly medium), t.d. 60-240 μm, r.d. 144-340 μm, mostly solitary or in radial multiples of 2-4, evenly distributed, 5-7 vessels per sq mm; tyloses present; vessels sometimes filled with dark contents (Pl. 3, fig. 11); vessel members 120-400 μm in height with truncated ends; perforations simple; intervessel pits small, alternate, oval to elliptic, about 4 μm in diameter, vestured. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform (Pl. 3, fig. 11), sometimes confluent when vessels are closely placed; apotracheal parenchyma aggregate and forming narrow lines of 1-3 cells wide at the growth rings; parenchyma cells oval to slightly elliptic in cross section, 16-28 μm in diameter, thin-walled, crystalliferous strands occasionally present with several chambers containing solitary crystals. *Xylem rays* fine, uniseriate, occasionally with paired cells (Pl. 3, fig. 12), 12-40 μm wide, 5-21 cells or 120-520 μm high; 14-16 rays per mm; ray tissue homogeneous to weakly heterogeneous, rays homocellular to weakly heterocellular consisting of procumbent cells with single marginal row of upright or squarish cells at one or both the ends (Pl. 3, fig. 12). *Fibres* aligned in radial rows, oval to polygonal in cross section, 8-16 μm in diameter, thick-walled, wall thickness about 4 μm, nonseptate; interfibre pits not seen.

AFFINITIES

The above characters indicate that the present fossil belongs to the genus *Terminalia* Linn. of the family Combretaceae.

The genus *Terminalioxylon* was established by Schönfeld in 1947 for the fossil woods of *Terminalia*. Mädel-Angeliewa and Müller-Stoll (1973) emended the diagnosis of the genus *Terminalioxylon* Schönfeld and merged the *Anogeissusoxylon* Navale (1964) and *Anogeissusoxylon* Louvet (1965) in it. Later, Prakash (1979, p. 54) disagreeing with the contention of Mädel-Angeliewa and Müller-Stoll again separated the genus *Anogeissusoxylon* Navale for the fossil woods of *Anogeissus* and *Terminalioxylon* Schönfeld for the fossil woods of all species of *Terminalia*. The genus *Terminalioxylon* is used here in its original sense as proposed by Schönfeld.

A large number of fossil woods have been described under the genus *Terminalioxylon* from India and abroad and 30 species have been listed by the author (1978). Recently, five more species, viz., *T. pachitanensis* Sukieman (1977), *T. doubingeri*, *Terminalioxylon* sp. Lemoigne (1978), *T. palaeomanni* Prakash (1981), *T. varkalaensis* Awasthi & Ahuja (1982) have been added to this list. Out of them, *Terminalioxylon felixii* Ramanujam (1956) appears almost identical to the present specimen in all the features except for minor variations in the number of vessels per sq mm. Hence, it is placed under the same species. *Terminalia arjuna* Bedd. and *T. tomentosa* W. & A. with which the present fossil resembles most, are large trees. *T. arjuna* is distributed throughout the greater part of India from Avadh southwards usually along the banks of rivers and streams, ravines and dry water courses and occurs in southern, western and central India, Bihar, Orissa, parts of Maharashtra, Tamil Nadu and Sri Lanka. *T. tomentosa* is very common and probably the most widely distributed of all the important forest trees of India. It occurs in the sub-Himalayan regions from the Punjab eastwards to Goalpara in Assam, ascending up to 1200 m elevation and throughout the greater part of the Peninsula except the arid zones of Rajasthan.

Specimen — B.S.I.P. Museum no. 36006.

Locality — Mothala, about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll, 1973

Pl. 3, figs 13, 14

In 1968, Prakash and Dayal described briefly a fossil wood of *Terminalia* from Kachchh, indicating its affinities with *Terminalia tomentosa* Wight & Arn. About its geological age they considered it to have been derived from the Deccan Intertrappean beds situated near Ratnal Railway Station on Gandhidham-Bhuj branch line of Western Railway. Since it was a stray piece and the Intertrappean beds are nowhere around, it seems plausible that the fossil was brought to this place somehow by some agency from the Pliocene beds of Kankawati Series exposed nearby from where identical specimens were also collected. These are being described here in detail.

Topography — *Wood* diffuse-porous (Pl. 3, fig. 13). *Growth rings* distinctly marked, demarcated by narrow lines of parenchyma and small vessels (Pl. 3, fig. 13). *Vessels* small to medium (mostly medium), t.d. 60-200 μm (average 120 μm), r.d. 90-270 μm, mostly solitary or in multiples of 2-4, evenly distributed, 6-10 vessels per sq mm; tyloses present; vessels occasionally filled with dark contents and crystals (Pl. 3, fig. 13); vessel-members 160-448 μm in height with truncated ends; perforations simple; intervessel pits alternate, oval to elliptic, sometimes coalescent, about 2-4 μm in diameter, vestured. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform and confluent (mostly aliform); apotracheal parenchyma forming narrow lines at the growth rings, 1-3 cells wide (Pl. 3, fig. 13); parenchyma cells round, oval to elliptic, 16-28 μm in diameter, thin-walled, crystalliferous strands occasionally present with several chambers containing solitary crystals. *Xylem rays* fine, 1-2 seriate, mostly uniseriate, occasionally with paired cells, 12-28 μm wide, 3-29 (mostly 11-15) cells or 40-480 μm high, 10-14 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular (Pl. 3, fig. 14), consisting of procumbent cells or with one row of marginal upright or squarish cell at one or both the ends. Upright *ray cells* 20-28 μm in vertical height, procumbent cells 12-20 μm in vertical height, radial lengths could not be measured. *Fibres* oval to polygonal in cross section, thick-walled, walls about 4 μm thick, 8-16 μm in diameter, occasionally septate; interfibre pits not seen.

AFFINITIES

All the above characters collectively indicate that the fossil belongs to the genus *Terminalia* Linn. On comparing it with a large number of woods of *Terminalia* species it was found that there is a close agreement between the fossil and modern wood of *Terminalia tomentosa* W. & A. in all the characters (Ramesh Rao & Purkayastha, 1972, p. 200).

Mädel-Angeliewa and Müller-Stoll (1973) instituted a new species of *Terminalioxylon*, viz., *Terminalioxylon burmense* to include the fossil woods referred to *Terminalia tomentosa* W. & A. by Chowdhury and Tandon (1964), Prakash (1966) and Prakash and Dayal (1968). Later, an illustrated account of the same was given by Kramer (1974) from the south-east Asia. Except for a few minor differences which are of variable nature, the present specimens show closest resemblance with *Terminalioxylon burmense*. Hence, they are placed under the same species.

Specimens — B.S.I.P. Museum no. 36007.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

FAMILY — PALMAE

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon kachchhensis sp. nov.

Pl. 3, figs 15, 16; Pl. 4, figs 17-21

The material consists of a single piece of fairly well-preserved petrified stem measuring 11 cm in length and 6.7 cm in diameter (Pl. 3, fig. 15). The cortical, dermal and the central zones are lacking and only the subdermal zone is present as indicated by the spacing and orientation of the fibrovascular bundles in the specimen.

Topography — Fibrovascular bundles obovate, orbicular, reniform and rarely ovate in shape (Pl. 4, figs 17, 19), usually regularly oriented, fairly distantly placed without touching the neighbouring bundles, 28-52 (average 40) bundles per sq cm; t.d. 0.75-1.4 (average 1.0) μm; r.d. 1.2-1.5 μm; f/v ratio varies from 5-10/1; sclerenchyma surrounded by 1-2 (3) layers of thin-walled more or less flattened cells of tabular parenchyma (Pl. 4, figs 20, 21); radiating parenchyma also present; dorsal sclerenchyma cap reniform or cordate type, auricular lobes rounded at their ends; ventral sclerenchyma cap not seen; sclerenchyma tissue highly disintegrated and impregnated by silica; the xylem consists of 1-3 (mostly 1-2) vessels, excluded, vessels filled with dark contents, annular thickenings seen in vessels; xylem parenchyma occasionally preserved; phloem between the xylem and median sinus almost disorganized except in a few fibrovascular bundles where it is seen as patch of badly preserved tissue; median sinus generally rounded or angular; stegmata present in the fibrous part of the fibrovascular bundles. *Leaf-trace bundles* present. The *ground parenchyma* consists of oval, polygonal and elongated (mostly elongated) cells, thin-walled, occasionally relatively thick-walled, forming radial plate-like structure (Pl. 3, fig. 16; Pl. 4, figs 18, 21), almost compact, occasionally small intercellular spaces present; crystals present between the neighbouring fibrovascular bundles in the ground parenchyma. *Fibre bundles* absent.

Discussion — The fossil palm stems have been assigned to the artificial genus *Palmoxylon* Schenk (1882). Though attempts have been made to resolve the fossil palms into their natural genera on the basis of the xylotomical characters by Schoute (1912), Kaul (1935, 1938), and Mahabale (1958, 1966), nevertheless it has not been possible so far to evolve a natural system of classification for them. Obviously, in the absence of natural system of classification various artificial classifications have been followed. Here, the artificial scheme adopted by Sahni (1943) (which is in fact a synthesis of classifications of Mohl, 1845 & Stenzel, 1904) is being followed. According to it the present fossil falls under two subgroups, viz., Cordata and Reniformia. In the absence of dermal and central regions in the present fossil it is difficult to decide that to which of the subgroups the present fossil exactly belongs.

Comparison with fossil Palmoxyla — A very large number of *Palmoxylon* species are known from India and abroad. A comprehensive list of these has been given by Prakash & Boureau (1968) and Prakash (1974). In addition, a few more species have been described afterwards. However, the following Indian species, viz., *Palmoxylon blanfordi* Schenk (1882), *P. chhindwarense* Prakash (1960), *P. compactum* Sahni (1964), *P. cordatum* Trivedi & Surange (1969), *P. cribriforme* Sahni (1964), *P. deccanense* Sahni (1964), *P. indicum* Sahni (1964), *P. khalsa* Sahni (1964), *P. puratanum* Ramanujam (1958), *P. rewahense* Sahni (1964), *P. sagari* Sahni (1964), *P. scotti* (Menon) Dayal & Menon (1965), *P. sinosum* Sahni (1964), *P. splendidum* Trivedi & Chandra (1971), *P. sundaram* var. *vidarbhai* Rao & Menon (1964), and *P. wadiai* Sahni (1964) with reniform or cordate type of dorsal sclerenchyma cap, more or less compact ground parenchyma and without fibre bundles, show apparent similarity with the present fossil. Besides *P. libycum* Stenzel (1904), *P. cottae* (*partschii*) (Unger) Stenzel (1904) and *P. tenue* Stenzel (1904) show some resemblance with the present fossil.

Palmoxylon blanfordi is based on central region hence, it cannot be compared with the present fossil which represents the subdermal region. In *P. chhindwarense*, *P. puratanum*, *P. scotti*, *P. splendidum* and *P. sundaram* var. *vidarbhai* fibrovascular bundles are much more and f/v ratio is much less in the corresponding region, whereas in *P. indicum* and *P. sagari* the fibrovascular bundles and f/v ratio is much less. In *P.*

compactum, *P. cribriforme*, *P. rewahense*, *P. sinuosum*, the ground parenchyma is of different type. In *P. wadiai*, the ground parenchyma is much more lacunar and somewhat stellate type and f/v ratio is much less. Fibrovascular bundles are also relatively less and moreover diminutive fibrovascular bundles are present in *P. wadiai*. *P. khalsa* differs in having usually 3-4 vessels as compared to 1-2 in the present fossil. *P. deccanense* and *P. cordatum* show better resemblance, however, the tabular parenchyma is absent and vessels are frequently in groups of 3-10 in addition to 2 main vessels in the former. The latter differs in relatively lesser f/v ratio. Similarly, *P. libycum*, *P. partschii* and *P. tenue* also differ from the present fossil in one or more characters.

Thus the present fossil is quite different from all the known species of *Palmoxylon* and therefore a new name, *P. kachchhensis* is assigned to it.

SPECIFIC DIAGNOSIS

Palmoxylon kachchhensis sp. nov.

Fibrovascular bundles obovate, orbicular, reniform, rarely ovate, fairly distantly placed without touching the neighbouring bundles; t.d. 0.75-1.4 (average 1.0) μm; r.d. 1.2-1.5 μm; 28-52 (average 40) bundles per sq cm; f/v ratio 5-10/1; dorsal sclerenchyma cap reniform or cordate type; xylem consists of 1-3 (mostly 1-2) vessels; stegmata present; ventral sclerenchyma cap and fibre bundles absent; tabular and radiating parenchyma present. *Leaf-trace bundles* present. *Ground parenchyma* consists of oval, polygonal and elongated (mostly elongated) cells, mostly thin-walled; occasionally relatively thick-walled forming radial plate-like structure between the neighbouring fibrovascular bundles; ground tissue almost compact occasionally with small intercellular spaces; crystals present in the ground parenchyma.

Holotype — B.S.I.P. Museum no. 36008.

Locality — Mothala, about 66 WWS from Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

ACKNOWLEDGEMENTS

The author is thankful to the authorities of the Forest Research Institute, Dehradun for consulting their xylarium. Thanks are also due to Dr R. N. Lakhanpal for going through the manuscript and to Dr N. Awasthi for useful suggestions.

REFERENCES

AWASTHI, N. (1974a). Occurrence of some dipterocarpaceous woods in the Cuddalore Series of South India. *Palaeobotanist*, **21** (3): 339-351.

AWASTHI, N. (1974b). Neogene angiospermous woods, pp. 341-358 in Surange, K. R. *et al.* (Eds) — *Aspects and Appraisal of Indian Palaeobotany*. Birbal Sahni Institute of Palaeobotany, Lucknow.

AWASTHI, N. (1980). Two new dipterocarpaceous woods from the Cuddalore Series near Pondicherry. *Palaeobotanist*, **26** (3): 248-256.

AWASTHI, N. (1981). Fossil woods belonging to *Sterculiaceae* and *Lythraceae* from the Cuddalore Series of Pondicherry. *Palaeobotanist*, **27** (2): 182-189.

AWASTHI, N. & AHUJA, M. (1982). Investigations of some carbonised woods from the Neogene of Varkala in Kerala Coast. *Geophytology*, **12** (2): 245-259.

BANDE, M. B. & PRAKASH, U. (1980). Four new fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla District, M.P. *Geophytology*, **10** (1-2): 268-271.

BANDE, M. B. & PRAKASH, U. (1983). Fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla District, Madhya Pradesh. *Palaeobotanist*, **31** (1): 13-29.

BISWAS, S. K. & RAJU, D. S. N. (1973). The rock stratigraphic classification of Tertiary sediments of Kutch. *Bull. Oil nat. gas Commn*, **10** (1-2): 37-45.

BOUREAU, E. (1949). Etude paléoxylologique du Sahara (VI).— Sur une forme nouvelle du *Sterculioxylon* (*Nicolia*) *aegyptiacum* (Unger) Kräusel, des couches post-Éocènens due Tibesti. *Bull. Mus., Ser.* 2ᵉ, **21** (6): 776-787.

BOUREAU, E. (1957). Étude palaéoxylologique du Sahara (XXIII). Sur une nouvelle, espéce de bois fossile de Sterculiaceae récoltée a Ouaou en Namous (Libya) *Sterculioxylon freulonii* n. sp. *Bull. Mus., Ser.* 2ᵉ, **29** (1): 112-120.

BOUREAU, E. & LOUVET, P. (1975). Sur deux espèces ligneuses Tertiaires nouvelles de la région de Ouaou en Namous (Libye). 95ᵉ *Congr. natn. soc. Savantes., Reimes, Sciences*, **3**: 11-42.

Chattaway, M. M. (1937). The wood anatomy of the Sterculiaceae. *Phil. Trans. R. Soc.*, **228**: 313-366.

Chiarugi, A. (1929). Legni fossili (di Giarabub). Dans Resultati scientifici della Missione alla Oasi di Giarabub, Parte III: La Palaeontologia: 397-430. *R. Società Geographica Italiana, Roma.*

Chiarugi, A. (1933). Legni fossili della Somalia Italiana. *Palaeont. ital.*, **32** (1): 97-167.

Chowdhury, K. A. & Ghosh, S. S. (1958). *Indian Woods.* **1.** Delhi.

Chowdhury, K. A. & Tandon, K. N. (1964). A fossil wood of *Terminalia tomentosa* W. & A. from the Tertiary of Burma. *Ann. Bot. N.S.*, **28**: 445-450.

Dayal, R. & Menon, V. K. (1965). *Palmoxylon scottii*: Revised name for *Palmoxylon sahnii* Menon. *Curr. Sci.*, **34** (15): 459.

Den Berger, L. G. (1927). Unterscheidungsmerkmale von rezenten und fossilen Dipterocarpaceengattungen. *Bull. Jard. bot. Buitenz.*, **3**: 495-498.

Desch, H. E. (1941). Dipterocarp timbers of the Malay Peninsula. *Malay Forest Rec.*, **14.**

Desch, H. E. (1957). Manual of Malayan timbers. 1. *Malay Forest Rec.*, **15**: 1-328.

Ghosh, P. K. & Roy, S. K. (1979). *Dipterocarpoxylon bolpurense* sp. nov., a fossil wood of Dipterocarpaceae from the Tertiary of West Bengal, India. *Curr. Sci.*, **48** (11): 495-496.

Ghosh P. K. & Roy, S.K. (1980). Fossil wood of *Terminalia* from the Tertiary of West Bengal. *Curr. Sci.*, **49** (14): 556-557.

Ghosh, S. S. & Ghosh, A. K. (1959). *Dipterocarpoxylon malavii* sp. nov., a new fossil record from the Pliocene of Kutch. *Sci. Cult.*, **25**: 328-332.

Greguss, P. (1969). *Tertiary Angiosperm Woods in Hungary.* Budapest.

Guleria, J. S. (1978). Study of Tertiary flora of Kutch. *Unpublished Ph.D. Thesis.* Lucknow Univ., Lucknow, India.

Hofmann, F. (1952). Pflanzenresteaus dem Phosphoritvorkommen von Prambachkirchen in Obserösterreich. II. *Palaeontographica*, **92B**: 122-183.

Kaul, K. N. (1935). A classification of palms based upon the ground-tissue of the stem. *Proc. 22nd Indian Sci. Congr., Calcutta*: 285-286 (Abst.).

Kaul, K. N. (1938). An analysis of the artificial genus *Palmoxylon* into natural genera. *Proc. 25th Indian Sci. Congr., Calcutta*: 149-150.

Kramer, K. (1974). Die Tertiären hölzer Sudöst-Asien (Unter ausschluss der Dipterocarpaceae). 2. Teil. The Tertiary woods of Southeast-Asia (Dipterocarpaceae excluded). 2. *Palaeontographica*, **145B**: 1-150.

Kräusel, R. (1939). Ergebnisse der Forschungsreisen. Prof. E. Stromers in den Wüsten Ägyptens. IV. Die fossilen floren Ägyptens. *Abh. bayer. Akad. Wiss.*, **47**: 5-140.

Kribs, D. A. (1959). *Commercial Foreign Woods on the American Market.* Pennsylvania.

Lakhanpal, R. N. & Guleria, J. S. (1981). Leaf-impressions from the Eocene of Kachchh, western India. *Palaeobotanist*, **28-29**: 353-373.

Lakhanpal, R. N., Prakash, U. & Awasthi, N. (1981). Some more dicotyledonous woods from the Tertiary of Deomali, Arunachal Pradesh, India. *Palaeobotanist*, **27** (3): 232-251.

Lakhanpal, R. N., Prakash, U. & Bande, M. B. (1978). Fossil dicotyledonous woods from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist*, **25**: 190-204.

Lalitha, C. & Prakash, U. (1980). Fossil wood of *Sindora* from the Tertiary of Assam with a critical analysis of anatomically allied forms. *Geophytology*, **10** (1-2): 174-187.

Lecomte, H. (1926). *Les Bois de l'Indochina.* Paris.

Lemoigne, Y. (1978). Flores Tertiaires de le Haute Vallee de L'omo (Ethiopie). *Palaeontographica*, **165B** : 89-157.

Louvet, P. (1965). Sur une Combretaceae fossile nouvelle du Tinrhert (Algerie). 89° *Congres Soc. Sav.*: 281-301.

Mädel-Angeliewa, E. & Müller-Stoll, W. R. (1973). Kritische studien über fossile Combretaceen hölzer: über hölzer vom typus *Terminalioxylon* G. Shönfeld mit einer revision der bischer zu *Evodioxylon* Chiarugi gestellten arten. *Palaeontographica*, **142B**: 117-136.

Mahabale, T. S. (1958). Resolution of the artificial genus *Palmoxylon*: A new approach. *Palaeobotanist*, **7**: 76-84.

Mahabale, T. S. (1966). Evolutionary trends in the Palmae with special reference to fossil palms. *Palaeobotanist*, **14**: 214-222.

Metcalfe, C. R. & Chalk, L. (1950). *Anatomy of the Dicotyledons.* **I** & **II**. Oxford.

Mohl Hugo von (1845). Über den Bau des Palmenstammes. *Vermischte Schriften botanischen Inhalts*: 129-185. Tübingen.

Moll, J. W. & Janssonius, H. H. (1906). *Mikrographie des Hölzer der auf Java Verkommenden Baumarten.* **III**. Leiden.

Müller-Stoll, W. R., und H. (1949). *Sterculioxylon rhenanum* nov. spec. aus dem alttertiär. Südwest Deutschlands. (Studien über fossile laub-hölzer, 1). *Palaeontographica*, **89B**: 204-217.

Navale, G. K. B. (1964). *Anogeissusoxylon indicum* gen. et sp. nov. from the Tertiary rocks near Pondicherry, India. *Palaeobotanist*, **11** (3): 154-158.

Pearson, R. S. & Brown, H. P. (1932). *Commercial Timbers of India.* **I** & **II**. Calcutta.

Prakash, U. (1960). Studies in the Deccan Intertrappean flora. Two palm woods from Mohgaon Kalan. *Palaeobotanist*, **7** (2): 136-142.

Prakash, U. (1966). Wood of *Terminalia tomentosa* Wight & Arn. from the Tertiary of Nagaland. *Publ. Cent. Adv. Study Punjab Univ.*, **3**: 27-31.

Prakash, U. (1973). Fossil woods from the Tertiary of Burma. *Palaeobotanist*, **20** (1): 48-70.

Prakash, U. (1974). Palaeogene angiospermous woods: pp. 306-320 in Surange, K. R. *et al.* (Eds) — *Aspects and Appraisal of Indian Palaeobotany.* Birbal Sahni Institute of Palaeobotany, Lucknow.

Prakash, U. (1975). Fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Palaeobotanist*, **22** (3): 192-210.

Prakash, U. (1978). Fossil woods from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist*, **25**: 376-392.

Prakash, U. (1979). Fossil dicotyledonous woods from the Tertiary of Thailand. *Palaeobotanist*, **26** (1): 50-62.

Prakash. U. (1981). Further occurrence of fossil woods from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist*, **28-29**: 374-388.

Prakash, U. & Boureau, E. (1968). Bois fossiles de Palmiers. *Mem. Sec. Sci.* **2** *Palaéobotanique, Minist. Edu. natn. Com. Trav. hist. scient.*: 130-146.

Prakash, U. & Dayal, R. (1968). Fossil wood of *Terminalia* from Kutch. *Curr. Sci.*, **37** (8). 233.

Prakash, U. & Tripathi, P. P. (1974). Fossil woods from the Tertiary of Assam. *Palaeobotanist*, **21** (3): 305-316.

Ramanujam, C. G. K. (1956). On two new species of *Terminalioxylon* Schönfeld from the Tertiary of South Arcot District, Madras. *J. Indian bot. Soc.*, **35** (1): 103-113.

Ramanujam, C. G. K. (1958). *Palmoxylon puratanum*, a new species of petrified palms from the Tertiary rocks of South Arcot District, Madras. *J. Indian bot. Soc.*, **37** (1): 128-137.

Ramesh Rao, K. R. & Purkayastha, S. K. (1972). *Indian Woods*. III. Delhi.

Rao, A. R. & Menon, V. K. (1964). On a new specimen, probably of *Palmoxylon sundaram* Sahni from Mohgaon Kalan, Madhya Pradesh. *Proc. Indian Acad. Sci.*, **59B**: 137-144.

Reyes, L. J. (1938). Philippine woods. *Tech. Bull. Dep. Agric. Commerce Philipp. Isl.*, 7: 27-449.

Sahni, B. (1943). A new species of petrified palm stems. *Palmoxylon sclerodermum* sp. nov. from the Deccan Intertrappean Series. *J. Indian bot. Soc.*, **72**: 209-224.

Sahni, B. (1964). *Revisions of Indian Fossil Plants. Part III— Monocotyledons. Monograph.* Birbal Sahni Institute of Palaeobotany, Lucknow, 1-89 pp.

Schenk, A. (1882). Die von den Gebrüdern Schlagintweit in Indien gesammelten fossiles Hölzer. *Engl. Bot. Jahrb.*, **3** (4): 353-358.

Schenk, A. (1883). Fossile hölzer in Zittal. K. A., Beitrage zur Geologie und Palaeontologie der Libyschen Wüste. III. *Palaeontographica*, **30**: 3-17.

Schönfeld, G. (1947). Hölzer aus dem Tertiär von Kolumbien. *Abh. senckenb. naturforsch. Ges.*, **475**: 1-53.

Schoute, J. C. (1912). Ueber das Dickenwachstum der Palmen. *Ann. Jard. Bot. Buitenzorg 2nd ser.*, **11**: 1-209.

Schuster, J. (1910). Über Nicolien und Nicolien Ähnliche Hölzer. *Kungl. svenska VetenskAkad. Handl.*, **45** (6): 1-18.

Sheikh, M. T. & Kolhe, P. D. (Mrs) (1980). Fossil wood resembling *Sterculia* from Deccan Intertrappean beds of Mahurzari. *Botanique*, **9** (1-4): 77-82.

Sukieman, S. (1977). Sur deux bois fossiles du gisement de la région Pachitan a Java. *Compte Rendus* 102^{e} *Congr. nat des Soc. sav. Limoges, Sciences, fasc.* **1**: 197-209.

Stenzel, K. G. (1904). Fossile Palmenholzer. *Beitr. Paläont. Geol. Öst. Ung.*, **16**: 106-287.

Trivedi, B. S. & Ahuja, M. (1978). *Sterculioxylon kalagarhense* sp. nov. from Kalagarh (Bijnor District), U.P., India. *Curr. Sci.*, **47** (1): 24-25.

Trivedi, B. S. & Ahuja, M. (1980). *Dipterocarpoxylon nungarhense* n. sp. from Kalagarh (Bijnor District), India. *Palaeobotanist*, **26** (3): 221-225.

Trivedi, B. S. & Chandra, R. (1971). *Palmoxylon splendidum* sp. nov. from the Deccan Intertrappean beds of Keria, M.P., India. *J. Indian bot. Soc.*, **50**: 349-355.

Trivedi, B. S. & Surange, S. R. (1969). *Palmoxylon cordatum*, a new species of petrified palm stem from the Deccan Intertrappean series of India. *Palaeobotanist*, **17** (3): 258-264.

Unger, F. (1859). Der versteinerte Wald bei Cairo und einige andere Lager verkieselten Holzes in Aegypten. *Sitzber. Akad. Wiss. Wien.*, **33**: 209-232.

Willis, J. C. (1973). *A Dictionary of the Flowering Plants and Ferns.* Eighth edn. revised by H. K. Airy Shaw, Cambridge.

EXPLANATION OF PLATES

Plate 1

Dipterocarpoxyoln malavii Ghosh & Ghosh, 1959

1. Cross section at low magnification showing the distribution of vessels, gum canals and xylem rays. × 7. Slide no. 6619.
2. Cross section magnified to show the nature and distribution of vessels, gum canals, xylem rays and parenchyma. × 50. Slide no. 6619.
3. Tangential longitudinal section showing the type and distribution of xylem rays. × 60. Slide no. 6620.
4. Radial longitudinal section showing heterocellular xylem rays. × 140. Slide no. 6621.

Dipterocarpoxylon pondicherriense Awasthi, 1974

5. Cross section at low magnification showing the distribution of vessels, gum canals, xylem rays and parenchyma. × 7. Slide no. 6622.

Plate 2

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

6. Cross section showing the nature and distribution of vessels, gum canals, xylem rays and parenchyma. × 10. Slide no. 6624.
7. A portion of cross section magnified to show the nature and distribution of vessels, parenchyma and xylem rays. × 30. Slide no. 6624.
9. Tangential longitudinal section showing uniseriate to multiseriate rays and storied parenchyma strands. × 50. Slide no. 6625.
10. Intervessel pits. × 600. Slide no. 6625.

Dipterocarpoxylon pondicherriense Awasthi, 1974

8. Tangential longitudinal section showing the type and distribution of xylem rays. × 60. Slide no. 6623.

PLATE 3

Terminalioxylon felixii Ramanujam, 1956

11. Cross section at low magnification showing the distribution of vessels, parenchyma, rays and growth rings. × 15. Slide no. 6626.
12. Tangential longitudinal section showing the nature and distribution of rays. × 120. Slide no. 6627.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll, 1973

13. Cross section at low magnification showing growth rings and nature and distribution of vessels, parenchyma and rays. × 15. Slide no. 6628.
14. Tangential longitudinal section showing the nature and distribution of xylem rays. × 120. Slide no. 6629.

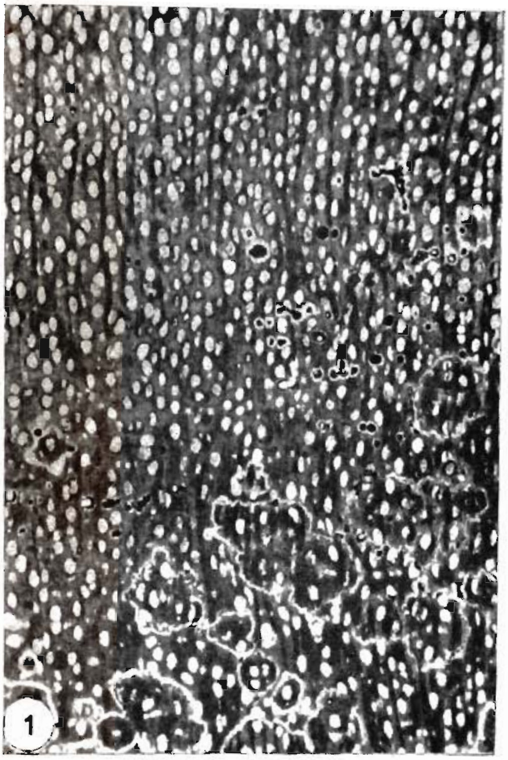
Palmoxylon kachchhensis sp. nov.

15. Cross section of the specimen, slightly enlarged than natural size.
16. Magnified cross section showing the nature of ground tissue. × 35. Slide no. 6630.

PLATE 4

Palmoxylon kachchhensis sp. nov.

17. Cross section of the outer zone showing the size, shape, orientation and general distribution of the fibrovascular bundles. × 8. Slide no. 6630.
18. Magnified cross section showing relatively thick-walled radial plate-like structure. × 30. Slide no. 6630.
19. Cross section of inner zone showing the size, shape, orientation and general distribution of the fibrovascular bundles. × 8. Slide no. 6630.
20. A fibrovascular bundle from the inner zone with tabular parenchyma. × 30. Slide no. 6630.
21. Magnified cross section of the inner zone showing the type and orientation of the fibrovascular bundles and the ground tissue. × 20. Slide no. 6630.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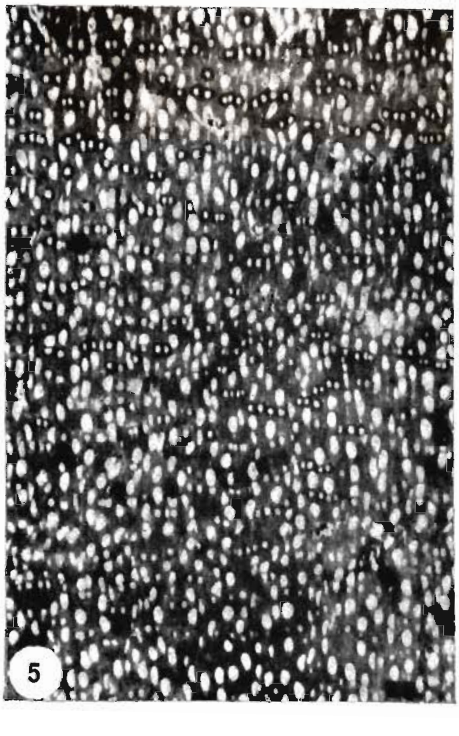
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PLATE 1

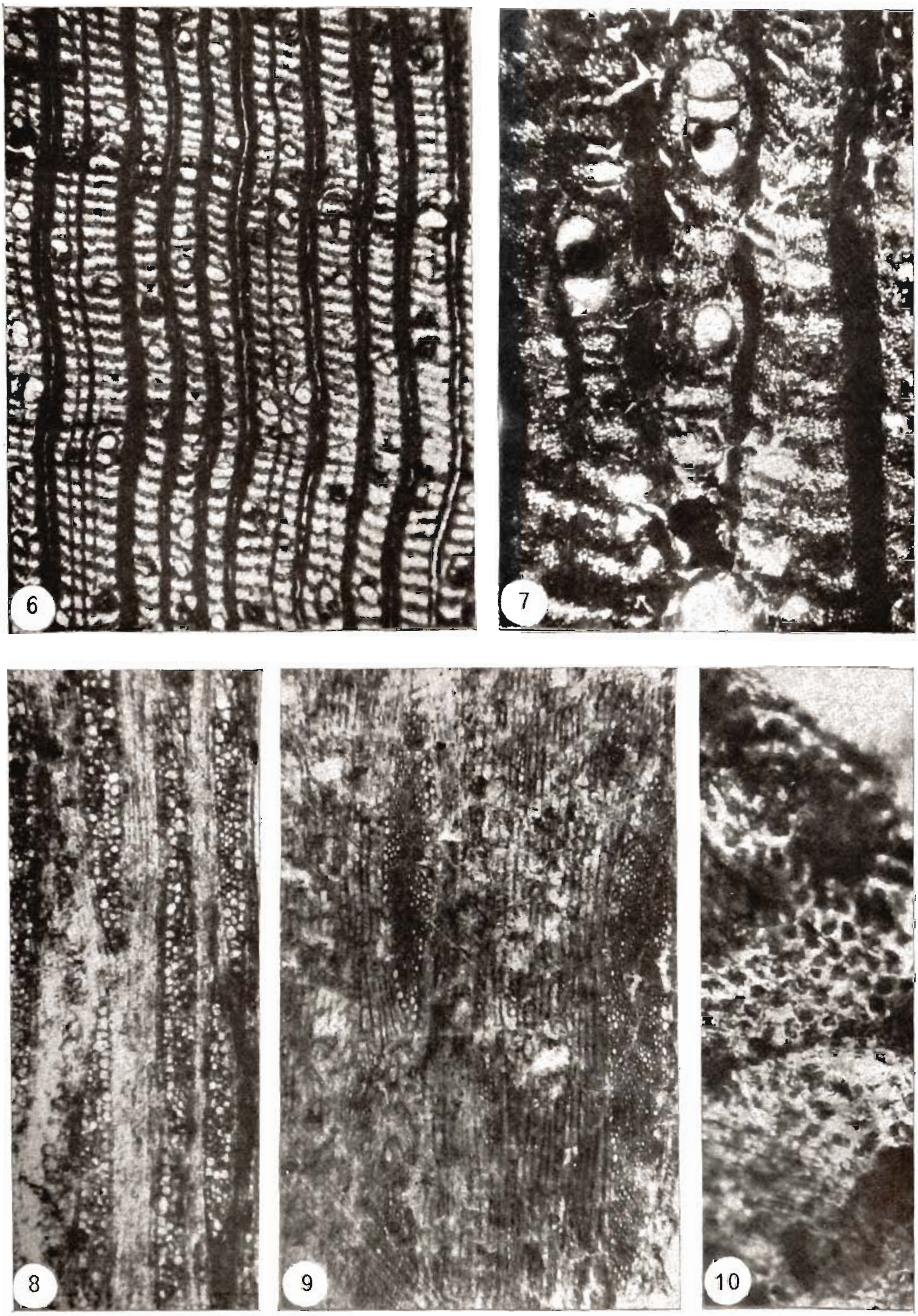
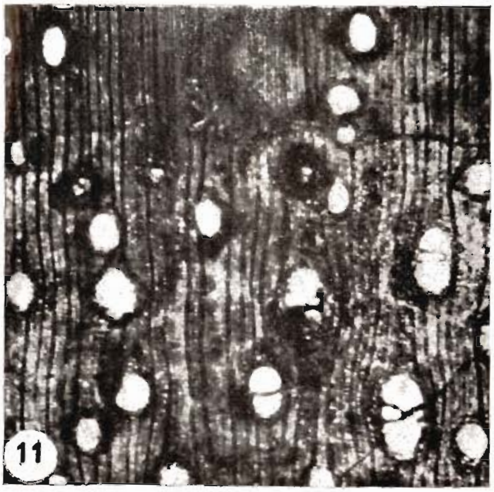


PLATE 2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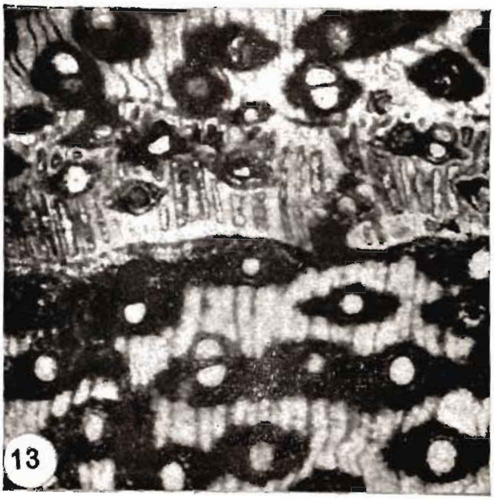
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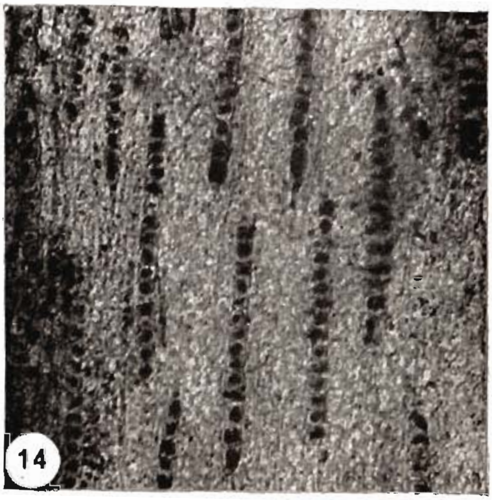
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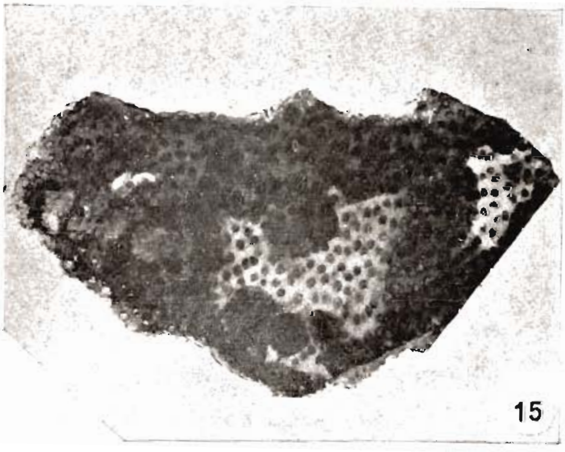
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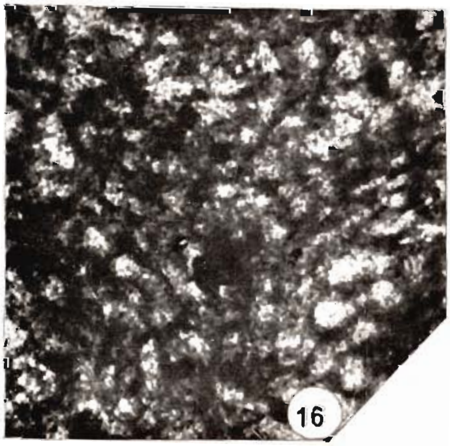
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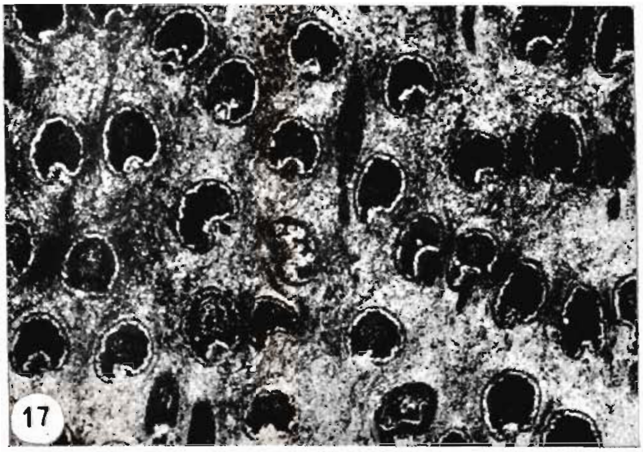
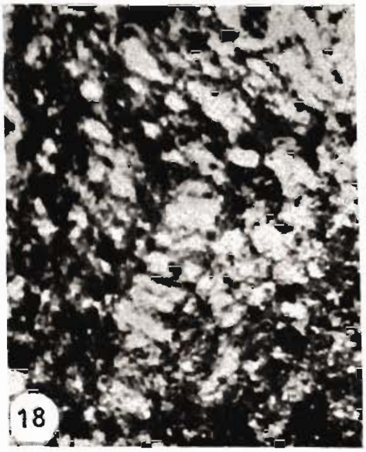
PLATE 3





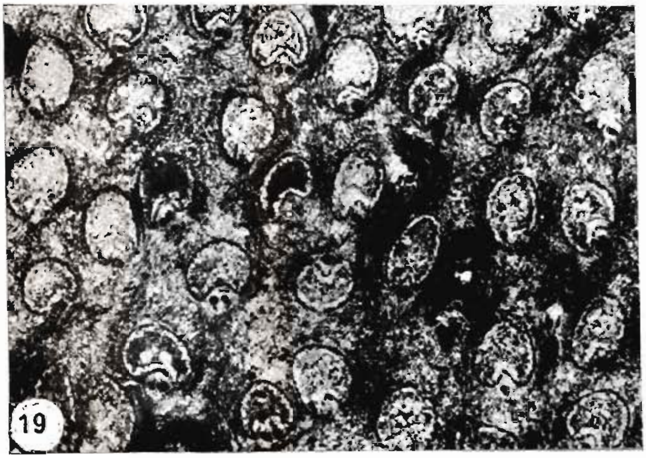


PLATE 4

The Palaeobotanist, 31(2): 129-142, 1983.

MICROBIOTA FROM VINDHYAN SUPERGROUP OF THE KARAULI-SAPOTRA REGION OF NORTH-EAST RAJASTHAN, INDIA

P. K. MAITHY & J. MANDAL

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

ABSTRACT

Microbiota comprising algae, acritarcha and a few taxa of unassignable affinities from the Semri, Rewa and Bhander groups of Vindhyan Supergroup in Karauli-Sapotra area is recorded. The assemblage comprises eleven genera of algae and four genera of acritarcha. Of these, two genera, viz., *Saccifera* and *Vindhyacapsiopsis* are new. The microbiota assemblage shows gradual increase in morphological complexity from older to younger horizons, though the number of forms are scanty.

Key-words — Microbiota, Algae, Acritarcha, *Saccifera*, *Vindhyacapsiopsis*, Karauli-Sapotra area, Vindhyan Supergroup, India.

साराँश

उत्तर-पूर्व राजस्थान (भारत) में करौली-सपोत्रा क्षेत्र के विंध्य महासमूह से प्राप्त सूक्ष्मजीविता – प्रभात कुमार माइती एवं जगन्नाथ प्रसाद मंडल

करौली-सपोत्रा क्षेत्र में विंध्य महासमूह के सेमरी, रीवा एवं भन्डेर समूहों से एक्रीटार्कों, शैवालों एवं अनिश्चित सजातीयताओं के कुछ वर्गकों से युक्त सूक्ष्मजीविताएें अभिलिखित की गयी हैं। इस समुच्चय में शैवालों के 11 वश तथा एक्रीटार्कों के चार वंश विद्यमान हैं। इनमें से दो वंश अर्थात् सैक्किफेरा एवं विंध्यकैप्सिऑप्सिस नवीन हैं। सूक्ष्मजीविता समुच्चय में हालाँकि प्रारूपों की संख्या कम है लेकिन प्राचीनतर से लेकर कम आयु के संस्तरों तक आकारिकीय जटिलना में उत्तरोत्तर वृद्धि व्यक्त होती है।

INTRODUCTION

The biota from the Vindhyan succession of North-east Rajasthan (Kotah-Karauli section) was reported earlier by Salujha, Rehman and Rawat (1971b). The recorded assemblage was dominated by acritarcha only. The present paper deals with the microbiota comprising mainly algae, acritarcha and other problematical remains previously unrecorded from this region.

STRATIGRAPHICAL SUCCESSION

The following is the stratigraphical succession of Vindhyans in the Karauli-Sapotra area, North-east Rajasthan (Dutta, Singh & Sinha, 1974-76 in Banerjee & Sinha, 1981).

UPPER VINDHYAN	
Bhander	Upper Bhander sandstone Sirbu shale Lower Bhander sandstone Semaria Shale and limestone (stromatolitic)
Rewa	Upper Rewa sandstone Jhiri shale (with limestone band) Lower Rewa sandstone Panna shale
Kaimur	Sandstone gritty and conglomeratic at base
- - - - - - Unconformity - - - - - -	
LOWER VINDHYAN	
Semri	Tirohan Breccia with porcellanites and conglomerate Tirohan limestone with stromatolite Basal Shale and conglomerate
- - - - - - GWALIORS - - - - - -	

MATERIAL AND METHODS

All the 20 samples were collected from outcrops. Organic matter was found in almost all of them. However, only 9 samples were suited better for study due to good preservation. The details of the samples is given below:

Study of samples is based on thin sections of about 30 μm thickness cut parallel to lamination, maceration residues and the residue of samples recovered after the rock in ultrasonic vibrator. For optical shaking study the method proposed by Pflug and Maithy (1977) has been followed.

No.	Sample No.	Locality	Nature of Rocks
		UPPER BHANDER SANDSTONE	
1.	16	2 km North of Karauli on Hinduan Road (Pachna Nala Section)	Siltstone and shale
		SIRBU SHALE	
2.	7	Opposite to locality of sample no. 6 in Karisal Bandh	Red coloured shale
		SEMARIA SHALE	
3.	17	Near wall of Ranipura, south-east of Karauli 26°28′40″: 77°00′40″	Stromatolitic limestone
		LOWER BHANDER SANDSTONE	
4.	14	Near Birwas Temple 26°28′55″: 76°48′30″	Red coloured sandstone
		JHIRI SHALE	
5.	18	Kota Village 26°26′40″: 76°55′30″	Red coloured sandstone
6.	13	Near Birwas Temple 26°26′55″: 76°48′30″	Chokolate brown shale
7.	12	Birwas Temple in Bajna Village	Shale and limestone
		PANNA SHALE	
8.	11	Bapoti Village, North of Sapotra 26°18′: 76°45′50″	Shale
9.	5	South of Sapotra 26°17′15″: 76°45′50″	Shale
		TIROHAN LIMESTONE	
10.	20	North-west of Kurgaon on Kurgaon-Gangapur city Road 26°27′50″: 76°51′30″	Limestone
11.	19	Mehrauli Village near Kota 26°25′40″: 76°54′30″	Limestone
12.	15	In a well on Sapotra-Gangapur Road near Dikoli Village 26°25′24″: 76°47′30″	Limestone
13.	10	Location opposite to sample no. 9	Limestone with cherty band
14.	9	West of Sapotra on Road side (west of Tirshanpura) 26°18′24″: 76°45′	Limestone with cherty band
15.	8	Dhulwasa Village	Limestone
16.	6	Karisal Bandh near Spilway 26°16′: 76°46′30″	Stromatolitic limestone
17.	4	Jirota Village, 26°17′55″: 76°39′10″	Upper Limestone band
18.	3	do	Lower Limestone band
19.	2	Naraoli Village	Limestone band
20.	1	Naraoli Fort, 26°19′45″: 76°38′55″	Shale band below Tirohan Breccia

SYSTEMATIC DESCRIPTION

Division — Cyanophyta
Class — Cyanophyceae
Order — Chroococcales
Family — Chroococcaceae

Genus — *Myxococcoides* Schopf, 1968

Type Species — *Myxococcoides minor* Schopf, 1968

Myxococcoides psilata n. sp.

Pl. 1, fig. 1

Diagnosis — Cells spherical, angular to ellipsoidal due to mutual compression, compactly aggregated in a globular colony up to 16 cells, 21-25.3 μm in diameter; cells 5.5-6.2 μm in diameter (on 6 cell count), thin-walled and smooth; extremely thin, hyaline sheath present around the colony; individual cells not ensheathed.

Etymology — With reference to smooth surface texture of cell.

Horizon — Panna Shale, Rewa Group.

Locality — Bapoti Village.

Holotype — Pl. 1, fig. 1; slide no. 6257 in macerated residues.

Comparison — *Myxococcoides psilata* n. sp. differs from all the known species of this genus due to thin-walled cells with smooth surface texture. Moreover, it is characterized by extremely thin sheath surrounding the colony. *M. konzalovae* Muir (1976) is morphologically similar to the present form in possessing nondeterminable enveloping sheath, but differs in having globular cells and the presence of common walls in between adjacent cells. *M. indicus* Venkatachala *et al.* (1974) is comparable due to its thin-walled cells but differs due to smaller size of the cells and the presence of distinct thin encircling sheath. *M. elongatus* Venkatachala *et al.* (1974) differs in having filamentous habit. *M. minor* Schopf (1968) and *M. reticulata* Schopf (1968) differ in being larger in size and the presence of thick sheath around the colony. Moreover in both species the cells have distinct ornamentation on surface. *M. inornata* Schopf (1968) agrees due to unornamented surface but differs due to large size of cells.

Genus — *Nanococcus* Oehler, 1977

Type Species — *Nanococcus vulgaris* Oehler, 1977.

Nanococcus vulgaris Oehler, 1977

Pl. 1, fig. 2

Description — Spherical cells, clumped irregularly in a loose colony, surrounded by a mucilagenous sheath. Cells rarely form small cluster. Up to 24 cells are counted in a colony. Cells measure 1.5-5.5 μm in diameter (16 cells counted; average 3.3 μm), surface texture smooth, margin thick; sheath around the individual cell absent.

Locality — Near Bapoti Village.

Horizon — Panna Shale, Rewa Group.

Figured Specimen — Slide no. 6258 in macerated residue.

Genus — *Corymbococcus* Awramik & Barghoorn, 1977

Type Species — *C. hodgkissii* Awramik & Barghoorn, 1977.

Corymbococcus vindhyanensis n. sp.

Pl. 1, fig. 3; Pl. 2, fig. 12

Diagnosis — Cells spheroidal to ellipsoidal, smooth, loosely and irregularly arranged in globular to oval colony within a non-lamellated amorphous sheath. Cells rarely arranged in diad and tetrad. Individual cells not ensheathed. Colony large, up to 50 cells in one colony. Diameter of cells 1.5-5.5 μm (commonly 1·5-2 μm), margin thick and rarely a black spot present in the centre of cell.

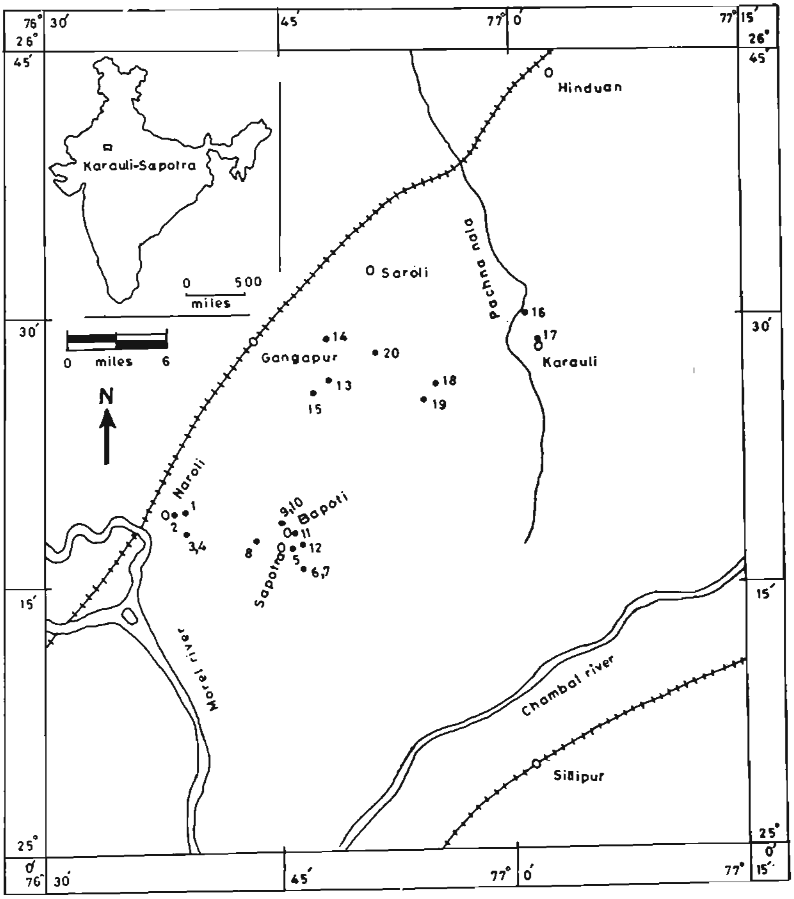
Etymology — With reference to occurrence in Vindhyan Supergroup.

Locality — Near Ranipura.

Horizon — Upper Bhander Sandstone, Bhander Group.

Holotype — Pl. 1, fig. 3; slide no. 6253 in thin section.

Comparison — *Corymbococcus vindhyanensis* sp. nov. differs from *C. hodgkissii* Awramik & Barghoorn (1977) recorded from the Gunflint stromatolite due to smaller size and smooth surface texture of cells.



MAP 1 — Map showing sampling localities.

Genus — *Sphaerophycus* Schopf, 1968

Type Species — *Sphaerophycus parvum* Schopf, 1968.

Sphaerophycus medium Horodyski & Donaldson, 1980

Pl. 2, figs 13-15

Description — Microfossils spherical to ellipsoidal, 2.2 to 6 μm without any enveloping sheath; mostly isolated, occasionally in diad, tetrad or closely and irregularly aggregate in small groups; a dark black spot 0.2 to 0.5 μm present in the centre of the cell. Surface texture smooth, marginal region thick, less than 1 μm and without any fold. In diad and tetrad position walls between the adjacent cells appear to be common.

Locality — South of Sapotra Town.

Horizon – Panna Shale, Rewa Group.

Figured Specimen — Slide no. 6255 in macerated residues.

Remark — *Sphaerophycus medium* is common in occurrence in various horizons from the Karauli-Sapotra area.

Genus — *Gloeocapsamorpha* Zalessky, 1916

Type Species — *Gloeocapsamorpha prisca* Zalessky, 1916.

Gloeocapsamorpha karauliensis Maithy & Mandal, 1982

Pl. 1, fig. 4

Description — Cells 2.3-7.8 μm, spherical, oval or angular due to mutual compaction, aggregated in a colony; daughter colony and cells within colony ensheathed by a non-lamellated amorphous sheath. Individual colony measuring up to 40 μm. Division of cells common and occur in two directions. Occasionally a large colony formed by a number of small groups of cells.

Locality — Near wall of Ranipura, South east of Karauli.

Horizon — Semaria Shale, Bhander Group.

Figured Specimen — Slide no. 5993 in macerated residues.

Genus — *Gloeodiniopsis* Schopf, 1968

Type Species — *G. lamellosa* (Schopf) Knoll & Golubic, 1979.

Gloeodiniopsis lamellosa (Schopf) Knoll & Golubic, 1979

Pl. 1, figs 5, 6; Pl. 2, fig. 30

Description — Cells commonly in groups, spherical to angular, measuring 1.2-6.5 μm in diameter (average 2.9 μm, 19 cells counted) surface texture psilate; groups globular or in the form of a chain, laterally flattened, 2-19 cells in each group which may be of different sizes; cells with sheath 7.5-19.8 μm in diameter (15 cells counted); sheath nearly hyaline, thin (coarsely granulated), broad and nonlamellated.

Locality — Bapoti Village.

Horizon — Panna Shale, Rewa Group.

Figured Specimens — Slide nos. 6249 and 6250 in thin section.

Remarks — Abundant and the only type of microfossils is present in the sample. The form is commonly found with distinct enveloping sheath. However, occasionally various stages of disintegration of sheath are seen. In the absence of sheath (Pl. 1, fig. 5) the form looks similar to the *Sphaerophycus* Schopf (1968). Since the transitory stages from sheath to non-sheath forms are present, therefore, the forms have been described under *Gloeodiniopsis*. However, this taxon is only found in thin section and could not be isolated by other techniques.

FAMILY — ENTOPHYSALIDACEAE

Genus — *Vindhyacapsiopsis* gen. nov.

Type Species — *Vindhyacapsiopsis bhanderensis* gen. et sp. nov.

Generic Diagnosis — Cells clumped together in a rectangular colony, ensheathed within an amorphous gelatinous mass; 4-6 cells in each vertical row arranged in opposite pairs; cells spherical or other shapes due to compression, individual cells not ensheathed.

Etymology — With reference to Vindhyan Supergroup.

Comparison — *Vindhyacapsiopsis* gen. nov. compares to *Myxococcoides* Schopf (1968), *Palaeoanacystis* Schopf (1968), *Corymbococcus* Awramik & Barghoorn (1977), *Nanococcus* Oehler (1977) and *Eoentophysalis* Hofmann (1976) due to colonial arrangement of cells enclosed in a sheath. *Myxococcoides* and *Palaeoanacystis* have globular colonies. In *Corymbococcus* the cells are loosely and irregularly arranged. *Nanococcus* is an irregularly arranged compact colony. *Eoentophysalis* differs due to palmelloid colony. Moreover, the cells are arranged in irregular clusters. In none of these genera, the arrangement of cells are in opposite pairs and in the form of rectangular colony. Hence, a new generic name is proposed here.

Similar looking form has been described earlier by Licari, Cloud and Smith (1969) as *Eucapsis* (?) from the Proterozoic of Queensland. This form was considered by them to be comparable with the modern algae *Eucapsis*. However, in *Vindhyacapsiopsis* the cells are arranged in more than one erect vertical rows and the colony is encircled by a common mucilage, however, the individual cells are uncovered. Hence, the genus has been included in Entophysalidaceae which has appearance like *Chlorogloea* Wille.

Vindhyacapsiopsis bhanderensis n. sp.

Pl. 1, fig. 7

Diagnosis — Cells arranged in vertical row in a rectangular colony, equal in size, measuring 2 to 2.5 μm in diameter (on 11 counts) surface texture smooth. Colony 16.5 μm long and 11 μm broad, up to 22 cells observed in a colony.

Etymology — With reference to the Bhander Formation from where the sample was collected.

Locality — North of Karauli Village.

Horizon — Upper Bhander Sandstone, Bhander Group.

Holotype — Pl. 1, fig. 7 in slide no. 6254 in macerated residue.

FAMILY — NOSTOCACEAE

Genus — *Gunflintia* Barghoorn, 1965

Type Species — *Gunflintia minuta* Barghoorn, 1965.

Gunflintia sp.

Pl. 1, fig. 8

Description — Trichome fragmentary, multicellular, uniseriate and unbranched; septae distinct, 6 μm apart, more or less uniformly placed. Cells elongated apparently without any sheath; apical cell rounded. Trichome 4.5 μm wide.

Remarks — Single well-preserved filament was observed in macerated sample of stromatolitic chert. Filament is broader than *G. minuta* Barghoorn. Furthermore, it does not show any constriction at the septae.

Locality — Near Spillway of Karisal Bandh.

Horizon — Tirohan Limestone, Semri Group.

Figured Specimen — Slide no. 6251 in macerated residues.

Division — ?Cyanophyta
Class — ?Chroococcales
Family — ?Chroococcaceae

Genus — *Palaeoglaucocystis* Maithy & Mandal 1982 emend.

Type Species — *Palaeoglaucocystis ghoshii* Maithy & Mandal, 1982.

Palaeoglaucocystis ghoshii Maithy & Mandal, 1982

Pl. 1, figs 9, 10

Emended Diagnosis — Cells spherical isolated or in loose groups; outer layer of cell uniform in thickness, lamellated and occasionally with vertical thickenings connecting inner layer; vertical thickenings may extend beyond the outer layer giving a sinuous margin; inner portion of cell thick with many short or long vertical parallel running thickenings giving reticulate appearance. Cells not enclosed within a sheath, but sometimes may be adhered to a matrix sheet. Reproduction by fission and budding (?). Cell division in single plane.

Palaeoglaucocystis was erected by Maithy and Mandal (1982). Recent examination of a large number of specimens reveals that the following characters were not observed in earlier specimen: (i) cells not enclosed within the sheath, (ii) and connection of outer layer with inner portion of cell by vertical rod-like thickenings. Therefore, the same are incorporated here.

INCERTAE SEDIS

Genus — *Archaeorestis* Barghoorn, 1965

Type Species — *A. schreiberensis* Barghoorn, 1965.

Archaeorestis sp.

Pl. 1, fig. 11

Description — Trichome slender, non-septate, tubular and possibly branched. Filament walls not parallel, occasionally lateral walls with zig-zag bulbose swellings. Filament maintains more or less constant diameter about 1 μm except at the swellings. The length extends up to 80 μm. Sheath absent.

Remarks — Single filament is recovered from the macerated residue. It is morphologically similar to *A. schreiberensis* Barghoorn, 1965 (in Tyler & Barghoorn, 1965), but is more slender. Hence, it is described as *Archaeorestis* sp.

Locality — Near Spillway of Karisal Bandh.

Horizon — Sirbu Shale, Bhander Group.

Figured Specimen — Slide no. 6260 in macerated residues.

Genus — *Saccifera* gen. nov.

Type Species — *Saccifera tirohanensis* sp. nov.

Diagnosis — Solitary or group of 2-4 cells enclosed in a broad, thick, fibrilar amorphous envelope.

Comparison— A large number of ensheathed colonial forms are known, viz., *Myxococcoides* Schopf (1968), *Palaeoanacystis* Schopf (1968), *Corymbococcus* Awramik & Barghoorn (1977), *Nanococcus* Oehler (1977), *Gloeocapsamorpha* Zalessky (1916) (see in Eisenack, 1960) and *Vindhyacapsiopsis* gen. nov. The present form differs from all of them in having a colony of only few cells enclosed in a very thick fibrilar amorphous envelope. Such form with distinct thick fibrilar envelope has so far not been recorded from Precambrian. As such it is not referable to any known group.

Binda (1972) reported similar looking dark spheroids from Zaire, but there is no evidence of the presence of cells within the envelope. He compared the structure with *Protoleiosphaeridium*.

Saccifera tirohanensis n. sp.

Pl. 2, figs 16-18

Diagnosis — Cells dark brown, angular to spherical, psilate, 2-3.5 μm with thick margin, solitary or up to 4 cells arranged in a group; cells enclosed in a thick fibrilar amorphous sheath, 9-30 μm in diameter (commonly within 21-24 μm).

Etymology — With reference to the Tirohan Formation of Vindhyan Supergroup.

Locality — Naraoli Fort.

Horizon — Tirohan Limestone, Semri Formation.

Holotype — Pl. 2, fig. 17 in slide no. 6251 in macerated residues after shaking in ultrasonic vibrator.

Remarks — Sheath is very thick and the cells are only visible after prolong acid treatment or by breaking the fibrilar sheath with the help of vibrations of ultrasonic vibrator. Therefore, the information on the cells morphology is limited though this form is abundant.

?GERMINATING CELL

Pl. 2, fig. 19

A few cells are found in macerated residues from the Lower and Upper Bhander with long (about 3.5 μm) thin structure attached with a thick-walled (about 1 μm) spherical body measuring up to 5 μm. It appears that the thin-walled structure is coming out of the thick-walled structure, i.e. as germinating stage of the cell.

Remarks — Such type of structure was observed by Edhorn (1973) from the Animikie Formation of Ontario, which she described as germinating condition of akinite. Cloud, Licari, Wright and Troxel (1969) figured a specimen (Pl. 1, fig. 10) which is morphologically similar to the present form. According to them it was a Chrysophycean cyst or statospore in germinating condition. Unfortunately, the problem remains open as only a few specimens are present in our collection. However, cells with inner large spot can be superficially compared with *Caryospheroides* Schopf.

Occurrence — Near Birwas Temple (Lower Bhander Sandstone Formation) and from 2 km north of Karauli on Hinduan Road (Upper Bhander Sandstone Formation).

Figured Specimen — Slide no. 6259 in macerated residues.

?BUDDING CELL

Pl. 2, figs 20-22

A few isolated, spherical to ellipsoidal budding cells are recorded in the Lower Bhander Sandstone Formation. These cells are 4.4-8.5 μm in diameter, smooth surface and devoid of any sheath. Each cell contains a dark body occupying ±1/2 to inner area of cells. These cells show different stages of cell division. The specimen figured in Pl. 2, fig. 21 shows a small protuberance of cell. The inner mass also expands from cell and protrudes into two cells nearly equally divided.

Remarks — Oehler (1977, Pl. 11, fig. E) reported similar type of cell division in *Bisacculoides*. Pykhova (1973) has also photographed similar structure in *Uniporata* sp. (Pl. 2, figs 16, 18).

Locality — Near Birwas Temple.

Horizon — Lower Bhander Sandstone, Bhander Group.

Figured Specimens — Slide nos. 6261 and 6263 in macerated residues.

Group — Acritarcha Evitt, 1963
Subgroup — Sphaeromorphitae Downie, Evitt & Sarjeant, 1963

Genus — *Protoleiosphaeridium* Timofeev, 1959

Type Species — *Protoleiosphaeridium conglutinatum* Timofeev, 1959.

Protoleiosphaeridium diatretus Salujha, Rehman & Rawat, 1971

Pl. 2, fig. 23

Description — Vesicles ash coloured, spherical to subspherical, 6.5 to 11 μm (8.4 μm average), exine smooth, wall thin with irregular folds and cracks on surface.

Locality — South of Sapotra and from near Birwas Temple.

Horizon — Panna Shale, Rewa Formation and Lower Bhander Sandstone, Bhander Formation.

Figured Specimen — Slide no. 6262 in macerated residues.

Protoleiosphaeridium cambriense Timofeev, 1959

Pl. 2, fig. 24

Description — Vesicles ash coloured, spherical, 14.3-18.7 μm, exine smooth, wall thin, folded towards margin.

Locality — South of Sapotra (near Birwas Temple).

Horizon — Panna Shale, Rewa Group.

Figured Specimen — Slide no. 6262 in macerated residues.

Protoleiosphaeridium densum Maithy, 1975

Pl. 2, fig. 25

Description — Vesicles spherical, 16.5 μm, wall thick about 0.3 μm, exine smooth.

Occurrence — (i) South of Sapotra and near Birwas Temple (Bhander Sandstone), (ii) South of Sapotra (Panna Shale and Jhiri Shale), and (iii) near Birwas Temple (Lower Bhander Sandstone).

Figured Specimen — Slide no. 6263 in macerated residues.

Genus — *Kildinella* Sepeleva & Timofeev, 1963

Type Species — *Kildinella giperboreica* Sepeleva & Timofeev, 1963.

Kildinella sp.

Pl. 2, fig. 26

Description — Vesicle solitary, spherical, folded, 40.5 μm; exine smooth, thin.

Locality — Near Bapoti Village (North of Sapotra).

Horizon — Panna Shale, Rewa Group.

Figured Specimen — Slide no. 6257 in macerated residue.

Genus — *Orygmatosphaeridium* Timofeev, 1959

Type Species — *O. ruminatum* Timofeev, 1959.

Orygmatosphaeridium plicatum Maithy & Shukla, 1977

Pl. 2, fig. 27

Description — Vesicle spherical, 66.5 μm in diameter, thin, surface pitted, pits small, closely and irregularly distributed all over, about 1-3 pits per micron, irregular folds at margin.

Locality — Near wall of Ranipura, South-east of Karauli.

Horizon — Semaria Shale, Bhander Group.

Figured Specimen — Slide no. 6265 in macerated residue.

Genus — *Granomarginata* Naumova, 1960

Type Species — *Granomarginata prima* Naumova, 1960.

Granomarginata minuta Maithy, 1975

Pl. 2, fig. 28

Description — Vesicles spherical, 12.2 μm, exine granulose to microbaculate, evenly distributed about 150 in number, ornamented structures less than 1 μm in height.

Locality — Near Karisal Bandh.

Horizon — Sirbu Shale, Bhander Group.

Figured Specimen — Slide no. 6260 in macerated residues.

Granomarginata prima Naumova, 1960

Pl. 2, fig. 29

Description — Vesicles in groups of 7 to 10 cells, circular, 7 to 8.5 μm in diameter

(7.7 µm in average). Exine granulose, grana small, closely set.

Locality — North of Karauli Village.

Horizon — Upper Bhander Sandstone, Bhander Group.

Figured Specimen — Slide no. 6266 in macerated residue.

DISCUSSION

The microbiota in the Karauli-Sapotra area of North-east Rajasthan are scanty. It comprises the algal remains, acritarcha and a few taxa of unassignable affinities. The algal remains are dominated by coccoid (isolated and colonial) forms. The filamentous forms are extremely rare. The isolated coccoid forms are *Sphaerophycus*, *Gloeodiniopsis* and a questionable cyanophyta *Palaeoglaucocystis*. Five genera represent the colonial forms, viz., *Vindhyacapsiopsis* n. gen., *Myxococcoides*, *Nanococcus*, *Gloeocapsamorpha*, *Corymbococcus* and *Saccifera* n. gen. The record of acritarcha is poor. Four genera and six species belonging to the subgroup ' Sphaeromorphitae ' are only known.

The distribution of biota in the succession is presented in Table 1. Most of the algal genera are restricted to a particular formation in the succession, except *Sphaerophycus medium* which has been recovered in the entire succession. In contrast, the acritarcha have been recorded only in Upper Vindhyan.

Salujha *et al.* (1971b) recorded the microbiota from the Kota-Karauli area of Rajasthan, which is dominated by acritarcha. Besides, the other elements are two genera of Chlorophyceae, trilete spores and a few fungal spores. However, the present assemblage differs in the dominance of algal remains and rarity of acritarcha. Salujha

TABLE 1 — DISTRIBUTION OF MICROBIOTA IN THE DIFFERENT SUCCESSION STUDIED

TAXON	LOWER VINDHYAN	UPPER VINDHYAN					
	Tirohan	Panna Shale	Jhiri Shale	Semaria	Lower Bhander	Sirbu Shale	Upper Bhander
Saccifera tirohanensis n. gen. n. sp.	*						
Gloeodiniopsis lamellosa (Schopf) Knoll & Golubic		*					
Myxococcoides psilata n. sp.		+					
Sphaerophycus medium Horodyski & Donaldson	+	+	+	+			+
Nanococcus vulgaris Oehler		+					+
Vindhyacapsiopsis bhanderensis n. gen. n. sp.							+
Corymbococcus vindhyanensis n. sp.				*			
Gloeocapsamorpha karauliensis Maithy & Mandal				*			
Palaeoglaucocystis ghoshi Maithy & Mandal (emend.)							*
Gunflintia sp.	+						
Archaeorestis sp.						+	
Protoleiosphaeridium diatretus Salujha, Rehman & Rawat		+			+		
P. cambriense Timofeev		+					
P. densum Maithy		+	+		+		
Orygmatosphaeridium plicatum Maithy & Shukla				+			
Granomarginata minuta Maithy						+	
G. prima Naumova							+
Kildinella sp.		+					

(* = common; + = rare).

et al. (1971a) recorded interesting microbiota from the Vindhyans of Son Valley. Their assemblage contains only acritarchs and unidentifiable remains. Therefore, a detailed comparison of both the assemblages is not possible as the algae are lacking. Maithy (1969) and Shrivastava (1972) reported microbiota from the Suket Shale Formation of Ramapura. It contains a few acritarchs and an alga. Later, Maithy and Shukla (1977) described a rich assemblage containing algae (both coccoid and filamentous) and acritarcha from the Suket Shale Formation of Ramapura. *Myxococcoides*, *Protoleiosphaeridium*, *Orygmatosphaeridium* and *Kildinella* are common in both the assemblages. The present assemblage is, however, not comparable as it represents the total Vindhyan succession of the Karauli-Sapotra area whereas the Suket Shale assemblage belongs to only one particular formation of the Lower Vindhyan.

Ghosh and Bose (1950), Jacob *et al.* (1953), Bose (1956) and Mathur (1964) described the recovery of spores and woody tissues from the Vindhyans. These records are controversial as the possibility of the occurrence of vascular plants in such older rocks is remote. However, there are more possibilities that they are either contamination from the atmosphere or from younger strata. Further, we are also of the opinion that some of the woody tissue-like elements may be animal plates (see Sah, Maithy & Bhargava, 1977, pl. 1, fig. 10).

A comparison of the microbiota recovered from the equivalent Precambrian rocks of other countries shows that the biota recorded earlier mostly contain either algae (Schopf, 1968; Schopf & Blacic, 1971; Oehler, 1977; Barghoorn & Tyler, 1965; Licari, 1978; Muir, 1976, etc.) or acritarcha (Timofeev, 1959, 1969, 1973; Timofeev *et al.*, 1976; Vidal, 1976; Binda, 1972, etc.). However, some assemblages are known with both algae and acritarcha. Maithy (1975) recorded algae and acritarchs from the BIIC of Bushimay Supergroup, Zaire. This assemblage cannot be compared in detail with the Vindhyan assemblage of Karauli-Sapotra area as the microbiota is recorded from the entire succession, whereas in Bushimay it is from only one formation. Peat *et al.* (1978) reported the assemblage containing algae and acritarcha from the Roper Group (1300 m.y.), Australia. A detailed comparison with this assemblage too is not possible as the details of biota are lacking.

REMARKS ON THE AGE OF VINDHYAN

Several opinions have been given in past regarding the age of Vindhyan. Salujha (1973) on the basis of the acritarch assemblage proposed that Upper Vindhyan extends up to Lower Palaeozoic (Early Silurian). Venkatachala and Rawat (1973) declined to accept the Cambrian-Silurian age assigned by Salujha (1973) due to (i) simplicity of morphology of the acritarcha, (ii) absence of complex spinose acritarchs, (iii) absence of true Chitinozoa, and (iv) absence of true trilete spores with morphological complexities. They suggested a Precambrian-Cambrian age to the Vindhyan sediments.

Radiometric data on the rocks of Semri and Kaimur groups are also available. Mathur (1964) by Rb-Sr method reported an age 1130 ± 20 m.y. for the Majhagawan diamond bearing pipe rock which is a intrusive into the Kaimur. Vingradov *et al.* (1964) on the basis of K-Ar method estimated that the Semri Group (Lower Vindhyan) may be between 1400 and 1100 m.y. whereas the Kaimur Group (lower part of Upper Vindhyan) to be between 940 and 910 m.y. On the basis of Rb-Sr method Crawford and Compston (1970) proposed that the age of the Vindhyan Supergroup extends over a long period from at least 1200 m.y. and possibly 1400 m.y. to perhaps 550 m.y. or even later. The base of the Upper Vindhyan is dated to about 1150 m.y. or more. Balasundaram and Balasubramanyam (1973) gave a date, i.e. 940 m.y. for Lower Kaimur host rock of Panna Kimberlite.

The present assemblage from the Vindhyan succession of Karauli-Sapotra area shows the absence of Acanthomorph acritarch which are commonly present in the Cambrian and younger sediments. The acritarch recorded from this assemblage belong to the group Sphaeromorphitae. These forms are dominant only in the Late Precambrian (Timofeev, 1973). Moreover, the recorded algal forms are so far known from Middle and Late Proterozoic. Thus the present record of biota favours the age of Vindhyan in this area not to be younger than Cambrian and possibly to be Late Proterozoic.

REFERENCES

Awramik, S. M. & Barghoorn, E. S. (1977). The Gunflint microbiota. *Precambrian Res.*, **5**: 121-142.

Balasundaram, M. S. & Balasubramanyam, M. N. (1973). Geochronology of the Indian Precambrian. *Bull. geol. Soc. Malaysia*, **6**: 213-226.

Banerjee, A. K. & Sinha, P. N. (1981). Structure and tectonics of Vindhyans in the eastern Rajasthan. "*Vindhyans of Central India*" *G.S.I. Misc. Publ.*, **50**.

Barghoorn, E. S. & Tyler, S. A. (1965). Microorganisms from the Gunflint chert. *Science*, **147**: 563-577.

Binda, P. L. (1972). Preliminary observations on the palynology of the Precambrian Katanga Sequence, Zambia. *Geologie Mijnb.*, **51** (3): 315-319.

Bose, A. (1956). Plant life in Vindhyans. *Nature*, **178**: 927-928.

Crawford, A. R. & Compston, W. (1970). The age of the Vindhyan System of Peninsular India. *Q. Jl geol. Soc. Lond.*, **125** (3): 351-371.

Cloud, P. E., Licari, G. R. (Jr.), Wright, L. A. & Troxel, B. W. (1969). Proterozoic eucaryotes from eastern California. *Proc. natn. Acad. Sci. U.S.A.*, **62** (3): 623-630.

Edhorn, Anna-Stina (1973). Further investigations of fossils from the Animikie, Thunder Bay, Ontario. *Proc. geol. Assoc. Can.*, **25**: 37-66.

Eisenack, A. (1960). Uber einige niedere Algen aus dem baltischen Silur. *Senckenberg. Leth.*, **40** (1/6): 13-26.

Ghosh, A. K. & Bose, A. (1950). Microfossils from the Vindhyans. *Sci. Cult.*, **15**: 330-331.

Hofmann, H. J. (1976). Precambrian microflora, Belcher Islands, Canada: Significance and systematics. *J. Paleontol.*, **50** (6): 1040-1073.

Jacob, K., Jacob, C. & Srivastava, R. N. (1953). Spores and tracheids of vascular plants from the Vindhyan System, India: The advancement of vascular plants. *Nature*, **172**: 166-167.

Licari, G. R. (1978). Biogeology of the Late Pre-Phanerozoic Beck Spring Dolomite of eastern California. *J. Paleontol.*, **52** (4): 767-792.

Licari, G. R., Cloud, P. E. (Jr.) & Smith, W. D. (1969). A new chroococcacean alga from the Proterozoic of Queensland. *Proc. natn. Acad. Sci., U.S.A.*, **62** (1): 56-62.

Maithy, P. K. (1969). On the occurrence of microremains from the Vindhyan Formation of India. *Palaeobotanist*, **17** (1): 48-51.

Maithy, P. K. (1975). Micro-organisms from the Bushimay System (Late Precambrian) of Kanshi, Zaire. *Palaeobotanist*, **22** (2): 133-149.

Maithy, P. K. & Mandal, J. (1982). Significance of algal remains from the Bhanders of Vindhyan Supergroup, Rajasthan. *Prof. A. K. Ghosh Comm. Volume*: 245-250.

Maithy, P. K. & Shukla, M. (1977). Microbiota from the Suket shales, Ramapura, Vindhyan System (Late Precambrian), Madhya Pradesh. *Palaeobotanist*, **23** (3): 176-188.

Mathur, S. M. (1964). Coaly matter in the Vindhyan System. *Indian miner.*, **18**: 158-165.

Muir, M. D. (1976). Proterozoic microfossils from the Amelia Dolomite, McArthur Basin, Northern Territory. *Alcheringa*, **1**: 143-158.

Oehler, D. Z. (1977). Pyrenoid-like structure in Late Precambrian algae from the Bitter Spring Formation of Australia. *J. Paleontol.*, **51** (5): 885-901.

Peat, C. J., Muir, M. D., Plumb, K. A., KcKirdy, D. M. & Norvick, M. S. (1978). Proterozoic microfossils from the Roper Group, Northern Territory, Australia. *BMR Jl Ausralia Geol. & Geophys.*, **3**: 1-17.

Pflug, H. D. & Maithy, P. K. (1977). Nachweisverfahren für organische Mikrofossilien in präkambrischen Tonschiefern. *Oberheiss. Natur. Zeit.*, **43**: 15-23.

Pykhova, N. G. (1973). Acritarchs of Precambrian sections of southern Urals, Siberia, eastern Europe Platform and their stratigraphic significance. *Proc. 3rd int. palynol. Conf., Novosibrisk (1971)* pp. 15-17. (in Russian).

Sah, S. C. D., Maithy, P. K. & Bharghava, O. N. (1977). Some significant palynomorphs from B Member of the Jutogh Formation of Simla Hills. *J. geol. Soc. India*, **18** (3): 139-145.

Salujha, S. K. (1973). Palynological evidence on the age of the Vindhyan sediments. *Proc. Indian natn. Sci. Acad.*, Part A, **39** (1): 62-68.

Salujha, S. K., Rehman, K. & Arora, C. M. (1971a). Plant microfossils from the Vindhyans of Son Valley, India. *J. geol. Soc. India*, **12** (1): 24-33.

Salujha, S. K., Rehman, K. & Rawat, M. S. (1971b). Fossil palynomorphs from the Vindhyans of Rajasthan (India). *Rev. Palaeobot. Palynol.*, **11**: 65-83.

Schopf, J. W. (1968). Microflora of Bitter Springs Formation, Late Precambrian, Central Australia. *J. Paleontol.*, **42**: 651-688.

Schopf, J. W. & Blacic, J. M. (1971). New microorganisms from the Bitter Springs Formation (Late Precambrian) of the north-central Amadens Basin, Australia. *J. Paleontol.*, **45**: 925-960.

Srivastava, R. N. (1972). Micro-organic remains from the Vindhyan Formation of India, pp. 1-4 in A. K. Ghosh *et al.* (eds) — "*Palaeopalynology and IndianStratigraphy, Calcutta (1971)*.

Timofeev, B. V. (1959). The ancient flora of Pre-Baltic and its stratigraphic significance. *Mem. VNIGRI*, **129**: 1-305 (in Russian).

Timofeev, B. V. (1969). Proterozoic sphaeromorphida. *Publ. 'NAUKA', Leningrad*: 1-146 (in Russian).

Timofeev, B. V. (1973). Proterozoic and Early Palaeozoic microfossils. Microfossils of the oldest deposits. *Proc. 3rd int. palynol. Conf., Novosibrisk (1971)*: 7-13.

Timofeev, B. V., German, T. N. & Mikhaileva, N. S. (1976). Microphyto fossils of Precambrian and Ordovician. *Acad. Sci. USSR., Publ. 'NAUKA', Leningrad*: 1-104 (in Russian).

Venkatachala, B. S. & Rawat, M. S. (1973). Organic remains from the Bhima Basin and remarks on the age of Vindhyans and subsurface sediments in the Ganga Valley. *Geophytology*, **2** (2): 107-117.

Vidal, G. (1976). Late Precambrian microfossils from the Visingo beds in southern Sweden. *Fossils & Strata*, **9**: 1-57.

Vingradov, A., Tugarinov, A., Zhykov, C., Stapnikova, N. & Bibikova, E. (1964). Geochronology of Indian Precambrian. *22nd int. geol. Cong., New Delhi*, Pt. **10**: 553-567.

EXPLANATION OF PLATES

(All the photographs are × 1000 unless otherwise stated. All the figured slides are preserved at the Museum, Birbal Sahni Institute of Palaeobotany, Lucknow).

PLATE 1

1. Two globular colonies of *Myxococcoides psilata*. Compactly arranged thin-walled cells surrounded by very thin sheath (pointed by arrow), slide no. 6257.
2. *Nanococcus vulgaris*, a colony of small spheroids surrounded by sheath, slide no. 6258.
3. *Corymbococcus vindhyanensis*, colony of irregularly arranged cells within a thick sheath, slide no. 6253.
4. *Gloeocapsamorpha karauliensis* showing arrangement of cells, slide no. 5993.

5, 6. *Gloeodiniopsis lamellosa* showing arrangement of cells. Isolated cell at left side of fig. 5 shows degraded sheath; fig. 6 shows small cell with thick sheath pointed by arrow, slide no. 6249.

7. *Vindhyacapsiopsis bhanderensis*, a group of colony showing vertical arrangement of cells in more than one rows and thick sheath around the colony, slide no. 6254.
8. *Gunflintia* sp. showing the trichome, slide no 6251.

9, 10. *Palaeoglaucocystis ghoshii* showing different exomorphic characters; fig. 9 — slide no. 5992; fig. 10 — slide no. 6264.

11. *Archaeorestis* sp., slide no. 6260.

PLATE 2

12. Grouping of cells in *Corymbococcus vindhyanensis*, slide no. 6253.

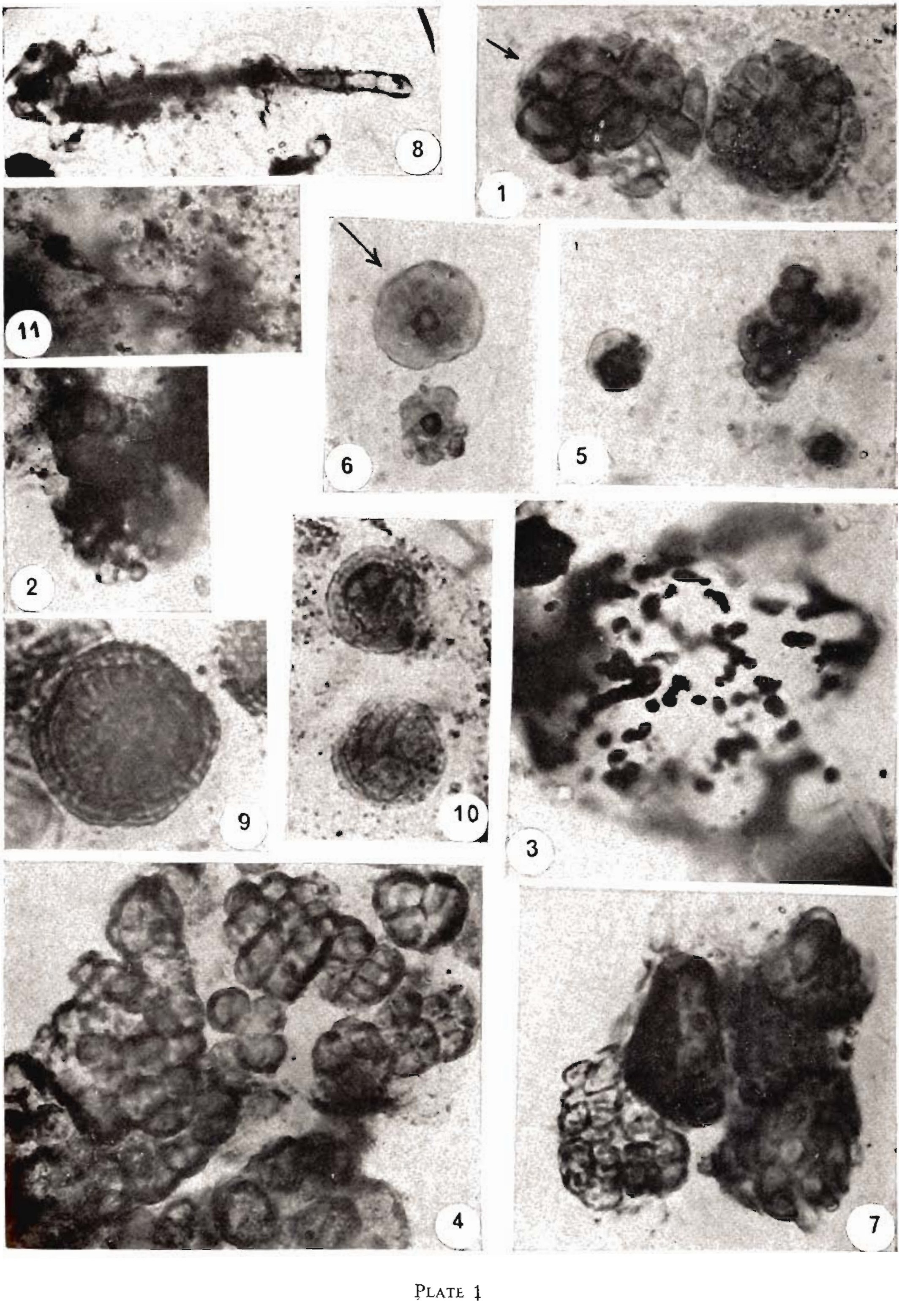
13-15. *Sphaerophycus medium* showing the different modes of arrangement and occasional dark spot at the centre, slide no. 6255.

16-18. *Saccifera tirohanensis*; fig. 16 showing the fibrilar nature of sheath and two cells at the centre, slide no. 6257; fig. 17 amorphous sheath broken after vibration following prolonged acid treatment showing three cells (arrow pointed), slide no. 6251; fig. 18 — Arrow pointing to a single cell at the centre, slide no. 6252.

19. ?Germinating cell. × 2000, slide no. 6259.

20-22. Different stages of probable budding cells, slide nos. 6162 and 6263.

23. *Protoleiosphaeridium diatretus* showing fold on surface, slide no. 6262.
24. *P. cambriense* showing irregular folds on the surface, slide no. 6262.
25. *P. densum* showing thick wall (crack at the centre), slide no. 6263.
26. *Kildinella* sp. folded specimen, slide no. 6257. × 500.
27. *Orygmatosphaeridium plicatum* showing folds at marginal region and pitted surface, slide no. 6265. × 450.
28. *Granomarginata minuta*, slide no. 6260.
29. *G. prima*, slide no. 6266.
30. *Gloeodiniopsis lamellosa*, cells arranged in chain, slide no. 6250.



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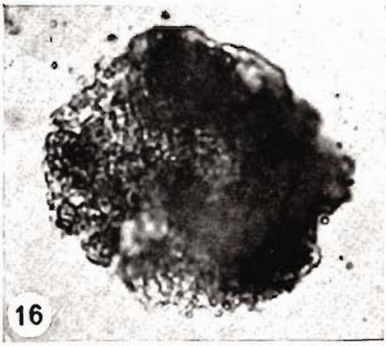
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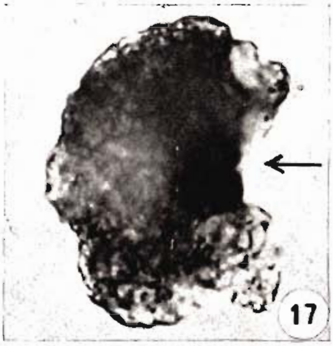
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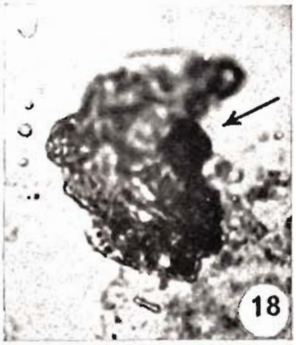
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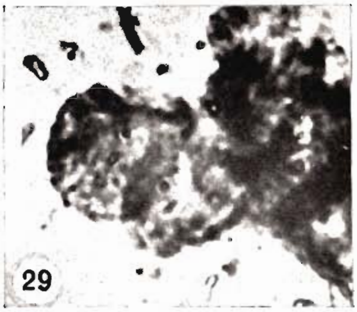
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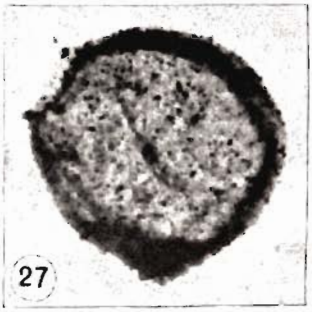
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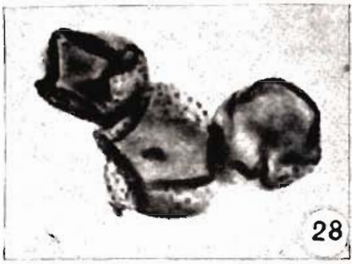
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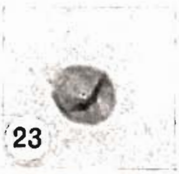
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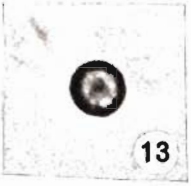
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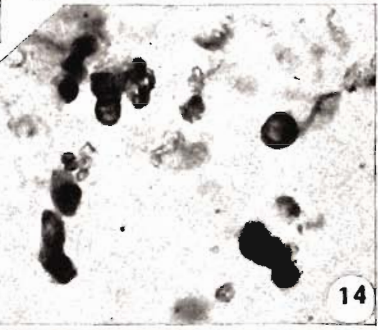
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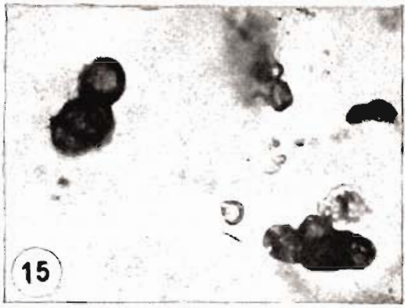
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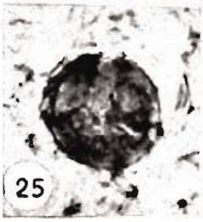
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PLATE 2

The Palaeobotanist, **31**(2): 143-147, 1983.

THE FILICALES FROM THE LOWER GONDWANAS OF HANDAPPA, ORISSA

SHAILA CHANDRA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India
&
J. F. RIGBY
Geological Survey of Queensland, P.O. Box 194, Brisbane 4001, Australia

ABSTRACT

Sterile filicalean remains from the Kamthi Formation, Handappa, Orissa are discussed. *Pantopteris gracilis* gen. et comb. nov. is proposed for fronds having large, decurrent pinnae with dichotomizing, occasionally anastomosing venation.

Key-words — Filicales, *Pantopteris*, Kamthi Formation, Lower Gondwana (India).

साराँश

उड़ीसा में हॅंडप्पा के अधरि गोंडवाना से फिलिकेल्स – शैला चन्द्रा एवं जॉन ऍफ़॰ रिगबी

उड़ीसा में हॅंडप्पा के कामथी शैल-समूह से बन्ध्य फिलिकेली अवशेष विवेचित किये गये हैं। द्विभाजी एवं यदा-कदा शाखामिलनी शिराविन्यास से युक्त बृहत् अधोवर्धी पत्रकों वाले प्रपर्णों के लिए पन्तॉप्टेरिस ग्रेसिलिस बंश व नव संयोजन प्रस्तावित किया गया है।

INTRODUCTION

PALAEOZOIC fern-like fronds referable to form genera are known from many parts of the world. In recent years some Gondwana forms have been recombined under new names on the basis of their morphologies which are distinct from Euramerican forms. As most are sterile, it is not possible to attribute them to any family within the class Pterophyta. Some of these fronds have been found with fertile structures having sporangia with spores and are described under new names, although the occurrence of such forms is rare.

The material described herein comes from a thick bed of hard, compact, buff coloured clayey shale exposed in the Hinjrida Ghati section (20°58′: 84°43′) in the Dhenkanal District of Orissa. The fossils are found as pinkish brown to maroon coloured impressions. Seventy hand specimens of ferns form the basis of this study. The study of other taxa will be presented elsewhere (Shaila Chandra, in preparation; and Shaila Chandra & Rigby, 1981).

DESCRIPTION

Form Genus — *Neomariopteris* Maithy, 1974

Type Species — *Neomariopteris polymorpha* (Feistmantel) Maithy, 1974.

1974 *Neomariopteris* Maithy, p. 70.

The lectotype for *Neomariopteris polymorpha* (Feistmantel) Maithy, 1974 is Geological Survey of India specimen 5165, selected by Surange (1966), from specimens described by Feistmantel (1876). The genus *Neomariopteris* was proposed by Maithy (1974) for fronds previously known as *Sphenopteris* when found in the Lower Gondwanas of India. Later in the same year, Pant and Khare (1974) proposed the genus *Damudopteris* for the same sphenopterid species. This specimen (no. 5165) is sterile.

Pant and Khare included the description of fertile structures in their diagnosis, based on material they had collected, but not on the type collection. If Pant and Khare had nominated one of their fertile specimens as holotype for the type species of *Damudopteris*, then this latter name may stand as the genus for some fertile species of Lower Gondwana ferns whose sterile fronds belong to the form genus *Neomariopteris*. We are convinced that some South American *Neomariopteris* species have fertile fronds distinct from the fertile fronds attributable to *Damudopteris*, e.g. the South American fertile fronds placed in *Ponsotheca* by Bernardes-de-Oliveira (1981). We propose below that *Damudopteris* be redefined and validated as one of the genera for fertile fronds having features of *Neomariopteris* when sterile.

The collection from Handappa includes two species of sterile fern fronds referable to *Neomariopteris*.

Neomariopteris hughesii (Zeiller) Maithy, 1977

Pl. 1, fig. 3

This is the first record of the species from Handappa, where it is the most common fern.

Neomariopteris khanii Maithy, 1977

Maithy (1977) also recorded this fern from Handappa.

Natural Genus — *Damudopteris* Pant & Khare, 1974 emend.

Type Species — *Damudopteris bengalensis* Chandra & Rigby sp. nov.

1974 *Damudopteris* Pant & Khare, p. 122 (in part)

Damudopteris bengalensis Chandra & Rigby sp. nov.

Lectotype — KP 7026A, Divya Darshan Pant Collection, University of Allahabad, Allahabad, India.

Diagnosis — See Pant and Khare, 1974, pp. 122, 123.

Locality & Horizon — Unknown, from the Raniganj Coalfield, West Bengal; Raniganj Formation.

This new name is proposed for specimens having fertile structures which would have been included in *Neomariopteris polymorpha* (Feistmantel) Maithy, 1977, when sterile. Because of the rarity of fertile specimens, it cannot be demonstrated that all fertile *N. polymorpha* have the same morphology. *N. polymorpha* is a species belonging to the form genus *Neomariopteris* whereas *D. bengalensis* is a species belonging to the natural genus *Damudopteris*. The specific epithet *polymorpha* has not been used as this would imply that all fertile specimens of *N. polymorpha* were *D. bengalensis*, which is completely unsubstantiated.

Pecopteris phegopteroides (Feistmantel) Arber, 1905

Pl. 1, fig. 2

Three specimens of sterile fronds were found.

We have not used Maithy's (1975) recombination *Dizeugotheca phegopteroides* (Feistmantel) Maithy as our material is sterile and the natural genus *Dizeugotheca* is reserved for fertile fern fronds. The form genus *Pecopteris* is used for certain fern and fern-like fronds of unknown affinity (Arber, 1905; Boureau & Doubinger, 1975; and elsewhere). This treatment is consistent with the argument for separating *Neomariopteris* and *Damudopteris* given above.

Genus — *Pantopteris* Shaila-Chandra & Rigby gen. nov.

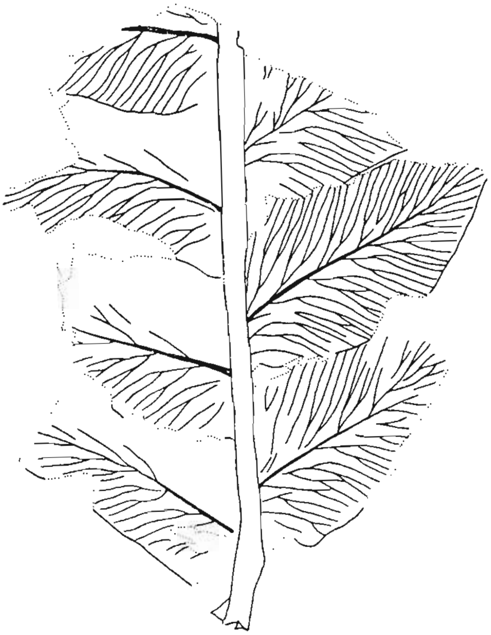
Type Species — *Pantopteris gracilis* (Lele) Shaila-Chandra & Rigby, comb. nov.

Pantopteris gracilis (Lele) Shaila Chandra & Rigby gen. et comb. nov.

Pl. 1, figs 1, 4; Text-fig. 1

1962 *Danaeopsis gracilis* Lele, p. 74, pl. 2, figs 18-20, text-figs 4-6

Holotype — Lele's specimen no. 8987, BSIP Museum, Lucknow.



TEXT-FIG. 1 — *Pantopteris gracilis* (Lele) Shaila-Chandra & Rigby, gen. et comb. nov., showing prominent pinna costa, and secondary venation with anastomoses forming occasional meshes, specimen no. 5459, × 2.

Diagnosis — Frond pinnate, rachis strong, irregularly ribbed, pinnae almost touching, subopposite, margin entire, decurrent along rachis, branching at about 60° to the rachis; inner costa prominent, extending almost to pinna apex where it breaks up into secondary venation; secondary venation twice, rarely thrice dichotomising towards pinna base, reducing to once, or rarely not dichotomising towards apex; anastomoses rare up to three in each pinna, usually basiscopically towards costa and associated with vein dichotomies but may occur anywhere, secondary venation rare in decurrent portion.

Description — In all, there are five specimens belonging to this genus in the collection. The frond is pinnate. The biggest frond which seems to be complete, measures 7.5 cm in length. The main rachis is quite strong, irregularly ribbed, up to 1.5 mm wide at the base, and without a wing. The pinnae almost touch each other. They have an entire margin, decurrent along rachis, and are subopposite. Each pinna receives a single vein from the pinna rachis which runs up to 3/4 of the pinna length and then divides into secondary venation. The pinnae are 14-32 mm in length along the midrib and 8-13 mm wide at half length. The secondary veins dichotomize twice, rarely thrice, in the basal part of the pinnae, whereas they may be unbranched towards the apical portion. There are occasional anastomoses towards the midrib, no more than five have been observed in any individual pinna.

Comparison & Discussion — Lele (1962) included two specimens of fern fragments from the Upper Triassic Parsora Formation in the genus *Danaeopsis*. We have compared our specimens with Lele's and found no characters to separate them even though our specimens come from the Upper Permian Kamthi Formation. These specimens cannot be placed in *Danaeopsis* because of the anastomoses in the pinnae venation.

Bunbury (1861, p. 332, pl. 10, fig. 1) described a fern fragment from Kamthi as "*Cladophlebis* ?". The sketch shows a few pinnae, one appearing to have a cross connection. Without inspecting the specimen, we are unable to confirm it as a record of *Pantopteris*.

The only fronds known to us that have a similar pattern of anastomoses are the morphologically dissimilar *Scoresbya* from the Jurassic of Greenland and elsewhere. Holmes (1977) based *Dunedoonia*, from the Permian of New South Wales on a fragment of a pinnate frond with pinnules lacking a midrib, but having a reticulate venation. Reticulations were frequent. A similar venation pattern occurs in the Laurasian Carboniferous genera *Linopteris* and *Lonchopteris*. The Cathaysian genus *Gigantopteris* has pseudoanastomoses caused by fusion between adjacent pinnules.

REFERENCES

ARBER, E. A. N. (1905). *Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Natural History).* British Museum, London. lxxiv+255 pp., 8 pl.

BERNARDES-DE-OLIVEIRA, M. E. C. (1981). Nouveau genre néomarioptidine fertile de la flore a *Glossopteris* du Bassin de Parana au Bresil. *Inst. Geosci., Univ. S. Paulo, Blon. 1G,* **11**: 113-119.

Boureau, E. & Doubinger, J. (1975). *Traite de Paléobotanique*, v. **4**, pt. 2, *Pteridophylla* (*First part*). Masson, Paris. 768 pp.

Bunbury, J. F. (1861). Notes on a collection of fossil plants from Nagpur, Central India. *Q. Jl geol. Soc. Lond.*, **17** (1): 325-346.

Chandra, S. & Rigby, J. F. (1981). Lycopsid, sphenopsid and cycadaceous remains from the Lower Gondwana of Handappa, Orissa. *Geophytology*, **11** (2): 214-219.

Feistmantel, O. (1876). Contributions towards the knowledge of the fossil flora in India. I. On some fossil plants from the Damuda Series in the Raniganj Coalfield, collected by Mr J. Wood-Mason. *J. Asiat. Soc. Bengal*, **45** (4): 329-382.

Holmes, W. B. K. (1977). A pinnate leaf with reticulate venation from the Permian of New South Wales. *Proc. Linn. Soc. NSW*, **102** (2): 52-57.

Lele, K. M. (1962). Studies in the Indian Middle Gondwana flora-2. Plant fossils from the South Rewa Gondwana Basin. *Palaeobotanist*, **10**: 69-83.

Maithy, P. K. (1974). A revision of the Lower Gondwana. *Sphenopteris* from India. *Palaeobotanist*, **21** (1): 70-80.

Maithy, P. K. (1975). Some contribution to the knowledge of Indian Lower Gondwana ferns. *Palaeobotanist*, **22** (1): 29-38.

Maithy, P. K. (1977). Three new fern fronds from the Glossopteris Flora of India. *Palaeobotanist*, **24** (2): 96-101.

Pant, D. D. & Khare, P. K. (1974). *Damudopteris* gen. nov.— A new genus of ferns from the Lower Gondwanas of the Raniganj coalfield, India. *Proc. R. Soc. Lond.*, **B186**: 121-135.

Surange, K. R. (1966). *Indian Fossil Pteridophytes*. C.S.I.R. Mongr. **4**. New Delhi. 209 pp.

EXPLANATION OF PLATE

1. *Pantopteris gracilis* (Lele) Chandra & Rigby, gen. et comb. nov., specimen enlarged to show anastomosing venation, decurrent pinnae and strong rachis, specimen no. 35459. × 4.
2. *Pecopteris phegopteroides* (Feistm.) Maithy, specimen no. 35452. × 1.
3. *Neomariopteris hughesii* (Zeiller) Maithy, specimen no. 35453. × 1.
4. *Pantopteris gracilis* (Lele) Shaila-Chandra & Rigby, gen. et comb. nov., specimen no. 35459. × 1.

PLATE 1

The Palaeobotanist, **31**(2): 148-153, 1983.

FUNGAL REMAINS FROM NEYVELI LIGNITE, SOUTH INDIA

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

ABSTRACT

The fungal remains recovered from Neyveli Lignite, South India include a few fungal spores as well as fruiting bodies belonging to Myxomycetes, Chytridiales, Deuteromycetes, Microthyriaceae and Ascomycetes. Attempts have been made to trace out their affinities with the present forms. The forms which are not assignable to any modern forms are kept under the artificial classification.

Key-words — Fungal remains, Myxomycetes, Chytridiales, Deuteromycetes, Microthyriaceae, Ascomycetes, Neyveli Lignite, South India.

साराँश

दक्षिण भारत के निवेली लगुडांगार से कवकीय अवशेष – कृष्ण अम्बवानी

दक्षिण भारत के निवेली लगुडांगार से उपलब्ध कवकीय अवशेषों में मिक्सोमाइसिटीज़, काइट्रिडिएल्स, ड्यूटॅरोमाइसिटीज़, माइक्रोथाइरियेसी एवं एस्कोमाइसिटीज़ से सम्बद्ध कुछ कवकीय बीजाणु तथा फलन-कायें उपलब्ध हुई हैं। वर्तमान प्रारूपों से इनकी सजातीयतायें खोजने के प्रयास किये गये हैं। जिन प्रारूपों को वर्तमान प्रारूपों से नामनीय नहीं किया जा सका, उन्हें कृत्रिम वर्गीकरण के अन्तर्गत् रखा गया है।

INTRODUCTION

WORK on the microflora of Neyveli Lignite was carried out by Navale (1961), Thiergart and Frantz (1962), and Ramanujam (1963a, 1963b). Later on Ramanujam (1966) gave a detailed illustrated account of the Neyveli Lignite pollen and spore assemblage belonging to pteridophytes, gymnosperms and angiosperms. Besides, Deb (1972) and Navale and Misra (1979) described the pollen grains of angiospermous plants from the Neyveli Lignite. In 1981, Ambwani *et al.* also reported the occurrence of pollen of *Ctenolophonidites* and later from the same beds Bande and Ambwani (1982) reported the presence of *Sclerosperma*-like pollen grains belonging to Palmae.

The present paper is based on the studies of the fungal remains from the Neyveli Lignite, South India and some noteworthy fungal forms belonging to Myxomycetes, Chytridiales, Deuteromycetes, Microthyriaceae as well as Ascomycetes have been described here. Besides, a few more fungal spores have been described under artificial classification.

Regarding the age of the Neyveli deposits it is believed as Upper Miocene or Pliocene (Krishnan, 1968; Lakhanpal, 1970; Ramanujam, 1966; Navale, 1973). However, Deb (1973) and Venkatachala (1973) on the basis of palynological studies of the Cauvery Basin suggested that the lower age limit of the lignite may even extend up to Eocene.

SYSTEMATIC DESCRIPTION

Genus — *Dicellaesporites* Sheffy & Dilcher, 1971

Dicellaesporites campanulatus sp. nov.

Pl. 1, fig. 1

Diagnosis — Inaperturate fungal spore bodies, two cells, uniseriate, dark brown to blackish in colour, size ±80 μm, shape ovate. Upper cell campanulate while basal cell round, two cells separated by a very thick septum about 12 μm thick. Exine thin and smooth.

Description — The inaperturate fungal spores are two-celled and uniseriate in structure, size ranges up to 80 μm and the shape is ovate. The upper cell is campanulate in appearance while the basal cell is round. Two cells are separated by a very thick septum about 12 μm in thickness. Exine is thin and laevigate.

Comparison — The present species resembles *Dicellaesporites elongatus* Ramanujam (1978) which bears a thick septum but the spore size is small and the shape is elongated. Further, it is bigger in size as well as the upper cell is campanulate in shape, hence the specific name *D. campanulatus* sp. nov. has been assigned.

Holotype — Pl. 1, fig. 1; size 80 μm.

Locality — Neyveli Lignite, South India.

Dicellaesporites disphaericus Sheffy & Dilcher, 1971

Pl. 1, fig. 2

Remarks — Inaperturate fungal spore body, two cells, uniseriate, brown in colour, size about 16 μm, individual spore ±8 μm in size; exine slightly thicker ±2 μm, laevigate, septum disc-shaped.

The present fossil spore is more or less identical in characters to *D. disphaericus* described by Sheffy and Dilcher (1971).

Multicellaesporites (Elsik) Sheffy & Dilcher, 1971

Multicellaesporites curvatus sp. nov.

Pl. 1, figs 3, 4

Diagnosis — Spores uniseriate, dark brown; 9-10 cells unite forming a curved filament, cells separated by septa, constriction present at the junction of two cells; size 100 μm. Each cell inaperturate circular, subcircular to ovate; measuring ±12 μm in size. Exine thick ±2 μm, laevigate.

Description — Fungal spores uniseriate, dark brown in colour about 9-10 cells unite to form a filament; filament curved in shape. Cells separated by septa; constriction present at the junction of two cells. Size of the filament ±100 μm. Individual spores inaperturate; circular, subcircular to ovate in shape measuring ±12 μm in size. Exine 2 μm, thick and laevigate.

Remarks — As far as the author is aware, the present species is different from all those similar fossil species of *Multicellaesporites* earlier described by Elsik (1968), Sheffy and Dilcher (1971) as well as Ramanujam (1978) in its curved nature and bigger size. The specific name of the present species has been suggested on the basis of the curved nature of the filament.

Holotype — Pl. 1, fig. 3; size 100 μm.

Locality — Neyveli Lignite, South India.

Multicellaesporites elsikii Kar & Saxena, 1974

Pl. 1, fig. 5

Description — Spores generally pentacellate, more or less elliptical in shape. Size ±60 μm and septate, septa thin and clear. Individual cells more or less of same size measuring 12-16 μm. Spore wall up to 1 μm thick and psilate.

Remarks — Spores are similar to those described by Kar and Saxena (1976) from the Matanomadh Formation (Kachchh) but differs only in having the apical cell slightly elongated.

Multicellaesporites sp.

Pl. 1, fig. 6

Description — Spores uniseriately arranged, brown in colour. Four individual cells unite to form a filamentous structure. Filament curved at the upper part, cells separated by thin septa; spores more or less round in shape measuring 10-12 μm in size; inaperturate. Exine thin ±1 μm thick and laevigate.

Remarks — The present specimen resembles the fungal spore of the extant genus *Curvularia* described by Chhaya Sharma (1974) from the Quaternary deposits of Malvan, Gujarat.

Staphlosporonites Sheffy & Dilcher, 1971

Staphlosporonites neyveliensis sp. nov.

Pl. 1, fig. 7

Diagnosis — About 17 fungal cells aggregate in an oblong structure measuring

± 105×60 μm in size; 2-3 cells wide tapering to a single cell thick. Each cell psilate ranging up to 20 μm in size. Exine thin and smooth.

Description — The fungal body consisting of about 17 fungal cells arranged in an oblong structure; brown in colour measuring about 105×60 μm in size. The fungal body is 2-3 cells wide and the whole mass tapering to a single cell thickness. Each cell is psilate measuring up to 20 μm in size. Exine of the spore is thin and smooth.

Comparison — The present species resembles *Staphlosporonites allomorphus* Sheffy & Dilcher (1971) in general appearance but differs in having more number of cells and larger size. It also resembles the spore type illustrated by Graham (1962) as *Alternaria* but differs in having larger number of cells and considerably bigger size.

Holotype — Pl. 1, fig. 7; size 105×60 μm.

Locality — Neyveli Lignite, South India.

Staphlosporonites tristriatus Sheffy & Dilcher, 1971

Pl. 1, fig. 8

Remarks — Spore body of about 8 cells, arranged in an ovate structure measuring about 60 μm in size; 2 to 3 cells wide, psilate, dark brown in colour septa opaque, varying in thickness and continuous with wall. Individual spore 14-16 μm in size.

Parmathyrites Jain & Gupta, 1970

Parmathyrites sp. Kar *et al.*, 1972

Pl. 1, fig. 9

Description — Ascostroma flattened, circular in shape, non-osteolate, about 65 μm in diameter and solitary. The whole body is single cell thick, hyphae radially arranged and interconnected throughout their length. Central cell more or less triangular surrounded by single row of thick-walled polygonal cells. Peripheral cells more elongated towards margin and provided with numerous glandular structures. Tangential wall of the marginal cells is extended in the form of long spines. Spines unequal acute up to 30 μm long.

Remarks — The present specimen closely resembles *Parmathyrites* sp. described by Kar *et al.* (1972) in all respects except smaller in size and having shorter spines.

Fungal remain cf. *Stemonitis*

Pl. 1, figs 10, 11

Description — The entire body is attached on a higher plant cell. The fungal body is divisible into a short stalk at the base and capillitial network composed of fibrous mass. The size of the body is about 160× 40 μm. Within the network columella runs vertically. The capillitial fibres anastomose forming a loose network; these fibres do not unite along the margin and hence forming an open type of net work. Columella not clearly seen. A few spores appear to be trapped in the capillitial net work. The spores are round to oval in shape, brown in colour and measure 6-8 μm in size. They are nonaperturate. The exine of the spore is laevigate and thin.

Remarks — Two specimens were observed in the slide with one partially preserved showing the capillitial threads only. The present fungal body resembles closely with the extant genus *Stemonitis*, a member of Myxomycetes in its structure having stalk, columella and capillitial threads. It was also compared with other members of the family as: *Physarum*, *Arcyria* and *Dictydium* but differs from all of them in having different nature of fruiting body.

Fungal remain cf. *Perithecium* of Ascomycetes

Pl. 1, figs 12-14

Description — A mature fungal fruiting body/ascocarp resembling *Perithecium* of Ascomycetes is round in shape and dark brown in colour. The size of the fungal body is about 200 μm in diameter. The whole fungal body appears to be a pseudoparenchymatous mass comprising of interwoven fungal hyphae which profusely anastomose themselves. The ascocarp shows a small circular opening probably an osteole from where a few ascospores appear to come out. The ascospores are brown in colour, oval in shape and measure about 6-8 μm in size. The exine of the spore is smooth and thin. The asci are not seen within the ascocarp wall.

Remarks — Similar fungal ascocarps are found in the family Ascomycetaceae. There are five types of ascocarps known according to the way they bear their asci: (i) those which bear naked asci without any fruiting body, (ii) those which produce their asci inside a completely closed ascocarp called a Cleistothecium, (iii) those whose ascocarp is more or less closed but at maturity is provided with a pore through which the ascospores escape, is known as Perithecium, (iv) those which produce their asci in an open ascocarp is called as Apothecium, and (v) those which form their asci directly in a cavity (locule) within the stroma (Allexopoulos, 1962). In addition various modified forms may also occur.

The present fossil specimen very well agrees with the third type of ascocarp which shows the presence of a small aperture (Pl. 1, figs 13, 14).

Fungal remain cf. Spore of *Coprinus*

Pl. 1, fig. 15

Description — Fungal spore is large in size about 80 μm, black in colour, ovate in shape and has an apical large aperture. Exine thick, dark black and smooth. A short coenocytic hypha appears to come out from the spore.

Remarks — Similar fungal spores are found in the Subclass Holobasidiomycetes of the Class Basidiomycetes. Such type of basidiospores are usually met within *Coprinus* Gaumann (1952, p. 262).

Fungal remain cf. *Helminthosporium*

Pl. 1, fig. 16

Description — Fungal spores 4-septate consisting of 5 cells. The basal cell is smaller while the two middle cells are largest in size. The size of the spore is about 70 μm. The individual cells range from 5 to 15 μm in size. Exine thick, brown in colour, ± 1.5-2 μm and smooth. Distinct pores are at different levels immediately above or below the septa.

Remarks — The present spore type resembles the conidiospore of the genus *Helminthosporium*, a member of Hyphomycetes (Subrahmanian, 1971) which has been classified under Deuteromycetes by Alexopoulos (1962).

Fungal remain — Type 1

Pl. 1, fig. 17

Description — Fungal remain containing 4 dark coloured cleistothecia arranged in a linear fashion. The cleistothecia are oval to round in shape, black in colour with smooth wall and vary from 30×24 to 36×24 μm.

Remarks — Such type of cleistothecia are generally met within Ascomycetaceous type of fungi.

Fungal remain — Type 2

Pl. 1, fig. 18

Description — Fungal sporangium is attached on the epidermal cell of a higher plant. The sporangium is a spherical body enclosing only a single large sporogenous mass in it. Size of the sporangium is about 80 μm and the sporangial wall is thin bearing fine spines. The sporogenous mass is dark in colour, oval in shape and about 60 μm in size. The exine is smooth.

Remarks — Similar structures belonging to the Chytridiales Group of fungi (Alexopoulos, 1962) are observed growing on the epidermis of higher plants. Further, the sporangia reported by Johnson (1974, pl. 20, fig. 223) and Dayal and Thakurji (1968, pl. 22, fig. 28) are the supporting evidence for the present fossil fungal remain.

Fungal/algal remain — Type 3

Pl. 1, fig. 19

Description — Fungal/algal hyphae/filaments uniseriate, two hyphae/filaments appear conjugating each other by means of an ovoid to circular outgrowths. One of the outgrowths forms a small unicellular hypha.

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REFERENCES

Alexopoulos, C. J. (1962) *Introductory Mycology.* John Wiley & Sons, Inc., New York.

Ambwani, K., Bande, M. B. & Prakash, U. (1981). Pollen grains of *Ctenolophonidites* from the Neyveli Lignite of South India. *Palaeobotanist,* **27** (1): 100-106.

Bande, M. B. & Ambwani, K. (1982). *Sclerosperma*-like pollen grains from the Neyveli lignite of India. *Palaeobotanist,* **30** (1): 63-67.

Deb, U. (1972). Some pollen grains from the Neyveli lignite. *Proc. Sem. Palynol. Indian Stratigr., Calcutta*: 220 (1971).

Deb, U. (1973). On the age of the Neyveli Lignite, a palynological approach. *Q. Jl geol. Min. metall. Soc. India,* **45** (1): 23-38.

Dayal, R. & Thakurji (1968). Studies in aquatic fungi of Varanasi. III. Observations on some aquatic Phycomycetes. *Annal. Mycol.,* Ser. 2, **22**: 278-283.

Elsik, W. C. (1968). Palynology of a Palaeocene Rockdale lignite. Milam county, Texas-1. Morphology and taxonomy. *Pollen Spores,* **10** (2): 263-314.

Gaumann, A. E. (1952). *The Fungi.* A description of their morphological features and evolutionary development. Hafnen Publishing Company, New York, London.

Graham, A. (1962). The role of fungal spores in palynology. *J. Palaeont.,* **36**: 60-68.

Jain, K. P. & Gupta, R. C. (1970). Some fungal remains from the Tertiaries of Kerala Coast. *Palaeobotanist,* **18** (2): 177-182.

Johnson, T. W. (1974). Aqatic fungi of Iceland: Biflagellate species. *Acta Nat. Isl.,* **23**: 1-40.

Kar, R. K. & Saxena, R. K. (1976). Algal and fungal microfossils from Matanomadh Formation (Palaeocene), Kutch, India. *Palaeobotanist,* **23** (1): 1-15.

Kar, R. K., Singh, R. Y. & Sah, S. C. D. (1972). On some algal and fungal remains from Tura Formation of Garo Hills, Assam. *Palaeobotanist,* **19** (2): 146-154.

Krishnan, M. S. (1968). *Geology of India and Burma.* Madras.

Lakhanpal, R. N. (1970). Tertiary floras of India and their bearing on the historical geology of the region. *Taxon,* **19** (5): 675-694.

Navale, G. K. B. (1961). Pollen grains and spores from Neyveli Lignite, South India. *Palaeobotanist,* **10**: 87-90.

Navale, G. K. B. (1973). Some contribution to palaeobotany of Neyveli Lignite, South India. *Palaeobotanist,* **20** (2): 179-189.

Navale, G. K. B. & Misra, B. K. (1979). Some new pollen grains from Neyveli Lignite, Tamil Nadu, India. *Geophytology,* **8** (2): 226-239.

Ramanujam, C. G. K. (1963a). Thriothecia of Asterinae from the South Arcot Lignite, Madras. *Curr. Sci.,* **32**: 327-328.

Ramanujam C. G. K. (1963b). On two new species of fossil fungi from the South Arcot Lignite. *Proc. 50th Indian Sci. Congr.,* **3** 396.

Ramanujam, C. G. K. (1966). Palynology of the Miocene Lignite from South Arcot District, Madras, India. *Pollen Spores,* **8** (1): 149-203.

Ramanujam, C. G. K. & Rao, K. P. (1978). Fungal spores from the Neogene strata of Kerala in South India. *IV int. palynol. Conf., Lucknow (1976-77),* **1**: 291-304.

Sharma, Chhaya (1976). Some fungal spores from Quaternary deposits of Malvan, Gujarat. *Palaeobotanist,* **23** (2): 79-81.

Sheffy, M. V. & Dilcher, D. L. (1971). Morphology and taxonomy of fungal spores. *Palaeontographica,* **133B** (1-3): 34-51.

Subramanian, C. V. (1971). *Hyphomycetes.* Indian Council of Agricultural Research, New Delhi.

Thiergart, F. & Frantz, W. (1962). Some spores and pollen grains from the Tertiary Brown Coal of Neyveli. *Palaeobotanist,* **11**: 43-45.

Venkatachala, B. S. (1973). Palynological evidence on the age of Cuddalore Sandstone. *Geophytology,* **3** (2): 145-149.

EXPLANATION OF PLATE

(All photomicrographs. × 500 except when mentioned)

1. *Dicellaesporites campanulatus* sp. nov., slide no. 6559.
2. *D. disphaericus,* slide no. 6560.
3, 4. *Multicellaesporites curvatus* sp. nov., slide nos. 6561-62.
5. *M. elsikii,* slide no. 6563.
6. *Multicellaesporites* sp., slide no. 6564.
7. *Staphlosporonites neyveliensis* sp. nov., slide no. 6565.
8. *S. tristriatus,* slide no. 6566.
9. *Parmathyrites* sp., slide no. 6567.
10. Fungal remain cf. *Stemonitis,* slide no. 6568.
11. Fungal remain cf. *Stemonitis.* × 1000, slide no. 6568.
12, 13. Fungal remain cf. Perithecium of Ascomycetes. × 250, slide no. 6569.
14. Fungal remain cf. Perithecium of Ascomycetes (osteolar portion). × 1000, slide no. 6570.
15. Fungal remain cf. *Coprinus,* slide no. 6571.
16. Fungal remain cf. *Helminthosporium,* slide no. 6572.
17. Fungal remain-Type 1, slide no. 6573.
18. Fungal remain-Type 2, slide no. 6574.
19. Fungal remain-Type 3, slide no. 6575.

PLATE 1

The Palaeobotanist, **31**(2): 154-164, 1983.

MICROBIOTA AND ORGANOSEDIMENTARY STRUCTURES FROM VINDHYAN SUPERGROUP AROUND CHANDREHI, MADHYA PRADESH*

P. K. MAITHY
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India
&
SUMANT GUPTA
Geological Survey of India, Palaeontology Laboratory, Nagpur, India

ABSTRACT

The present paper records the microbiota and stromatolite from Vindhyan Supergroup around Chandrehi Section in Madhya Pradesh. The microbiota is recorded from Semri, Rewa and Bhander groups. It comprises bacteria — *Biocatenoides*; algae — *Huronispora*, *Sphaerophycus*, *Aphanocapsiopsis*, *Corymbococcus*; acritarcha — *Orygmatosphaeridium*, *Bavlinella*, *Polyedryxium* and other problematical remains.

Key-words — Microbiota, Stromatolite, Vindhyan Supergroup, Pre-Cambrian, India.

साराँश

मध्य प्रदेश में चन्द्रेही के आस-पास स्थित विंध्य महासमूह से कार्बनिक अवसादीय संरचनायें एवं सूक्ष्मजीविता –
प्रभात कुमार माइती एवं सुमन्त गुप्ता

प्रस्तुत शोध-पत्र में मध्य प्रदेश में चन्द्रेही खंड के आस-पास स्थित विंध्य महासमूह से उपलब्ध सूक्ष्मजीविताओं एवं स्ट्रोमेटोलाइटों का अभिलेख है। सूक्ष्मजीवितायें सेमरी, रीवा एवं भन्डेर समूहों से अभिलिखित की गई हैं। इसमें जीवाणु – बायोकेटिनॉयडिस; शैवाल – ह्यूरोनिस्पोरा, स्फ़ेयरोफाइकस, ऍफेनोकेप्सिऑप्सिस, कोरिम्बोकोक्कस; ऍक्रीटार्क – ओरिग्मेटोस्फ़ेयरीडियम्, बावलिनेल्ला, पोलिएड्रिक्सियम् तथा अन्य समस्यात्मक अवशेष सम्मिलित हैं।

INTRODUCTION

BIOTA and organosedimentary structures from the Vindhyan Supergroup are known long back. The important contributions on microbiota are of Sitholey, Srivastava and Varma (1953), Salujha, Rehman and Rawat (1971), Salujha, Rehman and Arora (1971) and Maithy and Shukla (1977). Records of stromatolites have recently been summarized by Kumar (1980).

The present paper deals with the stromatolites, bacteria, algae, acritarch and other problematical forms along the Chandrehi Section in Madhya Pradesh. In 1981, Maithy and Gupta recorded archaeocyatha along Chandrehi Section.

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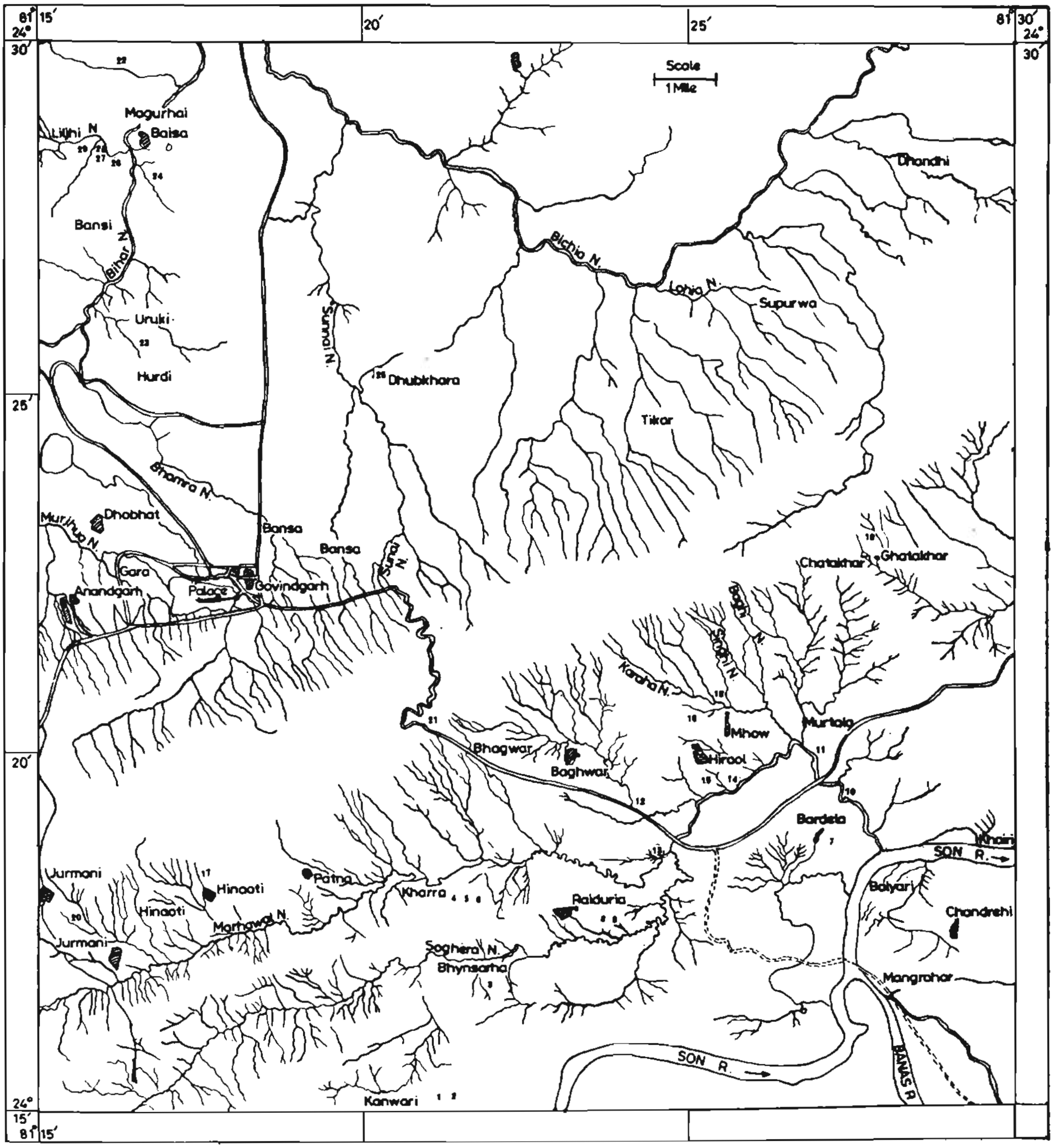
*Collaborative study of microbiota from Vindhyan Supergroup with Geological Survey of India, Madhya Pradesh Circle I.



Map 1 — Locality map showing sampling areas.

The geological succession of Vindhyan Supergroup along Chandrehi is as follows:

UPPER VINDHYAN	Bhander Group	Nagod Limestone Formation Simrawal Shale Formation
	Rewa Group	Govindgarh Sandstone Formation Kokah Shale Formation
	Kaimur Group	Kaimur Sandstone Formation
LOWER VINDHYAN	Semri Group	Baghwar Shale Formation Hinoti Limestone Formation Rampur Shale Formation Chorhat Sandstone Koldha Shale Formation Deonar Porcellanite Formation Kanwari Shale Formation Deoland Sandstone Formation

---------------------------- Unconformity ----------------------------

Archean

MATERIAL AND METHODS

In all 65 samples were collected from Semri, Rewa and Bhander groups (Map 1). These were studied in thin sections and also by maceration method. For maceration of samples all the precautions were taken as detailed by Pflug and Maithy (1978).

Only those samples which have yielded identifiable biota are detailed here:

No.	Sample No.	Locality	Group; Formation; Member	Description of Specimen
1.	219/SG/76-77	Close to Kanwari (24°15′81°20′)	Semri Group; Kanwari Shale Formation	Greenish grey and dirty white calcareous shale
2.	289/TKR/76-77	1.6 km N 44 W of Kanwari	Semri Group; Deonar Porcellanite Formation	Ash grey, and dirty white porcellanite
3.	208/SG/76-77	0.8 km South of Bhynsarha	Semri Group; Deonar Porcellanite Formation	Greenish, olive green porcellanite
4.	335/TKR/76-77	2.0 km S 88 W of Kharra	Semri Group; Koldha Shale Formation, Balyari Limestone Member	Light grey, cherty stromatolitic limestone
5.	337/TKR/76-77	1.8 km W of Kharra	Semri Group; Koldha Shale Formation; Kharra Shale Member	Light ash grey and khaki green splintry shale
6.	338/TKR/76-77	1.7 km N 86 W of Kharra	Semri Group; Koldha Shale Formation; Kharra Shale Member	Dark green and khaki green siltstone with fine grained sandstone interbeds

— Contd.

No.	Sample No.	Locality	Group; Formation; Member	Description of Specimen
7.	349/TKR/76-77	0.9 km S 21 W of Bardela	Semri Group; Koldha Shale Formation; Kharra Shale Member	Khaki greenish grey splintary shale
8.	138/SG/76-77	2.0 km N 76 E of Raiduria	Semri Group; Chorhat Sandstone Formation; Raiduria Sandstone Member	Khaki flaggy shale
9.	135/SG/76-77	1.2 km N 74 E of Raiduria	Semri Group; Chorhat Sandstone Formation; Raiduria Sandstone Member	Khaki siltstone
10.	275/SG/76-77	2.2 km S 33 E of Murtala	Semri Group; Rampur Shale Formation; Palaia Limestone Member	Light grey fine grained limestone
11.	269/SG/76-77	0.9 km South of Murtala	Semri Group; Rampur Shale Formation; Serajpur Shale Member	Black porcellanic shale
12.	133/SG/76-77	3.45 km S 43 E of Baghwar	Semri Group; Rampur Shale Formation; Serajpur Shale Member	Black porcellanic shale
13.	416/TKR/76-77	0.4 N 8 E of Selkasa	Semri Group; Rampur Shale Formation; Palia Limestone Member	Dark grey limestone with interbedded dirty yellow agrillaceous limestone
14.	386/TKR/76-77	0.8 km S 8 W Hiraol	Semri Group; Hinoti Limestone Formation	Dark grey, fine grained limestone
15.	385/TKR/76-77	0.6 km S 8 W of Hiraol	Semri Group; Hinoti Limestone	Rose-pink, argillaceous limestone
16.	391/TKR/76-77	1.4 km N 46 W of Mhow	Semri Group; Hinoti Limestone Formation	Dirty white, light grey fine grained limestone
17.	170/SG/76-77	1.15 km N 35 E of Hinaoti	Semri Group; Hinoti Limestone Formation	Light grey and ash coloured limestone
18.	277/SG/76-77	1.4 km N 51 W of Mhow	Semri Group; Hinoti Limestone Formation	Dirty white limestone

— Contd.

No.	Sample No.	Locality	Group; Formation; Member	Description of Specimen
19.	282/SG/76-77	1.8 km N 32 W of Ghotakahar	Semri Group; Baghwar Shale Formation, Daorahra Porcellanite Member	Thinly laminated dirty white and grey porcellanite
20.	185/SG/76-77	2.0 km N 62 E of Jurmani	Semri Group; Baghwar Shale Formation; Daorahra Porcellanite Member	Black thinly laminated and flabby porcellanite shale
21.	450/TKR/76-77	2.2 km S 25 W of Gaddi	Rewa Group; Kokah Shale Formation	Purple, thinly laminated shale
22.	306/SG/76-77	0.9 km S 37 W of Khujhua	Bhander Group; Simrawal Shale Formation	Purple and green calcareous shale
23.	18/TKR/76-77	0.8 km N 75 W of Hurdi	Bhander Group; Simrawal Shale Formation	Greenish calcareous siltstone
24.	22/TKR/76-77	0.8 km S 64 W of Baisa	Bhander Group; Nagod Limestone Formation	Argillaceous limestone
25.	10/SG/76-77	0.4 km N 60 W of Dhubkhara	Bhander Group; Nagod Limestone Formation	Chert band
26.	11/SG/76-77	1.0 km West of Baisa in Liljhi Nala	Bhander Group; Nagod Limestone Formation	Chert band
27.	9/TKR/76-77	1.1 km S 55 E of Kulwaru	Bhander Group; Nagod Limestone Formation	Dark grey limestone
28.	9/SG/76-77	1.8 km S 50 W of Jitouhi	Bhander Group; Nagod Limestone Formation	Black chert in light grey limestone
29.	23/TKR/76-77	1.6 km West of Baisa	Bhander Group; Nagod Limestone Formation	Ash grey argillaceous limestone

DESCRIPTION

BACTERIA

Biocatenoides Schopf, 1968

Biocatenoides sphaerula Schopf, 1968

Pl. 1, fig. 1

Description — Uniseriate, unbranched chains of rod-shaped coccoid cells, less than 1 μm broad (commonly less than 0.5 μm broad), chains up to 200 μm long, straight or recurved.

Occurrence — Nagod Limestone, Bhander Group.

Previous Records — *B. sphaerula* Schopf (1968) has earlier been recorded from the Bitter Spring Formation of Australia (900 m.y.) and by Hofmann (1976) from Belcher Island (1800 m.y.).

ALGAE

Huronispora Barghoorn, 1965

Huronispora microreticulata Barghoorn, 1965

Pl. 1, figs 2, 3

Description — Cells circular to spherical in outline, measuring 7-12 μm; exine with microreticulate structure, muri raised and thick.

Occurrence — Kanwari Shale Formation, Semri Group and Chorhat Sandstone Formation, Semri Group.

Previous Records — *H. microreticulata* Barghoorn (1965) has earlier been recorded from the Gunflint Iron Formation, Ontario (1400 m.y.) and Amelia Dolomite, Australia (1500 m.y.).

Huronispora psilata Barghoorn, 1965

Pl. 1, fig. 4

Description — Cells circular, solitary, 2-10 μm in size, exine smooth, enveloping sheath absent.

Occurrence — Kanwari Shale Formation, Semri Group; Koldha Formation, Semri Group; Rampur Shale Formation, Semri Group; Hinoti Limestone Formation, Semri Group; and Kokah Shale Formation, Rewa Group.

Previous Records — *Huronispora psilata* Barghoorn (1965) has earlier been recorded from the Gunflint Iron Formation (1400 m.y.) and Amelia Dolomite (Muir, 1967, 1500 m.y.).

Sphaerophycus Schopf, 1968

Sphaerophycus parvum Schopf, 1968

Pl. 1, figs 5, 6

Description — Cells spherical to somewhat ellipsoidal, commonly solitary or in pairs, less frequently arranged in loosely associated irregular groups of few to many cells or in uniseriate aggregates, few cells long, cell size 4-6 μm; individual cell encompassed by a sheath.

Occurrence — Baghwar Shale Formation, Semri Group and Nagod Limestone Formation.

Aphanocapsiopsis Maithy & Shukla, 1977

Aphanocapsiopsis sitholeyi Maithy & Shukla, 1977

Pl. 1, fig. 7

Description — Cells spherical, 5-15 μm, arranged in the form of a loose flat colony, composed of 20 to 40 cells, surface texture smooth.

Occurrence — Baghwar Shale Formation, Semri Group.

Previous Records — *Aphanocapsiopsis sitholeyi* Maithy & Shukla (1977) has earlier been reported from the Suket Shale Formation, Semri Group, Ramapura.

Corymbococcus Awramik & Barghoorn, 1977

Corymbococcus sp.

Pl. 1, fig. 8

Description — Spheroidal cells aggregated in colonies, entire colony encompassed in thick, ±circular unlamellated sheath, cells 2-10 μm in size with smooth exine.

Remarks — Due to paucity of specimens a detailed comparison is not possible with the known species. Hence, they are referred to *Corymbococcus* sp.

Occurrence — Koldha Formation, Semri Group; Chorhat Sandstone Formation, Semri Group; Hinoti Formation, Semri Group; and Simrawal Shale Formation, Bhander Group.

ACRITARCHA

Genus — *Orygmatosphaeridium* Timofeev, 1959

Orygmatosphaeridium plicatum Maithy & Shukla, 1977

Pl. 1, fig. 9

Description — Vesicle spherical with irregular folds on margin, measuring 60-120 μm, exine thin, surface pitted, pits small and closely arranged.

Occurrence — Koldha Shale Formation, Semri Group and Simrawal Shale Formation, Bhander Group.

Previous Records — *Orygmatosphaeridium plicatum* Maithy & Shukla (1977) has earlier been recorded from the Suket Shale Formation, Semri Group, Ramapura (Maithy & Shukla, 1977) and Penganga Formation, Ghughus (Maithy, 1981).

Bavlinella Schepelewa, 1962

Bavlinella nagodensis sp. nov.

Pl. 1, figs 10, 11

Diagnosis — Vesicles circular, measuring 15-40 μm, surface covered with closely spaced grana, a small area on one side free and psilate.

Holotype — Slide no. 6592; Pl. 1, fig. 11.

Locality — 1.0 km West of Baisa in Lilhi Nala.

Horizon — Nagod Limestone Formation, Bhander Group.

Comparison — *Bavlinella faveolata* Schepelewa (1962) differs due to more pronounced grana on the surface. *B. irishi* Sah, Maithy & Bhargava (1977) has sparsely arranged grana.

Polyedryxium Rudavskaja, 1973

Polyedryxium neftelenicum Rudavskaja, 1973

Pl. 1, figs 12, 13

Description — Cells spherical or globular in outline, surface smooth to granulate; cells enclosed in their hyaline structure, circular to octahedral in outline; occasionally a circular pore present; arranged solitary or in irregular groups.

Occurrence — Deonar Porcellanite Formation, Semri Group; Koldha Formation, Semri Group; and Rampur Shale Formation, Semri Group.

Previous Records — *P. neftelenicum* Rudavskaja (1973) was earlier reported from Riphean-Cambrian boundary deposits in South of East Siberia.

INCERTAE SEDIS

Exochobrachium Awramik & Barghoorn, 1977

Exochobrachium sp.

Pl. 1, fig. 14

Microbiota triangular in outline, 20 μm, with three arms radiating from central body in a triradiate fashion swollen at ends, each with a small sphere 5 μm in diameter, subcentral within each swollen ends, surface smooth. As there are only a few specimens in the collection, therefore, a detailed comparison is not possible with the known species. The only known species *E. triangulatum* Awramik & Barghoorn (1977) was recorded from the Gunflint microbiota.

Occurrence — Nagod Limestone Formation, Bhander Group.

STROMATOLITES

Stromatolite occurs only in Koldaha Shale Formation, Semri Group. The stromatolite belongs to *Conophyton* (Pl. 1, fig. 15). It is light grey in colour, cherty and was burried in the same colour of limestones. From top they show distinctly closely spaced concentric rings. In longitudinal section, it shows cone-like structure with fine straight laminations. Microbiota record is poor. Two types of microbiota have been recorded. The smooth spherical structure is comparable to *Orygmatosphaeridium plicatum* Maithy & Shukla (1977) and the other spherical cells with several small surface thickenings (Pl. 1, fig. 10) is comparable to *Granomarginata* Shepelewa.

DISCUSSION

The Vindhyan succession around Chandrehi comprises the following biota:

1. Bacteria — *Biocatenoides*
2. Algae — *Huronispora*, *Sphaerophycus*, *Aphanocapsiopsis*, *Corymbococcus*.
3. Acritarcha—*Orygmatosphaeridium*, *Bavlinella*, *Polyedryxium* and organo-sedimentary structures.
4. Stromatolite — *Conophyton* with biota comparable to *Orygmatosphaeridium* and *Granomarginata*.

TABLE 1 — DISTRIBUTION OF MICROBIOTA IN CHANDREHI SECTION, VINDHYAN SUPERGROUP

NAME OF SPECIES	SEMRI								REWA		BHANDER	
	Deoland	Kanwari	Deonar	Koldha	Chorhat	Rampur	Hinoti	Baghwar	Govindgarh	Kokah	Simrawal	Nagod
Biocatenoides sphaerula	−	−	−	−	−	−	−	−	−	−	−	+
Huronispora microreticulata	−	+	−	−	+	−	−	−	−	−	−	−
Huronispora psilata	−	+	−	+	−	+	+	−	−	+	−	−
Sphaerophycus parvum	−	−	−	−	−	−	−	+	−	−	−	+
Aphanocapsiopsis sitholeyii	−	−	−	−	−	−	−	+	−	−	−	−
Corymbococcus sp.	−	−	−	+	+	+	+	−	−	−	+	−
Orygmatosphaeridium plicatum	−	−	−	+	−	−	−	−	−	−	+	−
Granomarginata sp.	−	−	−	+	−	−	−	−	−	−	−	−
Bavlinella nagodensis	−	−	−	−	−	−	−	−	−	−	−	+
Polyedryxium neftelenicum	−	−	+	+	−	+	−	−	−	−	−	−
Exochobrachium sp.	−	−	−	−	−	−	−	−	−	−	−	+

The distribution of biota (see Table 1) shows that the Semri Supergroup is dominated by algae and acritarcha, *Polyedryxium*. The Rewa Supergroup is too poor in microbiota having only *Huronispora*. In Bhander Supergroup the acritarcha and bacteria are quite frequent. The algal records in Upper Vindhyan are poor in comparison to Semris. Microbiota from the Vindhyan Supergroup has earlier been described by Salujha, Rehman and Arora (1971) from the Son Valley and Salujha, Rehman and Rawat (1971) from Kota-Karauli area. A detailed comparison is not possible as only acritarch assemblages are known from these areas. Maithy and Shukla (1977) reported a rich assemblage from the Suket Shale Formation of Ramapura. The Chandrehi succession assemblages and Suket Shale assemblage have very few common forms both in algae and acritarch. Moreover, the Chandrehi assemblage cannot be compared in detail as it deals with the entire succession of Vindhyan Supergroup, whereas the assemblage of Maithy and Shukla (1977) is only from the Suket Formation.

Recently Maithy and Mandal (1983) recorded an interesting microbiota from the Sapotra-Karauli area. The microbiota record in Semri group is poor. The only comparable forms are *Sphaerophycus* and *Orygmatosphaeridium*. Moreover, the acritarch are totally absent in the Semris of Sapotra-Karauli area. The Bhanders of this area shows predominance of different algal forms, viz., *Vindhyacapsiopsis*, *Sphaerophycus*, *Gloeocapsomorpha* and *Paleoglaucocystis*. In contrary to this the Bhander succession around Chandrehi is poor in algal composition. Moreover, the youngest bed shows predominance of acritarch genus *Bavlinella* and the bacteria — *Biocatenoides*.

The age of Vindhyan Supergroup has remained a subject of controversy for a long time. Crawford and Compston (1971) and Vingradov *et al.* (1964) have given the lower limit of Vindhyan to be ± 1400 m.y. on basis of radiometric data. However, no precise data has been given for the upper limits. The evidence available on the basis of microbiota has been applied by Salujha (1973). According to him the Vindhyan ranges up to Silurian. Venkatachala and Rawat (1972) considered it to be Late Precambrian. The present biota recorded around Chandrehi, though poor in microbiota, is suggestive that the upper limit of Vindhyans cannot be younger than the Late Precambrian due to absence of typical acanthomorphitae acritarcha which are well found in Cambrian and younger succession of other countries.

REFERENCES

Awramik, S. M. & Barghoorn, E. S. (1977). The Gunflint microbiota. *Precambrian Res.*, **5** (2): 121-142.

Barghoorn, E. S. (1965). Microorganisms from the Gunflint chert. *Science*, **147** (3658): 563-577.

Crawford, A. R. & Compston, W. (1971). The age of Vindhyan System of peninsular India. *Quart. J. geol. Soc. Lond.*, **125**: 351-371.

Hofmann, H. J. (1976). Precambrian microflora, Belchar islands, Canada: Significance and systematics. *J. Palaeontol.*, **50** (6): 1040-1073.

Kumar, S. (1980). Stromatolites in Indian biostratigraphy: A review. *J. Paleont. Soc. India*, **23** & **24**: 166-183.

Maithy, P. K. & Gupta, S. (1981). Archaeocyatha from the Vindhyan Supergroup, India. *Indian J. Earth Sci.*, **8** (1): 76-81.

Maithy, P. K. & Mandal, J. (1983). Microbiota from the Vindhyan Supergroup, Karauli-Sapotra region, north-east Rajasthan. *Palaeobotanist*, **31** (2): 129-142.

Maithy, P. K. & Shukla, M. (1977). Microbiota from the Suket Shales, Ramapura, Vindhyan System (Late Precambrian), Madhya Pradesh. *Palaeobotanist*, **23** (3): 176-188.

Muir, M. D. (1976). Proterozoic microfossils from Amelia Dolomite, McArthur Basin, northern Tertiary. *Alcheringa*, **1** (2): 143-158.

Rudavskaja, V. A. (1973). Acritarchs from the Riphean-Cambrian boundary deposits in the South of East Siberia. Microfossils of the oldest deposits. *Proc. 3rd int. palynol. Conf. Moscow*, 1971: 17-20.

Sah, S. C. D., Maithy, P. K. & Bhargava, O. N. (1977). Some significant palynomorphs from B Member of the Jutogh Formation of Simla Hills. *J. geol. Soc. India*, **18** (3) : 139-145.

Salujha, S. K., Rehman, K. & Arora, C. M. (1971). Plant microfossils from the Vindhyans of Son Valley, India. *J. geol. Soc. India*, **12** (1): 24-33.

Salujha, S. K., Rehman, K. & Arora, C. M. (1971). Fossil palynomorphs from the Vindhyans of Rajasthan (India). *Rev. Palaeobot. Palynol.*, **11**: 65-83.

Schopf, J. W. (1968). Microflora of the Bitter Springs Formation, Late Precambrian, Central Australia. *J. Palaeontol.*, **42** (3): 651-688.

SITHOLEY, R. V., VARMA, C. P. & SRIVASTAVA, P. N. (1953). Microfossils from the Upper Vindhyans with a discussion on the age of Vindhyans in light of plant fossil discoveries. *Proc. natn. Inst. Sci. India*, **19** (2): 195-202.

VENKATACHALA, B. S. & RAWAT, M. S. (1973). Organic remains from the Bhima basin and remarks on the age of Vindhyans and subsurface sediments of Ganga Valley. *Geophytology*, **2** (2): 107-117.

VINOGRADOV, A., TUGARINOV, R., SHYKOV, C., STASSNIKOVA, N., BIBIKOVA, E. & KHORREN, K. (1964). Geochronology of Indian Precambrian. *Int. geol. Congr., New Delhi*. Pt. 10. *Archaean and Precambrian Geology*: 553-567.

EXPLANATION OF PLATE

(All photomicrographs are × 2000 unless mentioned before them. All slides are preserved at B.S.I.P. Museum).

1. *Biocatenoides sphaerula* Schopf, slide no. B.S.I.P. 6590; Nagod Limestone; Bhander.
2, 3. *Huronispora microreticulata* Barghoorn, slide no. B.S.I.P. 6583; Kanwari Shale Formation; Semri.
4. *Huronispora psilata* Barghoorn, slide no. B.S.I.P. 6586; Hinoti Limestone Formation; Semri.
5, 6. *Sphaerophycus parvum* Schopf, slide no. B.S.I.P, 6587; Baghwar Shale Formation; Semri.
7. *Aphanocapsiopsis sitholeyii* Maithy & Shukla, slide no. B.S.I.P. 6587; Baghwar Shale Formation; Semri. × 500.
8. *Corymbococcus* sp., slide no. B.S.I.P. 6585; Rampur Formation; Semri.
9, 17. *Orygmatosphaeridium plicatum* Maithy & Shukla, slide nos. B.S.I.P. 6588, Koldha Shale Formation, Semri; and B.S.I.P. 6589, Simrawal Shale Formation, Bhander. × 500.
10, 11. *Bavlinella nagodensis* sp. nov., slide no. B.S.I.P. 6592; Nagod Limestone Formation.
12, 13. *Polyedryxium neftelenicum* Rudavskaja, slide no. B.S.I.P. 6584; Deonar Porcellanite; Semri.
14. *Exochobrachium* sp., slide no. B.S.I.P. 6591; Nagod Limestone, Bhander.
15. *Conophyton* sp.; specimen no. B.S.I.P. 35448; Koldha Shale Formation; Semri. × 1/2.
16. *Granomarginata*, slide no. B.S.I.P. 6588; Koldha Shale Formation; Semri.

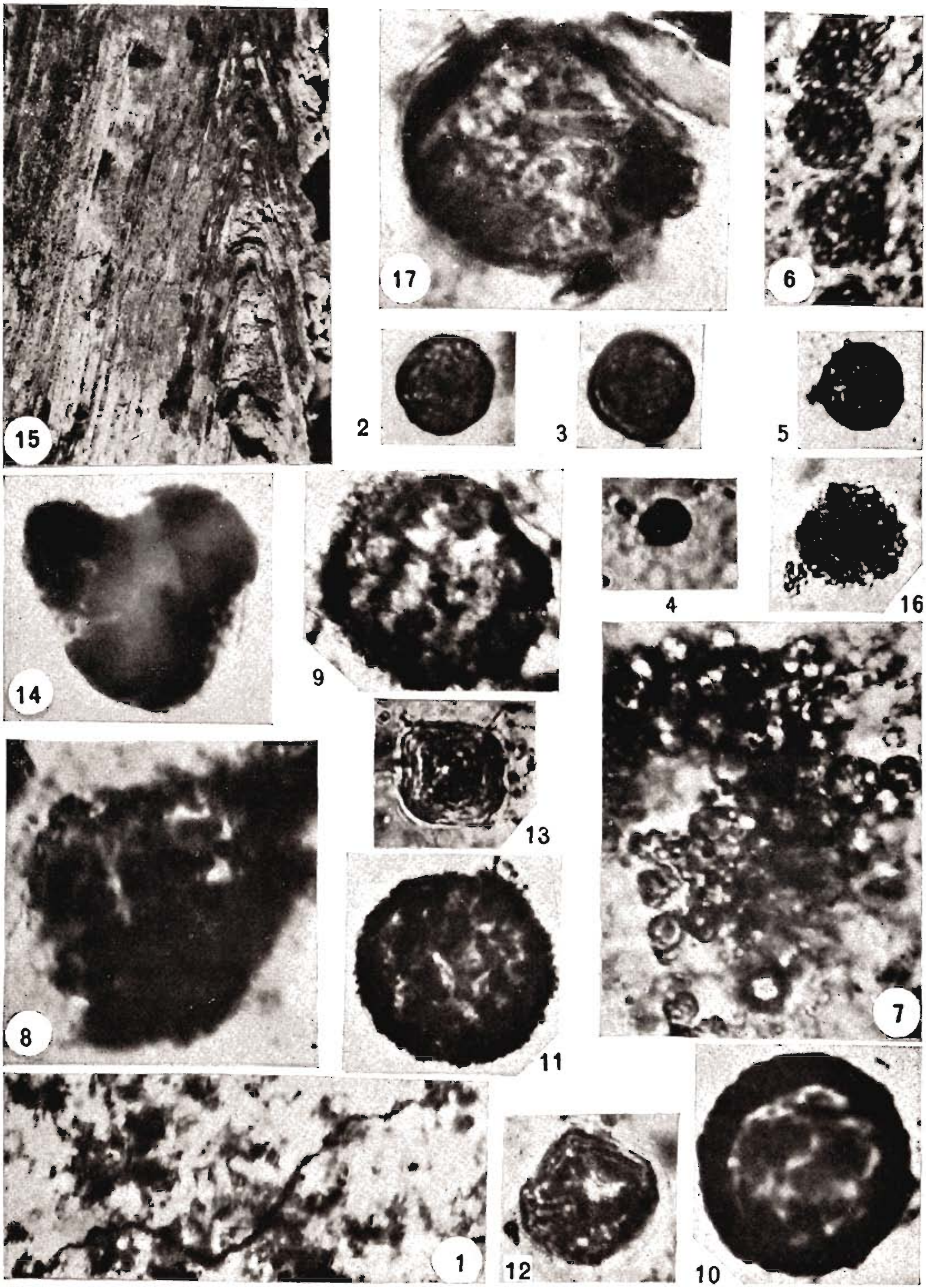


PLATE 1

The Palaeobotanist, **31**(2): 165-175, 1983.

PALYNOLOGICAL INVESTIGATIONS OF THE ARABIAN SEA: POLLEN/SPORES FROM THE RECENT SEDIMENTS OF THE GULF OF KACHCHH, INDIA

RAM RATAN & ANIL CHANDRA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

The pollen analysis of the surface sediments from the Gulf of Kachchh, India shows mainly the type of the surrounding vegetation. The pollen grains of *Avicennia marina*, Chenopodiaceae, Poaceae and Cyperaceae are dominant in the assemblage. The shrubs are represented by the pollen grains of Chenopodiaceae and *Salvadora persica*. The pollen grains of *Acacia*, *Prosopis* and Rhamnaceae (*Zizyphus*) are poorly represented. The quantitative analysis shows higher percentage of the pollen/spores in the mouth than in the head region of gulf. On the other hand, the occurrence of the Hystrichosphaerids is higher in the head region than in the mouth of the gulf.

Key-words — Palynology, Chenopodiaceae, Poaceae, Cyperaceae, Hystrichosphaerids, Gulf of Kachchh, India.

साराँश

अरब सागर का परागाणविक अन्वेषण : कच्छ की खाड़ी (भारत) के वर्त्तमान अवसादों से प्राप्त बीजाणु/परागकण–
राम रतन एवं अनिल चन्द्रा

कच्छ की खाड़ी के स्तरी अवसादों के परागाणविक विश्लेषण से मुख्यतया इसके आस-पास पाई जाने वाली वनस्पति का स्वरूप व्यक्त होता है। इस समुच्चय में एविसेनिआ मैरिना, कीनोपोडिएसी, पोएसी एवं साइप्रेसी के परागकणों की बाहुल्यता है। झाड़ीदार पौधे कीनोपोडिएसी कुल एवं साल्वेडोरा पर्सिका के परागकणों से निरूपित हैं। अकेसिआ, प्रोसोपिस एवं रहमनेसी (जिज़ीफ़स) के परागकण अल्प मात्रा में मिलते हैं। परिमाणात्मक विश्लेषण के आधार पर खाड़ी के शीर्ष-क्षेत्र की अपेक्षा मुख-क्षेत्र में परागकण/बीजाणुओं की उच्चतर प्रतिशतता व्यक्त होती है। इसके विपरीत मुख-क्षेत्र की अपेक्षा शीर्ष-क्षेत्र में हिस्ट्रिकोस्फ़ेयरिड्स अधिक मात्रा में मिलते हैं।

INTRODUCTION

THE palynological study of the oceanic sediments shows the relationship between marine and non-marine complexes. Such studies were carried out earlier by Koreneva (1964), Stanley (1966, 1969) Cross *et al.* (1966), Rossignol (1961), Horowitz (1966), Traverse and Ginsburg (1966), Muller (1959), Aoutin (1967) and Assemien (1969). Significant palynological contribution on the mangroves of India has been made by Das (1961-Calcutta, Goria & Sunberbone), Vishnu-Mittre and Guzder (1975—Bombay), Caratini *et al.* (1973—Pichavaram), Blasco and Caratini (1973—Pichavaram) and Mukherjee (1969, 1972—Gangetic Delta). On the basis of palynological studies Muller (1964) has shown the existence of mangroves in the Tertiary and Quaternary periods. Such studies are helpful in the interpretation of the palaeoclimate and may indicate the ancient shore lines (Assemien, 1969). Koreneva (1961) found that the content of spore and pollen in the terrigenous material of the surface sediments in the Mediterranean Sea is very low. She (1964) also observed the greatest concentration of the pollen grains in the argillaceous silts, high concentration in the depression sediments of the submarine relief and in the coastal region, where coarsely aleuritic and arenaceous fractions occur. Hystrichosphaerids are typical of near shore, shallow marine and brackish water environments

(Evitt, 1963). The fungal spores including other plant ingredients which are both terrigenous and marine in origin, do indicate the sedimentation and the distance from the coast.

In view of the great interest and importance attached to the oceanic sediments, a palynological exploration of these sediments from the Indian oceans was taken up in collaboration with the National Institute of Oceanography, Goa.

In 1982, Saxena, Chandra and Setty described the dinoflagellate cysts and acritarchs from the sediment cores of the Arabian Sea. Ratan and Chandra (1982) reported the occurrence of isolated thyriothecia from the subsurface sediments of the Arabian Sea.

The objectives of the present study are to find out the distribution and source of palynomorphs and their relationship with the major sediment types in the Gulf of Kachchh and also to observe the relationship of the pollen spectra with the surrounding vegetation in the high energy tide dominated environment in the Gulf of Kachchh. The present paper gives an account of the pollen/spore composition of the surface sediments (grab samples) from the Gulf of Kachchh and its relationship with the surrounding vegetation. The data on the pollen/spores, plant culticles and the hystrichosphaerids have also been discussed.

MATERIAL AND METHODS

The present study is based on the palynological analysis of 13 grab samples collected from the Gulf of Kachchh by the R. V. Gaveshani (Second Oceanographic Cruise, 1976). These samples were given to the Birbal Sahni Institute of Palaeobotany, Lucknow by the N.I.O., Goa for palynological investigations. The depth, latitude, longitude and texture of these sediments are shown in Table 1 and the location of the samples is shown in Text-fig. 1. The sediments are poor to extremely poor sorted and are polymodal indicating more than one source. The colour of the sediments is either medium light grey or light grey.

The samples were macerated by the standard procedure of Erdtman (1943). The pollen spectra are based on 100 grains per sample. The pollen identifiable up to family level have been assigned to their respective families. Plant cuticles have been categorized under two groups — those more than 100 μm and others less than 100 μm in size. The quantitative occurrence of the fungal spores was determined by counting them all under one group. Similarly all hystrichosphaerids have been counted under one group.

DESCRIPTION, BATHYMETRY AND GEOLOGY OF THE AREA

The Gulf of Kachchh, one of the identations found on either side of the Saurashtra

TABLE 1 — SHOWING THE STATION LOCATION AND OTHER DATA OF THE CRUISE SECOND R. V. GAVESHANI, GULF OF KACHCHH

No.	Station No. (Sample No.)	Position		Depth in m	Texture of the Sediments
		Latitude	Longitude		
1	36	22°50.2′N	69°08.2′E	17.0	Silty clay
2	37	22°55.4′N	68°57.9′E	16.0	Silty clay
3	38	22°51.0′N	68°58.6′E	15.0	Clayey silt
4	39	22°45.3′N	68°58.3′E	26.0	Silty clay
5	49	22°31.1′N	69°40.2′E	38.0	Sand silt clay
6	50	22°34.4′N	69°39.9′E	38.0	Silty clay
7	53	22°45.2′N	69°52.2′E	30.0	Sandy clay
8	54	22°41.7′N	69°52.2′E	39.0	Sandy clay
9	55	22°36.7′N	69°52.1′E	32.0	Clayey silt
10	56	22°39.4′N	70°03.1′E	22.0	Sand silt clay
11	57	22°44.4′N	70°03.1′E	21.0	Sand silt clay
12	58	22°49.5′N	70°03.0′E	21.0	Sand silt clay
13	59	22°47.0′N	70°08.2′E	15.0	Clayey silt

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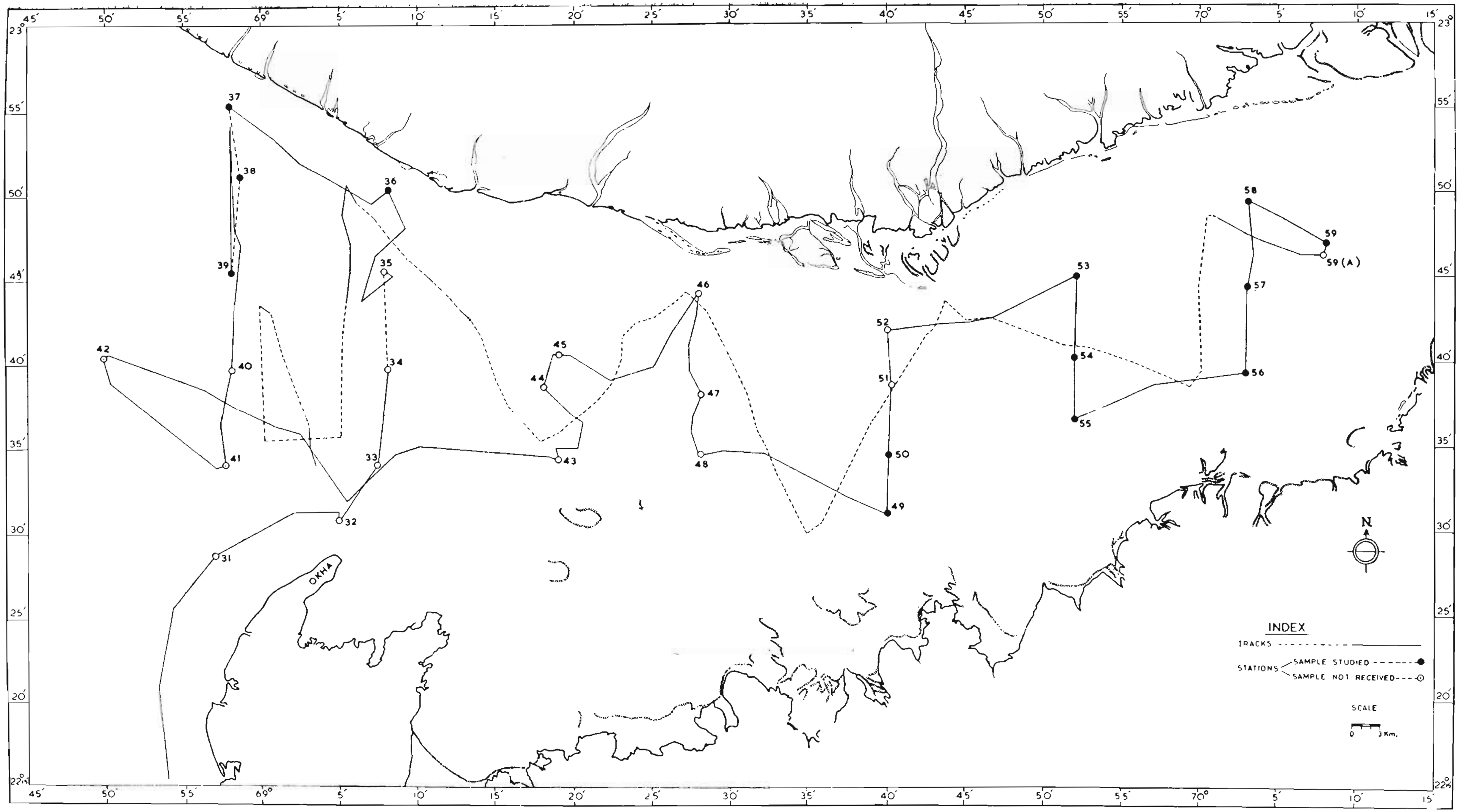


TEXT-FIG. 1 — Map showing the location of samples in the Gulf of Kachchh (from the Report of the Second Oceanographic Cruise, R. V. Gaveshani).

peninsula, has an area of about 7350 sq km and a maximum depth of 60 m. Its climate is semi-arid with the maximum rainfall of the order of 50 cm. It has, therefore, little run off from the land. The numerous rivers found on northern and southern coasts are mostly estuarine (Hashimi *et al.*, 1978). Bordering the Gulf at its head is the Rann of Kachchh, a desiccated region, which during the south-west monsoon gets innundated.

The Gulf is characterized by the strong prevailing water currents (average tidal range of 4 m) and rugged surface. Its floor is highly variable and consists of numerous topographic irregularities like pinnacles, as much as 10 m high separated by flat topped features. The topography at the north and at the middle of the Gulf is relatively more rugged as compared to the head of the Gulf (Hashimi *et al.*, 1978). The eastern part of the Gulf has rocks while most of the other areas are devoid of rocks. Near the mouth of the Gulf, Coralline algae and non-carbonate sands are found while reef corals are extensively developed in the centre. Towards the head, the corals are followed by shelly limestones and sandstones and at the head, the bottom is composed of fine clays. Numerous islands also occur along the southern shores in water depths of 20 m or less.

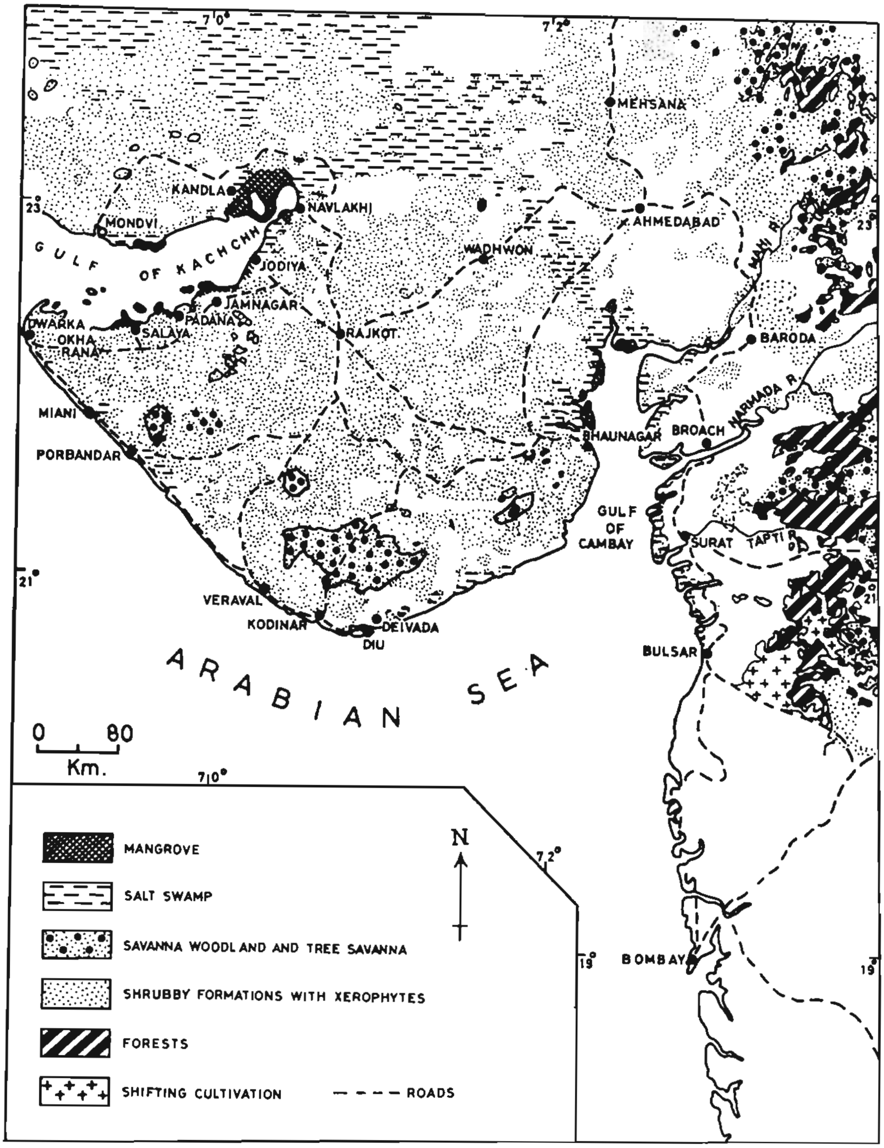
In 1972, Ahmad suggested that shelf will readily be formed in such situation where islands lie close to the mainland and the intervening basin would be rapidly filled by the sediments brought from the land. Kathiawar coast is marked by a lava interior. The south coast of Kathiawar appears to have been dominated by an East-West fault which might be a prolongation of the Narmada rift. The structural features of the lava influence the coast in north where basalt directly occurs on the shore. In other areas there is ribbon of coastal Tertiaries and Pleistocene wind blown sediments where terrestrial deposition is dominant and has stepped the coastal features (Ahmad, 1972).

The drainage divide of the area is formed by the discontinuous hilly back-bone in Kachchh. Rising from its southern slope, numerous streams abound from Kori creek in the west to the eastern terminus of the Gulf of Kachchh. They carve out their valleys for a few kilometers before uniting with the Gulf. North flowing streams (Kathiawar) unite with the Gulf and little rann, while south flowing streams get merge in the Arabian Sea. Thus the Gulf of Kachchh does not receive any permanent river.

VEGETATION SURROUNDING THE AREA

Mangrove Vegetation — The Gulf of Kachchh is surrounded by the largest ligneous halophytic formations of the region (Text-fig. 2). The growth of the mangrove vegetation is very poor in this area. The most common formation has a physiognomy of lowly cropped thickets (less than 2 m), continuous in some places but generally very open. The members of the Rhizophoraceae are very rare on the entire coast. *Avicennia marina* var. *acutissima* is the most important woody species which forms the gregarious population in this area. Under the best conditions, where the ruminants are absent, some *Avicennia* attain 7-8 m height and stand out distinctly from rest of the vegetation. The zonation is reduced to a zone of *Avicennia* (probably *A. marina* var. *acutissima*), behind which the back-mangroves are composed of *Salicornia brachiata* and a grass *Urochondra sentulosa* (Trin.) Hubbard. On the sandy clayey sites with high salinity, *Suaeda fruticosa* and *Atriplex stocksii* form the local thickets.

Tropical Thorny Forest — Shrubby xerophytic vegetation is mainly bushy and thorny. *Acacia arabica*, *Prosopis juliflora*, *Salvadora persica*, *Capparis decidua* and *Ziziphus* are some common plants of this region. The physiognomy of the vegetation is an under-shrubby discontinuous thicket and the soil appears almost naked, as though sterile, over vast areas. The vegetation becomes more dense locally, but it is never closed. Even amongst the dwarf under shrubs the flora is poor. It consists of *Suaeda fruticosa* (the commonest), *Salsola baryosma* and *Holoxylon salicornicum*. On the other hand, Poaceae and Cyperaceae seem to be better adopted to the hydromorphic conditions. These are more diversified and include *Aleuropus lagopoides*, species of *Cenchrus* (*C. setigerus*, *C. ciliaris*), *Sporopolus* (*S. marginatus*, *S. helvecticus*) and *Cyperus rotundus* amongst the sedges (Blasco, 1975, 1977).



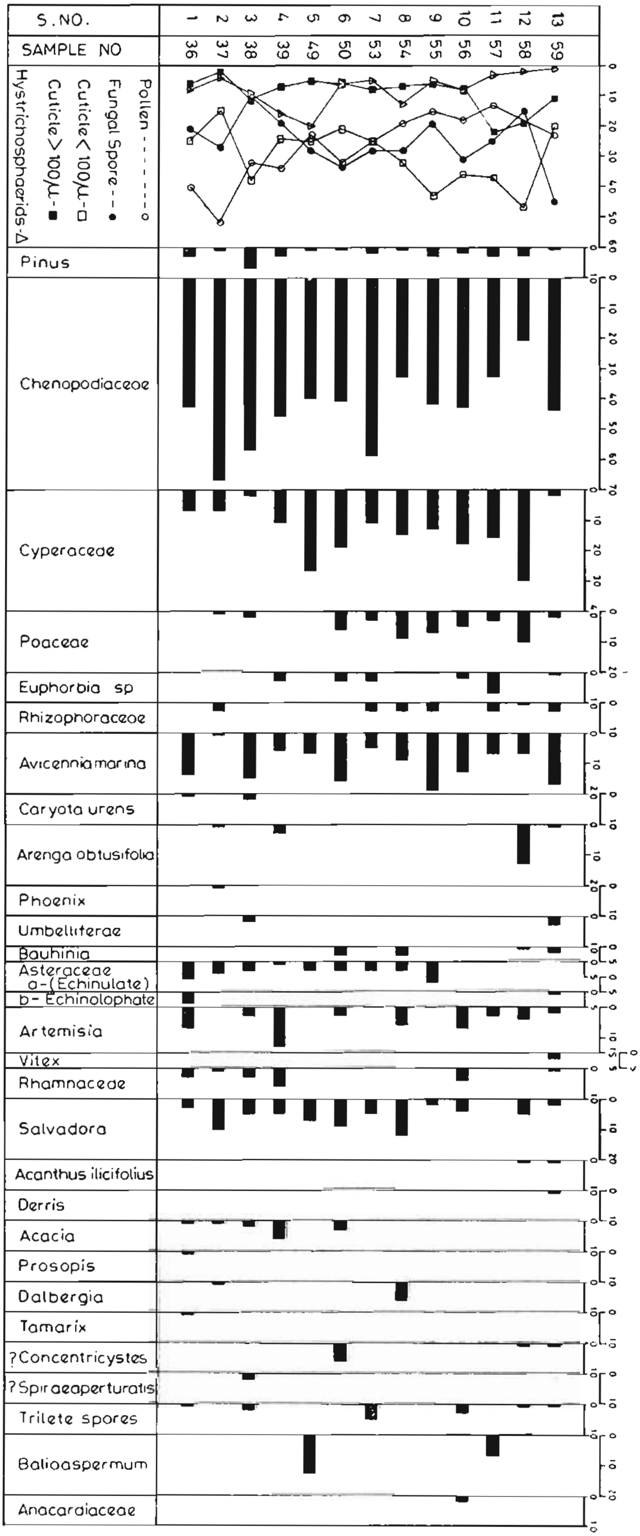
TEXT-FIG. 2 — A part of the map showing the vegetation map of Kathiawar (from Blasco, 1975).

Climate of the Area — The bioclimate of the mangroves of Kathiawar is hot with a rather cold season, sub-desertic with a very strong average thermal amplitude, i.e. about 12°C. The absolute minimum temperature in the Gulf of Kachchh is about 6°C during January. The soil is sandy loamy to silty loamy with moderately alkaline reaction. In January, the greater parts of Kachchh, Kathiawar and the area south of Cambay record temperature over 20°C, whereas the remaining north-eastern parts register between 17.5° and 20°C. During the month of April, the isothermal lines of 27.5° and 30°C trend north-south. The isobars of 1016 and 1017 mb. bend northward in Gujarat. The low pressure bars indicate pressure between 1002 and

999 mb. in July and the winds are westerly. The northern limit of the summer monsoon is marked by a line running from west to east and passing through the tip of the Gulf of Cambay. The climate of Gujarat in the south and south-west is mostly moist with an average rainfall of 150 cm; while the north-eastern portion is dry verging towards southern Rajasthan with a rain fall of about 50 cm. The topography and the direction of the winds govern the seasonal distribution of the rain fall which is uneven and irregular in several segments of the region.

POLLEN/VEGETATIONAL RELATIONSHIPS AND DISCUSSION

The pollen spectrum (Text-fig. 3) shows uniformity in pollen distribution in almost all the samples (4 to 24 km off the coast) collected from the Gulf of Kachchh. The pollen grains of Chenopodiaceae, Cyperaceae Poaceae and *Avicennia* are well-represented in all the samples. The dominance of shrubby and herbaceous pollen shows the open vegetation around the Gulf of Kachchh. The percentage frequency of the pollen grains of Chenopodiaceae is from 21-67%. Sample no. 37 (6 km off the coast) from the head region of the Gulf shows the highest percentage (67%) of Chenopodiaceae pollen. This is followed by the pollen grains of Cyperaceae (2-30%, highest in sample no. 58, 12 km off the coast), *Avicennia* (1 to 19%, highest in sample no. 55, 15 km off the coast), *Artemisia* (2-13%, highest in sample no. 39, 24 km off the coast), *Salvadora* (2-12%, highest in sample no. 54, 20 km off the coast), *Poaceae* (1-10%, highest in sample no. 58, 12 km off the coast) and other herbaceous pollen. The pollen grains of *Rhizophora mucronata* and *Rhizophora apiculata* are very much alike and those of *Bruguiera* and *Ceriops* are slightly different. All of them have been put under the family Rhizophoraceae for they all have the same ecology. The pollen spectrum shows very sparse occurrence of this group as is evident from the local vegetation also. The pollen grains of *Avicennia marina* have been found in all the 13 grab samples and this coincides with the dominance of *Avicennia* in the mangroves of this area. The members of Chenopodiaceae, viz., *Salicornia brachiata*, *Suaeda fruticosa* and *Atriplex stocksii* are dominant in the back mangroves while *Salsola baryosma* and *Haloxylon solicoricum* dominate the thorny vegetation and form the local thickets. The occurrence of Chenopodiaceae, *Avicennia marina*, Poaceae and Cyperaceae pollen and their uniform representation in all the samples can be understood by presuming that the travel time of a pollen grain from the source towards the Gulf is considerable to the extent that the pollen spectrum is not influenced immediately at the time of the pollination. The travel of the pollen grains is influenced by river-discharge, tidal cycles and the wind driven currents and this varies in duration from time to time and from particle to particle. The pollen/spores from different sources ultimately become mixed up so as to show their uniform distribution in various samples. Hirschberg and Schubel (1979) and Platt (1979) stated that much of the sediment is derived from the resuspension and this is an important mechanism near the sea bed. Praglowski (1977) showed that the transport by the currents and redeposition influence the pollen spectra. The small difference in the quantity of pollen deposition may be explained due to the action of water currents on the material sedimented on the bottom. The sediment which is stirred up every where from the bottom, from the basins rich in organic material and from the overlying unconsolidated, almost semifluid sediment stratum seems to remain in the lower water layers. This resuspended sediment is then transported by water currents and mixed up with the other sediment originating from different parts of the basin and from the different depositional strata. The resuspension of the pollen grains in the bottom and in the semifluid sediment is a continuous process. This is more intensive in shallow waters than in the deep water which occurs less in the central areas of the water basins than near the shores. Hashimi *et al.* (1978) on the basis of their study inferred that the nature of distribution of sediments is influenced by the high velocity tidal currents of the Gulf. As a sedimentary environment the Gulf may be said to be tide dominated. The principal tidal influence appears to have its role in transporting sediments from adjoining shelf into the



TEXT-FIG. 3 — Histogram showing the percentage frequency of pollen/spores in various samples.

Gulf. Redistribution of the sediments results from the interaction of the tidal current with irregular topography of the Gulf.

The genus *Pinus* grows in the Himalayas and its occurrence in all the samples from the Gulf of Kachchh obviously shows long distance transport by wind. The pollen grains of *Bauhinia*, *Caryota* and *Arenga* are mainly wind transported from the inland vegetation. The pollen grains of *Phoenix* and *Tamarix* which have been found in sample nos. 37 and 36 (6 km and 4 km off the coast) may be wind transported. The components of shrubby vegetation, *Acacia* (6%), *Prosopis* (1%) and Rhamnaceae (6%) are poorly represented. *Salvadora* is represented almost in all the samples (up to 12%). The pollen grains of Asteraceae have been grouped under Echinulate, Echninolophate and *Artemisia* types. *Artemisia* pollen grains have fair representation and are more common towards the head region of the Gulf (maximum up to 13%). The pollen grains of *Artemisia* are very small and are produced in large numbers. These are easily dispersed and so may be found in samples far from the nearest occurrence of this genus. On the whole, it has been found that the percentage frequency of the pollen/spores is higher in the grab samples collected from the mouth than those from the head region of the Gulf of Kachchh.

In addition to the pollen and spores, other plant fragments, formed by the break down of the plant matter, have been found in the bottom sediments. Cuticular material, dissociated woody tissues and other vascular fragments are also found in significant quantity in all the samples. The distribution of cuticle, woody fragments and fungal spores show higher concentration in the mouth region than in the head of the Gulf of Kachchh. We believe that the majority of the tracheids and fragmentary cuticles have been derived from the mainland. The coarser plant fragments settle earlier and near the shore. In general, the larger plant fragments are found near the shore. On the contrary, it has been observed that the percentage frequency of the hystrichosphaerids (Text-fig. 3) is higher in the surface sediments from the head region (5-15%) than those of the mouth (1-12%) in the Gulf of Kachchh. This may be because of the increase of marine influence in the head region. ?*Concentricystes*, an artificial genus of unknown affinity (probably fluviatile in origin), has been found in a few samples (nos. 50, 58, 59 approx. 18, 12 and 18 km off the coast respectively) from the mouth region. Another spore-like body ?*Spiraeaperturatis*, 10-15 μm in diameter, with spiral bands was found only in sample no. 38 (12 km off the coast).

CONCLUSION

The pollen grains of mangrove plants are present in all the bottom samples from the Gulf of Kachchh. The herbaceous pollen grains dominate the spectra. The inland thorny vegetation is represented poorly by *Acacia*, *Salvadora*, *Prosopis* and *Tamarix*. The wind transported pollen of *Arenga*, *Caryota* and *Phoenix* in our samples should have been derived from the western coast of India.

The presence of *Avicennia* pollen in significant percentage in our samples may be due to water turbulence. Pollen of the wind pollinated plants are shed into the air and most of them settle in a few kilometres unless the air is extremely turbulent. Once delivered to water, either directly or indirectly being washed away from the terrestrial surface, pollen grains behave in the same way as any other particle would do with the similar physical properties. So the distribution of pollen may be the result of sedimentary process. It has also been observed that the relative frequencies of pollen/spore are extremely low in the coarser sediments. Cross *et al.* (1966) showed that most of the sediments with more than 75 per cent sand are nearly barren of pollen and spore in the Gulf of California. Muller (1959), Hoffmeister (1954), De Jekhowsky (1963), and Van Andel and Postma (1954) have indicated the typical pattern of decrease of pollen and spore off the shore. This pattern, however, is not applicable in the Gulf of Kachchh (a restricted basin) where much control of pollen and spore distribution is exerted by both wind and water deposition from the three shores. Furthermore, the circulation is modified by various geomorphological features of the basin, wind pattern, etc. The high concentration of the pollen-spore in the mouth region of the Gulf of Kachchh may be the result of higher deposition rate and the action of marine current.

Our studies based on the grab samples from the Gulf of Kachchh support the idea that the pollen once delivered to the water are sedimented in the same way as other particles do in the same range of size and specific gravity. The pollen types found in the sediments are mainly common to the species found on the bank. Proximity to the source vegetation, however, is not a limiting factor, for respectable concentration of pine pollen is found in the sediments. Pine pollen is buoyant and has been reported to travel great distance in the air. It is suggested that further palynological studies should be carried out on the sediments from the Indian oceans in space and time and this study is likely to add promising results to this interesting aspect of Oceanography — the marine palynology.

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REFERENCES

AHMAD, E. (1972). *Coastal Geomorphology of India*. Orient Longman. 222 pp.

ANONYMOUS (1976). *Report on Second Oceanographic Cruise of R.V. Gaveshani, N.I.O., Goa*. (Unpublished).

AOUTIN, J. (1967). Les pollen et les spores des sèdiments du delta de l'Ogouè (Gabon). *Mem. E.P.H.E. Montpellier*, 160 pp.

ASSEMIEN, P. (1969). Pollen fossile de Rhizophora a'Boguè' (Basse vallèe du Sènègal). *Pollen Spores*, **11** (1): 73-81.

BLASCO, F. (1975). The mangroves of India. Inst. Frans. Pondicherry. *Trans. Sect. Sci. Tech.*, **14:** 180 pp.

BLASCO, F. (1977). Outlines of ecology, botany and forestry of the Mangals of the Indian Subcontinent, pp. 241-260 in V. J. Chapman (ed.)— *Ecosystems of the World I. Wet Coastal Ecosystems*.

BLASCO, F. & CARATINI, C. (1973). Mangrove de Pichavaram (Tamil Nadu, Inde du Sud) *Phytogeographie et Palynologie. Bordeaux, Centre d'Etudes de Gèographie Tropicale. Tr. et. Do.c de. Gèogr. Trop.*, **8**: 163-179.

CARATINI, C., BLASCO, F. & THANIKAIMONI, G. (1973). Relation between the pollen spectra and the vegetation of a South Indian mangrove. *Pollen Spores*, **15** (2): 281-292.

CROSS, A. T., THOMPSON, G. G. & ZAITZEFF, J. B. (1966). Source and distribution of palynomorphs in bottom sediments, southern part of Gulf of California. *Mar. Geol.*, **4** (6): 467-524.

DAS, P. (1961). Recent microscopic flora from the Bengal delta, India. *Micropalaeontology*, **7** (1): 87-94.

DE JEKHOWSKY, B. (1963). Variations laterales on palynologie quantitative et Passage du continental au marin: Doegger superieus du Sud-Quest de Madagascar. *Rev. Inst. Franc. Petrole Ann. Combust. Liquides*, **18**: 977-995.

ERDTMAN, G. (1943). *An Introduction to Pollen Analysis*. Chronica Botanica Co., Waltham Mass, 239 pp.

EVITT, W. R. (1963). A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs, *I. Proc. natn. Acad. Sci. U.S.*, **49**: 158-164.

HASHIMI, N. H., NAIR, R. R. & KIDWAI, R. M. (1978). Sediments of the Gulf of Kutch — A high energy tide dominated environment. *Indian J. Mar. Sci.*, **7**: 1-7.

HIRSCHBERG, D. J. & SCHUBEL, J. R. (1979). Recent geochemical history of flood deposits in the nothern chesapeake Bay. *Estuar. Coast Mar. Sci.*, **9**: 771-84.

HOFFMEISTER, W. S. (1954). Microfosil prospecting for Petroleum. U.S. Pat. 2,686,108: 4 pp.

HOROWITZ, A. (1966). Tropical and northern pollen and spores in recent sediments from the Bay. Elat. (Aquaba). *Israel J. Earth Sci.*, **15**: 125-130.

KORENEVA, E. V. (1961). Research according to method of spore-pollen analysis of two cores of marine sediments from the Japanese Sea. *OKeanologiya*, **1** (4): 651-657 (in Russian).

KORENEVA, E. V. (1964). Distribution of spores and pollen of terrestrial plants in bottom sediments of the Pacific Ocean, p. 31 in *L. M. Cranwell (Editor). Ancient Pacific Floras: The Pollen Story*. Univ. Hawaii Press, Honolulu, Hawaii.

MUKHERJEE, B. B. (1969). Vegetational history of southern part of west Bengal with an introduction to the pollen flora of Sundarbans. *D. Phil. Thesis. Univ. of Calcutta*.

MUKHERJEE, B. B. (1972). Pollen analysis of a few Quaternary deposits of Lower Bengal Basin, in *Proc. Seminar on Palaeo-palynology and Indian Stratigraphy*. Calcutta Univ.

MULLER, J. (1959). Palynology of Recent Orinoco delta and shelf sediments. *Micropalaeontology*, **5** (1): 1-32.

MULLER, J. (1964). A palynological contribution to the history of the mangrove vegetation in Borneo, pp. 32-42 in *L. M. Cranwell (Ed.) — Ancient Pacific Floras: The Pollen Story*. Univ. Hawaii Press. Honolulu, Hawaii.

PLATT, H. M. (1979). Sedimentation and the distribution of organic matter in a sub-Arctic marine bay. *Estuar. Coast. Mar. Sci.*, **9**: 51-63.

PRAGLOWSKI, J. (1977). Pollen deposition on and under the water surface. *Grana*, **16**: 203-209.

RATAN, R. & CHANDRA, A. (1932). Isolated thyriothecia from the surface (bottom) sediments of the Arabian Sea. *Geophytology*, **12** (2): 260-263.

ROSSIGNOL, M. (1961). Analyse pollinique de sediments marins Quaternaires en Israel, I. ediments Recents. *Pollen Spores*, **3** (2) : 303-324.

SAXENA, R. K., CHANDRA, A. & SETTY, M. G. A. P. (1982). Palynological investigation of the sediment cores from the Arabian Sea. 2. Dinoflagellate cysts and acritarchs. *Geophytology*, **12** (1): 81-94.

STANLEY, E. A. (1966). The application of palynology to oceanology with reference to the North western Atlantic. *Deep Sea Res.*, **13** (5): 921-923.

STANLEY, E. A. (1969). Marine palynology. *Ann. Rev. Oceanogr. Mar. Biol.*, **7**: 277-292.

TRAVERSE, A. & GINSBURG, R. N. (1966). Palynology of surface sediments of Great Bhama Bank, as related to water movement and sedimentation. *Mar. Geol.*, **4**: 417-459.

VAN ANDEL, TJ. H. & POSTMA, H. (1954). Recent sediments of the Gulf of Paria: Reports of the Orinoco Shelf expedition. 1. *Verhandel. Koninkl. Ned. Akad. Wetenschap. Afdel. Natuurk. Sect., I.*, **20** (5): 246 pp.

VISHNU-MITTRE & GUZDER, S. (1975). Stratigraphy and palynology of the Mangrove swamps of Bombay. *Palaeobotanist*, **22** (2): 111-117.

The Palaeobotanist, 31(2): 176-190, 1983.

LITHOSTRATIGRAPHY AND PALYNOSTRATIGRAPHY OF THE LOWER GONDWANA FORMATIONS IN THE HUTAR COALFIELD, PALAMAU DISTRICT, BIHAR, INDIA

MANOJ SHUKLA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

The paper deals with the various aspects of lithostratigraphy of the Hutar Coalfield alongwith the palynoflora recovered from the various formations. The palynozonation of the Lower Gondwana formations has been done on the basis of palynofloras recovered from the samples belonging to three measured sections along Deori Nala, Saphi Nala and Koel River. Extension of these zones in various other nalas of the Hutar Coalfield has been traced. Comparison of these palynozones with those in other Lower Gondwana coalfields has also been done. Assemblage Zone 5 of the Barakar Formation contains a palynoflora similar to the Barren-Measure Formation of other coalfields.

Key-words — Palynostratigraphy, Lithostratigraphy, Lower Gondwana, Hutar Coalfield, India.

सारांश

बिहार (भारत) में पालामऊ जनपद के हुतार कोयला-क्षेत्र में अधरि गोंडवाना शैल-समूहों का शैलस्तरिकीय एवं परागाणुस्तरिकीय अध्ययन – मनोज शुक्ला

प्रस्तुत शोध-पत्र में विभिन्न शैल-समूहों से उपलब्ध परागाणविक वनस्पतिजात के साथ-साथ हुतार कोयला-क्षेत्र की शैलस्तरिकी के विभिन्न पहलुओं का विवेचन किया गया है। अधरि गोंडवाना शैल-समूहों का परागाणविक मंडलन देवरी नाला, साफी नाला एवं कोयल नदी के साथ-साथ तीन अनुमापित खंडों के नमूनों से प्राप्त परागाणविक-वनस्पतिजात के आधार पर किया गया है। हुतार कोयला-क्षेत्र के दूसरे भिन्न-भिन्न नालों में इन खंडों का विस्तार अन्वेषित किया गया है। इन परागाणविक मंडलों की तुलना अन्य अधरि गोंडवाना कोयला-क्षेत्रों से भी की गई है। बाराकार शैल-समूह के समुच्चय-मंडल – 5 से ऐसा परागाणविक वनस्पतिजात प्राप्त हुआ है जो कि अन्य कोयला-क्षेत्रों के बैरन मेज़र्स शैल-समूहों से मिलता-जुलता है।

INTRODUCTION

THE Hutar Coalfield (latitude, 23°44′ to 23°52′ and longitude, 83°53′ to 84°11′) lies in east-west trending Gondwana belt along Koel Valley. Earlier, Ball (1880) and Rizvi (1972) prepared the detailed geological maps of this coalfield. They recognized only three groups of sediments, viz., Talchir, Barakar and Mahadeva. Recently, Shukla (1982) demarcated the Karharbari Formation in this coalfield and revised the geological map of Rizvi (1972). The presence of Karharbari sediments was earlier inferred by Festimantel (1886) on the basis of plant fossils, viz., *Glossopteris indica*, *G. damudica*, *Gangamopteris cyclopteroides* var. *attenuata*, *G. cyclopteroides* var. *subauriculata*, coniferous branch and equisetaceous stems, found near the northern mergin of the Hutar Coalfield. Ghosh, Singh and Acharyya (1977) reported the presence of Barren Measures Formation in the Hutar Coalfield without giving any details. Palynological analysis of the Talchir Formation has been done by Lele and Shukla (1981).

The Gondwana sediments in the Hutar Coalfield form a syncline. They are surrounded on all sides by Archaeans. The Talchir Formation rests nonconformably over the Archaeans. The Talchir sediments are succeeded by the Karharbari Formation. A conglomerate between the Talchir and Karharbari sediments indicates a hiatus between these two formations. The Karharbari-Barakar boundary is mostly faulted except in the east and north-eastern parts of the coalfield. Normal contacts are marked by the ridge forming chocolate brown to red Lower Barakar sandstone in this coalfield. Dhankutia, Dhaj and Ranimai hillocks mark this contact in the eastern and north- north-eastern portion of the coalfield. The Barakar sandstone is overlain by massive red sandstone of the Mahadeva Formation with an angular unconformity.

LITHOSTRATIGRAPHY

The Archaeans surrounding the Hutar Coalfield belong to a series of metamorphic rocks consisting of granites, gneisses with mica, hornblende and quartz veins. Regionally these rocks are uniform in nature.

The area in the south of the Hutar Coalfield is covered by granite gneisses, in which quartz veins having general trend of E15° N-W 15°S are also seen. Some of these veins are up to 30 cm thick. Towards north-west, black synite is present. In the west of the coalfield, the area is covered with gneisses, traversed by pegmatite and quartz veins. Granite gneisses traversed by dolerite dykes are seen in the East of the coalfield. These dykes are trending east-west.

TALCHIR FORMATION

This formation is distinguishable into the following three members in ascending order. The scheme proposed by Ghosh and Mitra (1969) has been followed here for stratigraphic classification.

1. *Basal Sandstone Conglomerate Member* — It is characterized by lateral and vertical variations in the lithology from conglomerate to sandstone. Towards southern side of the coalfield the boulder bed is seen grading into sandstone and shale. Some conglomeratic lenses have also been noticed in the sandstone. Boulders and pebbles forming these beds range from 1 cm to 1 m in size and are subrounded in nature. Striations on the boulders are rarely seen. The granite gneisses, vein-quartz, amphibolite schist, pegmatite, quartzite and Jespar form most of the pebbles while boulders are made of granite gneisses. They are embedded in a sandy matrix.

The sandstone varies from fine to medium grained and is poorly sorted. In a vertical section the member shows pseudostratification.

2. *Shale Member* — This member overlies the Basal Sandstone Conglomerate Member. It shows two lithological facies:

(i) *Shale facies* comprising greenish-yellow, fine-grained splintery shales which break into small needle-like fragments.

(ii) *Rhythmite facies* is represented by varves and shale siltstone alternations. The varves are best exposed in the Saphi Nala near Ukamnar Village and in the Behra Nala near Putvagarh Village. They show alternation between dark green clayey and light grey silty layers. These layers invariably exhibit graded appearance within the laminae and vary in thickness Variation is more frequent in the light coloured silty layers. Laterally as well as vertically the varves grade into shales. In the Ukamnar area they are seen affected by reverse faulting. Ripple marks, current bedding, slump structure, etc. are also observed in the sediments associated with them. The shales, immediately overlying the varves, show dropstones.

The siltstone alternation are exposed in Deori Nala, Ukamnar area and the Behra Nala exposures. The silty layers vary in thickness from 2-20 cm and can be distinguished from the shales due to differential type of weathering, massive appearance and compact nature. These beds are laterally traceable in the field for long distances.

3. *Upper Sandstone Member* — It is coarse-grained and greenish in colour and constituted mostly of immature subrounded quartz grains and rock fragments. The sandstone is overlain by a conglomerate.

KARHARBARI FORMATION

The Karharbari Formation in the Hutar Coalfield is seen overlying the Talchir

Formation without any discordance in dips, but the beds of the two formations are separated by a bed of conglomerate indicating a hiatus. This conglomerate bed is noticeable both in the Koel and the Deori Nala sections. Some good sections of the Karharbari Formation are exposed in deeper nala — and river-cuttings through the Barakar sandstones. This formation consists of thick succession of gritty ferruginous sandstones separated by thin coal-shale beds.

1. *Basal Conglomerate Member* — The pebbles are mostly of granite gneiss, hornblende-schist, mica schist, chlorite-schist, quartzite, vein-quartz, Talchir Shale and epidiorites, which are set in a fine sandy matrix. In the past, this conglomerate was classified with the Talchir boulder beds due to apparent lithological similarities. In the present work it is taken as a basal unit of the Karharbari Formation, as it marks the beginning of the Karharbari cycles of sedimentation.

2. *Gritty Sandstone Member* — It consists of two distinct types of sediments, viz., sandstones and coal-shales. Four coal-shale beds have been observed in the Deori Nala Section, where the Karharbari Formation is best exposed.

Sandstones — They are medium-to coarse-grained, reddish brown, poorly sorted and mainly composed of subrounded quartz and feldspar grains. Occasionally, the sandstones are gritty to pebbly. At places iron nodules are also seen in the sandstone. These nodules are often washed off by water action, leaving behind rounded cavities. Frequently the sandstones are strongly, current-bedded with laminae sloping towards east.

Coal-Shales — The coal beds show sharp contacts with the sandstone on the upper side while the lower contact is transitional passing through coaly shale-shale-sandy shale to sandstone. The coal is generally dull, hard, compact, non-banded and durain type in appearance. Rarely lenses of vitrain are also seen. The shales occurring near the sandstones are rich in sandy material and show transitional contact with sandstones whereas, the shales present near the coal seams are rich in carbonaceous material. The shales are generally grey but also show various shades of black colour.

BARAKAR FORMATION

It has been divided into following three members:

1. *Compact red Sandstone Member* — It is a characteristic member which can be taken as marker horizon to separate the Barakar and Karharbari formations. Due to hard and compact nature of the sediments in this member it stands out in the form of a number of hillocks which mark the Karharbari-Barakar boundary. The sandstone is red to chocolate brown, coarse-grained and poorly sorted. Occasionally, the lenses of conglomerate are also present. Pebbles are mostly of quartz.

2. *Gritty Sandstone Member* — This member is also composed of two distinct lithologies, viz., gritty sandstone and coal shale.

Sandstone — It is coarse grained and occasionally gritty. The grains are subrounded. Lenses of conglomerate made up of immature quartz pebbles are also seen. It is less ferruginous than the Karharbari sandstones. Iron nodules are also rare. At few places, carbonaceous grits associated with shale beds have also been seen.

Coal-Shale bed — The lower Barakar sediments of this coalfield are characterized by thick and frequent coal seams. The coal is generally shaly and dull in nature. The coal seams show gradational contact with sandstones passing through shale and sandy shale beds. Sometimes thin streaks of coaly matter are also seen in the sandstones associated with these beds.

3. *Ferruginous Sandstone-Shale Member* — It consists of two types of lithologies, viz., the sandstones and clay-shale beds.

Sandstone — It is gritty to pebbly, ferruginous, mostly constituted of poorly sorted immature quartz grains. In extreme west, near the Barakar-Mahadeva contact, these sandstones show a typical greenish-black colour. The sandstones in general have a tendency to become more pebbly near top.

Clay and shales — This zone shows near absence of carbonaceous matter. The shales are fine-grained and show various green and red shades. The clays are massive, non-laminated and yellow in colour. Occasionally, their surface is stained with iron. The significant feature of these shale and clay beds is their similarity with the Talchir shales. This type of lithology is not common in the Barakar Formation of other areas.

MAHADEVA FORMATION

It is represented by a thick massive sandstone which dips 10-12° in S 25°W. It overlies the Barakar Formation with a marked angular unconformity. The hills formed by these sandstones have steep escarpment with uneven top. The sandstones are feldspathic at the base with an occasional thin bed of red ferruginous shale. Extension of the various members in the Hutar Coalfield is given in Table 1.

MATERIAL

Three sections along Deori Nala, Koel River and Saphi Nala were measured. The samples were collected along these and other nala and river cuttings. Details of samples in these sections alongwith the thickness of individual beds is shown in Text-fig. 1 and Table 2. Palynozonation has been done in the three measured sections and their extension has also been traced in other sections.

MIOFLORAL COMPOSITION AND DISTRIBUTION

Forty-six genera and 98 species of pollen and spores are represented in the miofloral complex present in the Hutar Coalfield. The palynofossils, recorded from each formation, are listed below:

TALCHIR FORMATION

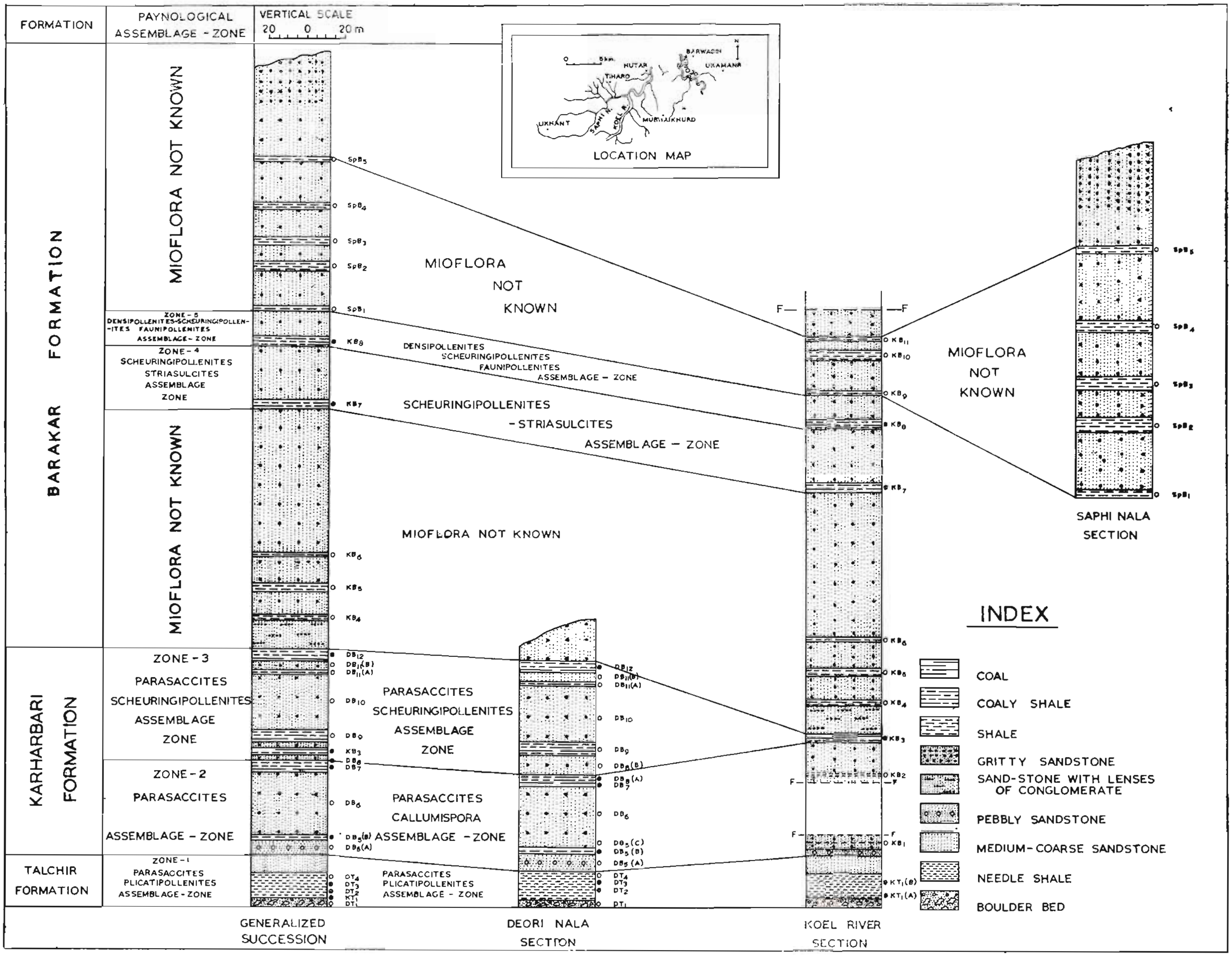
Psilalacinites triangulus Kar, 1969; *Callumispora tenuis* var. *minor* Bharadwaj & Srivastava, 1969; *Verrucosisporites* sp.; *Horriditriletes curvibaculosus* Bharadwaj & Salujha, 1964; *Jayantisporites pseudozonatus* Lele & Makada, 1972; *J. conatus* Lele & Makada, 1972; *Plicatipollenites indicus* Lele, 1964; *P. gondwanensis* (Balme & Hennelly) Lele, 1964; *P. trigonalis* Lele, 1964; *P. diffusus* Lele, 1964; *P. densus* Srivastava, 1970; *Cannanoropollis obscurus* (Lele) comb. nov. (= *Virkkipollenites obscurus* Lele, 1964, pl. 2, fig. 17, p. 60); *Potonieisporites neglectus* Potonié & Lele, 1961; *P. jayantiensis* Lele & Karim, 1971; *P. densus* Maheshwari, 1967; *P. crassus* Lele & Chandra, 1973; *Parasaccites distinctus* Tiwari, 1965; *P. bilateralis* Tiwari, 1965; *P. obscurus* Tiwari, 1965; *P. diffusus* Tiwari, 1965; *P. talchirensis* Lele & Makada, 1972; *P. densicorpus* Lele, 1975; *Tuberisaccites tuberculatus* (Maheshwari) Lele & Makada, 1972; *Caheniasaccites distinctus* Lele & Makada, 1972; *Vesicaspora* sp.; *Faunipollenites goraiensis* (Potonié & Lele) Maithy, 1965; *Crescentipollenites amplus* (Balme & Hennelly) Lele & Shukla, 1981.

KARHARBARI FORMATION

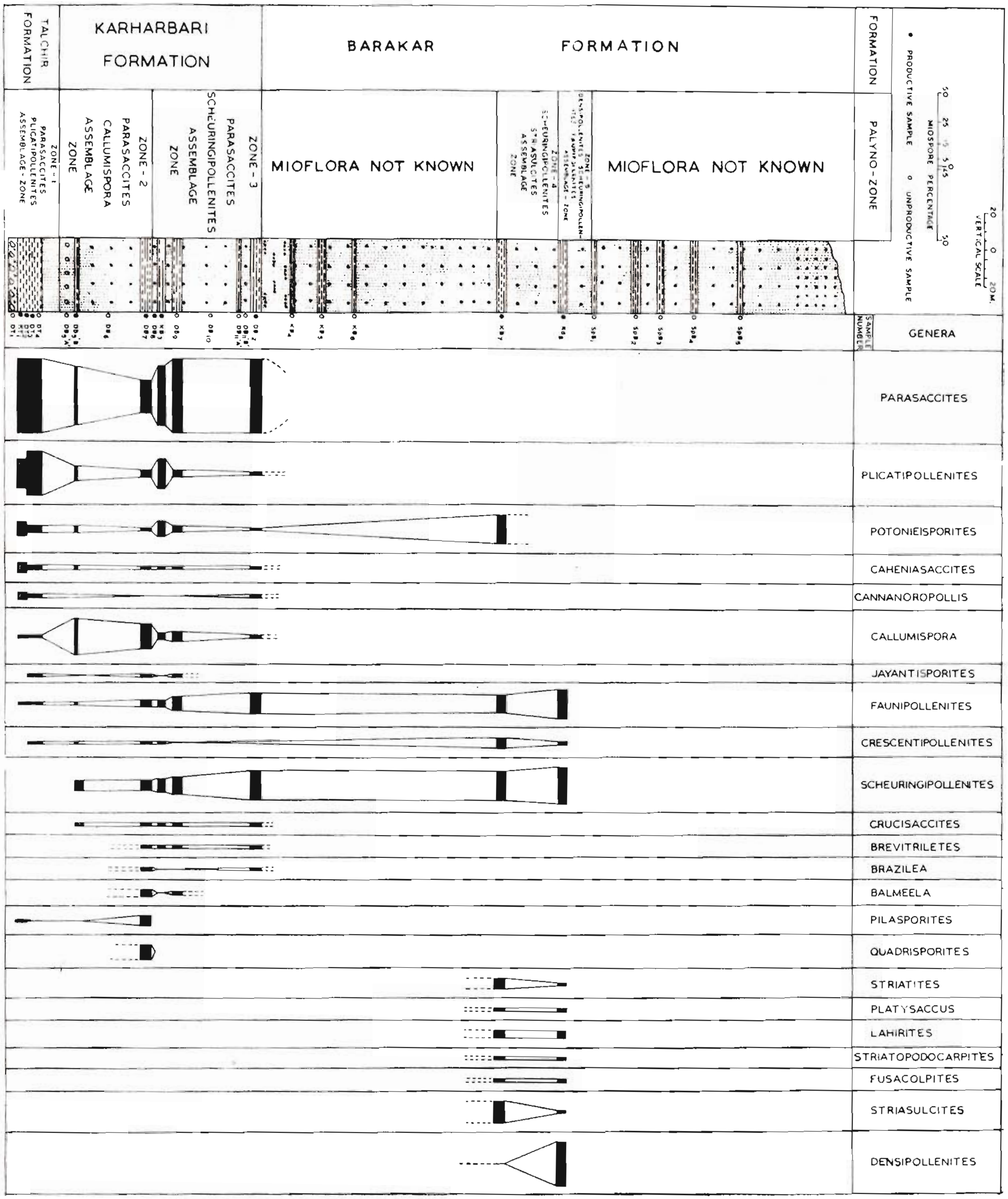
Callumispora tenuis; *C. tenuis* var. *minor*; *Leiotriletes* sp., *Brevitriletes levis* (Balme & Hennelly) Bharadwaj & Srivastava, 1969; *Microbaculispora indica* Tiwari, 1965; *Jayantisporites pseudozonatus* Lele & Makada, 1972; *Plicatisporites distinctus* Lele & Makada 1972; *Tiwariasporis simplex* (Tiwari), Maheshwari & Kar, 1967; *Pilasporites calculus* Balme & Hennelly, 1973; *Brazilea punctata* Tiwari & Navale, 1967; *Greinervillites undulatus* Bose & Kar, 1967; *Balmeela tetragona* Pant & Mehra, 1953; *B. gigantea* Bose & Maheshwari, 1968; *Quadrisporites horridus* (Hennelly) Potonié & Lele, 1961; *Parasaccites korbaensis* Bharadwaj & Tiwari, 1964; *P. distinctus*; *P. diffusus*; *P. obscurus*; *P. bilateralis*; *P. densicorpus*; *P. plicatus* Lele & Makada, 1972; *P. invasus* Tiwari, 1968; *Crucisaccites latisulcatus* Lele & Maithy, 1964; *C. indicus* Srivastava, 1970; *Stellapollenites talchirensis* Lele, 1965; *S. indicus* Lele & Kulkarni, 1970; *Stellapollenites* sp., *Divarisaccus lelei* Venkatachala & Kar, 1966; *Caheniasaccites decorus* Lele & Makada, 1972; *C. granulatus* Lele & Makada, 1972; *C. granulatus* Lele & Chandra, 1972; *Plicatipollenites indicus*; *P. gondwanensis*; *P. diffusus*; *P. trigonalis*; *Kibambites corius* Bose & Kar, 1967; *Cannanoropollis orientalis* (Tiwari) comb. nov. (= *Virkkipollenties orientalis* Tiwari, 1968, p. 23, pl. 34, fig. 38); *Potonieisporites triangulatus* Tiwari, 1965; *P. monosaccoides* (Bose & Maheshwari) Lele, 1975; *P. neglectus*; *P. jayantiensis*; *P. densus*; *P.* sp. cf.

TABLE 1 — EXTENSION OF LITHOSTRATIGRAPHIC UNITS IN THE HUTAR COALFIELD

FORMATION	MEMBERS	DEORI NALA (SOUTH)	DEORI NALA (NORTH)	KOEL RIVER (NORTH)	SAPHI NALA (NORTH)	BEHRA NALA	SAPHI (UKAMNAR AREA)	KELHA NALA	GHORASUM NALA	DURIA-KHAR	CHELHA-PANIKHAR
Mahadeva	Ferruginous pebbly sandstone				+						
	ANGULAR UNCONFORMITY			(Fault)							
Barakar	Ferruginous sandstone-shale			+	+	+		+		+	+
	Gritty sandstone			+		+				+	+
	Compact red sandstone			+			+				
								(fault)			
Karharbari	Gritty sandstone	+	+	+			+	+	+		
	Basal conglomerate	+		+			+				
	EROSIONAL BREAK		(Fault)								
Talchir	Upper sandstone		+	+		(Fault)	+				
	Shale	+	+	+		+	+				
	Basal sandstone conglomerate	+	+	+		+					
	NONCONFORMITY										
Archean	Granite, gneiss schists	+	+	+			+				


FORMATION
PAYNOLOGICAL ASSEMBLAGE - ZONE
VERTICAL SCALE
20 0 20 m
BARAKAR FORMATION
KARHARBARI FORMATION
TALCHIR FORMATION
MIOFLORA NOT KNOWN
ZONE - 5
DENSIPOLLENITES-SCHEURINGIPOLLENITES FAUNIPOLLENITES ASSEMBLAGE - ZONE
ZONE - 4
SCHEURINGIPOLLENITES STRIASULCITES ASSEMBLAGE ZONE
MIOFLORA NOT KNOWN
ZONE - 3
PARASACCITES SCHEURINGIPOLLENITES ASSEMBLAGE ZONE
ZONE - 2
PARASACCITES ASSEMBLAGE - ZONE
ZONE - 1
PARASACCITES PLICATIPOLLENITES ASSEMBLAGE - ZONE
SpB5
SpB4
SpB3
SpB2
SpB1
KB8
KB7
KB6
KB5
KB4
DB12
DB11(B)
DB11(A)
DB10
DB9
KB3
DB8
DB7
DB6
DB5(B)
DB5(A)
DT4
DT3
DT2
KT1
DT1
O 5 km
N
BARWADIH
HUTAR
UKAMANR
TIHARO
UKHANT
SAPHI N.
KOEL R.
MURMAIKHURD
LOCATION MAP
MIOFLORA NOT KNOWN
DENSIPOLLENITES SCHEURINGIPOLLENITES FAUNIPOLLENITES ASSEMBLAGE - ZONE
SCHEURINGIPOLLENITES - STRIASULCITES ASSEMBLAGE - ZONE
MIOFLORA NOT KNOWN
PARASACCITES SCHEURINGIPOLLENITES ASSEMBLAGE ZONE
PARASACCITES CALLUMISPORA ASSEMBLAGE - ZONE
PARASACCITES PLICATIPOLLENITES ASSEMBLAGE - ZONE
DB12
DB11(B)
DB11(A)
DB10
DB9
DB8(B)
DB8(A)
DB7
DB6
DB5(C)
DB5(B)
DB5(A)
DT4
DT3
DT2
PT1
F
KB11
KB10
KB9
KB8
KB7
KB6
KB5
KB4
KB3
KB2
KB1
KT1(B)
KT1(A)
MIOFLORA NOT KNOWN
SpB5
SpB4
SpB3
SpB2
SpB1
SAPHI NALA SECTION
INDEX
COAL
COALY SHALE
SHALE
GRITTY SANDSTONE
SAND-STONE WITH LENSES OF CONGLOMERATE
PEBBLY SANDSTONE
MEDIUM-COARSE SANDSTONE
NEEDLE SHALE
BOULDER BED
GENERALIZED SUCCESSION
DEORI NALA SECTION
KOEL RIVER SECTION

TEXT-FIG. 1


TALCHIR FORMATION
KARHARBARI FORMATION
BARAKAR FORMATION
FORMATION
ZONE - 1 PARASACCITES PLICATIPOLLENITES ASSEMBLAGE - ZONE
ZONE - 2 PARASACCITES CALLUMISPORA ASSEMBLAGE ZONE
ZONE - 3 PARASACCITES SCHEURINGIPOLLENITES ASSEMBLAGE ZONE
MIOFLORA NOT KNOWN
ZONE - 4 SCHEURINGIPOLLENITES STRIASULCITES ASSEMBLAGE ZONE
ZONE - 5 DENSIPOLLENITES SCHEURINGIPOLLENITES FAUNIPOLLENITES ASSEMBLAGE - ZONE
MIOFLORA NOT KNOWN
PALYNO-ZONE
MIOSPORE PERCENTAGE
50 25 15 5 0 5 15 25 50
● PRODUCTIVE SAMPLE ○ UNPRODUCTIVE SAMPLE
VERTICAL SCALE
20 0 20 M.
DT1
DT4
DB5 B
DB6
DB7
DB9
DB10
DB Z
KB4
KB5
KB6
KB7
KB8
SPB1
SPB2
SPB3
SPB4
SPB5
SAMPLE NUMBER
GENERA
PARASACCITES
PLICATIPOLLENITES
POTONIEISPORITES
CAHENIASACCITES
CANNANOROPOLLIS
CALLUMISPORA
JAYANTISPORITES
FAUNIPOLLENITES
CRESCENTIPOLLENITES
SCHEURINGIPOLLENITES
CRUCISACCITES
BREVITRILETES
BRAZILEA
BALMEELA
PILASPORITES
QUADRISPORITES
STRIATITES
PLATYSACCUS
LAHIRITES
STRIATOPODOCARPITES
FUSACOLPITES
STRIASULCITES
DENSIPOLLENITES

TEXT-FIG. 7

TABLE 2 — DETAIL OF SAMPLES COLLECTED FROM OTHER NALAS, EXPOSING LOWER GONDWANA BEDS (BESIDES THREE MAIN TRAVERSES) IN THE HUTAR COALFIELD

No.	Sample No.		Formation	Location
1	DT15	Needle shale with siltstone	Talchir	Near Barwadih Village in Deori Nala
2	BT2, BT3	Needle shale with siltstone	Talhchir	Behra Nala, N-W of Dhaj Pahar
3	DB16	Shale — Coal	Karharbari	Deori Nala, near Hutar Colliery
4	K1K2	Coal	Karharbari	Kelha Nala, nearly 100 meter from confluence of the Kelha Nala and Deori Nala
5	GB2	Shale — Coal	Karharbari	Ghorasum Nala, near its confluence with Deori Nala
6	SB10	Coaly shale	Karharbari	Satbahni Nala, 0.5 km south-east of Hot-water spring
7	SB1	Carbonaceous shale	Barakar	Satbahni Nala
8	SB3	Sandy carbonaceous shale	Barakar	do
9	SB8	Shale	Barakar	do
10	CB3	Sandy carbonaceous shale	Barakar	Chelha-Panikhar Nala

P. lelei Maheshwari, 1967; *Scheuringipollenites maximus* (Hart) Tiwari, 1973; *S. barakarensis* (Tiwari) Tiwari, 1973; *S. tentulus* (Tiwari) Tiwari, 1973; *Ibisporites diplosaccus* Tiwari, 1968; *Korbapollenites* sp.; *Faunipollenites varius* Bharadwaj, 1962; *F. perexiguus* Bharadwaj & Salujha, 1964; *F. parvus* Tiwari, 1964; *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj, Tiwari & Kar, 1974; *Ginkgocycadophytus cymbatus* (Balme & Hennelly) Potonié & Lele, 1961.

Barakar Formation

Indotriradites surangei Tiwari, 1965; *Densipollenites indicus* Bharadwaj, 1962; *D. invisus* Bharadwaj & Salujha, 1964; *D. minimus* Venkatachala & Kar, 1968; *D. brevis* Lele & Srivastava, 1977; *Crucisaccites* sp., *Vesicaspora distincta* Tiwari, 1965; *Plicatipollenites indicus*; *Potonieisporites concinnus* Tiwari, 1965; *P. triangulatus*; *P. monosaccoides*; *P. bilateralis* Singh, 1964; *P. densus*; *Potonieisporites* sp., *Illinites delasaucei* (Potonié & Klaus) Grebe & Schweitzer, 1962; *Scheuringipollenites maximus*; *S. barakarensis*; *S. tentulus*; *Platysaccus hingirensis* Tiwari, 1964; *Ibisporites diplosaccus*; *Korbapollenites* sp., *Rhizomaspora fimbriata* Tiwari, 1965; *Faunipollenites varius*; *F. perexiguus* Bharadwaj & Salujha, 1965; *F. parvus*; *F. goraiensis*; *F. bharadwajii* Maheshwari, 1967; *Faunipollenites* sp-, (cf. Tiwari, 1965). *Striatopodocarpites labrus* Tiwari, 1965; *S. decorus* Bharadwaj & Salujha, 1964; *Lahirites fructus* Tiwari, 1965; *L. alutas* Venkatachala & Kar, 1968; *L. rarus* Bharadwaj & Salujha, 1965; *L. incertus* Bharadwaj & Salujha, 1965; *Crescentipollenites fuscus*; *C. globosus* (Maithy), Bharadwaj, Tiwari & Kar, 1974; *Striatites implicatus* Bose & Maheshwari, 1968; *S. cancellatus* (Balme & Hennelly) Potonié, 1956; *S. multistriatus* (Balme & Hennelly) Tiwari, 1965; *S. ornatus* Venkatachala & Kar, 1968; *Distriatites insolitus* Bharadwaj & Salujha, 1964; *Ginkgocycadophytus cymbatus*; *Fusacolpites fusus* Bose & Kar, 1966; *Striasulcites tectus* Venkatachala & Kar, 1968; *S. ovatus* Venkatachala & Kar, 1968.

PALYNOLOGICAL SUCCESSION

Palynological succession of the Lower Gondwana sediments in the Hutar Coalfield has been worked out on the basis of percentage distribution of genera (Text-fig. 2). However, some species found in the miofloral assemblage of the Hutar Coalfield show a restricted distribution in time (Table 3) and therefore are useful at least for broad local correlation.

TABLE 3 — DISTRIBUTION OF MIOSPORES SPECIES IN THE LOWER GONDWANA FORMATION OF THE HUTAR COALFIELD

SPECIES	TALCHIR	KARHARBARI	BARAKAR
Parasaccites talchirensis	×		
Plicatipollenites densus	×		
Potonieisporites crassus	×		
Caheniasaccites distinctus	×		
Cannanoropollis obscurus	×		
Parasaccites densicorpus	×	×	
Plicatipollenites trigonalis	×	×	
Plicatipollenites gondwanensis	×	×	
Parasaccites plicatus		×	
Callumispora tenuis		×	
Brevitriletes levis		×	
Crucisaccites indicus		×	
Scheuringipollenites tentulus		×	×
Potonieisporites concinnus			×
Potonieisporites barralis			×
Faunipollenites perexiguus			×
Faunipollenites bharadwajii			×
Crescentipollenites globosus			×
Illinites delasaucei			×
Striatites multistriatus			×
Striatites ornatus			×
Distriatites insolitus			×
Rhizomaspora fimbriata			×
Striatopodocarpites labrus			×
Striatopodocarpites decorus			×
Lahirites rarus			×
Lahirites incertus			×
Lahirites alutus			×

The palynological succession in the Hutar Coalfield is divided into 5 Assemblage-zones.

1. *Parasaccites-Plicatipollenitcs Assemblage Zone* — This zone is marked by the dominant presence of *Parasaccites* and *Plicatipollenites*. Other important genera are — *Potonieisporites, Caheniasaccites, Cannanoropollis, Callumispora, Jayantisporites, Vesicaspora, Limitisporites, Faunipollenites*. It is best identified in the Deori Nala Section, though it is also encountered within the Koel River and Behra Nala sections. The miospore frequency distribution is shown in Table 4.

2. *Parasaccites-Callumispora Assemblage Zone* — This zone is marked by the dominant presence of *Parasaccites* and *Callumispora*. The other important genera present in the zone are *Plicatipollenites, Scheuringipollenites, Faunipollenites, Caheniasaccites, Potonieisporites, Crescentipollenites* and *Crucisaccites*. An important feature of this zone is the presence of alete genera, viz., *Quadrisporites, Balmeela, Pilasporites* and *Brazelia* in the upper part (sample no. DB_7-DB_8) of the zone. This zone is identified in the Deori Nala Section only. The miospore frequency distribution is shown in Table 5.

3. *Parasaccites-Scheuringipollenites Assemblage Zone* — This zone shows the dominant presence of *Parasaccites* and *Scheuringipollenites*. Other important genera are *Faunipollenites, Plicatipollenites, Callumispora, Potonieisporites, Caheniasaccites, Brevitriletes, Crucisaccites, Jayantisporites, Microbaculispora, Tiwariasporis, Balmella, Brazelia, Stellapollenites, Vesicaspora, Divarisaccus, Kibambites, Cannanoropollis* and *Ibisporites*. Genera like *Scheuringipollenites, Crucisaccites* and *Faunipollenites* gradually increase while *Callumispora, Brevitriletes, Plicatipollenites* and *Potonieisporites* gradually decrease. This zone is best exposed in the Deori Nala Section though it is also encountered within the Koel River Section, Kelha Nala, Ghorasumi Nala and Satbahni Nala. The miospore frequency distribution is given in Table 5.

4. *Scheuringipollenites-Striasulcites Assemblage Zone* — This zone is marked by the dominant presence of *Scheuringipollenites* and *Striasulcites*. Other important genera present include *Potonieisporites, Faunipollenites, Striatites, Crescentipollenites, Lahirites, Platysaccus, Tiwariasporis, Vesicaspora, Illinites, Ibisporites, Striatopodocarpites, Distriatites, Ginkgocycadophytus* and *Fusacolpites*. This zone is best exposed in the Koel River Section, though it is also encountered with in Chelha-Panikhar Nala and Satbahni Nala. Miospore frequency is given in Table 6.

5. *Densipollenites-ScheuringipollenitesFaunipollenites Assemblage Zone* — This Assemblage-zone is marked by the dominant

TABLE 4 — DISTRIBUTION OF PALYNOMORPHS IN VARIOUS SAMPLES OF THE TALCHIR FORMATION (ASSEMBLAGE ZONE-1) IN THE HUTAR COALFIELD

	Deori Nala		Koel River	Behra Nala	
	DT_2+DT_3	DT_{15}	KT_1	BT_3	BT_4
Psilalacinites	+	—	—	—	—
Callumispora	2	6.5	3	4	2
Verrucosisporites	+	—	—	—	+
Horriditriletes	+	—	—	—	+
Jayantisporites	0.7	2	—	+	1
Parasaccites	51.9	53	54	59	56
Tuberisaccites	0.2	—	—	—	—
Caheniasaccites	3.2	4.5	8.5	5	4
Vesicaspora	0.7	1	—	—	—
Cannanoropollis	3.2	4.5	8.5	5	4
Plicatipollenites	31.7	21.5	19.5	22	24
Potonieisporites	5.7	8.5	12.5	8	8
Faunipollenites	0.5	—	0.5	—	2
Crescentipollenites	0.2	0.5	—	—	+
Foveofusa	—	—	+	+	—
Botryococcus	—	—	+	—	—

occurrence of genera *Densipollenites*, *Scheuringipollenites* and *Faunipollenites*. Genera *Striasulcites*, *Platysaccus*, *Crescentipollenites*, *Striatites*, *Fusacolpites*, *Lahirites*, *Rhizomaspora* and *Verticipollenites* are also present.

This zone is best developed in the Koel River Section, though it is also encountered within Satbahni Nala. Miospore frequency is given in Table 6.

DISCUSSION

The Lower Gondwana succession in the Hutar Coalfield has been divided into Talchir, Karharbari and Barakar formations. Palynologically, it is divided into 5 zones, viz., (i) *Parasaccites-Plicatipollenties* Assemblage-zone, (ii) *Parasaccites-Callumispora* Assemblage-zone, (iii) *Parasaccites-Scheuringipollenites* Assemblage-zone, (iv) *Scheuringipollenites-Striasulcites* Assemblage-zone, and (v) *Densipollenites-Scheuringipollenites - Faunipollenites* Assemblage - zone. The lithostratigraphic units and palynostratigraphic units show a close agreement (Table 7).

Assemblage-zone 1 represents the mioflora of the Talchir Formation in this coalfield. This zone is dominated by radial monosaccates (85%) genera like: *Parasaccites* and *Plicatipollenites*, whereas the triletes (1.9%) and bisaccates (0.6%) are rare. This zone shows resemblance with miofloral zones in the North Karanpura (Zone I of Kar, 1973), Korba (lower part of Zone-1 of Bharadwaj & Srivastava, 1973), Mohpani (Zone-1 of Bharadwaj & Anand-Prakash, 1972), Giridih (older part of Zone 1 of Srivastava, 1973), Bokaro (late Talchir flora of Lele, 1975), Jayanti (middle to upper set of Talchir flora of Lele & Makada, 1972), Johilla (late Talchir mioflora of Chandra & Lele, 1979) and Manendragarh area (Bharadwaj *et al.*, 1979). All these miofloras show dominance of radial monosaccates, *viz.*, *Parasaccites*, *Cannanoropollis* and *Plicatipollenites* with *Potonieisporites*, *Caheniasaccties* and *Vesicaspora* ranging from rare to subdominant. Triletes, especially *Callumispora*, do not form more than 9% of the assemblage except for one sample each in the Jayanti and Korba coalfields.

Records of bisaccate pollen are quite inconsistent in the Talchir Formation and they should not be allowed to diffuse the real picture which is primarily based on radial monosaccates and triletes. Earlier, the only broadly possible zonation in the Talchir flora was given by Lele (1975), i.e. of late and early Talchir flora based on the diversification and paucity of genera. Lower middle and upper set of miofloras in the Jayanti Coalfield (Lele & Makada, 1972) are all part of late Talchir mioflora.

TABLE 5 — SHOWING DISTRIBUTION OF VARIOUS MIOSPORES IN THE KARHARBARI FORMATION (ASSEMBLAGE ZONE-2 AND 3) OF HUTAR COALFIELD

(DB=Deori Nala; KB=Koel River; KIB=Kelha Nala; GB=Ghorasum Nala; SB=Satbahni Nala)

GENERA	ZONE-2					ZONE-3						
SAMPLE NO.	DB5	DB7 (A)	DB7 (B)	DB8 (A)	DB8 (B)	DB9	DB12	DB16	KB_3	KIB_2	GB_2	SB_{10}
Callumispora	24	16	10	31.5	17.8	8	1	2.5	6.5	6	3	2
Leiotriletes	—	2	—	—	3.5	—	—	—	—	—	0.5	1
Brevitriletes	—	3	0.5	0.5	2.5	2	0.5	1.5	1	—	2	—
Microbaculispora	—	2	—	—	3.5	1	—	2.5	—	—	0.5	—
Jayantisporites	—	2	0.5	—	3.5	1	—	—	—	—	—	—
Plicatipollenites	—	—	0.5	1	—	—	—	—	—	—	1.5	1
Tiwariasporis	—	—	—	—	—	—	1·5	0.5	—	1	0.5	—
Pilasporites	—	1	20	0.5	7	—	—	0.5	—	1	1	1
Brazilea	—	—	3	0.5	2	—	1.5	—	—	—	—	—
Greinervillites	—	—	1	—	—	—	—	—	—	—	1.5	—
Balmeela	—	2	17.5	—	2	1	—	—	—	1	—	—
Quadrisporites	—	—	42.5	—	—	—	—	—	—	—	—	—
Parasaccites	44	34	1.5	42	18.5	49	47	38	37.5	44	35.05	60
Crucisaccites	1	—	—	3	—	1	3	1.5	1	—	3	—
Stellapollenites	—	—	—	—	—	—	1	0.5	0.5	0·5	1.5	—
Divarisaccus	—	—	—	—	—	—	0.5	0.5	—	—	1	—
Caheniasaccites	4	2	0.5	2	2	2	2	5.5	2.5	1	3	3
Plicatipollenites	11	16	—	3	7	6	2.2	8	18.6	3	6	13
Kibambites	—	—	—	—	—	—	2.0	0.5	—	—	1	3
Cannanoropollis	—	—	—	0.5	—	—	1.5	2	—	—	2.5	—
Potonieisporites	4	5	—	2.5	6.5	6	1.7	3.5	10.5	—	2.5	1
Scheuringipollenites	8	6	2.5	9.5	12	13	20	23.5	17.5	32	18.05	11
Ibisporites	—	—	—	—	—	—	0.6	—	—	—	—	—
cf. *Korbapollenites*	—	—	—	—	—	—	—	0.5	0.6	1	1	—
Faunipollenites	1	8	—	4	9.5	9	14	5.5	4.6	9	11.05	3
Crescentipollenites	2	—	—	0.5	1	—	—	3	5.1	1	2.5	1
Ginkgocycadophytus	1	1	—	—	1	—	—	—	—	—	—	—

TABLE 6 — DISTRIBUTION OF MIOSPORES IN VARIOUS SAMPLES OF BARAKAR FORMATION (ASSEMBLAGE-ZONE-4 AND 5)

(KB=Koel River; CB=Chelhapanikhar Nala; SB=Salbahni Nala)

GENERA	ZONE-4			ZONE-5		
	KB_7	CB_3	SB_8	KB_8	SB_1	SB_6
Microbaculispora	—	—	—	+	+	+
Indotriradites	+	+	+	—	—	—
Densipollenites	+	+	+	36	38	39
Vesicaspora	1	2	3	—	—	—
Plicatipollenites	+	—	—	—	—	—
Potonieisporites	20	10	12	—	—	—
Scheuringipollenites	20	22	23	25	22	18
Illinites	1	+	1	—	—	—
Ibisporites	3	3	3	—	—	—
Platysaccus	3	3	3	1	2	1
Rhizomaspora	—	—	—	2	1	3
Faunipollenites	12	15	15	22	23	28
Striatopodocarpites	+	+	—	3	4	4
Lahirites	4	3	2	5	4	3
Crescentipollenites	8	8	8	1	2	1
Striatites	8	11	9	2	1	1
Distriatites	1	1	1	—	—	—
Fusacolpites	2	4	3	1	2	+
Striasulcites	17	17	15	1	1	3
Ginkgocycadophytus	1	1	1	—	—	1

The three zones given by Tiwari (1975) are somewhat hypothetical and need to be demonstrated in continuous succession. Recently, Chandra and Lele (1979) published an exhaustive study of the Talchir miofloras from a number of areas in South Rewa Gondwana Basin in which they identify two miofloral zones in the Talchir Formation. The lower zone is characterized by the prevalence of *Plicatipollenites* over *Parasaccites*; whereas in the upper zone the picture is reversed. A similar conclusion has been drawn by Bharadwaj *et al.* (1979) from their study of the Manendragarh Talchir miofloras.

Assemblage zone-2 represents mioflora of the lower part of the Karharbari Formation. This mioflora shows a sudden increase in the triletes and decrease in monosaccates. This abrupt change in miofloral picture indicates a hiatus between the deposition of the Talchir and the Karharbari formations. This hiatus is also indicated by the presence of a conglomeratic horizon above the Talchir Formation, both in the Koel River Section near Hutar Village and in the Deori Nala section near Barwadih Village.

This zone shows resemblance with miofloral zones in the North Karanpura (Zone II of Kar, 1973), Korba (upper subzone in Zone 1 of Bharadwaj & Srivastava, 1973), Giridih (younger part in Zone 1 of Srivastava, 1973), Raniganj (*Callumispora* zone of Tiwari, 1973), Umrer Quarry, Nagpur (Zone 1 of Bharadwaj & Anand Prakash, 1974), Jayanti Coalfield (flora of samples D18 and 19, Lele & Makada 1974), West Bokaro Coalfield (Anand-Prakash, Srivastava & Tiwari, 1979) and Auranga Coalfield (Lele & Srivastava, 1979). Zone II of the Mohpani Coalfield which shows a flora dominated by *Sulcatisporites* (= *Scheuringipollenites*) and apiculate genus *Brevitriletes*, is miofloristically nearer to the Lower Barakar mioflora and hence has been placed there in the present work.

Assemblage-zones 1 and 2 of the Hutar Coalfield together correspond with the Zone 1 of the Korba Coalfield (Bharadwaj & Srivastava, 1973) and Zone 1 of the Giridih Coalfield (Srivastava, 1973). However, in both these coalfields two sets of mioflora, i.e. lower and upper are recognized which compare with the Assemblage-zone 1 and 2 of the Hutar Coalfield respectively.

TABLE 7 — COMPARISON OF LITHOSTRATIGRAPHIC AND PALYNOSTRATIGRAPHIC UNITS IN THE HUTAR COALFIELD

FORMATION	LITHOSTRATIGRAPHY				PALYNOSTRATIGRAPHY			
	Member	Deori Nala	Koel River	Saphi Nala	Biozone	Deori Nala	Koel River	Saphi Nala
MAHADEVA				+	Mioflora not known			+
BARAKAR	Sandstone shale — clay Member		+	+	do		+	+
	Sandstone Coal-shale Member		+		Zone V *Densipollenites* — *Scheuringipollenites* — *Faunipollenites* Assemblage zone		+	
					Zone IV *Scheuringipollenites* — *Striasulcites* Assemblage zone		+	
	Compact red Sandstone Member		+		Assemblage not known	-?-?-?-?-?-?-?-?-?-?-?-?-?-?-?		
KARHARBARI	Sandstone and shale coal Member	+	+		Zone III *Parasaccites* — *Scheuringipollenites* Assemblage zone	+	+	
					Zone II *Parasaccites* — *Callumispora* Assemblage zone	+		
	Basal conglomerate Member	+	+					
TALCHIR	Upper Sandstone Member	+	+					
	Shale-Varve-siltstone Member	+	+		Zone I *Parasaccites* — *Plicatipollenites* Assemblage zone	+	+	
	Basal-sandstone — conglomerate Member	+	+					
ARCHEAN		+	+					

Assemblage-zone 3 represents the mioflora of the upper part of the Karharbari Formation. This zone shows the dominance of the genera *Parasaccites* and *Scheuringipollenites*. *Callumispora*, which was dominant in Assemblage-zone 2, gradually declines in this zone. Thus, miofloristically zone 2 and 3 do not show any sudden change. Lithostratigraphically too, the beds yielding the mioflora of Assemblage-zone 2 and 3 are conformable.

The best development of the Karharbari Formation may be seen in the Deori Nala Section and consequently both the palynozones of this formation are represented here. The Karharbari Formation thins out towards west and consequently in the Koel River Section very small thickness of the Karharbari sediments are represented. The beds which should have the mioflora of Assemblage-zone 2 are also thin on this side. Unfortunately, these beds did not yield any mioflora. Further, the bed which yielded the mioflora of the zone 3, is also thin.

Assemblage-zone 3 shows resemblance with miofloral zones in North Karanpura (Zone III of Kar, 1973), Korba (Zone II of Bharadwaj & Srivastava, 1973), Raniganj (*Parasaccites* Zone of Tiwari, 1973) and Umrer Quarry, Nagpur (Zones II & III of Bharadwaj & Anand-Prakash, 1974).

The lower and middle part of the Barakar Formation in this coalfield is represented by huge thickness of chocolate brown sandstone with lenses of conglomerate (best seen in the Ranimai, Dhaj, Chelha, Panchpahari and Dhankutia hillocks), carbonaceous grits and gritty sandstone (Koel River Section) but it did not yield any mioflora. Elsewhere the lower — middle Barakar flora is represented by dominance of *Scheuringipollenites* apiculates and zonate trilete genera (Tiwari, 1974).

Assemblage-zone 4 represents the mioflora of the upper part of the Barakar Formation. The mioflora of this assemblage shows the first appearance of many striate-bisaccate and colpate pollen and sudden disappearance of the spores of lower plants. This flora is quite distinct from the miofloral assemblage of the Assemblage-zone 3. This sudden change in the miofloristic picture is due to the absence of any miofloral evidences from lower and middle parts of the Barakar. Further, this zone of the Coalfield is part of the Upper Barakar mioflora which is dominated by striate-bisaccates and *Scheuringipollenites* with triletes as rare forms (Tiwari, 1974; Bharadwaj, 1971). *Striasulcites* may also form significant proportion of the flora (Kar, 1973). The high incidence of *Potonieisporites* in the Hutar Coalfield is somewhat exceptional to the known Upper Barakar miofloras. This Assemblage-zone shows some resemblance with miofloral zone in the North Karanpura (Zone-VI of Kar, 1973) and the Raniganj Coalfield (*Striatopodocarpites-Faunipollenites* zone of Tiwari, 1973).

Assemblage-zone 5 shows first appearance and dominance of the genus *Densipollenites*. *Potonieisporites* which formed 20 per cent of the mioflora in Assemblage-zone 4 is absent. The monocolpate genus *Striasulcites* (1%) also shows a sudden decline. This change strongly suggests a miofloral break between the Assemblage-zones 4 and 5. Incidentally, the mioflora of Assemblage-zone 5 shows a general similarity with the middle Barren Measures mioflora in the dominance of bisaccates and *Densipollenites* and in absence of triletes (Bharadwaj, 1971; Kar, 1973). It is also important that the lithology of beds immediately overlying this zone is devoid of carbonaceous facies, and thus shows a general similarity with the Barren Measures Formation.

Besides, this zone compares with the miospore assemblages described from Barren Measures of the Jharia Coalfield (Bharadwaj, Sah & Tiwari, 1965), North Karanpura Coalfield (Kar, 1969), and Brahmni Coalfield (Srivastava & Maheshwari, 1974). All these have abundance of genus *Densipollenites*.

This assemblage has been recovered from sediments which normally on the basis of lithology are grouped with the upper part of the Barakar Formation. However, the palynological evidence indicates that these sediments may be homotaxial with a part of the Barren Measures Formation. Further field and laboratory work are recommended to solve this problem.

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REFERENCES

ANAND-PRAKASH, SRIVASTAVA, S. C. & TIWARI, R. S. (1979). The nature of grooved pavement and palynology of overlying Talchir and Karharbari sediments in West Bokaro Coalfield, Bihar, India. *Palaeobotanist*, **26** (1): 63-71.

BALL, V. (1880). On Auranga and Hutar coalfields and iron ores of Palamau and Toree. *Mem. geol. surv. India*, **15** (2): 1-90.

BHARADWAJ, D. C. (1971). Palynostratigraphy of Lower Gondwana succession in India. *Int. Gondwana Symp. Aligarh Muslim Univ., 1970. Annls Geol. A.M.U.*, **5** & **6**: 390-419.

BHARADWAJ, D. C. & ANAND-PRAKASH (1972). Geology and palynostratigraphy of Lower Gondwana formations in Mohpani Coalfield, Madhya Pradesh, India. *Geophytology*, **1** (2): 103-115.

BHARADWAJ, D. C. & ANAND-PRAKASH (1974). Palynostratigraphy of Lower Gondwana sediments from Umrer Quarry, Nagpur, Maharashtra, India. *Geophytology*, **4** (2): 130-135.

BHARADWAJ, D. C. & SRIVASTAVA, S. C. (1973). Subsurface palynological succession in Korba Coalfield, M.P., India. *Palaeobotanist*, **20** (2): 137-151.

BHARADWAJ, D. C., SRIVASTAVA, S. C. & ANAND-PRAKASH (1979). Palynostratigraphy of the Talchir Formation from Manendragarh, Madhya Pradesh, India. *Geophytology*, **8** (2): 215-225.

BHARADWAJ, D. C., SAH, S. C. D. & TIWARI, R. S. (1965). Sporological analysis of some coals and carbonaceous shales from Barren Measure Stage (Lower Gondwana) of India. *Palaeobotanist*, **13** (2): 222-226.

CHANDRA, A. & LELE, K. M. (1979). Talchir miofloras from South Rewa Gondwana Basin, India and their biostratigraphical significance. *Proc. IV int. palynol. Conf., Lucknow (1976-77)*, **2**: 117-151.

FEISTMANTEL, O. (1886). The fossil flora of Gondwana System. The fossil flora of some of the coalfields in western Bengal. *Mem. geol. surv. India Palaeont. Indica*, **4** (2): 1-66.

GHOSH, P. K. & MITRA, N. D. (1969). History of the Talchir sedimentation in Damodar Valley basins. *Mem. geol. surv. India*, **105**: 1-117.

GHOSH, S. C., SINGH, C. & ACHARYYA, S. K. (1977). Barren Measure/Kulti Formation. *Geol. Surv. India, Misc. Publ.*, **36**: 18-19.

KAR, R. K. (1969). Palynology of North Karanpura Basin, Bihar, India-4. Subsurface palynology of bore core no. K5. *Palaeobotanist*, **17** (1): 9-21.

KAR, R. K. (1973). Palynological delimitation of the Lower Gondwana in the North Karanpura sedimentary basin, India. *Palaeobotanist*, **20** (3): 300-317.

LELE, K. M. (1964). Studies in Talchir flora of India-2. Resolution of the spore genus *Nuskoisporites* Pot. & Kl. *Palaeobotanist*, **12** (2): 147-168.

LELE, K. M. (1975). Studies in the Talchir flora of India-10. Early and late microfloras from the West Bokaro Coalfield, Bihar. *Palaeobotanist*, **22** (3): 219-235.

LELE, K. M. & MAKADA, R. (1972). Studies in Talchir flora of India-7. Palynology of Talchir Formation of Jayanti Coalfield, Bihar. *Geophytology*, **2** (1): 41-73.

LELE, K. M. & MAKADA, R. (1974). Palaeobotanical evidences on the age of the coal-bearing Lower Gondwana Formation in the Jayanti Coalfield, Bihar. *Palaeobotanist*, **21** (1): 81-106.

LELE, K. M. & SHUKLA, M. (1981). Studies in the Talchir flora of India-12. Palynology of the Talchir Formation of Hutar Coalfield, Bihar. *Geophytology*, **10** (2): 231-238.

LELE, K. M. & SRIVASTAVA, A. K. (1979). Lower Gondwana (Karharbari to Raniganj Stage) miofloral assemblages from Auranga Coalfield and their significance. *IV int. Palynol. Conf., Lucknow (1976-1977)*, 2: 152-164.

RIZVI, S. R. A. (1972). Geology and sedimentation trends in Palamau Coalfield, Bihar, India. *Mem. geol. surv. India*, **104**: 1-99.

SRIVASTAVA, S. C. (1973). Palynostratigraphy of the Giridih Coalfield. *Geophytology*, **3** (2): 184-194.

SRIVASTAVA, S. C. & MAHESHWARI, H. K. (1974). Palynostratigraphy of the Damuda Group in Brahmini Coalfield, Rajmahal Hills, Bihar. *Geophytology*, **4** (1): 35-45.

SHUKLA, M. (1982). Lithostratigraphy and structure of Hutar Coalfield, Palamau District, Bihar. *Palaeobotanist*, **30** (2): 168-180.

TIWARI, R. S. (1968). Palynological investigation of some coal seams in Ib River Coalfield (Orissa), India. *Palaeobotanist*, **16** (3): 222-242.

TIWARI, R. S. (1973). Palynological succession in the Barakar type area. *Geophytology*, **3** (2): 166-184.

TIWARI, R. S. (1974). Inter-relationship of palynofloras in the Barakar stage (Lower Gondwana), India. *Geophytology*, **4** (2): 109-127.

TIWARI, R. S. (1975). Palynological composition of the basal Gondwana in India. *Bull. Soc. belge. Geol.*, **84** (1): 11-17.

MICROBIOTA AND CATAGRAPHS FROM THE VARIKUNTA AREA OF CUDDAPAH SUPERGROUP

J. MANDAL, P. K. MAITHY
Birbal Sahni Institute of Palaeobotany, 53 University Road, Luckuow 226 007, India
&
S. H. MEHDI**
Southern Circle, Geological Survey of India, Hyderabad

ABSTRACT

Cryptarchs namely *Granomarginata*, *Lophosphaeridium* and *Protoleiosphaeridium* belonging to Sphaeromorphitae and catagraphs — *Vesicularites* and *Conferta* — are recorded from the subsurface samples of the Cuddapah Supergroup. The catagraphs are supposed to be formed by the exobiogenic activities of Cyanophyceae and bacteria. No comment on the age could be made on the basis of poor occurrence of biota, as they show wide geological distribution from Late Proterozoic to Devonian.

Key-words — Cryptarchs, Catagraphs, Cuddapah Supergroup, Proterozoic, Devonian, India.

सारांश

कडापाह् महासमूह् के वेरिकुन्त क्षेत्र से सूक्ष्मजीविता एवं कैटाग्राफ़ – जगन्नाथ प्रसाद मंडल, प्रभात कुमार माइती एवं ऍस० ऍच० मेहदी

कडापाह् महासमूह् के उपस्तरी नमूनों से स्फ़ेयरोमोर्फिटी से सम्बद्ध क्रिप्टार्क – ग्रेनोमार्जिनेटा, लोफ़ोस्फ़ेयरीडियम् – तथा कैटाग्राफ़ – वैसिकुलाराइटिस एवं कॉनफर्टा, अभिलिखित किये गये हैं। कैटाग्राफ़ अनुमानत : स्यैनोफ़ाइसी एवं जीवाणुओं की वाह्य-जीवजनित क्रियाशीलता के फलस्वरूप बने हैं। जीविता की कम प्राप्ति के आधार पर इस समुच्चय की आयु पर कोई टिप्पणी नहीं की जा सकी क्योंकि जीविता अन्तिम प्रागजीवी से लेकर डिवोनी युग तक व्यापक वितरण प्रदर्शित करती है।

INTRODUCTION

ORGANOSEDIMENTARY structures and palynomorphs were previously known from the Cuddapah Supergroup. Rao in 1943 first reported the algal structures from the Lower Cuddapah near Royalcheruvu. These structures appeared to be oolitic, but the author confirmed their biogenecity after critical examination. He opined them to be resembling to a cross section of a thallus of Dasycladaceae. In 1944, he reported the organic structure similar to *Cryptozoon*. Further in 1949, he recorded algae in the thin sections of rocks. They were described as: (i) encrusting type, (ii) annular type, (iii) filamentous type, and (iv) branching type together with *Cryptozoon*-like structure. The structures reported by Rao (1943) as cross section of the thallus of Dasycladaceae have been postulated to be similar to Archaeocyatha by Balakrishnan (1974) and Maithy and Gupta (1981). However, from the photograph published by Rao (1943, fig. 1) appears to be a Catagraphia particularly *Vesicularites* type.

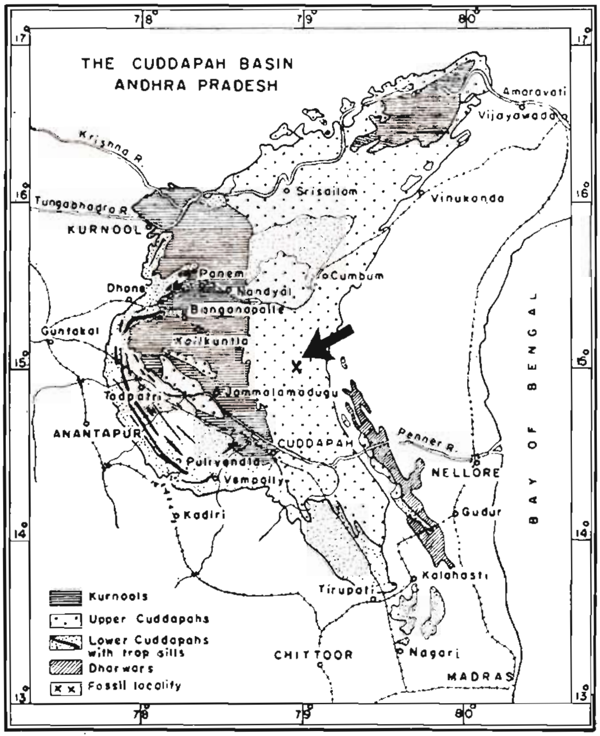
Sahni and Srivastava (1962) claimed the recovery of monolete and trilete spores from the Jonk River Section of Cuddapah Supergroup, Madhya Pradesh. These spores in all probability seem to be contaminants because such evolved forms are not expected in this older rock. Schopf and Prasad (1978) reported an assemblage comprising single cells, filaments and other micro-organisms. All were found in *Collenia*-like stromatolites from the Vemapalle Formation (Papaghni Group) of South-Central India. The unique finding in this report was the presence of large single cells above 20 μm which according to authors may be eukaryotic.

The present paper deals with the organosedimentary structures, cryptarchs and few curious microfossils recovered in the drill core samples from Varikunta area, Nallamalai Group, Cuddapah Supergroup.

GEOLOGY

The Cuddapah Supergroup is deposited in various parts of the peninsular India and rests over the Dharwar sediments. The reasons for the development of the ensialic, shallow water Cuddapah Basin are not understood. It is possible that the deposition of the sediments by erosion of existing uplifted areas resulted in the formation of basin (Naqvi *et al.*, 1978). The rocks of Cuddapah have been subjected to intense folding and metamorphism. The Cuddapah Basin forms a crescent-shaped compact area occupying about 35,000 sq km. The vast pile of sediments is exposed in two major groups — one in Andhra Pradesh and the other in Orissa and Madhya Pradesh. The Cuddapah Supergroup is subdivided into four groups, viz., (i) Papaghni, (ii) Cheyair, (iii) Nallamalai, and (iv) Kistna in ascending order. All the groups are well demarcated from each other by unconformity.

The Varikunta area is situated towards the northern end of the Zangamrajupalle-Varikunta mineralized belt about 5 km north-west of Varikunta (15°03′: 78°52′, 57 1/16) (Text-fig. 1), Cuddapah District, Andhra Pradesh. The Dolomite Member of the local Varikunta Formation constitutes the host rocks for Zn-Pb-Cu mineralization.



TEXT-FIG. 1 — Map of Cuddapah basin in which the arrow indicates the 'drilling site'.

The formation exposed throughout the belt is considered by previous workers, belonging to the Cumbum Formation (Nallamalai Group) of the Cuddapah Supergroup. A variety of shales associated with two main horizons of dolomite or dolomitic rocks are also present in this formation. A detailed study of drill core of the dolomite member helps in distinguishing four main lithologies or subfacies of the dolomite. The distribution pattern of individual subfacies within the main carbonate facies and the variation in the thickness of submembers give rise to a possibility that the dolomite belongs to a reef complex. The lithologies seem to be controlled by certain features of contiguation of the basin floor. Such variations in the topography of the basin floor within a relatively small area of deposition of mainly chemogenic sediments and generally shallow environments seem to be possible in a lagoonal environment.

The stratigraphic succession of different lithofacies constituting the local members in the Varikunta Formation in ascending order is as follows:

ROCK TYPES	THICKNESS
Banded green-pink shale	40 m
Siliceous dolomite and quartzite	30-40 m
Green banded shale	30-40 m
Carbonaceous shale	20-40 m
Dolomite	30-70 m
Green shale	20-30 m
Pink shale	400 m

MATERIAL

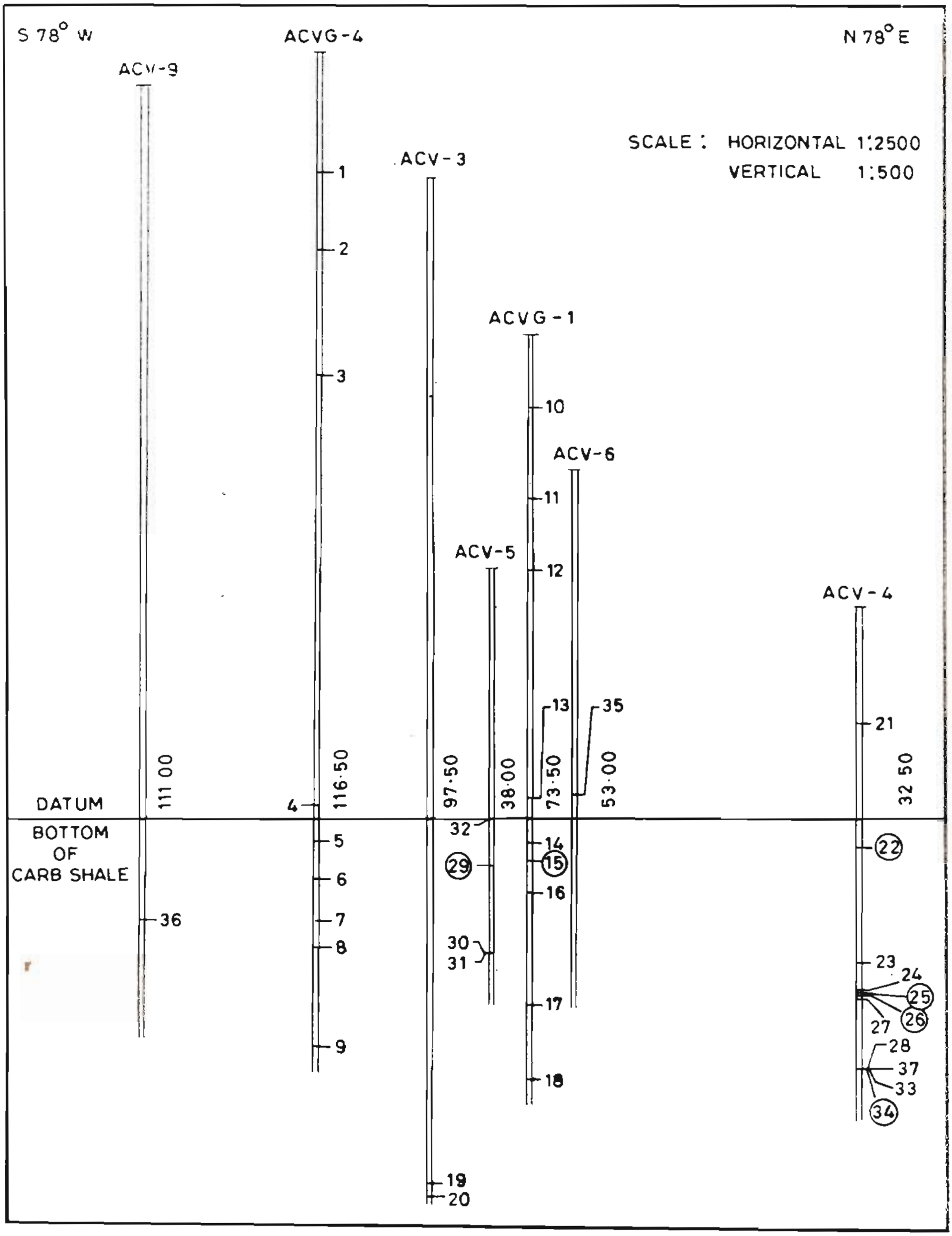
In the present paper 37 samples from seven drill cores have been studied which were supplied by G.S.I. (S. H. Mehdi). The samples consists of chert, dolomite and shale. The position of the samples in the drill cores is shown in Text-fig. 2 and the detail of samples is given in Table 1. Microfossils have been studied both in thin sections and from the acid resistant residues. In all, 85 thin section slides and 60 slides of acid resistant residues were studied. Organic remains were preserved in most of the slides, but only five samples were found to be suitable for the study of biota. Most of the observations have been made from the macerated residues, as the morphology of biota was not clearly visible in thin sections.

TABLE 1

SAMPLE No.	BORE CORE No.	DEPTH IN METER	NATURE OF SAMPLE
1	ACVG-4	(17.80)	Green banded shale
2	do	(29.90)	Carbonaceous shale
3	do	(49.00)	Carbonaceous shale
4	do	(114.70)	Cherty carbonaceous shale
5	do	(119.70)	Chert
6	do	(125.55)	Dolomite
7	do	(131.95)	Cherty dolomite
8	do	(136.10)	Cherty dolomite
9	do	(151.20)	Green shale
10	ACVG-1	(11.22)	Green banded shale
11	do	(24.75)	Green banded shale
12	do	(35.60)	Carbonaceous shale
13	do	(69.80)	Carbonaceous shale
14	do	(77.02)	Chert
15	do	(79.97)	Dolomite
16	do	(84.65)	Cherty dolomite
17	do	(102.03)	Dolomite
18	do	(113.00)	Green shale
19	ACG-3	(153.20)	Cherty dolomite
20	do	(154.80)	Cherty dolomite
21	ACV-4	(18.00)	Carbonaceous shale
22	do	(36.50)	Cherty dolomite
23	do	(54.25)	Cherty dolomite
24	do	(58.60)	Cherty dolomite
25	do	(59.20)	Cherty dolomite
26	do	(59.20)	Cherty dolomite
27	do	(59.50)	Cherty dolomite
28	do	(70.50)	Cherty dolomite
29	ACV-5	(44.80)	Chert
30	do	(58.30)	Chert
31	do	(58.30)	Chert
32	do	(38.10)	Carbonaceous chert
33	ACV-4	(70.70)	Cherty dolomite
34	do	(70.80)	Cherty dolomite
35	ACV-6	(49.10)	Carbonaceous shale
36	ACV-9	(126.50)	Cherty dolomite
37	ACV-4	(70.50)	Cherty dolomite

DESCRIPTION

Recently, Diver and Peat (1979) have introduced a new group 'Cryptarch', partly parallel to 'Acritarch' of Evitt (1963) and transferred all the 'Sphaeromorphitae' of Downie, Evitt and Sarjeant (1963) to accommodate simple and organic walled microfossils of uncertain affinities. The two other new subgroups are — 'Synaplomorphitae' and 'Nematomorphitae' within the group Cryptarch which include filaments and the simple colonial or intimately aggre-



TEXT-FIG. 2 — Location of core samples studied for microbiota and organosedimentary structures (number within the circle denote productive sample).

gated forms. Sphaeromorphitae has been emended as spherical or ellipsoidal forms that occur singly or in loose association. No doubt, this new classification helps better in describing the organic walled microfossils of uncertain affinities. In the present work the classification of Diver and Peat (1979) has been followed.

Group — Cryptarch Diver & Peat, 1979
Subgroup — Sphaeromorphitae (Downie *et al.*) Diver & Peat, 1979

Genus — *Granomarginata* Naumova, 1960

Type Species — *G. prima* Naumova, 1960.

Granomarginata prima Naumova, 1960

Pl. 1, figs 1, 2

Description — Vesicles 5.5 to 10.2 μm (8.5 μm in average), subspherical with occasional folds on the surface; grana more or less uniformly distributed and reduced in number on one surface.

Remarks — The present form is smaller in size than the type specimen and the size of grana is also robust.

Figured Specimen — Slide no. 6608 from macerated residues of sample no. 15.

Genus — *Protoleiosphaeridium* Timofeev ex Timofeev, 1960

Type Species — *P. conglutinatum* Timofeev ex Timofeev, 1960.

Protoleiosphaeridium sp.

Pl. 1, figs 3-6, 14

Description — Vesicles 4.5 to 22 μm in diameter (9.5 μm in average), spherical, exine thin, smooth, sometimes with reticulate structure.

Remarks — This is the most abundant form with wide size range. A statistical approach on 49 vesicles did not indicate any break in the series of size range. The form is morphologically comparable with *Huronispora* Barghoorn (1965). However, *Huronispora* is known from thin section and *Protoleiosphaeridium* is known from the macerated acid resistant preparation.

Figured Specimen — Slide nos. 6606, 6610, 6609, 6602 from macerated residues of sample nos. 22, 25 and 26.

Genus — *Lophosphaeridium* Timofeev, 1959

Type Species — *Lophosphaeridium rarum* Timofeev, 1959.

Lophosphaeridium kurnooleii Salujha, Rehman & Arora, 1972

Pl. 1, fig. 7

Description — Vesicle spherical, dark colour, disc-like 35.5 μm in diameter; exine granulate; grana irregular, often few grana touch each other and form pseudoreticulate structure, grana ±1 μm broad.

Remarks — Morphologically similar to *L. kurnooleii* but bigger in size than the type specimen of *L. kurnooleii*. The form is rare.

Figured Specimen — Slide no. 6603 from macerated residue of sample no. 25.

INCERTAE SEDIS

1. A number of irregular forms have apiculate structures (Pl. 1, figs 9-12) or spines (Pl. 1, fig. 8). These forms are very dark with variable shape and size. The size ranges from 3 to 16 μm (±10 μm common). Surface is covered with apiculi of varying shape and size. Spines are rare, 2.3 μm long and 1 μm in diameter at base.

Figured Specimens — Slide nos. 6605, 6606 and 6607 from the macerated residues of sample nos. 13 and 26.

2. A few irregular shaped colonies are observed which have been formed by irregularly arranged cells embedded within a gelatinous mass (Pl. 1, fig. 13). Cells are uniform in size, 5 to 7.3 μm in diameter. The number of cells in a colony could not be counted due to overlapping.

Figured Specimen — Slide no. 6604 from the macerated resudue of sample no. 25.

ORGANOSEDIMENTARY STRUCTURES

The rocks are predominantly made up of sparry calcite, well sorted with stretched, elliptical, ovoid or bean-shaped, subrounded to rounded siliceous, carbonaceous and oolitic structures. The oolite forms are about 2% to 30% of the total volume of the detrittal clasts. Mostly the typical rounded shape of the structures is not present as it is fragmented, stretched and in few cases shows preferred orientation along bedding due to turbulent current action. The core of the structures is mainly made up of carbonates surrounded by rims of carbonaceous matter and is being later replaced by cryptocrystalline silica which is also occurring as concentric rims. The cryptocrystalline silica (chert) is seen replacing the sparry calcite and carbonaceous matter as matrix-possibly formed during the diagenesis and leaving behind relic minerals. The possibility of the cryptocrystalline chert in the interior part of the structures representing the silica secreted by algae is not ruled out. Such cherty structures are not infrequently impregnated with carbon dust. The same is absent in the overall cherty matrix in which these cherty structures are embedded. This feature also suggests the biogenic origin of such structures. Moreover, petrographic study has revealed that the carbonaceous matter are organic in nature and not opaque ore minerals.

These problematic carbonate structures have been identified as 'Catagraphia', which are regarded as a result of the activity of Cyanophycean algae and bacteria. The organic nature of the oncolites and catagraphs becomes apparent, if the fossil carbonate nodules are compared with the calcareous concretions and tufa formed by recent algae (Zhuravleva, 1964; Bertrand-Sarfati, 1976). The present form of catagraphs appears similar to *Vesicularites* Reitlinger and *Conferta* Klinger but detail comparison up to form level is not possible due to distortion of rocks.

Catagraphia Maslov, 1953

Vesicularites Reitlinger, 1959

Type Form — *V. flexuosus* Reitlinger, 1959

Vesicularites sp.

Pl. 1, fig. 15

Description — Circular, oval or irregular shaped in cross section; a circular small lumen at centre. Lamellation absent, outer wall thick and dark.

Remarks — Morphologically the present form is comparable with *V. parvus* Zabrodin, 1968 but *V. parvus* is larger in size.

Figured Specimen — Slide no. 6612. In thin section from sample no. 34.

Conferta Klinger, 1968

Type Form — *Conferta rara* Klinger, 1968

Conferta sp.

Pl. 1, fig. 16

Description—Elongated canal-like appearance in cross section; ends mostly tapering and lateral walls straight or bumpy. Lamellation absent, outer wall thick and dark.

Remarks — The present form is comparable with *Conferta rara* but differs due to larger in size.

Figured Specimen — Slide no. 6611. In thin section from sample no. 29.

DISCUSSION

A poor assemblage of biota comprising three genera of cryptarch, namely *Granomarginata*, *Lophosphaeridium* and *Protoleiosphaeridium* belonging to 'Sphaeromorphitae', a few unidentifiable isolated apiculate forms, colonies and organosedimentary structures are recorded. The synsedimentary nature of the recovered microfossils is demonstrable by the facts: (i) colour of microfossils is same as in the surrounding matrix, (ii) acid treatment microfossils are easily separable from rocks and the rock matrix remain stuck to the wall of biota even after maceration (Pflug & Maithy, 1977), and (iii) comparable taxa are known to occur from other places.

The problematic sedimentary structures i.e. catagraphia are simple in nature. They are recorded in almost all the drill core samples at different depths. The position of samples has been shown in Text-fig. 2. Their significance in stratigraphical correlation in different drill cores remains still open.

A number of radiometric age data of the Cuddapah Supergroup rocks are known. A model age of 1400 Ma has been suggested for the Lower Cuddapah sequence by Crawford, 1969; Vingradov *et al.*, 1964; Aswathanarayana, 1962b; Compston, 1973; and Rusell and Slawson, 1962. Schopf and Prasad (1978) have also made remarks on the age of the Cuddapah rocks. Aswathanarayana (1962a) ascertained the model age of Zangamrajupalle (14°45′, 78°51′), Galena by lead isotopic study as 780-840 Ma. The present studied rocks belonging to the Varikunta Formation most likely may have the same age. An attempt to date these rocks on basis of the poorly recorded biota and catagraphs is not feasible. Moreover, the recorded biota shows a wide range of distribution, i.e. from Proterozoic to Devonian. Much stress also cannot be laid upon the records of few forms with apiculate structures or spines. Occurrence of typical acanthomorphs is known from the Cambrian onwards (Downie, 1967). However, the stray occurrence may be due to local basinal factor. Therefore, a critical comment on the age can only be given on the basis of well-preserved biota in near future.

ACKNOWLEDGEMENTS

We acknowledge the receipt of drill core samples for the study of biota from Mr B. N. Jairam, Director, Airborne Mineral Surveys and Exploration Wing, Southern Circle, G.S.I. Sincere thanks are due to Dr A. Ghosh, Geology Department, Jadavpur University. We are also thankful to Mrs B. Bhattacharya and R. N. Srivastava, Petrology Lab., Northern Region, G.S.I. for their help in the petrographic study of thin sections and critical comments on the organosedimentary structures.

REFERENCES

ASWATHANARAYANA, U. (1962a). Age of the Cuddapah, India. *Nature*, **193**: 470.

ASWATHANARAYANA, U. (1962b). Age of the Cuddapah, India. *Nature*, **194**: 566.

BERTRAND-SARFATI, J. (1976). An attempt to classify Late Precambrian stromatolite microstructures, pp. 251-259 in Walter, M. R. (ed.)— *Development in Sedimentology*-20: *Stromatolite*.

CRAWFORD, A. R. (1969). India, Ceylon and Pakistan; new age data and comparison with Australia. *Nature*, **223**: 380-384.

CRAWFORD, A. R. & COMPSTON, W. (1973). The age of the Cuddapah and Kurnool Systems, Southern India. *J. geol. Soc. Aust.*, **19** (4): 453-464.

DIVER, W. L. & PEAT, C. J. (1979). On the interpretation and classification of Precambrian organic walled microfossils. *Geology*, **7**: 401-404.

DOWNIE, C. (1967). The geological history of microplankton. *Rev. Palaeobot. Palynol.*, **1**: 269-281.

DOWNIE, C., EVITT, W. R. & SARJEANT, W. A. S. (1963). Dinoflagellates, hystrichospheres and the classification of acritarchs. *Stanford Univ. Publ.*, Ser. *Geol. Sci.*, **7** (3): 1-16.

MAITHY, P. K. & GUPTA, S. (1981). Archaeocyatha from the Vindhyan Supergroup of India. *Indian Jl Earth Sci.*, **8** (1): 76-81.

NAQVI, S. M., RAO, D. & HARI NARAIN (1978). The primitive crust: Evidence from the Indian shield. *Precambrian Res.*, **6**: 323-345.

PFLUG, H. D. & MAITHY, P. K. (1977). Nachweisverfahren fur organische Mikrofossilien in präkambrischen Tonschieferen. *Oberheiss. Nätur Zeit.*, **43**: 15-23.

RAO, M. R. S. (1943). Algal structures from the Cuddapah limestones (Pre-Cambrian), South India. *Curr. Sci.*, **12**: 207-208.

RAO, M. R. S. (1944). Algal structures from the Cuddapah limestones (Pre-Cambrians), S. India. *Curr. Sci.*, **13**: 75.

RAO, M. R. S. (1949). Algal structures from the Cuddapah limestones (Pre-Cambrian), S. India. *J. Mysore Univ.*, Sec. B., *Sci.*, **9** (4): 67-72.

RUSSELL, R. D. & SLAWSON, W. F. (1962). Age of the Cuddapahs, India. *Nature*, **194**: 565-566.

SAHNI, M. R. & SRIVASTAVA, R. N. (1962). On the occurrence of microspores of vascular plants in the Cuddapah sediments of Jonk River Section, Raipur District, Madhya Pradesh. *Rec. geol. Surv. India*, **87** (3): 477-484.

SCHOPF, J. W. & PRASAD, K. N. (1978). Microfossils in *Collenia*-like stromatolites from the Proterozoic Vemapalle Formation of the Cuddapah Basin, India. *Precambrian Res.*, **6** (3): 347-366.

VINGRADOV, A., TUGARINOV, A., ZHYKOV, C., STAPNIKOVA, N., BIBIKOVA, E. & KHORRE, K. (1964). Geochronology of Indian Precambrian. *22nd int. geol. Congr., New Delhi. Proc. Sect.*, **10**: 553-567.

ZHURAVLEVA, Z. A. (1965). Oncolites and catagraphs in the Riphean and Cambrian of eastern Siberia and their stratigraphic significance. *DOKLADY of the Acad. Sci. USSR — Earth Sci. Sec.* **158** (1-6): 37-39 (Russian original, 1964).

EXPLANATION OF PLATE

(All the photographs are × 1000 unless otherwise stated. All the slides are preserved at the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow).

1, 2. *Granomarginata prima* in two focuses showing grana and folds. Grana appears to be reduced on one surface as in fig. 2, slide no. 6608, stage reading (Leitz) 46 × 102.5.

3-6, 14. *Protoleiosphaeridium* sp. showing a range of size variation; fig. 3, slide no. 6609, stage reading 54 × 99.5; fig. 4, slide no. 6610, stage reading 42.5 × 111.5; fig. 5, slide no. 6609, stage reading 60.5 × 101; fig. 6, slide no. 6606, stage reading 50 × 105.3; fig. 14 showing grana-like structure on the surface, slide no. 6602, stage reading 53.4 × 102.

7. *Lophosphaeridium kurnooleii* showing grana on the surface, slide no. 6603, stage reading 36.3 × 98.7.

8-12. Showing spinose and apiculate forms and the size variation of the biota, fig. 8, slide no. 6607, stage reading 38.7 × 106; fig. 9, slide no. 6606, stage reading 66.4 × 103.5; fig. 10, slide no. 6605, stage reading 32.8 × 102.7; fig. 11, slide no. 6606, stage reading 35 × 94.9; fig. 12, slide no. 6606, stage reading 30.5 × 96.

13. A distorted colony of irregularly arranged cells within the gelatinous mass, slide no. 6604, stage reading 38.4 × 114.6.

15. *Vesicularites* sp., slide no. 6612. × 14.

16. *Conferta* sp., slide no. 6611. × 14.

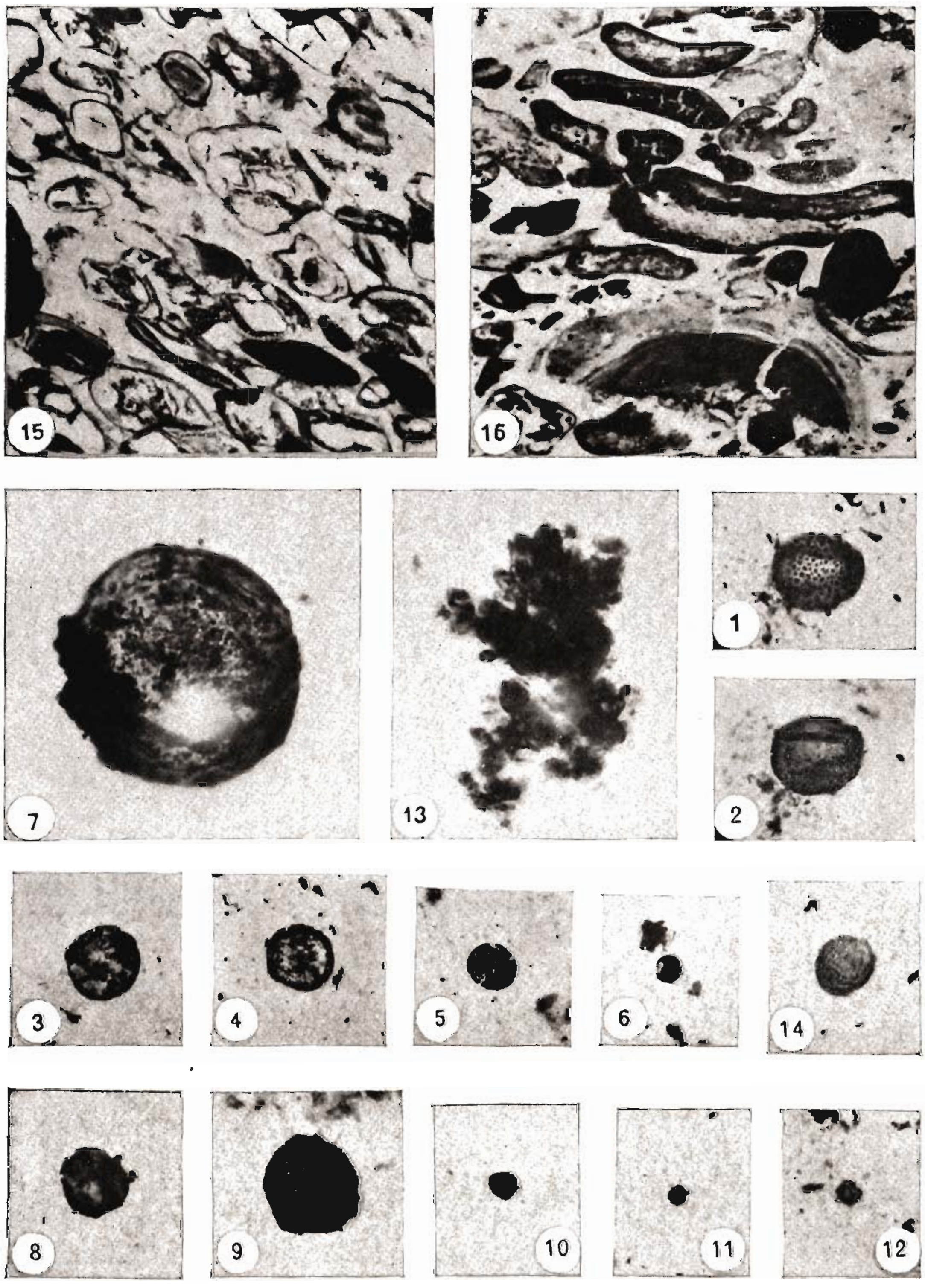


PLATE 1

The Palaeobotanist, **31**(3), 201-207, 1984.

A FOSSIL FAN PALM FROM THE LIYAN FORMATION OF LADAKH (JAMMU AND KASHMIR)

*R. N. LAKHANPAL, **GYAN PRAKASH, **J. L. THUSSU & *J. S. GULERIA
*Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India
**Geothermal Division, Geological Survey of India, Nagpur, India

ABSTRACT

A fossil palm based on truly palmate leaves is described from the Liyan Formation (Miocene) of Ladakh in Jammu and Kashmir. It has been identified with the genus *Trachycarpus* H. Wendl. and assigned to a new species, *T. ladakhensis*. It is the first megafossil record of a member of the temperate element which seems to have entered the Himalaya during the Miocene from the mainland of Asia on the north.

Key-words — Megafossil, *Trachycarpus*, Liyan Formation, Miocene (India).

सारांश

लद्दाख (जम्मू-काश्मीर) के लियान शैल-समूह से एक पंखाकार ताड़-पर्णाश्म – राजेन्द्र नाथ लखनपाल, ज्ञान प्रकाश, जे० एल० थुसु एवं जसवंत सिंह गुलेरिया

जम्मू-काश्मीर में लद्दाख के लियान शैल-समूह (मध्यनूतन) से वस्तुत : हस्ताकार पत्तियों पर आधारित एक ताड़-पर्णाश्म वर्णित किया गया है। यह ऍच्० वैन्डलैन्ड के ट्रेकिकार्पस वंश से अभिनिर्धारित तथा एक नवीन जाति, ट्रे० लद्दाखेन्सिस, से नामाँकित किया गया है। शीतोष्ण तत्व के एक सदस्य का यह पहला गुरुपादपाश्मीय अभिलेख है जो कि उत्तर में एशिया की मुख्य भूमि से मध्यनूतन काल में हिमालय में प्रविष्ट हुआ प्रतीत होता है।

INTRODUCTION

IN 1974 a party of the Geological Survey of India, engaged in geothermal exploration in the Puga-Chumathang hot spring region of Ladakh, came across a few leaf-impressions of a palm near Liyan at an altitude of 5,400 m above mean sea level, across the Great Himalayan Range in Upper Indus Valley, Ladakh (Jammu & Kashmir). The rocks bearing the impressions were purplish sandy shale or greenish gray sandstone exposed in the Changlung Nala section at a locality about 20 km east-southeast of Puga hot springs and 15 km west-southwest of Nyoma (Text-fig. 1). This locality is approachable from these places by foot-track. Because of high altitude and severe cold and dry climatic conditions prevailing in this area, field work here can only be undertaken in the form of a well organized expedition for which July-August is most suitable.

The occurrence of these palm fossils was already reported in a preliminary note by Gyan Prakash and Thussu (1975). Their detailed study is being presented in this paper.

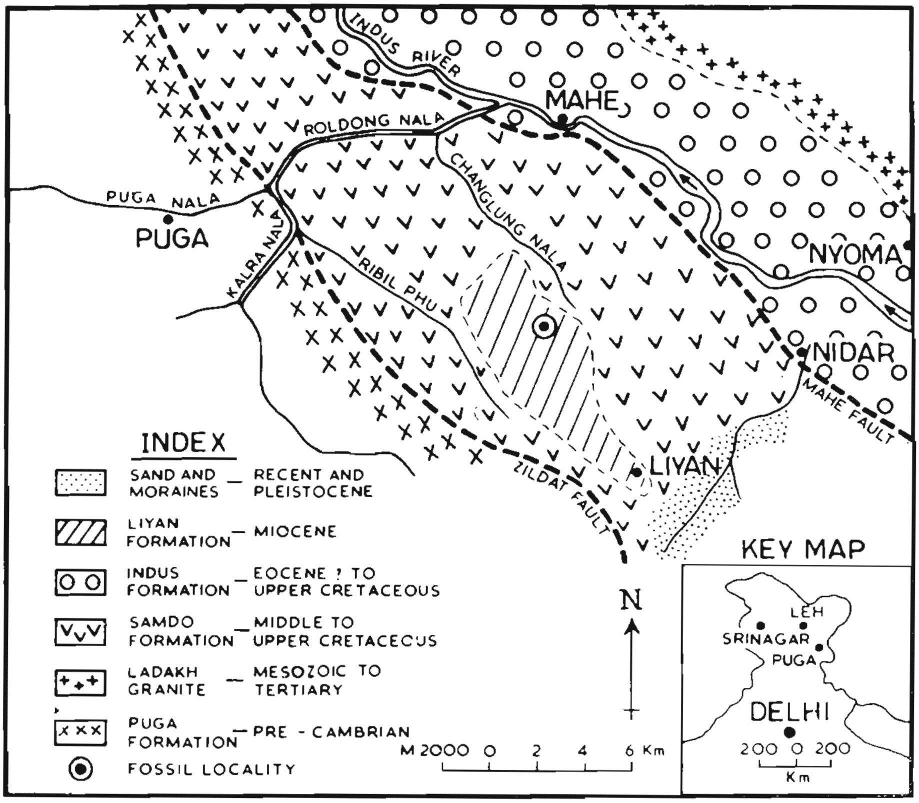
BRIEF GEOLOGICAL BACKGROUND

The area around Puga and Liyan is located in a region of the collided junction of two crustal plates which were involved in the Himalayan orogeny and witnessed intense basic and ultrabasic plutonic and submarine volcanism of Middle to Upper Cretaceous age (Ophiolites) and several phases of wide-spread acid igneous activity from Upper Cretaceous to Upper Tertiary times. In terms of the concept of plate tectonics, the region is divisible into three tectonic belts (Ravi Shanker *et al.*, 1975) — the Southern belt (the southern crustal plate), the Central belt (the oceanic crust with associated sedimentaries), and the Northern belt (the northern crustal plate).

The Southern belt exposes the Puga Formation comprising Precambrian paragneisses, schists and phyllites with occasional bands of limestone and is intruded by granite (Palaeozoic?), garnet amphibolite and tourmaline-quartz veins. The Central belt consists of the Samdo Formation and Liyan Formation, the latter unconformably resting over the former. The Samdo Formation comprises basalts, ultrabasic rocks, tuffs, agglomerates and associated sedimentary rocks (at times fossiliferous) of Cenomanian to Maestrichtian age and represents the remnant of the uplifted wedge of oceanic crust, now compressed between two continental masses. The Liyan Formation consists of a sequence of green and purple shale, sandstone, grit and conglomerate of Miocene age. It is the shale-sandstone assemblage of this formation that bears the palm-leaf fossils described in this paper. The Liyan Formation seems to be equivalent to the Kargil Mollasse (Ravi Shanker *et al.*, 1975, 1982) described by Tewari (1964).

The Northern belt exposes the Indus Formation consisting of a thick sequence of coarse clastic sediments of shallow marine to fluvial origin ranging in age from Cenomanian to Eocene and deposited unconformably over older granite basement (Mesozoic). The rocks are shale-sandstone-grit-conglomerate alternations, at places interlayered with fossiliferous limestone and intruded by granite of Tertiary age.

These three tectonic belts are separated from one another by high angle faults — the Zildat Fault along which the rocks of the Central belt (Samdo Formation) are juxtaposed against the Puga Formation (Southern belt) and the Mahe Fault along which the former is juxtaposed against the rocks of the Northern belt (Text-fig. 1).



TEXT-FIG. 1 — Geological map of Upper Indus Valley between Nyoma and Puga, district Ladakh (Jammu & Kashmir) showing the fossil locality (based on Ravi Shanker *et al.*, 1975).

The Mahe Fault is the same as the ' Counter Thrust ' of Berthelson (1951).

SYSTEMATIC DESCRIPTION

FAMILY — PALMAE

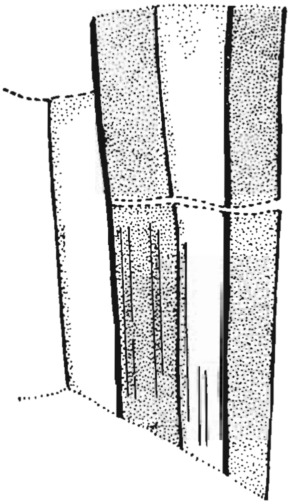
Genus — *Trachycarpus* H. Wendl.

Trachycarpus ladakhensis sp. nov. Lakhanpal & Guleria

Pl. 1, fig. 1; Pl. 2, figs 2, 3; Text-fig. 2

The species is based on three incomplete but fairly well preserved specimens. They are all impressions of leaves. The best preserved specimen depicting the basal part of the lamina has been chosen as the holotype. The other two are fragmentary and represent different parts of the lamina somewhere between the base and margin.

Description — Leaf simple, palmate, preserved lamina length 10.5-19.0 cm, maximum preserved width 14.6 cm; petiole not preserved; hastula present as an irregular semi-lunar rim, about 2 mm wide in the middle; mid-costa seemingly absent; a large number of segments (about 34 discernible) radiating out from the base of the lamina, maximum width of segments about 1.8 cm, preserved segments fused, each with a mid-vein; in very few segments some fine veins visible running parallel to the midrib (Text-fig. 2).



TEXT-FIG. 2 — Part of Pl. 1, fig. 1 enlarged to show the finer venation, × 2·5.

Affinities — The main characters of the fossil leaf seem to be its truly palmate nature, rather medium size, a narrow hastula along the more or less rounded base of the lamina and approximately about 40 plicate segments whose maximum individual width might have been about 2 cm.

The true palmate leaves are found only in two sub-families of Palmae, i.e. Coryphoideae and Lepidocaryoideae (Corner, 1966, pp. 347, 349, 351). In Lepidocaryoideae there are only three palmate genera, viz., *Mauritia* L. f., *Mauritiella* Burret and *Lepidocaryum* Mart., the rest being pinnate. However, all these three genera are confined to America. Hence, Lepidocaryoideae can be safely ruled out.

Of the five palmate Coryphoid genera found in India (Brandis, 1906, p. 644) only two, *Licuala* Thunb. and *Trachycarpus* H. Wendl. have true palmate leaves, the remaining three have costa-palmate leaves. There are two species of *Licuala* known from India. In having circular or nearly orbicular, peltate laminae with deeply partite cuneate segments, they are quite different from our fossil. On the other hand leaves of *Trachycarpus* exhibit a very close resemblance with the Ladakh impressions.

At present two species of *Trachycarpus*, viz., **T. martiana* H. Wendl. and *T. takil* Becc. are known from India. Based on the description of these species given by Blatter (1926) the leaves of *T. martiana* have " Blade orbicular, consisting of 30-40 linear segments, 15-20 inches** (about 38-50 cm) long, connate to one-third or one-half their length " while *T. takil* has " Blade $\frac{3}{4}$ orbicular, $3\frac{1}{3}$-4 feet (about 114-122 cm) in diameter, with 45-50 divisions measuring $2\frac{1}{3}$-$2\frac{5}{6}$ feet (about 71-86 cm) from the top of the petiole to the apex of the median segment ". Considering the size, the lamina (blade) of *T. martiana* is closer to the fossil leaf although the latter is not orbicular. Blatter has also described a third species, *T. excelsa* (called *T. fortunei* by McCurrach, 1960, p. 250) growing from Upper Burma (which previously was a part of British India) to China and Japan. Its lamina is more like that of *Chamaerops* with numerous deeply cut segments and therefore can be

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*McCurrach (1960, p. 251) has given this species as *T. martianus*.

**The figures in brackets are ours to represent the metric equivalents of inches and feet.

easily differentiated from that of the fossil. Thus it seems quite clear that our fossil belongs to *Trachycarpus* though not identical with any of its three species growing in the Indian region of Himalaya and Burma.

Comparison with Fossil Palmate Leaves — As far as we are aware, there are six records of fossil fan palm leaves from India. These are (i) a fan palm reported by Sahni and Bhatnagar (1962) from the Eocene (?) of Kargil, (ii) *Sabalites microphylla* and (iii) *Sabalites* sp. described by Sahni (1964) from the Miocene beds of Kasauli, Himachal Pradesh and Chakoti, Kashmir, respectively, (iv) *Palmophyllum* sp. Chaudhri (1969) from the Lower Miocene of Kasauli, (v) a palmate leaf described by Trivedi and Chandra (1971) from the Deccan Intertrappean beds of Mohgaon Kalan, Madhya Pradesh, and (vi) *Palmacites khariensis* Lakhanpal & Guleria (1982) from the Miocene of Kachchh, Gujarat. Besides, Bose and Sah (1964, p. 220; pl. 1, fig. 1) have reported as *Sabalites*?, a palm leaf most probably from the Lower Tertiary of Assam. However, from its photograph it is clearly a pinnate palm and hence is not being considered for comparison here.

The photographs of the two fan palm specimens described by Sahni and Bhatnagar (1962) from Kargil show the apical portions of hardly 3-4 segments which might have been united below in the form of a palmate leaf. However, as such they can not be identified with our fossil. *Sabalites microphylla* of Sahni (1964) can easily be ruled out as it is a costapalmate leaf in contrast to the present fossil which is true palmate. *Sabalites* sp. Sahni (1964) does not possess either the base or the apical part of the lamina and thus besides being a palmate leaf cannot be compared any further. *Palmophyllum* sp. of Chaudhri (1969) is too small to be comparable with our specimen. From the characters described for this species, it is not even certain if it is at all a palm. The leaf reported by Trivedi and Chandra (1971), though plicate and palmate, is much larger in size. Its segments are 3-4 times wider than those of the present fossil. Moreover, they seem to be wedge-shaped in contrast to the linear segments of the Ladakh palm. *Palmacites khariensis* Lakhanpal & Guleria (1982) also differs in having relatively narrow lamina (maximum width 9.0 cm) with greater number of segments (about 45). Further, the segments in *P. khariensis* are also narrower (0.1 to 0.5 cm) than in our fossil.

As the present fossil differs from all the known Indian species of palm leaf, a new specific name, *Trachycarpus ladakhensis*, is assigned to it. The specific epithet indicates the area from where the fossil was collected.

Holotype — B.S.I.P. Specimen no. 36030.

Paratypes — B.S.I.P. Specimen nos. 36031 and 36032.

Locality — 20 km ESE of Puga, Ladakh (Jammu & Kashmir).

Horizon — Liyan Formation.

Age — Miocene.

DISCUSSION

Usually the occurrence of palms is associated with hot and humid climate. However, Corner (1966, p. 352) has mentioned *Trachycarpus* and *Chamaerops* as temperate fan palms. Considering the occurrence of *Trachycarpus martiana* and *T. excelsa* even at altitudes around 1,250 m in the hills of Khasia and Manipur in eastern India, this genus may be regarded as temperate to warm temperate. It is distributed in the Himalaya, Upper Burma, China and Japan. Of the two Indian species, *T. martiana* grows in Central Himalaya, Nepal at altitudes about 1,550-2,450 m; Khasia Hills, 1,250-1,550 m; Manipur, about 1,875 m and Upper Burma, Kachin Hills, 1,250-2,200 m. The other species, *T. takil*, is found growing on Mount Takil in Kumaon at a height of about 2,200-2,450 m where it is annually covered with snow (Blatter, 1926, pp. 51, 54, 55). As mentioned by Takhtajan (1958, p. 1674) " The genus *Trachycarpus* belongs to the most frost-resistant palms extending farthest to the north and enduring frost up to −14°C ".

Although traces of northern temperate flora in the form of Abietinean pollen grains, which might have flown in from the northern hills, are known from the Middle Miocene deposits of the Siwalik beds (Lakhanpal, 1970) there are so far no records of temperate plant megafossils from the Miocene beds of India. In this regard the present record of *Trachycarpus* would be the first temperate plant megafossil to be described from our country. According to Takhtajan (1958) *Trachycarpus rhapifolia* was the most widely distributed fan palm in the Tertiary of U.S.S.R. This species is known from many localities of the Eocene of Ukraine as well as from the Eocene of the north-eastern part of Kazakhstan. It has further been reported from the Eocene of Geiseltal in East Germany (Rüffle, 1976). Being regarded as a Sino-Japanese genus, it was obviously occupying a very wide area from East Asia to Ukraine and even further west into Europe during the early Tertiary period. At that time, there was still the barrier of Tethys between India and the mainland of Asia on the north side. But by Miocene, with considerable rise of the Himalaya, land connection had been established between these two regions. That was most probably the time when the northern temperate element had entered the Himalaya and *Trachycarpus* was one of its components. It is presumed that some other temperate plants must also have accompanied *Trachycarpus*. A thorough search for these associates in the Liyan Formation of Ladakh might reveal their identity as well as help in collecting better and more complete specimens of this interesting palm.

REFERENCES

BERTHELSON, A. (1951). A geological section through the Himalaya. *Medd. Fra. Danks. Geol. For.*, **12** (3): 102-104.

BLATTER, E. (1926). *The Palms of British India and Ceylon*. Humphery Milford, Oxford Univ. Press.

BOSE, M. N. & SAH, S. C. D. (1964). Fossil plant remains from Laitryngew, Assam. *Palaeobotanist*, **12** (3): 220-223.

BRANDIS, D. (1906). *Indian Trees*. Fifth impression, 1971, Dehradun.

CHAUDHRI, R. S. (1969). Some leaf-impressions from the Kasauli Series of Simla Hills. *Curr. Sci.*, **38** (4): 95-97.

CORNER, E. J. H. (1966). *The Natural History of Palms*. Weidenfeld and Nicolson, London.

GYAN PRAKASH & THUSSU, J. L. (1975). A note on the new finds of fossil in the Upper Indus Valley, Ladakh, Jammu and Kashmir State. *Indian Miner.*, **29** (1): 93-95.

LAKHANPAL, R. N. (1970). Tertiary floras of India and their bearing on historical geology of the region. *Taxon*, **19** (5): 675-694.

LAKHANPAL, R. N. & GULERIA, J. S. (1982). Plant remains from the Miocene of Kachchh, western India. *Palaeobotanist*, **30** (3): 279-296.

McCURRACH, J. C. (1960). *Palms of the World*. Harper & Brothers, New York.

RAVI SHANKER, PADHI, R. N., ARORA, C. L., GYAN PRAKASH, THUSSU, J. L. & DUA, K. J. S. (1975). Geothermal exploration of the Puga and Chumathang geothermal fields, Ladakh, India. *Proc. II U.N. Symp. Develop. and Use of Geothermal Res. San Francisco Proc. Lawrence Berkeley Lab. California Univ.*: 245-258.

RAVI SHANKER, PADHI, R. N., GYAN PRAKASH, THUSSU, J. L. & DAS, R. M. (1982). The evolution of Indus Basin, Ladakh, India. *Misc. Publ. geol. Surv. India*, **41**, pt. III: 157-172.

RÜFFLE, L. (1976). Eozäne floren des Geiseltales. *Abh. Zentr. geol. hist. Palaont.*, **26**: 337-438.

SAHNI, B. (1964). *Revisions of Indian Fossil Plants. Part* III — *Monocotyledons. Monograph No.* 1. Birbal Sahni Institute of Palaeobotany, Lucknow, pp. 1-89.

SAHNI, M. R. & BHATNAGAR, N. C. (1962). Fresh water mollusca and plant remains from the Tertiaries of Kargil, Kashmir. *Rec. geol. Surv. India*, **87** (3): 467-476.

TAKHTAJAN, A. L. (1958). A taxonomic study of the Tertiary fan palms of the U.S.S.R. *Bot. Zh. SSSR*, **43** (12): 1661-1674.

TEWARI, A. P. (1964). On the Upper Tertiary deposits of Ladakh Himalayas and correlation of various geotectonic units of Ladakh with those of Kumaon-Tibet region. *Proc. 22nd int. geol. Cong, New Delhi*, **9**: 37-58.

TRIVEDI, B. S. & CHANDRA, R. (1971). A palm leaf from The Deccan Intertrappean Series of Mohgaonkalan (M.P.), India. *Curr. Sci.*, **40** (19): 526-527.

EXPLANATION OF PLATES

PLATE 1

Trachycarpus ladakhensis sp. nov.

1. Leaf showing the basal part of the lamina, natural size.

PLATE 2

2, 3. Leaves showing different parts of the lamina, natural size.

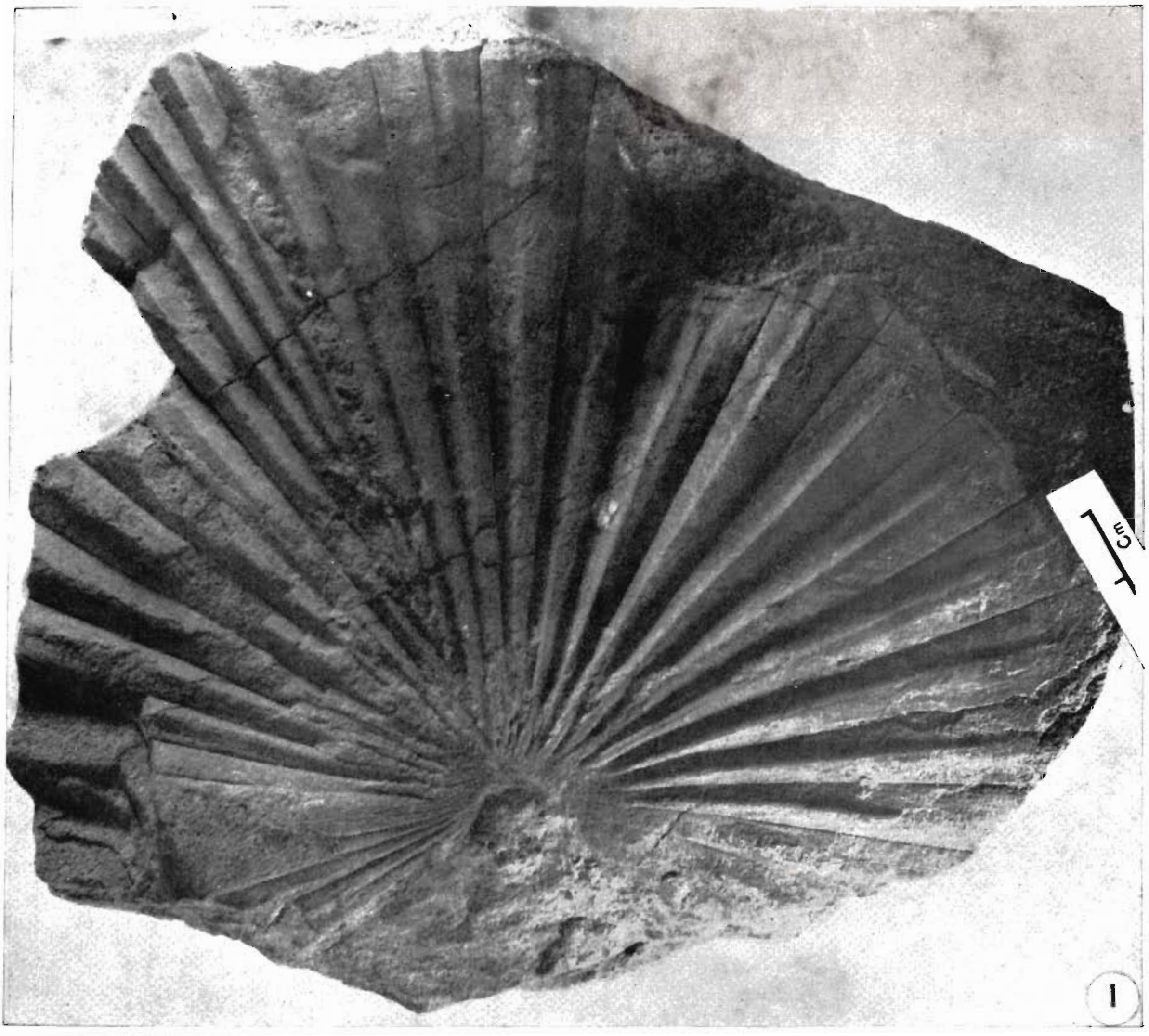


PLATE I

2

3

PLATE 2

The Palaeobotanist, **31**(3): 208-212, 1984.

UTKALIA DICHOTOMA GEN. ET SP. NOV.— A FOSSIL FRUCTIFICATION FROM THE KAMTHI FORMATION OF ORISSA, INDIA

SHAILA CHANDRA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

Utkalia dichotoma gen. et sp. nov. is a possible seed bearing fossil fructification. The main axis of the fructification is dichotomously branched, each dichotomy bearing mostly alternatel atral branches. The lateral branches further dichotomize and the altimate branches bear seeds singly.

Key-words — *Utkalia*, Pteridosperm, Fructification, Kamthi Formation, Upper Permian (India).

साराँश

उत्कलिआ डाइकोटोमा नव वंश व नव जाति : उड़ीसा (भारत) के कामथी शैल-समूह से एक फलनाश्म – शैला चन्द्रा

उत्कलिआ डाइकोटोमा नव वंश व नव जाति कदाचित् एक बीज उत्पादक फलनाश्म है। इसकी मुख्य अक्ष द्विभाजी शाखित है। प्रत्येक द्विभाजी शाखा अधिकतर एकान्तर पार्श्व शाखाओं को जन्म देती है। इन पार्श्व शाखाओं का फिर एक बार द्विभाजन होता है तथा इस प्रकार बनी प्रत्येक अन्तिम शाखा एक बीज में परिवर्तित हो जाती है।

INTRODUCTION

SEVERAL sporangia and seed bearing fructifications were described from the Kamthi Formation in Handappa Village belonging to Dhenkanal District of Orissa (Surange & Maheshwari, 1970; Surange & Chandra, 1973, 1974 in a series of papers). The seed bearing genera so far reported from this locality are *Partha*, *Denkania*, *Lidgettonia*, *Indocarpus*, *Scutum* and *Cistella*. Of these fructifications, some are found attached with *Glossopteris* leaves while others in detached condition and accordingly their affinities are related.

In the present paper a new type of seed bearing fructification is described and its affinities and relationships are discussed.

Genus — *Utkalia* gen. nov.

Type Species — *Utkalia dichotoma* gen. et sp. nov.

Pl. 1, figs 1, 2; Text-figs 1, 2

Diagnosis — Main axis dichotomously branched, primary branches giving out mostly alternate branches on either side, each alternate branch repeatedly dichotomizing, each ultimate branch bearing a single terminal seed-like body without any scale or bract.

Description — There are four specimens in the collection. They are brown impressions on a buff coloured hard, fine grained, clayey shale. One of the most complete specimens with its counterpart is best preserved. The main axis is 3 cm long and 1 mm broad. Each dichotomy is about 3.5 cm in length and has 10-15 mostly alternate branches which further dichotomize once or several times (Pl. 1, fig. 1). Each ultimate branch bears a single terminal seed-like body without any scale or bract between them. The seed-like bodies are unwinged, 2.5 mm long and 1-1.5 mm broad (Pl. 1, fig. 2).

I have every reason to believe that these fruiting bodies are seeds. This is suggested by the facts that (i) these excellently preserved seed-like bodies are of the same size as the numerous scattered seeds found eleswhere on the shales in abundance, (ii) the sporangia so far known from the

TEXT-FIG. 1 — Actual specimen drawn to show the dichotomy of the main axis and the manner of seed attachment on the ultimate branchlets, × 2.

Glossopteris flora are different in shape and much smaller in size.

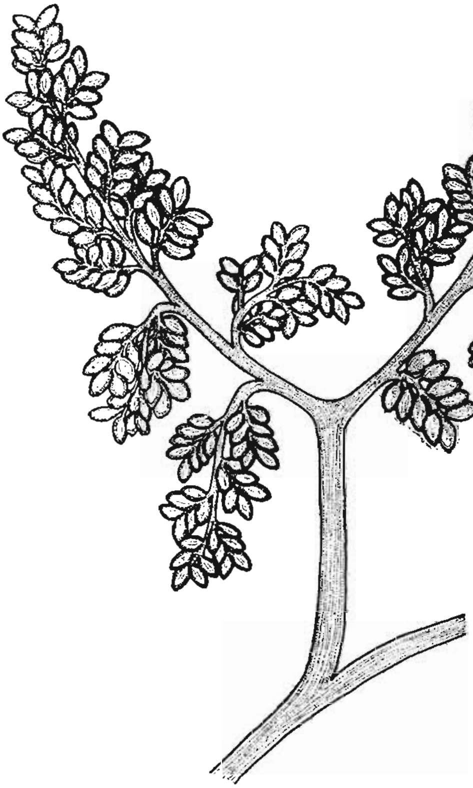
Holotype — B.S.I.P. specimen no. 35470.

Horizon — Kamthi Formation, Upper Permian.

Locality — Near Handappa Village, Hinjrida Ghati, Dhenkanal District, Orissa, India.

Comparison — *Utkalia dichotoma* gen. et sp. nov. is unlike any fructification known so far in the *Glossopteris* flora. The only comparable genus is *Wankiea*, instituted by Lacey and Huard-Moine (1966) from the Karroo flora in the Wankie District of southern Rhodesia. *Wankiea bondii* is a seed bearing fructification consisting of longitudinally striated axis bearing lateral branches of at least two orders probably pinnately arranged. The ultimate branchlet form lateral clusters where each one of the 4-6 branchlet ends in an ovate seed-like body. According to Lacey and Huard-Moine (1966) the manner of seed attachment was not clear but they thought that the seeds were possibly borne on a peltate expansion or the scale-like extensions of the branchlets. *Utkalia* is distinct and different from *Wankiea* in having a dichotomous primary branching of the axis and singly borne terminal seeds on the ultimate branches.

Delevoryas and Gould (1971) described an unusual fossil fructification from the Jurassic of Oaxaca, Mexico and named it as *Perezlaria oaxacensis*. This fructification had branches arising from all sides, some laterals once forked, bearing short appendages usually tapering distally, each with 5-8 sac-like bodies borne in a whorl at the apex. The genus *Utkalia* is distinct in having dichotomous branching system and singly borne terminal seeds. Moreover, the authors have interpreted these sac-like bodies as the sporangia showing dehiscence line. *Nystroemia pectiformis* Halle (1929) described from the Permian of China is



TEXT-FIG. 2 — Restoration of *Utkalia dichotoma* gen. et sp. nov. drawn on the basis of specimen no. 35470, × 2.

based on portions of a branch system that has the general organization of a fern frond. The ultimate subdivisions divide several times, each branchlet terminating in a small two horned body about 3 mm long that is presumed to be a seed.

Thus, apart from some similarities with the known fructifications like *Wankiea* and *Perezlaria*, the differences are pronounced enough to distinguish *Utkalia dichotoma* from any other known fructification.

Derivation of the Name — The genus is named after the ancient State Utkal which is presently known as Orissa.

Affinities — it is interesting to speculate with available evidences about the relationship of *Utkalia dichotoma*. In the same assemblage I found the vegetative forms of lycopods, Equisetales, Sphenophyllales, Filicales, cycads and glossopterids. The present fructification on the basis of its peculiar organization and possible seed bearing nature could belong to some gymnosperm. Due to the lack of any associated sporophyll it seems quite reaonable that this fructification has pteridospermous affinities. From the same assemblage we have already described a number of pteridospermous fructifications like *Partha*, *Denkania* and *Lidgettonia* and *Utkalia* is one more type added to the list. Actual connection or at least some more reliable circumstantial evidences will be required before we can be sure of its affinities with a particular leaf genus.

ACKNOWLEDGEMENT

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REFERENCES

DELEVORYAS, T. & GOULD, R. E. (1971). An unusual fossil fructification from the Jurassic of Oaxaca, Mexico. *Amer. J. Bot.*, **58** (7): 616-620.

HALLE, T. G. (1929). Some seed bearing pteridosperms from the Permian of China. *K. svenska VetenskAad. Handl.*, **6**: 8): 1-24.

LACEY, W. S. & HUARD-MOINE, D. (1966). Karroo floras of Rhodesia and Malawi — Part 2. The Glossopteris flora in the Wankie District of southern Rhodesia. *Symposium on Floristics and Stratigraphy of Gondwanaland*: 13-25. Birbal Sahni Institute of Palaeobotany, Lucknow.

SURANGE, K. R. & MAHESHWARI, H. K. (1970). Some male and female fructifications of Glossopteridales from India. *Palaeontographica*, **129B** (4-6): 178-192.

SURANGE, K. R. & SHAILA CHANDRA (1973b). *Denkania indica* gen. et sp. nov. a glossopteridean fructification from the Lower Gondwana of India. *Palaeobotanist*, **20** (1): 264-268.

SURANGE, K. R. & CHANDRA, S. (1973c). *Partha*, a new type of female fructification from the Lower Gondwana of India. *Palaeobotanist*, **20** (3): 356-360.

SURANGE, K. R. & CHANDRA, S. (1974a). Fructifications of Glossopteridales from India. *Palaeobotanist*, **21** (1): 1-17.

SURANGE, K. R. & CHANDRA, S. (1974b). *Lidgettonia mucronata* sp. nov. female fructification from the Lower Gondwana of India. *Palaeobotanist*, **21** (1): 121-126.

EXPLANATION OF PLATE

(The specimen is deposited at the B.S.I.P. Museum)

1. *Utkalia dichotoma* gen. et sp. nov. — Specimen showing dichotomous axis, each dichotomy bearing mostly alternate branches on either side. Holotype no. 35470. × 3.
2. A portion of above specimen enlarged to show the nature and attachment of seed. × 8.

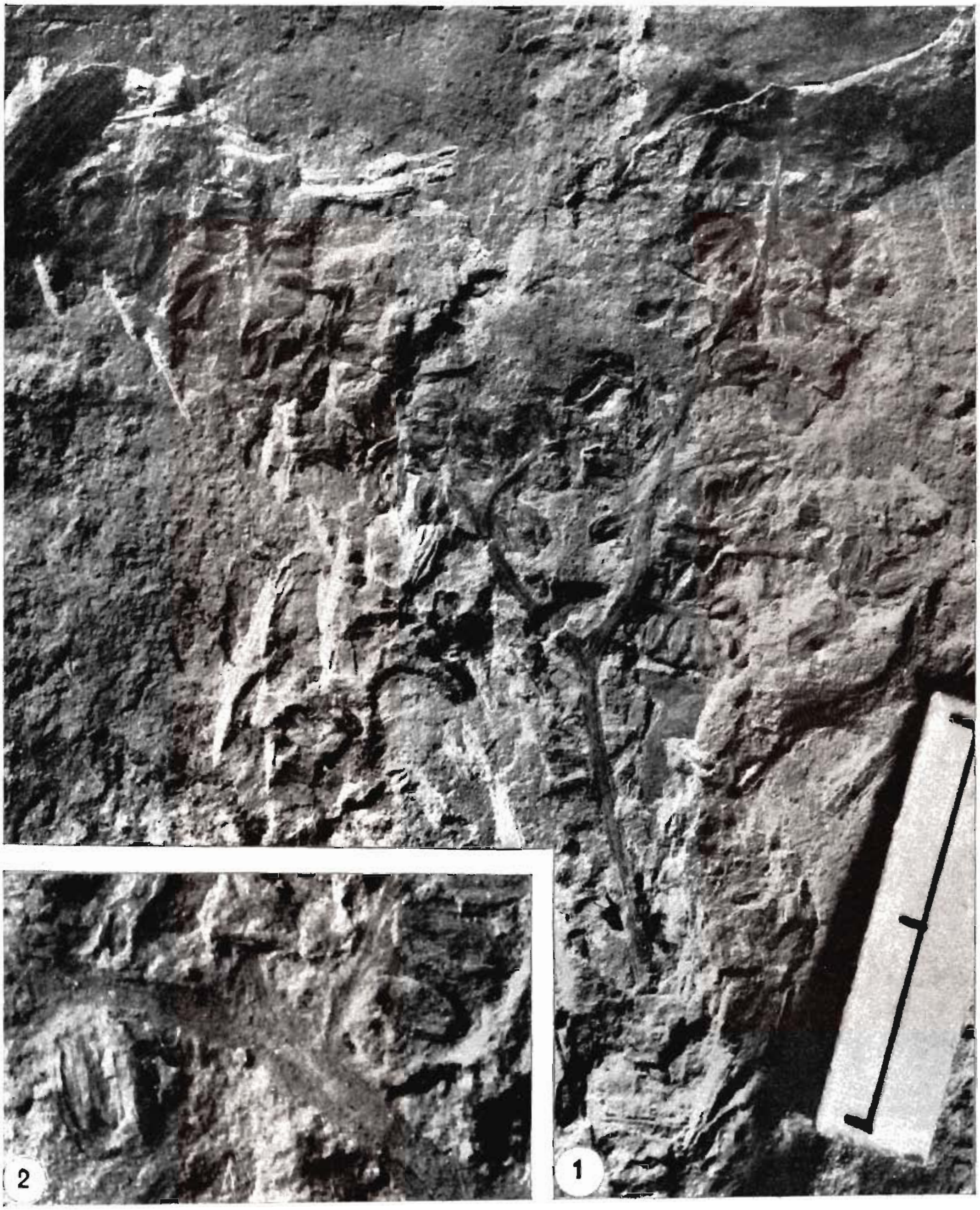


PLATE 1

The Palaeobotanist, **31**(3): 213-217, 1984.

PALMOXYLON SILTHERENSIS SP. NOV. FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT, MADHYA PRADESH

K. AMBWANI

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

ABSTRACT

A fossil palm wood, *Palmoxylon siltherensis* sp. nov., collected from the Deccan Intertrappean beds of Shahpura near the village Silther in Mandla District has been described. The fossil wood is characterized by the compact ground parenchyma and presence of one metaxylem vessel in the fibrovascular bundles.

Key-words — Xylotomy, *Palmoxylon*, Deccan Intertrappean beds, ? Palaeocene-Eocene (India).

सारांँश

मध्य प्रदेश में मँडला जनपद के दक्खिन अन्तर्ट्रैपी संस्तरों से पाल्मॉक्सीलॉन सिलथरेन्सिस नव जाति – कृष्ण अम्बवानी

मँडला जनपद में सिलथर नामक गाँव के समीप शाहपुरा के दक्खिन अन्तर्ट्रैपी संस्तरों से एकत्रित एक ताड़-काष्ठाश्म, पाल्मॉक्सीलॉन सिलथरेन्सिस नव जाति, का वर्णन किया गया है। यह काष्ठाश्म संहत भरण मृदूतक एवं वाहिनी बंडलों में विद्यमान एक अनुदारु वाहिनी से अभिलक्षणित है।

INTRODUCTION

A NEW species of a fossil palm wood has been described here from the Deccan Intertrappean beds of Shahpura in Mandla District. The fossiliferous locality is situated near the village Silther in Shahpura (Ambwani & Prakash, 1983). So far only a few dicotyledonous fossil woods (Bande & Prakash, 1981), a fossil palm wood, *Palmoxylon ghuguensis* sp. nov. resembling the extant genus *Chrysalidocarpus* (Ambwani & Prakash, 1983), *P. shahpuraensis* (Ambwani, 1983) and a fossil palm fruit resembling the present day *Hyphaene* (Bande *et al*., 1981) have been described from the Deccan Intertrappean beds of Shahpura.

SYSTEMATIC DESCRIPTION

FAMILY — PALMAE

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon siltherensis sp. nov.

Pl. 1, figs 1-4

The wood is 7 cm in length and 12 cm in diameter and is well preserved to reveal all the detailed anatomical features. It shows usually a single small metaxylem vessel per fibrovascular bundle and has compact ground tissue.

The common anatomical features observed in the dermal, subdermal as well as central zones of *Palmoxylon siltherensis* are: the presence of usually reniform type of dorsal sclerenchymatous sheath (Pl. 1, figs *1*-4) consisting of thick-walled sclerenchymatous cells with a narrow lumen. The median sinus is concave and the auricular sinus is indistinct whereas the auricular lobes are round (Pl. 1, figs 1-4). Usually one small excluded metaxylem vessel is present in each fibrovascular bundle of these zones (Pl. 1, figs 1-4). One to two layers of tabular parenchyma may be seen around each fibrovascular bundle while the radiating parenchyma are absent (Pl. 1, figs 1-4). Sometimes one to two very narrow protoxylem vessels are seen associated with the metaxylem vessel. The protoxylem and the metaxylem elements have spiral to annular and scalariform to reticulate thickenings respectively. A very narrow ventral sclerenchymatous sheath may also be found in each fibrovascular bundle (Pl. 1, figs 1-4).

Diminutive fibrovascular bundles may sometimes be seen (Pl. 1, fig. 3).

Besides, the dissimilar anatomical features observed in the different zones of the stem are as follows:

Dermal Zone — The fibrovascular bundles are mediumly large, slightly sparse and their frequency varies from 130 to 140 per cm². They are regularly oriented. The shape of these bundles varies from oval to slightly traingular. The size of the fibrovascular bundles varies from 960×480 to 800 ×720 μm. The f/v ratio varies from 18/1 to 23/1.

Subdermal Zone — The fibrovascular bundles are slightly larger in size, their frequency varies from 100 to 110 per cm² and they are more or less regularly oriented. The shape of the fibrovascular bundles varies from round to oval and the size of the fibrovascular bundles varies from 800×800 to 1020×640 μm and the f/v ratio ranges from 24/1 to 30/1.

Central Zone — The fibrovascular bundles are generally larger as compared to those of the dermal and subdermal zones and sparsely placed; more or less irregularly oriented (Pl. 1, fig. 3) and round to oval in shape. The frequency of the fibrovascular bundles varies from 80 to 85 per cm². The size of the fibrovascular bundles varies from 720×640 to 1300×800 μm. The f/v ratio is almost similar as in the subdermal zone.

Diminutive Fibrovascular Bundles — These bundles are present throughout the stem section. They measure from 240×320 to 480×480 μm and reveal similar structure to that of the larger fibrovascular bundles. They are irregularly dispersed (Pl. 1, fig. 3).

Leaf-trace Bundles — These are present throughout the stem wood but more common in the central zone. They are easily distinguished by their protruded tongue-like vascular part with a number of smaller vessels (Pl. 1, figs 1, 2).

Ground Tissue — The ground tissue is characteristic and compact throughout the stem. It is scanty in the dermal zone and is composed of slightly thick-walled parenchymatous cells generally rectangular to horizontally as well as vertically elongated in shape, sometimes oval cells may also be observed between the fibrovascular bundles. They are mostly arranged in tiers (Pl. 1, fig. 1).

In the subdermal zone the ground tissue cells are also somewhat thick-walled; round to oval as well as elongated in shape, sometimes rectangular to squarish cells may also be observed. The frequency of the elongated cells in this zone is greater than other types of cells. These elongated cells are seen vertically and obliquely placed between the fibrovascular bundles. The elongated cells are observed below the xylem portion of leaf-trace bundles which may be confused with the radiating parenchyma (Pl. 1, fig. 1).

The ground tissue in the central zone is also compact and composed of generally rectangular squarish as well as circular to oval cells. A few elongated cells may also be seen. The frequency of elongated cells is greater in the ground tissue (Pl. 1, fig. 3).

SPECIFIC DIAGNOSIS

The specific anatomical features observed in the dermal, subdermal as well as central zones of the fossil wood are: presence of reniform type of dorsal sclerenchymatous sheath, median sinus concave, auricular sinus indistinct, auricular lobes round, usually one small excluded metaxylem vessel present in each bundle, one to two layers of tabular parenchyma present, radiating parenchyma absent; sometimes one to two very narrow protoxylem vessels present; protoxylem and metaxylem elements show annular to spiral and scalariform to reticulate thickenings respectively; a narrow ventral sclerenchymatous sheath present, diminutive fibrovascular bundles sometimes seen.

Besides, the dissimilar anatomical features in each zone are as follows:

Dermal Zone — Fibrovascular bundles mediumly large, slightly sparse; frequency ranges 130-140 per cm², regularly oriented; shape oval to slightly triangular; size varies from 960×480 to 800×720 μm, f/v ratio 18/1-23/1.

Subdermal Zone — Fibrovascular bundles slightly larger in size, frequency 100-110 per cm²; more or less regularly oriented; size 800×800-1020×640 μm; f/v ratio 24/1-30/1.

Central Zone — Fibrovascular bundles generally larger than dermal and subdermal zones, sparsely placed (Pl. 1, fig. 3) irregularly oriented; frequency 80-85 per cm², shape round to oval, size 720×640-1300×800 µm; f/v ratio almost similar to subdermal zone.

Ground tissue compact throughout, cells generally rectangular, elongated as well as circular sometimes oval and squarish. Cells in dermal zone generally arranged in tiers between two adjacent fibrovascular bundles; cells in subdermal and central zones round, oval as well as elongated; frequency of elongated cells greater in central zone.

Holotype — B.S.I.P. Museum no. 36034.

Locality — Silther, Mandla District, Madhya Pradesh.

Horizon — Deccan Intertrappean Series.

Age — ?Palaeocene-Eocene.

Palmoxylon species with compact ground tissue comparable with the present fossil species are: *Palmoxylon sahnii* Rode (1933), *P. sclerodermum* Sahni (1931, 1964), Shukla (1946), *P. surangei* Lakhanpal (1955), *P. rewahense* Sahni (1964), *P. liebigianum* Sahni (1964), *P. coronatum* Sahni (1964), *P. compactum* Sahni (1964), *P. maheshwarii* Rao & Menon (1963), *P. raoi* Menon (1968), *P. puratanum* Ramanujam (1958), *P. mohgaonensis* Trivedi & Surange (1970), *P. splendidum* Trivedi & Chandra (1971), and *P. mandlaensis* Lakhanpal *et al.* (1979) but the present fossil species is closely comparable only with *Palmoxylon sclerodermum*.

Palmoxylon sclerodermum in its general anatomy shows scanty parenchyma in the ground tissue and usually one rarely two metaxylem vessels in each fibrovascular bundle. It also resembles the present fossil wood in shape and size of the fibrovascular bundles as well as in having 1-2 layers of tabular parenchyma around the fibrous part of the fibrovascular bundle; both have rounded auricular lobes. The diminutive fibrovascular bundles are present in both the species.

But it differs from *P. sclerodermum* which has generally cordate type of dorsal sclerenchymatous sheath. The f/v ratio in the present species is 18/1-23/1 in dermal and 24/1-30/1 in the subdermal and central zones whereas in the dermal, subdermal and central zones of *P. sclerodermum* it is 9/1-18/1, 20/1 and 23/1 respectively. The frequency of the fibrovascular bundles in both the species also differs and is greater in the present species, being 130-140 in the dermal, 100-110 in subdermal and 80-85 per cm^2 in the central zone respectively while it is 105 in the dermal, 75 in subdermal and 55-70 per cm^2 in the central zone of *P. sclerodermum*. The median sinus in the present species is concave whereas it is cordate in *P. sclerodermum*. Generally one rarely two small vessels are seen in each fibrovascular bundle of all the zones in the present species while one to two or more vessels in each fibrovascular bundle are present in *P. sclerodermum*.

The ground tissue in the present species is compact throughout the stem while it is slightly lacunar in the dermal zone of *P. sclerodermum*. The parenchymatous cells of the ground tissue in the present species vary from round, oval, rectangular, squarish and sometimes elongated whereas they are usually isodiametric in *P. sclerodermum*. The fibrous bundles are absent throughout the stem in the present species while they are present in *P. sclerodermum*.

Further, the present fossil species can also be compared with *Palmoxylon speciosum* Stenzel (1904) to some extent. The size and shape of fibrovascular bundles closely resemble in both. The size ranges from 1000 to 1400 µm in *P. speciosum* whereas the dorsal sclerenchymatous sheath is reniform in both. The f/v ratio is more or less similar, bundles show presence of ventral sclerenchymatous patch below the xylem of the fibrovascular bundle. Presence of 1-2 layers of tabular parenchyma may also be seen in the fibrovascular bundles with concave median sinus in both the species.

However, the present fossil species differs from *P. speciosum* in having greater frequency of the fibrovascular bundles, being only 21 per cm^2 in *P. speciosum*. The fibrous bundles are absent in the present fossil species whereas they are present in *P. speciosum*. The diminutive fibrovascular bundles are observed in the present species while they are absent in *P. speciosum*. There is usually one small metaxylem vessel in the fibrovascular bundle of the present species while generally two metaxylem vessels are present in *P. speciosum*. The dorsal sclerenchymatous sheath of the fibrovascular bundles in the present species is usually reniform while it is lunaria as well as sagittata in *P. speciosum*. The ground tissue is compact in the present species, whereas it is lacunar in *P. speciosum*.

Thus the present species differs from all the above mentioned species of *Palmoxylon* and therefore a new species *Palmoxylon siltherensis* has been created. The specific name has been assigned after the locality from which the specimen was collected.

REFERENCES

AMBWANI, K. (1983). *Palmoxylon shahpuraensis* sp. nov. resembling *Licuala* from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **31** (1): 52-59.

AMBWANI, K. & PRAKASH, U. (1983). *Palmoxylon ghuguensis* sp. nov. resembling *Chrysalidocarpus* from the Deccan Intertrappean beds of Mandla District in Madhya Pradesh. *Palaeobotanist*, **31** (1): 78-81.

BANDE, M. B., PRAKASH, U. & AMBWANI, K. (1980). A fossil palm fruit *Hyphaeneocarpon indicum* gen. et sp. nov. from the Deccan Intertrappean Series, India. *Palaeobotanist*, **30** (3): 303-309.

BANDE, M. B. & PRAKASH, U. (1981). Fossil dicotyledonous woods from the Deccan Intertrappean beds near Shahpura, Mandla District, Madhya Pradesh. *Geophytology*, **10** (2): 168-171.

LAKHANPAL, R. N. (1955). *Palmoxylon surangei*, a new species of petrified palm from the Deccan Intertrappean Series. *Palaeobotanist*, **4**: 15-21.

LAKHANPAL, R. N., PRAKASH, U. & AMBWANI, K. (1979). Two petrified palm woods from the Deccan Intertrappean beds of Mandla District, Madhya Pradesh. *Palaeobotanist*, **26** (2): 119-129.

MENON, V. K. (1968). A new petrified palm wood from the Deccan Intertrappean beds of Mohgaon Kalan. *Palaeobotanist*, **16**: 101-108.

RAMANUJAM, C. G. K. (1958). *Palmoxylon puratanum*, a new species of petrified palm from the Tertiary rocks of South India. *J. Indian bot. Soc.*, **37** (1): 128-137.

RAO, A. R. & MENON, V. K. (1963). *Palmoxylon maheshwarii* — a new petrified palm wood from the Deccan Intertrappean beds. *Proc. natn. Inst. Sci. India*, **29B** (4): 423-433.

RODE, K. P. (1933). Petrified palms from the Deccan Intertrappean beds II. *Q. Jl geol. Min. metall. Soc. India*, **5** (3): 105-114.

SAHNI, B. (1931). Materials for a monograph of the Indian petrified palms. *Proc. Acad. Sci.* U.P., **1**: 140-144.

SAHNI, B. (1964). *Revision of Indian Fossil Plants. III. Monocotyledons. Monograph no.* 1. Birbal Sahni Institute of Palaeobotany, Lucknow.

SHUKLA, V. B. (1946). *Palmoxylon sclerodermum* Sahni from the Eocene beds of Nawargaon, Wardha District. *J. Indian bot. Soc.*, **25** (3): 105-116.

SCHENK, A. (1882). Die von den Gebrudern Schlagintwett in Indien gesammelten fossil Hölzer in engler. *Bot. Jahr. Syst.*, **3**. Lepzig.

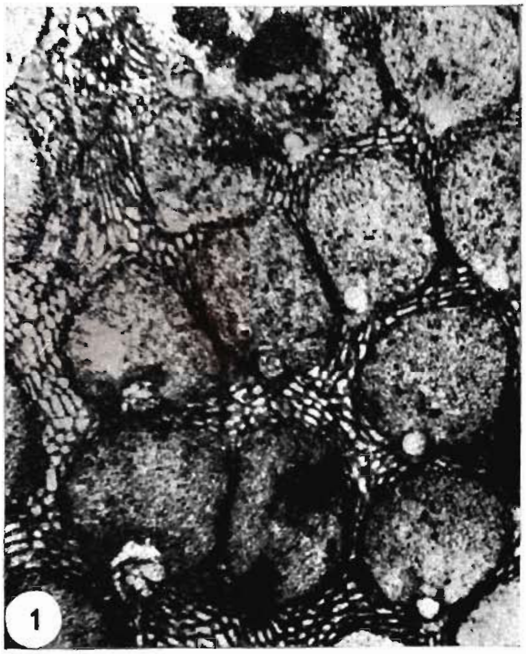
STENZEL, K. G. (1904). Fossil palmen hölzer Beitr. *Palaont. Geol. Ost. Ung.*, **16**: 107-287.

TRIVEDI, B. S. & CHANDRA, R. (1971). *Palmoxylon splendidum* sp. nov. from the Deccan Intertrappean beds of Keria, M.P., India. *J. Indian bot. Soc.*, **50**: 349-355.

TRIVEDI, B. S. & SURANGE, K. R. (1970). *Palmoxylon mohgaonensis*, a new species of petrified palm stem from the Deccan Intertrappean Series of India. *Palaeobotanist*, **18** (1): 1-7.

EXPLANATION OF PLATE

1. Cross section of *Palmoxylon siltherensis* sp. nov. passing through dermal zone. Note the nature of the fibrovascular, leaf-trace bundles and the ground tissue cells. Note the presence of diminutive bundle. × 30. Slide no. 6703.
2. Cross section of the same showing subdermal zone. Note the presence of tabular parenchyma around the fibrous part of fibrovascular bundle. × 30. Slide no. 6703.
3. Cross section of the Central zone of stem enlarged, showing irregularly oriented fibrovascular bundles and leaf-trace bundle. Note the presence of diminutive bundle. × 30. Slide no. 6703.
4. Cross section showing a single enlarged fibrovascular bundle with different types of ground tissue cells. × 60. Side no. 6703.
5. L.S. showing stegmata. × 60. Slide no. 6703A.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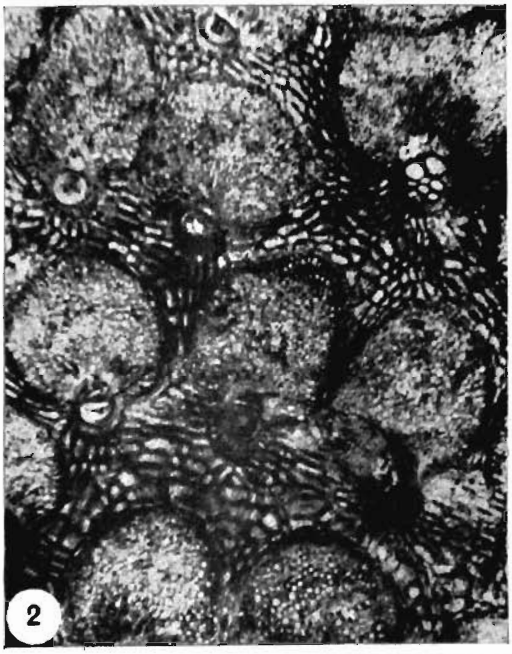
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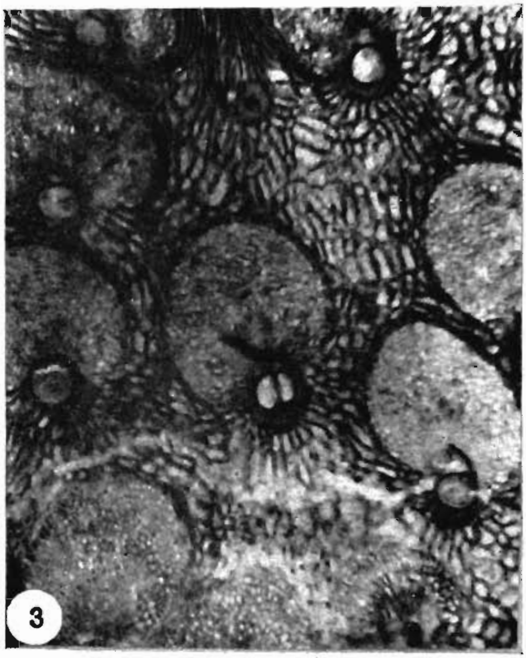
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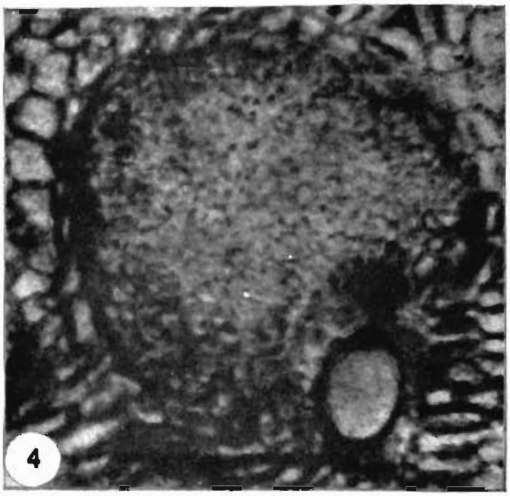
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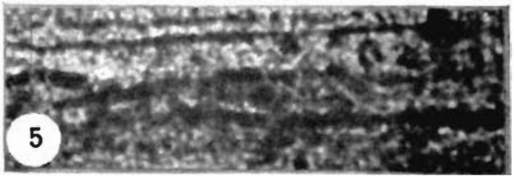
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PLATE 1

The Palaeobotanist, **31**(3): 218-233, 1984.

PALYNOLOGICAL INVESTIGATION OF THE ARABIAN SEA: POLLEN/SPORES FROM THE RECENT SEDIMENTS OF THE CONTINENTAL SHELF OFF BOMBAY, INDIA

RAM RATAN & ANIL CHANDRA
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

The palynological analysis of 22 bottom sediments from the continental shelf off Bombay shows mixed pollen spectra which is the reflection of the adjoining mangroves, tropical evergreens and the mixed deciduous type of vegetation. Herbaceous pollen and pteridophytic spores dominate over the trees in all the samples. It has been observed that the palynomorphs in the sediments from station numbers 22 to 28 are derived from the vegetation of the Saurashtra coast, while in other samples from station numbers 1 to 4, 5 to 15 and 20, the pollen appear to have been derived from the Bombay coast vegetation. The quantitative analysis of the assemblage shows comparatively higher frequency of pollen/spores in the samples collected from near the coast. Corroded grains have been found in all the samples and their percentage is higher in the samples collected from near the coast between Bombay and Marmugao.

Key-words — Palynology, Mangroves, Continental shelf, Arabian Sea (India).

साराँश

अरब सागर का परागाणविक अन्वेषण : भारत में मुम्बई के महाद्वीपीय अपतट के वर्तमान अवसादों से प्राप्त परागकण / बीजाणु – राम रतन एवं अनिल चन्द्रा

मुम्बई के महाद्वीपीय अपतट से प्राप्त 22 तलीय अवसादों के परागाणविक विश्लेषण से मिश्रित परागकण स्पेक्ट्रम प्रदर्शित होते हैं जो कि आस-पास में उगने वाले दलदली पौधों, उष्णकटिबंधीय सदाहरित एवं मिश्रित पर्णपाती वनस्पति का प्रतिस्वरूप है। सभी नमूनों में वृक्षों की अपेक्षा शाकीय परागकणों एवं टेरिडोफ़ाइटी बीजाणुओं का बाहुल्य है। यह प्रेक्षित किया गया है कि प्रेक्षण स्थल संख्या 22 से 28 तक के अवसादों में परागाणविकरूपक सौराष्ट्र तट की वनस्पति से व्युत्पादित हैं जबकि प्रेक्षण स्थल संख्या 1 से 4, 5 से 15 तथा 20 से प्राप्त नमूनों में परागकण मुम्बई तट की वनस्पति से व्युत्पादित प्रतीत होते हैं। तट के समीप से एकत्रित नमूनों में समुच्चय का परिमाणात्मक विश्लेषण तुलनात्मक दृष्टि से परागकण/बीजाणुओं की उच्चतर बारम्बारता व्यक्त करता है। क्षीण कण सभी नमूनों में मिलते हैं तथा इनकी बारम्बारता मुम्बई तथा मारमुगाव के बीच में तट के समीप से एकत्रित नमूनों की अपेक्षाकृत उच्चतर है।

INTRODUCTION

TERRESTRIAL microfossils were first described from the marine cores and the coastal water sediments by Erdtman (1921) and Halden (1922). Since then significant contributions to the marine palynology have been made by various workers (Koreneva, 1957, 1964a, b, 1966, 1968, 1971, 1980; Muller, 1959; Ingram *et al.*, 1969; Rossignol, 1961; Livingstone, 1964; Panov *et al.*, 1964; Cross & Shaefer, 1955; Stanley, 1965, 1966a, b, c, d, 1967, 1969; Groot, 1966; Groot & Groot, 1966; Cross *et al.*, 1966; Traverse & Ginsburg, 1966; Horowitz, 1966; Boulouard & Delange, 1966; Zagwijn & Veenstra, 1966; Aoutin, 1967; Assemien, 1969; Davey, 1971; Florer, 1973; Heusser & Florer, 1973; Heusser & Balsam, 1977; Maljasowa, 1980; Vronsky, 1980 etc.). In India, palynological studies of the mangrove sediments have been carried out by Das, 1961; Mukherjee, 1969, 1972; Vishnu-Mittre and

Gupta, 1972; Vishnu-Mittre and Guzder, 1975; Blasco and Caratini, 1973; Caratini *et al.*, 1973; Gupta, 1981 and many others.

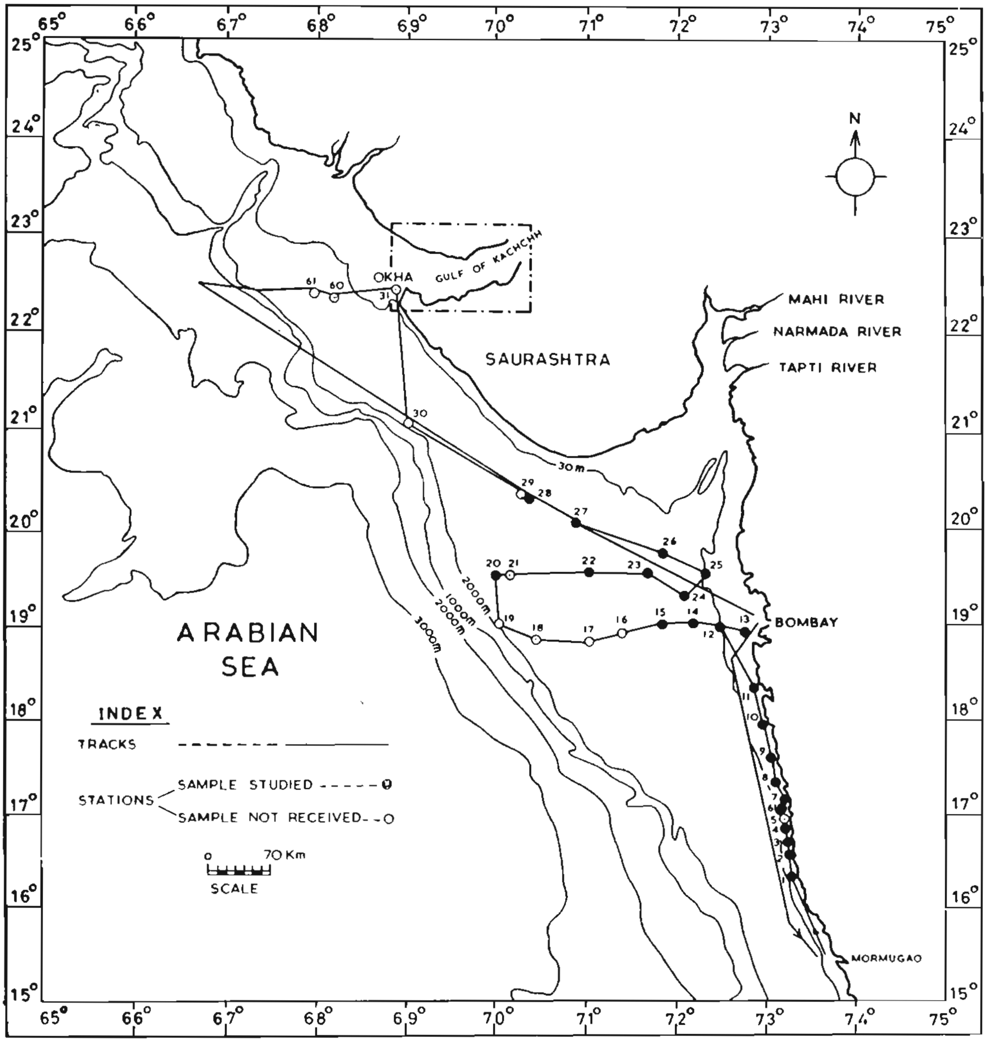
The present contribution on the palynology of the oceanic sediments deals with the study of 22 bottom surface (grab) samples from the continental shelf off Bombay. These samples were collected along the western coast of India (between 16° 17.8′N: 73°19.3′ E and 20°19.5′N: 70°20.5′ E) by R. V. Gaveshani of the National Institute of Oceanography, Goa under its second Oceanographic Cruise. The objectives of the present study are to investigate the distribution and source of the palynomorphs and their relationship with the major sediment types in the continental shelf off Bombay and also to observe the relationship of the pollen spectra with the surrounding continental vegetation.

MATERIAL AND METHOD

All the 22 grab samples (bottom sediments) were collected from the continental shelf off Bombay by the R. V. Gaveshani (Second Oceanographic Cruise, 1976). These samples were received from the National Institute of Oceanography, Goa for palynological investigations. The lithology of the sediments is clay, sandy clay, silty clay, sandy silt and silty sand. The water depth of the stations is from 10.5 to 88.5 metres. The distance of stations nearest and farthest off the coast is approximately 7 km and 154 km. Samples from station numbers 1 to 4, 13 and 22 to 26 are from the inner shelf while those from station numbers 14, 15, 27, 28 are from the outer shelf. The depth, latitude, longitude and lithology of these sediments are shown in Table 1 and the location of these samples is shown in Text-fig. 1. The samples have been macerated by the standard procedure of Erdtman (1943). Pollen grains have been assigned to their respective families and those which could not be identified have been categorized as ‘ unknown ’ pollen. The distribution of maximum concentrated pollen/spore taxa have been shown in Contour maps (Text-figs 3-15). The source area of the pollen grains except that of Poaceae, Cyperaceae, Asteraceae, Cheno/Ams which are ubiquitous, have been shown by shade.

TABLE 1 — SHOWING THE STATION LOCATION AND OTHER DATA OF THE CRUISE II — R. V. GAVESHANI

No.	Station No. (Sample No.)	Position		Depth in Meters	Lithology of the Sediments
		Latitude	Longitude		
1	1	16°17.8′N	73°19.3′E	26.5	Silty clay
2	2	16°33.4′N	73°17.0′E	18.5	Clay
3	3	16°41.1′N	73°15.3′E	20.5	Clay
4	4	16°51.9′N	73°14.4′E	20.5	Clay
5	6	17°03.0′N	73°13.5′E	18.5	Silty clay
6	7	17°06.0′N	73°14.5′E	16.5	Silty clay
7	8	17°18.0′N	73°08.1′E	22.5	Silty clay
8	9	17°34.1′N	73°06.1′E	12.0	Clay
9	10	17°57.6′N	72°59.2′E	10.5	Clay
10	11	18°18.5′N	72° 5.8′E	10.5	Clay
11	12	18°58.1′N	72°30.0′E	33.5	Clay
12	13	18°53.1′N	72°42.3′E	15.0	Clay
13	14	19°00.0′N	72°11.0′E	62.5	Sandy silt
14	15	18°58.0′N	71°50.0′E	70.0	Sandy silt
15	20	19°30.0′N	70°00.0′E	88.5	Silty sand
16	22	19°31.5′N	71°01.5′E	48.0	Sandy silt
17	23	19°30.5′N	71°44.8′E	47.0	Clay
18	24	19°16.0′N	72°03.0′E	48.0	Clay
19	25	19°30.5′N	72°20.5′E	24.0	Clay
20	26	19°43.5′N	71°51.0′E	31.0	Clay
21	27	20°03.0′N	71°00.0′E	68.0	Clay
22	28	20°19.5′N	70°20.5′E	78.0	Sandy clay



TEXT-FIG. 1 — Map showing the location of samples (from the Report of Second Oceanographic Cruise, R. V. Gaveshani).

DESCRIPTION, BATHYMETRY AND GEOLOGY OF THE AREA

The area under study lies between 16°15′: 22°30′N and 67°45′: 73°30′E. According to Nair (1975) the shelf width off Bombay is about 300 km, of which the outer 225 km between depths of 65 and 100 m is composed of pinnacles (commonly 1-2 m in height) with or without adjacent troughs (usually 1-2 m deep). There are a number of large (C. 2000 to 4000 m in width) mound-shaped protuberances with a relief of 6 to 8 m on the outer shelf at depths of 80 to 85 m. Off Ratnagiri the shelf narrows down to about 100 km and the shelf break takes place at 130 m. Pinnacles and troughs, restricted to depths between 95 and 100 m are poorly developed as compared to those off Bombay. Progressive narrowing of the shelf is reflected in 60 km wide shelf off Goa, the shelf break occurring at a depth of 130 m. Pinnacles with relatively gentle depression occur on a sloping shelf between the sea floor depths of 62 and 84 m. Unlike off Ratnagiri, the shelf slopes smoothly to the upper continental slope.

According to Hashimi *et al.* (1978) the continental shelf off Bombay is floored with three types of sediments: (i) the nearshore sand zone which extends from shore to water depth of 5-10 m, (ii) the muds (silt and clay) which extend to a water depth of 60-70 m, and (iii) the calcareous sediments (seaward of the mud zone and extending to shelf edge) composed of shells of various organisms, oolite and algae. The sediments of the inner shelf (0-60 m) are geologically recent. They represent the contribution made by the present day rivers of the west coast. According to Nair and Hashimi (1980), the modern sands of the shore zone occur within a few kilometers of the coast and extend to about 10 m water depth. These are derived as a result of the wave erosion of cliffs and promontories of the west coast. Beyond 10 to 20 m the modern muds are found. The source of these muds are the rivers which drain the western Ghats and the coastal plain at their foot.

The coastal geology is varied. On the west coast along Kachchh shore recent deposits of newer alluvium are met with. Over the western shore of the Saurashtra too the newer alluvium are found with small pockets of a foraminiferal limestone known as meliolite, and of rocks which have been correlated with the Gaj Series (of Sind) of the Lower Miocene age. The Deccan Traps dominate the Maharashtra coast. Further south along the Karnataka and Kerala shores, up to Kanyakumari the most important formation is recent alluvium, though Pleistocene alluvium, Archaean genissic complex, laterites and Miocene sandstones (Warkali beds) are also encountered.

Drainage — The entire Maharashtra is drained by three principal river systems, the Tapti, the Godavari and the Krishna. Except Tapti basin which is drained to Arabian Sea, the rest of the region is drained to the Bay of Bengal. The radial drainage pattern of Kathiawar is guided by two hill masses of Rajkot (383 m) and Gir range (728 m) which are linked by tortuous narrow neck of high land. The North flowing streams unite with the Gulf of Kachchh and little Rann, while the south flowing streams merge in the Arabian Sea. Carving out their valleys in the Surat sea coast, the Bhadar and Ojat rivers together with other west flowing streams terminate in the Arabian Sea, whereas the eastward drainage discharges its waters in the Gulf of Cambay (Singh, 1971).

Coastal Environment — The west coast line of India is long and more or less straight from Cape Comorin in the south to the 20° parallel north and includes two peninsula-Saurashtra and Karnataka and is spread into the states of Gujarat, Maharashtra, Karnataka and Kerala. These two major inshore ecosystems, strand and estuary lie between the coastline and the adjacent plains. The climate along the coast line is relatively uniform over extensive areas and on the basis of humidity it has been classified into five climatic groups, viz., prehumid, humid, subhumid, semiarid and arid as already recognized by Thorrthwaite (1948). In the extreme north of west coast in the vicinity of Kachchh and Okha-Dwaraka shores, the climate is arid. Further down and along the south western shores stretching into the states of south Gujarat, Maharashtra, Karnataka and Kerala the humid climate exists.

The influence of marine climate on upland part of the coastal biosphere is affected by the combined action of precipitation and local topography and all the prevailing influence of sea is felt only in low lying coastal areas. The nature of vegetation is greatly influenced by the upland sandy relief which alters the influence of climate and the properties of soils due to variations in environmental factors. On the contrary, the effect of land climate is not appreciable in the low lying coastal areas. Here they are chiefly influenced by tides, waves, sea winds, saline water and nature of substratum.

Water Currents — The general surface circulation in the Arabian Sea is counter clockwise during north-east monsoon. By February, this system is gradually reversed into a clockwise circulation which intensifies during south-west monsoon. Currents in the continental shelf are a combination of tidal currents, density currents, wind induced currents, currents due to surface and internal waves and those due to the land drainage. The tidal currents are strong farther from the shore.

The tidal currents off Mangalore are of rotary type. The rotary nature of the currents, however, is not very regular which may be due to the effect of winds and waves, etc. The tidal influence on the currents decreases in the off shore direction and ultimately becomes negligible. The seasonal currents show an increase in the speed in the off-shore direction. The currents are weakest (about 5 cm per second) in December. During May to October they are strong and the maximum speed is about 50 cm per second or even more. The currents are southerly from April to October and northerly from November to February and show the tendency to change from north to south during the transition months of February and March. The currents are governed by the tides during the non-monsoon seasons (Varma & Gopinathan, 1977; Gouvenia & Varadachari, 1979).

Vegetation — The coastal vegetation is influenced by the marine environment. The vegetation, in the transition zone of sea and land, and upland vegetation are discussed separately. The coastal vegetation of India has been extensively studied by Champion and Seth (1968), Rao and Sastry (1974) and Blasco (1975, 1977).

The littoral forest occurs all along the coast where the sandy beach, sandy bars on the sea face and river deltas are found. *Hyphaene indica* is common on the sandy beaches of Saurashtra only while *Borassus flabellifer* and *Cocos nucifera* are common on the entire western coast of India. *Casuarina equisetifolia* often forms almost along pure fringe on the sandy beaches and dunes along the sea face. There are scattered evergreen smaller trees with fewer deciduous trees and these form the dominant canopy in absence of *Casuarina*. The common sand binders are *Canavalia maritima*, *Ipomoea pescaprae* and *Launea sarmentosa*. The succulents and bulbous plants (*Hydrophyllax maritima* and *Crinum latifolium*) are also common. The transition from open dunes to sandy near shore is made by shrubs like *Scaevola frutescens*, *Pandanus fasicularis*, *Calophyllum inophyllum*, etc.

The best conserved halophytic population is found near Ratnagiri, in Bombay and Salsette islands. The large areas of halophytes are on the point of extinction, particularly in Kolaba area. On the whole, only a few dense but bushy stands of *Avicennia alba* Bl. are seen out of the original littoral formations and the swamps are completely covered by *Acanthus ilicifolius* here and there. The other mangrove species, particularly members of Rhizophoraceae, still survive in some places. They are very few in number and generally scattered. In some places these along with some other species, have been completely destroyed in the recent past. In these regions where the mangroves are preserved three zones can be recognized. These are: (i) " the Rhizophoraceae zone " (*Rhizophora mucronata*, *R. apiculata*, *Ceriops tagal*, *Bruguiera cylindrica* and *B. parviflora*) — towards the sea, (ii) a zone of *Avicennia alba* (and *A. officinalis*) — a little retreated, and (iii) a zone of a sort of grasses. These grasses with the dominance of *Aleuropus agallocha* are found in the continental regions of the back mangrove.

On the Saurashtra coast the mangrove vegetation is very poor. The most common formations have a physiognomy of lowly cropped thickets (less than 2 m) which are very open but continuous in some places. The members of Rhizophoraceae are very rare. *Avicennia* forms gregarious populations. Some avicennias attain 7-8 m height and stand out distinctly from the rest of the vegetation to form a zone of *Avicennia* (*Avicennia marina* var. *acutissima*). The back mangrove behind this zone is composed of *Salicornia brachiata* and grass *Urochondra setulosa*. On the sandy clayey sites with salinity, *Suaeda fruticosa* and *Atriplex stocksii* may be locally abundant.

The tropical moist deciduous forest is distributed in Maharashtra, Karnataka and Kerala. The top canopy is characterized by *Tectona grandis*, *Terminalia* spp., *Pterocarpus* sp., *Salmalia malabarica* and *Lagerstroemia* sp. *Adina* is found in drier condition. The common second storey trees are *Schleichera* and *Careya*. The important constituents of the top canopy in non-teak bearing forest are *Pterocarpus marsupium*, *Salmalia malabarica*, *Terminalia* spp., *Anogeissus latifolia*, *Dalbergia latifolia*, *Lannea coromandelica* and *Madhuca indica*. The second canopy is characterized by *Miliusa*, *Gravia*, *Diospyros*, *Flacourtia* and *Polyalthia*. The main shrubs are represented by *Zizyphus*, *Casuarina*, *Helicteres* and *Desmodium*.

Tropical semi-evergreen forest occurring in strips between moist deciduous forest

TABLE 2 — DISTRIBUTION OF MAIN HALOPHYTES IN BOMBAY REGION

FAMILY	GENERA AND SPECIES	MANGROVE	BACK MANGROVE	OLD MANGROVE	SALINE SAND	GEOGRAPHICAL DISTRIBUTION
Acanthaceae	*Acanthus ilicifolius* L.	+	⊕	⊕		Tropical Asia+ Australia
Aizoaceae	*Sesuvium portulacastrum* L.		+	⊕		Pantropical
Avicenniaceae	*Avicennia alba*	⊕	⊕	⊕		Asia, Australia
	A. officinalis L.	⊕	⊕			Tropical Pacific
Chenopodiaceae	*Arthrocnemum indicum* Moq.		+	⊕	+	India, Africa, Indonesia
	Salicornia brachiata Roxb.		⊕	⊕		India
	Salsola foetida Delile			+	⊕	India + Pakistan + Africa
	S. kali L.			+	⊕	Pantropical + Europe
	Suaeda fruticosa Forsk.		+	+		± Cosmopolitan
	S. maritima (L.) Dum		⊕ ⊕	+		± Cosmopolitan
	S. monoica Forsk.			+		India + Africa Moy. Orient.
Combretaceae	*Lumnitzera littorea* (Mack) Voigt.	⊕	+			Palaeotropical
Euphorbiaceae	*Excoecaria agallocha* L.	+	⊕	⊕		Asia Tropical + Pacific
Gramineae	*Aleuropus lagopoides* (L.) Trin.		⊕	⊕		Asia + Mediterranean + N. Africa
Myrsinaceae	*Aegiceras corniculatum* (L.) Bl.	⊕	+			Palaeotropical
Papillionaceae	*Derris trifoliata* Lour.	⊕	+			Palaeotropical
Potamogetonaceae	*Zannichellia palustris* L.			⊕		± Cosmopolitan
Rhizophoraceae	*Bruguiera cylindrica* W. et A.	⊕	+			Palaeotropical
	B. parviflora W. et A.	⊕				Tropical Asia + Australia
	Ceriops tagal (Perr.) Rob.	⊕	+			Pantropical
	Rhizophora apiculata Bl.	⊕				Asia Tropical
	R. mucronata L.	⊕				Palaeotropical
Salvadoraceae	*Salvadora persica* L.			⊕	+	India + Africa
Sonneratiaceae	*Sonneratia apetala* Buch. Ham.	⊕	+			India + Ceylon + Burma
	S. caseolaria (L.) Engl.	⊕	⊕			Asia+Australia tropical
Verbenaceae	*Clerodendrum inerme* Gaertn.		+	⊕	+	Palaeotropical (or Pantropical)

⊕, Formation where it is more frequent.
+, Formation where it is occasionally found (from Blasco, 1975).

is characterized by *Terminalia paniculata* with *Diospyros* sp., *Lagerstroemia lanceolata*, *Holigrana arnottiana*, *Lophopetalum wightianum*, *Machilus macrantha*, *Cinnamomum* sp., *Hopea parviflora* and *Artocarpus hirsuta*. The main associates of the second canopy are *Elaeocarpus* sp., *Mallotus*, *Diospyros assimilis* and *Ixora arborea*. The shrubs are characterized by *Strobilanthes* spp., *Webera* and *Ixora malabarica*.

The tropical dry deciduous forest occurs throughout the Indian Peninsula and it merges with tropical thorn forest lee-ward of the Ghats. *Tectona grandis* is the characteristic constituent of the teak bearing forests and its typical associates are *Anogeissus latifolia* and *Terminalia* which are dominant in the non-teak-bearing forests and are accompanied by *Diospyros*, *Boswelia* and *Sterculia*.

The tropical thorn forest is distributed in Maharashtra, Mysore, Saurashtra and Kachchh. *Acacia* with a number of species and other allied genera are the characteristics of the southern thorn forest while fleshy euphorbias and *Capparis* are the important constituents. In the thorny forest of Kachchh and Saurashtra *Acacia* is widespread and *Capparis decidua* is the important tree. The fleshy *Suaeda* and *Salsola* are common on the saline soils while *Calligonum polygonoides* is common on the sandy soils.

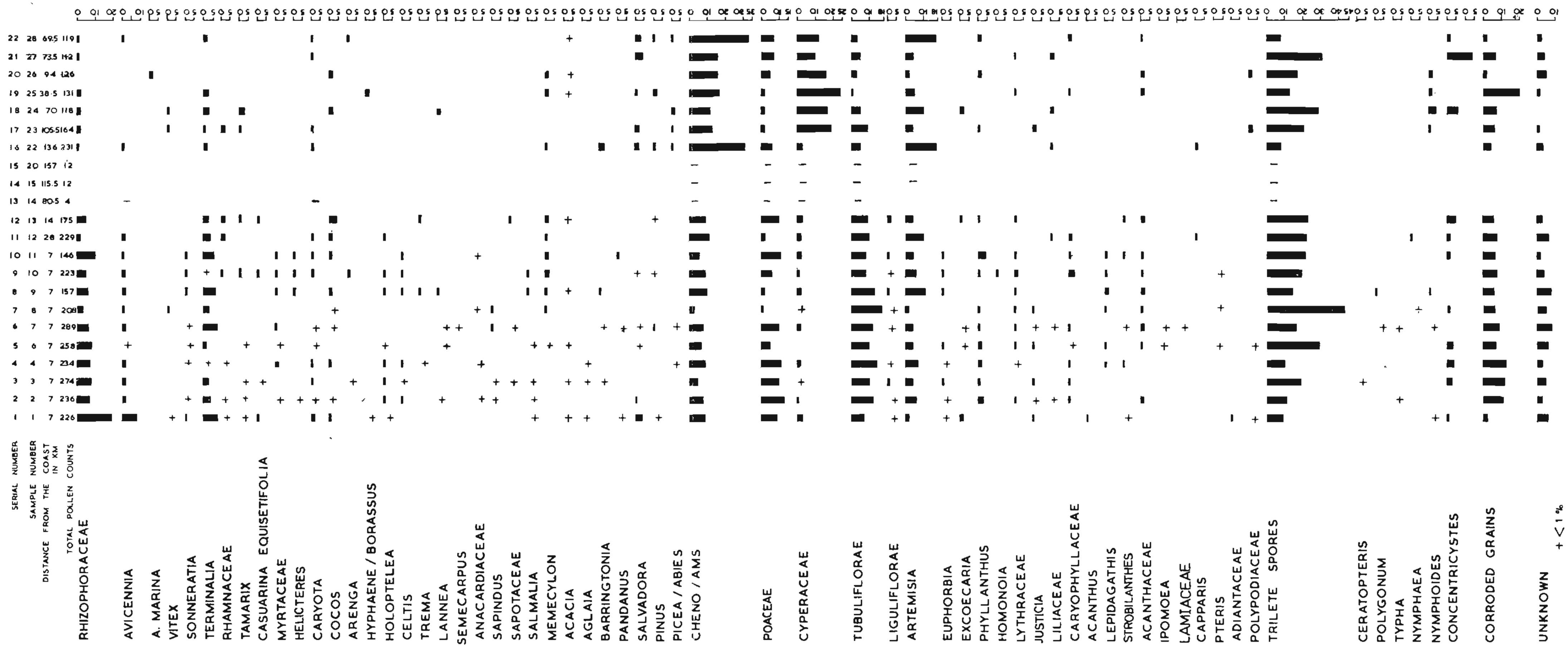
RESULTS AND DISCUSSION

All the 22 grab samples (except sample nos. 14, 15 & 20) have yielded a rich assemblage of pollen/spores. Pollen of mangrove vegetation trees and herbs and the pteridophytic spores have been identified while remaining ones have been kept as 'unknown' (Text-fig. 2). Corroded grains, which could not be identified, have also been counted.

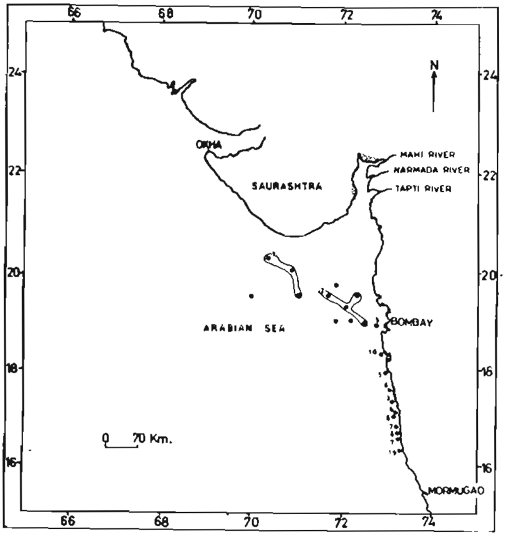
Distribution of Mangrove Pollen — The pollen of Rhizophoraceae are present (1-19 per cent) in most of the samples (Text-fig. 3) but are rich in sample nos. 1 to 4 and 6 to 13 from the shelf off Bombay. As these samples are from along the margin (off the coast) the variation in pollen frequencies is directly controlled by the population of the Rhizophoraceae in the mangroves. The sample nos. 22 to 28 from the shelf off Saurashtra have poor representation of Rhizophoraceae and this may be the reflection of poor occurrence of the Rhizophoraceae members in the salt swamps. The pollen of *Avicennia* are common (0.5-4 per cent) in the samples from the shelf off Bombay (Text-fig. 4). The percentage of the pollen of Rhizophoraceae and *Avicennia* in sample no. 1 is higher in comparison to all others. This may be due to some local effect or because of very healthy growth of mangroves in the area resulting in the high influx of pollen grains. The pollen of *Avicennia marina* have been found in sample no. 26 only. The pollen of *Sonneratia* have been found up to one per cent in the sample nos. 1, 9, 10 11 and are also present in sample nos. 2, 4, 6, 7 off Bombay (Text-fig. 5). *Salvadora persica* and *S. oleoides* which grow in salt swamps and mangroves are represented up to 4 per cent. Herbaceous species of mangroves, i.e. *Excoecaria* (1-2 per cent in sample nos. 1, 13, 14; present in sample nos. 6 and 7) and *Acanthus* (1 per cent in sample no. 1) have been recorded in a few samples from the continental shelf off Bombay. Pteridophytic spore resembling to that of *Acrostichum* (Adiantaceae), which is a typical mangrove plant, has been recorded in sample no. 1 only (less than 1 per cent). The pollen of Cheno/Ams (3-33 per cent) are found in all the samples and their percentage in the samples (nos. 22 to 28) from the shelf off Saurashtra is higher than in those off Bombay (Text-fig. 6).

Distribution of Arboreal Pollen Grains — The arboreal pollen of tropical forest are present in the samples off Bombay. The pollen of *Terminalia* range from 0.5 to 8 per cent and are higher in the sediments off Bombay (Text-fig. 7). The tropical forest taxa are represented by the pollen of *Salmalia* (0.5-1 per cent, Text-fig. 8), Sapotaceae (0.5-1 per cent), *Acacia* (0.5 per cent), Myrtaceae (0.5-1 per cent), *Helicteres* (0.5-1 per cent), *Sapindus* (0.5-1 per cent), *Memecylon* (0.5-2 per cent, Text-fig. 10), *Arenga* (0.5-1 per cent), *Caryota* (0.5-1 per cent, Text-fig. 9) *Acacia* 0.5-1 per cent), *Holoptelea* (0.5-1 per cent), *Trema* (0.5-1 per cent), *Celtis* (0.5-1 per cent) and Rhamnaceae (0.5-2 per cent).

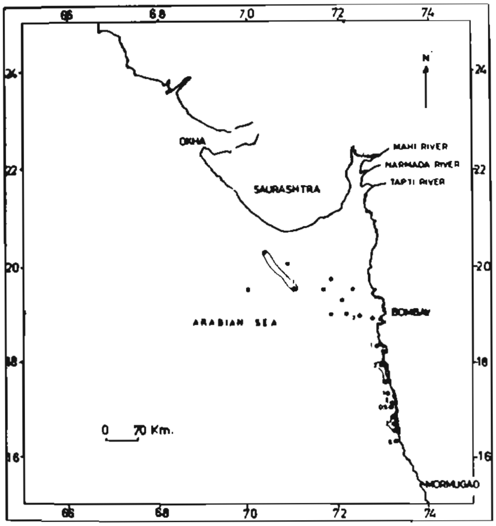
The beach forest taxa are represented by the pollen of *Cocos*, *Hyphaene* and *Borassus* (sample nos. 1, 2, 4, 7-9 & 11-13). The pollen grains of *Borassus* and *Hyphaene* are morphologically similar though each of them has a different phytogeographical distribution. *Borassus* is cultivated along the western coast of India while *Hyphaene indica* is cultivated in Saurashtra. The pollen representation of these plants is poor in our samples and from the phytogeographic point of view the pollen grains in the samples off Bombay may be regarded as of *Borassus* and those found in the samples off Saurashtra may be taken as of *Hyphaene*. The pollen grains of *Pandanus*



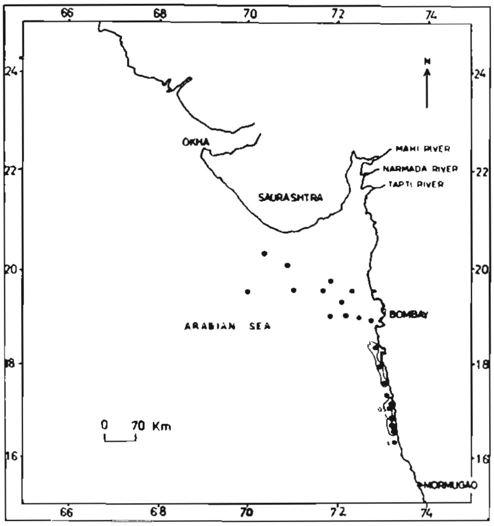
TEXT-FIG. 2 — Histogram showing the percentage frequency of pollen/spores in various samples.



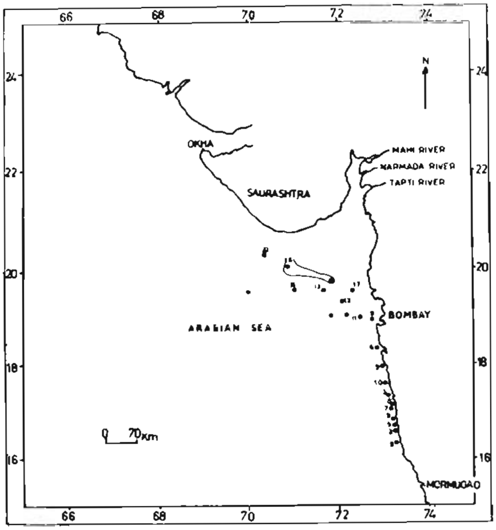
TEXT-FIG. 3 — Percentage distribution of Rhizophoraceae pollen.



TEXT-FIG. 4 — Percentage distribution of *Avicennia* pollen.



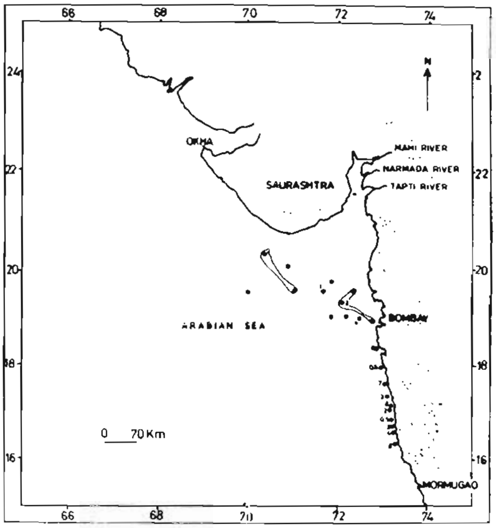
TEXT-FIG. 5 — Percentage distribution of *Sonneratia* pollen.



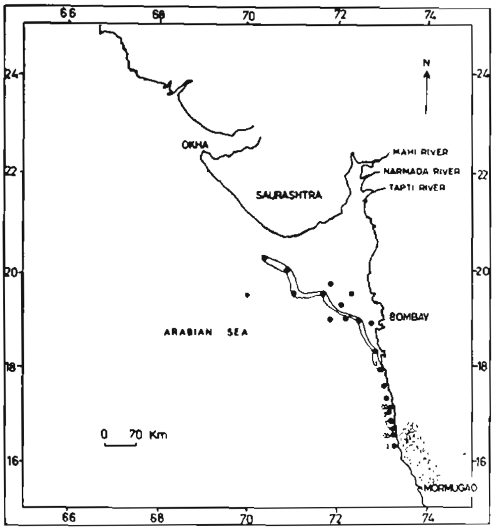
TEXT-FIG. 6 — Percentage distribution of Cheno/Ams pollen.

(0.5-1 per cent) is poorly represented in the near shore sediments off Bombay. *Casuarina equisetifolia* (0.5-1 per cent) is poorly represented in the samples off Bombay. The pollen grains of *Barringtonia* have poor representation in our samples. The *Tamarix* pollen (0.5-3 per cent) has the maximum concentration in sample no. 24, collected from 70 km off the coast.

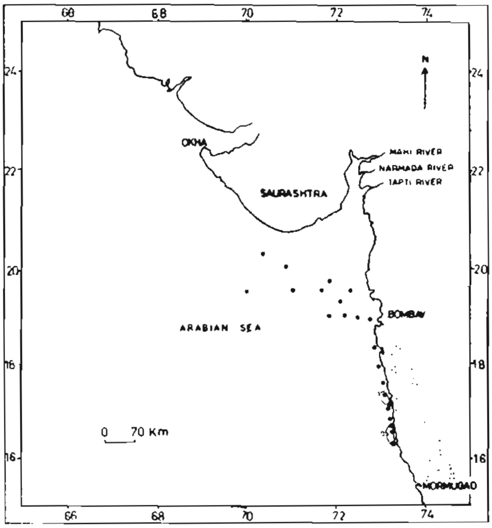
The pollen grains of *Pinus*, *Picea/Abies*, growing in Himalayas, are represented up to two per cent. The long distance transport of Pine pollen is due to wind transport. The Pine pollen equipped with air sacs are



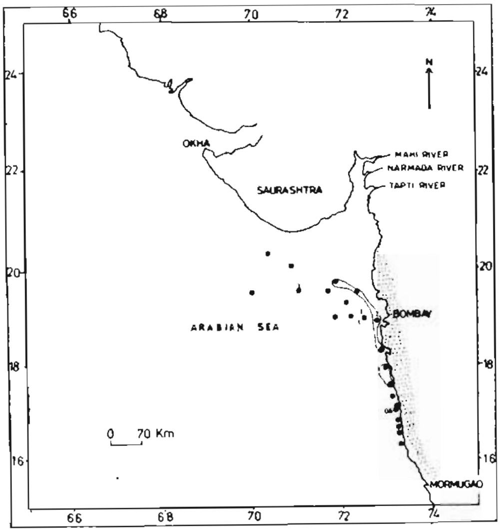
TEXT-FIG. 7 — Percentage distribution of *Terminalia* pollen.



TEXT-FIG. 9 — Percentage distribution of *Caryota* pollen.



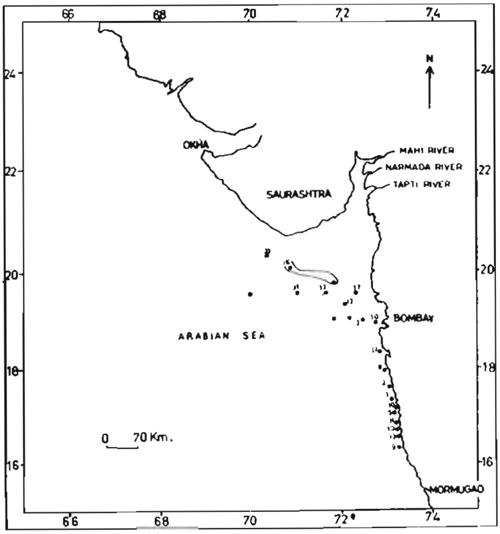
TEXT-FIG. 8 — Percentage distribution of *Salmalia* pollen.



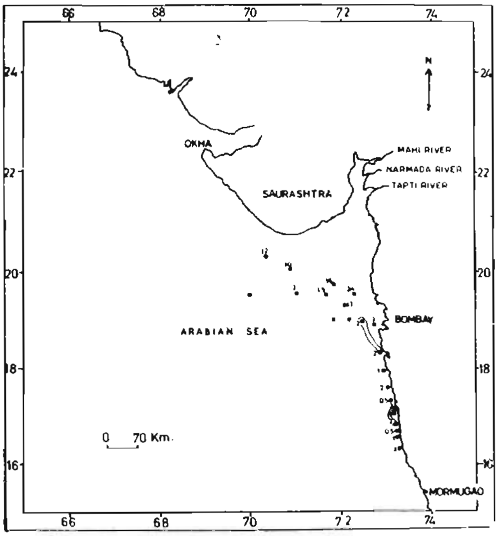
TEXT-FIG. 10 — Percentage distribution of *Memecylon* pollen.

much favoured for wind as well as water transport.

Distribution of nonarboreal Pollen Grains — The pollen grains of Poaceae (2-13 per cent) are present in all the samples (Text-fig. 11). Their percentage is higher in the samples off Bombay than those off Saurashtra. The members of Cyperaceae grow both on lake margins and the land (aquatic or upland) and their pollen percentage (0.5-24 per cent, Text-fig. 12) is higher in the samples off Saurashtra. The Asteraceae has been divided into Tubuliflorae, Liguliflorae and *Artemisia* type of

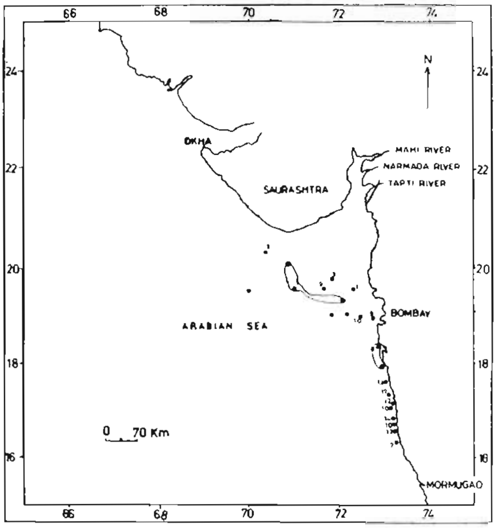


TEXT-FIG. 11 — Percentage distribution of Poaceae pollen.

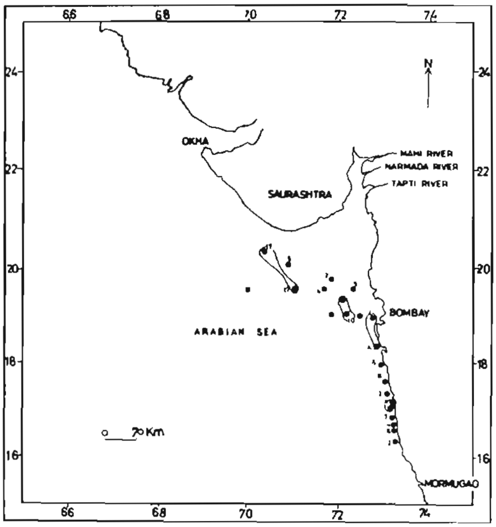


TEXT-FIG. 12 — Percentage distribution of Cyperaceae pollen.

pollen. The pollen grains of Tubuliflorae (1-17 per cent) are common in all the samples and their relative frequency is higher in samples off Bombay (Text-fig. 13). Liguliflorae pollen (0.5-2 per cent) are found in a few samples (nos. 3, 9, 11, 13; present in nos. 1, 2, 4, 7, 8, 10) off Bombay and their representation is below 2 per cent.



TEXT-FIG. 13 — Percentage distribution of Tubuliflorae pollen.



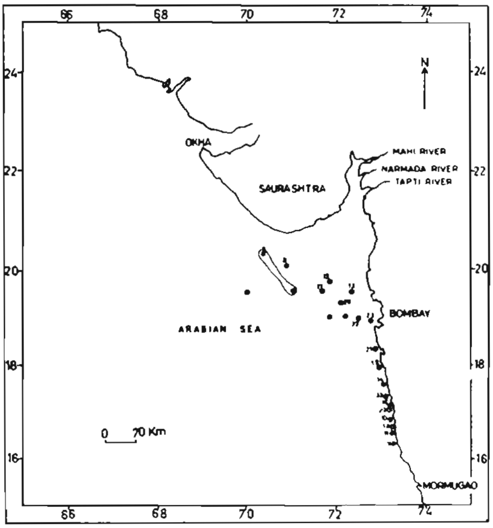
TEXT-FIG. 14 — Percentage distribution of *Artemisia* pollen.

The species of *Artemisia* are herbaceous to small shrubs; *A. parviflora* is a common herb which is found on the eastern side of Mahabaleshwar hills and on the road sides. *A. vulgaris* is abundant on the Ghats and Mahabaleshwar hills. The pollen (2-17 per cent) of this species have been found in all the samples (Text-fig. 14).

The relative frequency is 2-10 per cent except in two samples (22, 28) where it goes up to 17 per cent. The pollen grains of Euphorbiaceae belong to *Euphorbia* (0.5-2 per cent), *Phyllanthus* and *Homonoia*. The occurrence of *Phyllanthus* has been noticed almost in all the samples (1 to 4 per cent). The pollen of *Homonoia* have been recorded in sample no. 10 only. The herbaceous Lythraceous pollen (0.5-2 per cent) are more common in samples from the continental shelf off Bombay. The pollen of the herbaceous Fabaceae are occasionally found in some samples (up to 3 per cent). Caryophyllaceae pollen are common in the samples off Bombay. The pollen of *Justicia* (0.5-2 per cent), *Lepidagathis*, *Strobilanthes* and other types grouped under Acanthaceae (1-2 per cent) are poorly represented. *Lepidagathis*, an erect herb common in dry places, has been noticed in a few samples (1-2 per cent in sample nos. 4, 6, 8, 9, 10, 11). The pollen grains of *Strobilanthes* type have been recorded in a few samples (up to 1 per cent in sample no. 4 and 11; present in 1 and 6). *Strobilanthes* is a small shrub and is very common in under storey of evergreen and semievergreen forests. The pollen of *Ipomoea* (present in sample nos. 6 & 7), *Capparis* (less than 1 per cent in sample nos. 12, 22) and Laminaceae (present in sample no. 6) and Caryophyllaceae (0.5-3 per cent) are poorly represented in a few samples.

Distribution of Pteridophytic Spores — The spores of *Pteris* (0.5 per cent, present in sample nos. 6, 8, 10) and Polypodiaceae (2 per cent in sample no. 23, present in sample nos. 1, 6) have been identified. These spores are poorly represented in a few samples off Bombay. The spores of Osmundaceous, Ophioglossaceous and Selaginellaceous affinity have been grouped together as trilete spores and are common (8-43 per cent) in near shore sediments (Text-fig. 15). The presence of trilete spores may be explained from the river and lake discharge in the sea. The megaspore of Salaginellaceous affinity was recorded in sample no. 2 (off Bombay).

Distribution of Aquatic Spores and Pollen Grains — *Ceratopteris thallictroides*, a monotypic genus, grows throughout the tropics in quiet fresh water. The spores (0.5-1 per cent) of this plant are transported to sea by the river and lake discharge and these have been recorded in sample no. 3 off Bombay. Pollen of *Polygonum* (1 per cent in sample no. 9; present in sample no. 7), *Typha* (present in sample nos. 2, 7), *Nymphaea* (1 per cent in sample no. 12; present in sample no. 8) and *Nymphoides* (1-4 per cent in sample ncs. 9, 23 to 26; present in sample nos. 1 & 7) have been noticed. *Concentricystes* Rossignol (1962) is common in most of the samples (1-6 per cent) except in sample no. 26 where it goes up to 14 per cent.



TEXT-FIG. 15 — Percentage distribution of trilete spores.

Corroded grains which could not be identified have been found in all the samples (2-20 per cent). These grains are comparatively higher in the samples off Bombay. This may be because of the high rate of biological and chemical degradation and the physical effect of the water currents. As the samples do not represent off coast distance in one latitude, the corrosion effect could not be correlated with the distance. Fagerstrom (1964) concluded that in the marine environment dispersal and weathering processes are the most important component and the degree of corrosion is directly proportional to the distance off the coast. Absence or low number of thin-walled pollen such as those produced by the grasses in the marine sediments has been noted by Koreneva (1964a), Stanley (1966a), Zagmijn and Veenstra (1967) and others.

The distribution of pollen/spores in marine sediments collected from the continental shelf off Bombay shows the significance of fluvial transport as an important factor controlling the pollen/spores influx. The wind transported taxa are poorly represented and most of the taxa seem to have been derived from the vegetation, relatively closer to the coast. It has been observed from the present study that the bottom sediments from the station numbers 22, 23, 24, 25, 26 27 and 28 have poor percentage of Rhizophoraceae with higher percentage of Chenopodiaceae and Cyperaceae. The growth of Rhizophoraceae is poor while that of Chenopodiaceae and Cyperaceae is comparatively higher on the Saurashtra coast. The pollen spectra of the bottom sediments from station nos. 22 to 28 is comparable to that of the vegetation in stand of the Saurashtra coast. The pollen of *Avicennia marina* have been found in one sample from the station number 26 (140 km off shore). *Avicennia marina* grows on the Saurashtra coast. This shows the transport of *Avicennia marina* pollen up to 140 km off the coast. On the other hand, samples from station nos. 1 to 13 show higher concentration of pollen of Rhizophoraceae. These samples have been collected along the coast (from the continental shelf) between Bombay and Marmugao. This result coincides with the vegetation along the coast in a general way.

The bottom sediments from the station numbers 14, 15 and 20 are almost barren of pollen/spores. The lithology of these sediments is sandy silt, sandy silt and silty sand respectively. Station numbers 14, 15 and 20 are approximately 73.5 km, 105 km, and 154 km from the nearest coast at water depth of 62.5, 70.0 and 88.5 m respectively. The poor representation of pollen grain in sample no. 20 (silty sand) is understandable which has more sand than silt. This observation to some extent matches with the finding of Cross *et al.* (1966) who showed that most of the sediments with more than 75 per cent sand are nearly barren of pollen and spores in the Gulf of California. The lithology of the sediments from station numbers 14, 15 and 22 is sandy silt. With varying depths, varying distances from the coast but with similar lithology, these sediments show different palynological results. Sample nos. 14 and 15 show poor yield of pollen/spores while the pollen/spore recovery from the sample no. 22 is quite high. It is not possible at the moment, exactly to interpret the reason about this variation in the percentage yield of pollen/spores from these samples having identical lithology. This may, however, be said that water depth of the stations and their distance (far or near) from the coast, are not the factors to explain the mentioned variation. Possibly the topography, certain chemical action or any other factor unknown to us have not allowed the deposition/preservation of pollen/spores in the sediments at the station nos. 14 and 15.

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REFERENCES

ANONYMOUS (1976). *Report on Second Oceanographic Cruise of R. V. Gaveshani, N.I.O., Goa* (Unpublished).

AOUTIN, J. (1967). Les pollen et les spores des sediments du delta de l'ogne (Gabon). *Mein. E.P.H.E. Montpellier,* 160 p.

ASSEMIEN, P. (1969). Pollen fossil du *Rhizophora* a 'Bogue' Basse Vallee du Senegal. *Pollen spores,* **11** (1): 73-81.

BLASCO, F. (1975). The mangroves of India. *Inst. Franc. Pondicherry, Trans. Sect. Sci. Tech.,* **14**: 180 pp.

Blasco, F. (1977). Outlines of ecology, botany and forestry of the mangals of the Indian subcontinent, pp. 241-260 in V. J. Chapman (ed.) — *Ecosystems of the World. I. Wet Coastal Ecosystems.*

Blasco, F. & Caratini, C. (1973). Mangrove du Pichavaram (Tamil Nadu, Inde du sud). Phytographic et palynologie. *Cing. Etudes geomorphol. Palynol.*, **2**: 165-179.

Boulouard, C. & Delauze, H. (1966). Analyse palynoplanatologique de sediments prélevés par le bathyscaphe, Archimède dans la fosse du Japon. *Mar. Geol.*, **4** (6): 461-466.

Caratini, C., Blasco, F. & Thanikaimoni, G. (1973). Relation between pollen spectra and the vegetation of a south Indian mangrove. *Pollen Spores*, **15** (2): 281-292.

Champion, H. G. & Seth, S. K. (1968). *A Revised Survey of the Forest types of India.* Delhi.

Cross, A. T. & Shaefer, B. L. (1965). Palynology of modern sediments, Gulf of California and environs. *Bull. Am. Assoc. Petrol. Geol.*, **49**: 337 (abstract).

Cross, A. T., Thompson, G. G. & Zaitzeff, J. B. (1966). Source and distribution of palynomorphs in bottom sediments, southern part of Gulf of California. *Mar. Geol.*, **4** (6): 467-524.

Das, P. (1961). Recent microscopic flora from the Bengal delta, India. *Micropalaeontology*, **7**: 87-94.

Davey, R. J. (1971). Palynology and palaeoenvironmental studies, with special reference to the continental shelf sediments of south Africa. *Planktonic Conf. Proc.*, **1**: 331-347.

Erdtman, G. (1921). Pollen analytisiche untersuchungen von Torfmooren und marinen sedimenten in Sudwest-Schweden. *Ark. Bot.*, **17**: 10.

Erdtman, G. (1943). *An Introduction to Pollen Analysis.* Chronica Botanica Co., Waltham Mass, 239 pp.

Fagerstrom, J. A. (1964). Fossil communities in palaeoecology: Their recognition and significance. *Bull. geol. Soc. Am.*, **75**: 1197-1216.

Florer, L. E. (1973). Pollen analysis of marine sediments off the Washington coast. *Mar. Geol.*, **14**: 73-78.

Gouvenia, A. D. & Varadachari, V. V. R. (1979). Coastal and near shore circulation off Mangalore. *Mahasagar*, **12** (3): 175-182.

Groot, J. J. (1966). Some observations on pollen grains in suspension in the estuary of Delware River. *Mar. Geol.*, **4**: 409-416.

Groot, J. J. & Groot, C. R. (1966). Marine palynology, possibilities, limitations and problems. *Mar. Geol.*, **4**: 387-395.

Gupta, H. P. (1981). Palaeoenvironments during Holocene time in Bengal Basin, India as reflected by palynostratigraphy. *Palaeobotanist*, **27** (2): 138-160.

Halden, B. E. (1922). Tvanne intramarina torvbildnigar inorra Halland Jamte aldre och nyare synpukter pa saltvattensdiat omaceen. *Sveriges Geol. Unders-Afh(e)*, **310**.

Hashimi, N. H., Guptha, M. V. S., Kidwai, R. M. & Nair, R. R. (1978). Sediment and sedimentary processes on the continental shelf off Bombay. *Mahasagar*, **11** (3 & 4): 155-161.

Heusser, C. J. & Florer, L. E. (1973). Correlation of marine and continental Quaternary pollen records from the northeast Pacific and western Washington. *Quat. Res.*, **3**: 661-670.

Heusser, L. & Balsam, W. L. (1977). Pollen distribution in the northeast Pacific Ocean. *Quat. Res.*, **7**: 45-62.

Horowitz, A. (1966). Tropical and northern pollen and spores in Recent sediments from the Baay Elat (Aquaba). *Israel J. Earth. Sci.*, **15**: 125-130.

Ingram, H. A. P., Anderson, M. C., Andrews, S. M., Chinery, J. M., Evans, G. B. & Richards, C. M. (1959). Vegetational studies at Semerwater. *Naturalist*: 113-127.

Koreneva, E. V. (1957). Spore-pollen analysis of bottom sediments from the sea of *Okhotsk. Tr. Inst. Okeanol. Akad. Nauk. USSR*, **22**: 221-251.

Koreneva, E. V. (1964a). Distribution of spores and pollen of terrestrial plants in bottom sediments of Pacific Ocean, p. 31 in L. M. Cranwell (ed.) — *Ancient Pacific Floras: The Pollen Story.* Univ. Howaii Press, Honolulu, Hawaii.

Koreneva, E. V. (1964b). Spores and pollen from bottom sediments in the western part of the Pacific Ocean. *Tr. Akad. Nauk. U.S.S.R.*, **9**: 1-88, 27 plates (in Russian).

Koreneva, E. V. (1966). Marine palynological researches in the USSR. *Mar. Geol.*, **4** (6): 565-574.

Koreneva, E. V. (1968). Distribution and preservation of pollen in sediments in the western part of the Pacific Ocean. *Geol. Bull.*, **2**: 1-17.

Koreneva, E. V. (1971). Spores and pollen in Mediterranean bottom sediments, pp. 361-371 in B. M. Funnel and W. B. Reidel (eds) — *The Micropalaeontology of Oceans.*

Koreneva, E. V. (1980). The present day state of marinopalynological studies. *Proc. IV int. palynol. Conf., Lucknow (1976-77)*, **2**: 450-455.

Livingstone, D. A. (1964). The pollen flora of submarine sediments from Nantucket Shoals. *Am. Jour. Sci.*, **262**: 479-487.

Maljasowa, E. S. (1980). Palynology of the bottom sediments of the White Sea and the relation of vegetation of littoral regions in palynocomplexes. *Proc. IV int. palynol. Conf., Lucknow (1976-77)*, **2**: 491-496.

Mukherjee, B. B. (1969). Vegetational history of southern part of West Bengal with an introduction to the pollen flora of Sunderbans. *D. Phil. Thesis*, Univ. of Calcutta.

Mukherjee, B. B. (1972). Pollen analysis of a few Quaternary deposits of Lower Bengal Basin, pp. 257-374 in A. K. Ghosh *et al.* (eds) — *Proc. of the Seminar on Palaeopalynology and Indian Stratigraphy, 1971.* Bot. Deptt., Calcutta Univ., Calcutta.

Muller, J. (1959). Palynology of Recent Orinoco delta and shelf sediments. *Micropalaeontology*, **5**: 1-32.

Nair, R. R. (1975). Nature and origin of small scale topographic prominences on the western Continental Shelf of India. *Indian Jour. Mar. Sci.*, **4**: 25-29.

Nair, R. R. & Hashimi, N. H. (1980). Holocene climatic inferences from the sediments of the western Indian continental shelf. *Proc. Indian Acad. Sci., (Earth Planet Sci.)*, **89**: 299-315.

Panov, D. G., Vronsky, V. A. & Aleksandrov, A. N. (1964). Distribution and composition of pollen and spores in the surface layer of sediments in the sea of Azov. *Dokl. Akad. Nauk. U.S.S.R.*, **155** (4): 818-821 (in Russian).

RAO, T. A. & SASTRY, A. R. K. (1974). An outline of the coastal vegetation of India. *Bull. bot. Surv. India*, **16** (1-4): 101-115.

ROSSIGNOL, M. (1961). Analyse pollinique de sediments marins Quaternaires en Israel. I. sédiments Recent. *Pollen Spores*, **3**: 303-324.

ROSSIGNOL, M. (1962). Analyse pollinique de sediments marins Quaternaires en Israel II sédiments Plèistocenes. *Pollen Spores*, **4** (1): 121-148.

SINGH, R. L. (ed.) (1971). *India: A Regional Geography*. Varanasi, 992 pp.

STANLEY, E. A. (1965). Abundance of pollen and spores in marine sediments off the eastern coast of the United States. *Southeastern Geol.*, **7** (1): 25-33.

STANLEY, E. A. (1966a). The application of palynology to oceanology. *Deep Sea Res.*, **13** (5): 921-939.

STANLEY, E. A. (1966b). Palynology of marine sediments off the eastern coast of the United States Program, 1966. *Annual Meeting of the Southeastern section of the Geol. Soc. Am.*, **41** (Abstr.).

STANLEY, E. A. (1966c). Palynology of some ocean bottom cores collected between Argentina and the Mid-Atlantic Ridge, Program, 1966. *Annual Meeting of the Southeastern section of the Geol. Soc. Am.*, **24** (Abstr.).

STANLEY, E. A. (1966d). The problem of reworked pollen and spores in marine sediments. *Mar. Geol.*, **4** (6): 397-408.

STANLEY, E. A. (1967). Palynology of six ocean bottom cores from the southwestern Atlantic Ocean. *Rev. Palaeobot. Palynol.*, **2**: 195-203.

STANLEY, E. A. (1969). Marine palynology. *Ann. Rev. Oceanogr. Mar. Biol.*, **7**: 277-292.

THORNTHWAITE, C. W. (1948). An approach towards a rational classification of climate. *Geogr. Rev.*, **38**: 55-94.

TRAVERSE, A. & GINSBURG, R. N. (1966). Palynology of surface sediments of Great Bhama Bank, as related to water movement and sedimentation. *Mar. Geol.*, **4**: 417-459.

VARMA, K. K. & GOPINATHAN, C. K. (1977). Currents off Bombay during February, 1976. *Mahasagar*, **10** (182): 1-8.

VISHNU-MITTRE & GUPTA, H. P. (1972). Pollen analytical study of Quaternary deposits in Bengal Basin. *Palaeobotanist*, **19** (3): 297-306.

VISHNU-MITTRE & GUZDER, S. (1975). Stratigraphy and palynology of the mangrove swamps of Bombay. *Palaeobotanist*, **22** (2): 111-117

VRONSKY, V. A. (1980). Palynological researches of modern sediments of southern seas of the U.S.S.R. and their relationship with the vegetation of shores. *Proc. IV int. palynol. Conf., Lucknow (1976-77)*, **2**: 456-461.

ZAGWIJN, W. H. & VEENSTRA, H. J. (1966). A pollen analytical study of cores from the outer silver pit, North Sea. *Mar. Geol.*, **4** (6): 539-551.

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*MESOZOIC SPORAE DISPERSAE FROM ZAIRE — IV. FURTHER CONTRIBUTION TO THE PALYNOLOGY OF STANLEYVILLE AND LOIA GROUPS

HARI K. MAHESHWARI
Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

In this communication, results of palynological examination of some more samples of Stanleyville and Loia groups are reported. The Stanleyville samples are dominated by the *Classopollis* pollen. The palynologically productive range of the Loia Group in Samba bore-hole is now extended up to 682.42 m where *Equisetosporites* pollen predominate.

Key-words — Palynology, *Classopollis*, Stanleyville and Loia groups, Jurassic-Cretaceous, Zaire.

सारांश

जायरे से मध्यजीवी युगीन विकरणित बीजाणु – स्तानलॅविलॅ एवं लोग्राया समूहों के परागाणविक ग्रध्ययन पर ग्रौर ग्रंशदान – हरि कृष्ण माहेश्वरी

प्रस्तुत शोध-पत्र में स्तानलॅविलॅ एवं लोग्राया समूहों के कुछ ग्रौर नमूनों के परागाणविक ग्रध्ययन के परिणामों का उल्लेख किया गया है। स्तानलॅविलॅ के नमूने क्लासोपॉलिस के परागकणों से प्रभावी हैं। साम्बा वेध-छिद्र में लोग्राया समूह की परागाणु-धारक सीमा ग्रब 682.42 मीटर तक बढ़ा दी गई है जहाँ पर कि इक्वीसीटोस्पोराइटिस के परागकणों की बाहुल्यता है।

INTRODUCTION

THE Jurassic-Cretaceous sediments in Zaire are represented by 3 groups, viz., Stanleyville, Loia and Bokungu, in ascending order. The Stanleyville Group (±450 m) outcrops in the east and north-east of the central basin of Zaire and rests disconformably on the Triassic Haute-Lueki Group or unconformably over the Precambrians. The group basically comprises argillites and sandstones, sometimes with shales or bituminous layers, particularly in the middle portion.

The Loia Group disconformably overlies the Stanleyville Group and is subdivisible, particularly so in the Samba bore-hole, into three distinct lithostratigraphical units. It is disconformably overlain by the essentially red facies of the Bokungu Group (see Cahen *et al.*, 1959).

About 160 samples from the three groups were palynologically analysed by Maheshwari, Bose and Kumaran (1977a, 1977b). A number of depth intervals which were earlier found to be palynologically barren have been re-examined by repeat processing of the samples, and the data collected is presented here.

RESULTS

A total of 17 samples, 8 from the Stanleyville Group and 9 from the Loia Group, were reprocessed for pollen and spores. Of these only 7 samples, 2 from the Stanleyville Group and 5 from the Loia Group, proved to be palynologically productive.

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*The paper is dedicated to the late Mr L. S. Cahen, former Director of the Museé Royal de l' Afrique centrale, Tervuren, Belgium.

All the 4 samples from complex 5 (Stanleyville Group) of the Samba bore-hole again proved to be unfossiliferous. Of the 4 C.F.L. bore-hole samples, only 2, one from the top of bed 1 and the other from the base of bed 2, yielded palynomorphs. All the 9 samples from the Loia Group are from the same sequence in the Samba bore-hole as palynologically investigated earlier (Maheshwari, Bose & Kumaran, 1977a). The depths represented by these samples were earlier reported to be barren of spores and pollen. However, the fresh samples representing the same depths show presence of palynomorphs in 5 samples, one from formation 4c, one from formation 4b and 3 from formation 4a. So far no palynomorphs were known from formation 4a of the Loia Group.

In general, the palynomorph recovery has been very poor, and most of the palynomorphs are covered by amorphous organic structureless debris. No technique could be devised to remove these debris and hence a substantial number of palynomorphs could not be identified with confidence. As such, a statistical approach to understand the distributional pattern of the miospore taxa was not found feasible.

STANLEYVILLE GROUP

Both the samples, i.e. RG 78817 (near the top of bed 1, 123.5-124.4 m in C.F.L. bore V) and RG 78853 (near the base of bed 2, 134.8-137.6 m in C.F.L. bore VI), are dominated by the species of the genus *Classopollis*, particularly *C. aquistanus* Reyre and *C. indicus* Maheshwari. The other commonly occurring taxon is the genus *Cycadopites*.

Sample RG 78853 also yielded one specimen each of *Cyathidites australis* Couper, *Converrucosisporites* sp., *Retitriletes* sp. and ?*Araucariapollenites* sp. Some of the smaller specimens presently included under the genus *Cycadopites* could possibly be bennettitalean pollen, but the preservation is not good enough for a definite identification. No bennettitalean cuticle was recovered in the macerates.

The palynological assemblage is too poor to be of any help in age determination of the sediments. However, in the dominance of the genera *Classopollis* and *Cycadopites*, the present assemblage from beds 1 and 2 is totally different from the assemblage from beds 3 and 7. The dominance of the genus *Classopollis* has little significance stratigraphically as we know that this taxon has had several peaks during Lower Jurassic to Middle Cretaceous periods (Srivastava, 1966; Reyre, 1973).

LOIA GROUP

Formation 4c of the Loia Group is represented by the sediments between 564.98 and 678.70 m in the Samba bore-hole. The samples between 673.27 and 678.70 m were earlier proved to be palynologically productive (Maheshwari, Bose & Kumaran, 1977a). The productive range of this formation is now extended to 662.42 m. This sample, i.e. RG 35465 has a mioflora dominated by *Equisetosporites* pollen; *Classopollis indicus* pollen are frequent whereas *Ephedripites mesozoica* pollen are also present. Thus this sample has an assemblage virtually similar to that of the samples RG 35467 and RG 35468, except for the apparent absence of the genus *Tricolpites*.

Sample RG 35495 from the base of formation 4b, representing the sediments between 738.33 and 739.65 m, has now yielded a mioflora comprising ?*Deltoidospora*, ?*Cicatricosisporites*, *Ephedripites*, ?*Bennettiteaepollenites*, *Classopollis* and *Liliacidites* (*Clavatipollenites*), and fungal bodies. This flora is much too poor as compared to the one from the immediately overlying sediments between 736.48 and 737.08 m, which shows the dominance of the genera *Perotrilites* and *Cyathidites*, and the presence of the genera *Couperisporites*, *Schizosporis* and *Tricolpites*, none of which is present in the sample RG 35495.

Samples RG 35502, RG 35506 and RG 35507 represent formation 4a between the depth 755.97 and 765.67 m. The palynological assemblage from these samples is dominated by *Classopollis* sp. cf. *C. indicus*; *Ephedripites mesozoica* is fairly represented while *Cycadopites* type pollen are common. *Equisetosporites* spores are rare. This assemblage is therefore quite different from that of the formation 4b which is dominated by the genus *Perotrilites*.

Thus, the palynologically productive range of the Loia Group in the Samba bore-hole is now extended up to 682.42 m.

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REFERENCES

CAHEN, L., FERRAND, J. J., HAARSMA, M. J. F., LEPERSONNE, J. & VERBEEK, T. (1959). Description du Sondage de Samba. *Annls Mus. r. Afr. centr.*, ser. in-8°, *Sci. géol.*, **29**: 1-53.

MAHESHWARI, H. K., BOSE, M. N. & KUMARAN, K. P. N. (1977a). Mesozoic Sporae dispersae from Zaire II — The Loia and Bokungu groups in the Samba bore hole. *Annls Mus. r. Afr. centr.*, ser. in-8°, *Sci. géol.*, **80**: 1-43.

MAHESHWARI, H. K., BOSE, M. N. & KUMARAN, K. P. N. (1977b). Mesozoic Sporae dispersae from Zaire III — Some miospores from the Stanleyville group. *Annls Mus. r. Afr. centr.*, ser. in-8°;, *Sci. géol.*, **80**: 45-56.

REYRE, Y. (1973). Palynologie du Mesozoique saharien. *Mem. Mus. nat. Hist. nat.*, ser. C, **27**: 1-284.

SRIVASTAVA, S. K. (1966). Jurassic microflora from Rajasthan, India. *Micropaleontology*, **12** (1): 85-103.

EXPLANATION OF PLATE

(All photomicrographs are. × 500)

1. *Todisporites major* Couper, 1953.
2, 3. *Deltoidospora* sp., fig. 3 in lateral view.
4. *Dictyophyllidites* sp.
5. *Stereisporites* sp.
6. ?*Lycopodiumsporites* sp.
7. *Schizaeoisporites* sp.
8. *Converrucosisporites* sp. cf. *C. variverrucosus* (Delcourt & Sprumont) Brenner, 1963.
9. *Verrucosisporites* sp.
10. *Perotrilites pannuceus* Brenner, 1963.
11. *Microcachryidites* sp.
12, 15. *Ephedripites mesozoica* Maheshwari *et al.*, 1977.
13. *Cycadopites* sp.
14. *Equisetosporites* sp.
16. *Clavatipollenites* sp. (?*Liliacidites* sp.).
17. *Tricolpites* sp.
18. *Klukisporites pseudoreticulatus* Couper, 1958.
19-21. *Classopollis* sp. cf. *C. indicus* Maheshwari, 1974.
22. *Cycadopites gracilis* Sah & Jain, 1965.
23. Incertae sedis.
24. *Alternaria* sp.
25. Fungal spore.

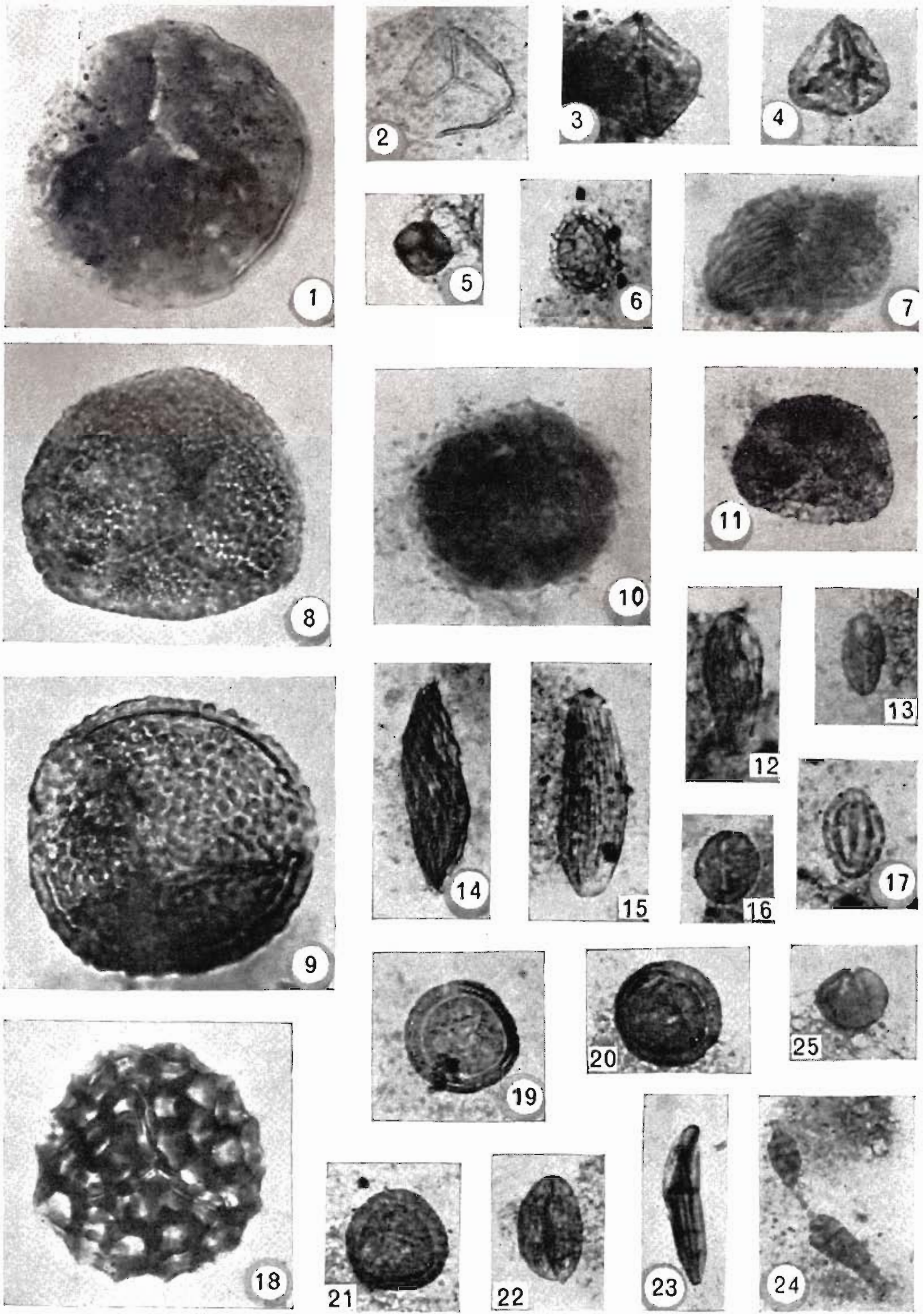

PLATE 1

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LEGUMINOUS WOODS FROM THE TERTIARY OF DISTRICT KACHCHH, GUJARAT, WESTERN INDIA

J. S. GULERIA

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

ABSTRACT

The paper deals with eight fossil leguminous woods representing the modern woods of *Albizia*, *Afzelia-Intsia*, *Cynometra*, *Dialium*, *Isoberlinia* and *Millettia-Pongamia*. They have been reported for the first time from the Tertiary (Pliocene?) of district Kachchh. The first two genera are represented by two species each and the remaining by a single species. Among these, *Dialium* and *Isoberlinia* have been reported for the first time from India. The occurrence of tropical African genus *Isoberlinia* is phytogeographically important as it indicates the possibility of migration of some of the African and Arabian elements in the Indian flora.

Key-words — Xylotomy, *Albizinium*, *Cynometroxylon*, *Dialiumoxylon*, *Isoberlinioxylon*, *Millettioxylon*, *Pahudioxylon*, Kachchh, Pliocene? (India).

साराँश

गुजरात (पश्चिमी भारत) में कच्छ जनपद से प्राप्त तृतीयक युगीन लैगुमिनोसीय काष्ठाश्म – जसवंत सिंह गुलेरिया

इस शोध-पत्र में एल्बीज़िया, ॲफ्ज़ीलिआ-इन्टसिआ, सायनोमेट्रा, डाऐॅलियम्, आइसोबर्लीनिया एवं मिलॅट्टिआ-पोंगॅमिआ की वर्तमान काष्ठों से निरूपणीय आठ लैगुमिनोसीय काष्ठाश्मों का वर्णन किया गया है। ये काष्ठाश्म कच्छ जनपद के तृतीयक (अतिनूतन ?) युग से पहली बार अभिलिखित किये गये हैं। पहले दो वंश दो-दो जातियों से निरूपित तथा अन्य प्रत्येक वंश एक जाति से निरूपित है। इनमें से डाऐॅलियम् तथा आइसोबर्लीनिया का भारत से पहली बार वर्णन किया गया है। उष्णकटिबंधीय अफ्रीकी वंश, आइसोबर्लीनिया, की प्राप्ति पादप-भौगोलिक दृष्टि से महत्वपूर्ण है क्योंकि इससे भारतीय वनस्पति में कुछ अफ्रीकी एवं अरबी तत्वों के अभिगमन की संभावना व्यक्त होती है।

INTRODUCTION

So far only a few fossil woods are known from the Tertiary (Kankawati Series) of Kachchh. These are *Podocarpoxylon kutchensis* of Podocarpaceae (Lakhanpal *et al.*, 1975); *Dipterocarpoxylon malavii* and *D. pondicherriense* of Dipterocarpaceae (Ghosh & Ghosh, 1959; Guleria, 1983); *Pterospermoxylon kutchensis* (Awasthi *et al.*, 1980) and *Sterculinium kalagarhense* (Guleria, 1983) of Sterculiaceae; *Euphorioxylon indicum* and *Schleicheroxylon kachchhensis* of Sapindaceae (Awasthi *et al.*, 1982); *Terminalioxylon felixii* and *T. burmense* of Combretaceae and *Palmoxylon kachchhensis* of Palmae (Guleria, 1983). Thus it is obvious that no leguminous wood has yet been recorded from the Kankawati Series of Kachchh which according to Biswas and Raju (1973) is of probable Pliocene age. But the occurrence of Leguminosae in the Lower Miocene megaflora of Kachchh has already been recorded by Lakhanpal and Guleria (1982). The assemblage consists of *Bauhinia*, *Cassia*, *Millettia* and a large number of small legume leaflets and pods. This family is still unreported in the Eocene megaflora of Kachchh (Lakhanpal & Guleria, 1981; Guleria & Lakhanpal, in press).

SYSTEMATIC DESCRIPTION

Family — Leguminosae
Subfamily — Mimosaceae

Genus — *Albizinium** Prakash, 1975

Albizinium eolebbekianum Prakash, 1975

Pl. 1, figs 1, 2

This species is represented by two small pieces of fairly well-preserved petrified wood.

Topography — *Wood* diffuse-porous (Pl. 1, fig. 1). *Growth rings* present, delimited by thin lines of terminal parenchyma. *Vessels* medium to large (mostly large), mostly solitary or in radial multiples of 2-3, rarely 4, sometimes forming small clusters, evenly distributed, about 3-6 per sq mm, tyloses not seen; vessels sometimes filled with gummy material; round to oval in cross section (Pl. 1, fig. 1), t.d. 120-480 μm, r.d. 220-480 μm, wall 4-6 μm thick; vessel members 160-360 μm long with truncated ends; perforations simple; intervessel pits oval to elliptical, 4-8 μm in diameter, bordered, alternate, vestured. *Parenchyma* paratracheal and apotracheal (Pl. 1, fig. 1); paratracheal parenchyma forming narrow sheaths round the vessels, vasicentric, mostly aliform with very short extensions, sometimes aliform-confluent due to aggregation of vessels; apotracheal parenchyma represented by thin terminal lines of 1-3 cells wide; parenchyma cells round, oval to elliptical in cross section, thin-walled, t.d. 16-24 μm; crystalliferous parenchyma strands containing solitary crystals in each chamber. *Xylem rays* 1-5 (mostly 3-4) seriate (Pl. 1, fig. 2) or 12-100 μm broad, 6-9 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells, 3-25 cells or 48-360 μm high; elongated, tangential height 12-32 μm and radial length 40-100 μm, infiltration dark. *Fibres* aligned in radial rows, circular to oval in cross section, t.d. 12-20 μm, wall 4-6 μm thick, septate, fibre length 40-100 μm, interfibre pits present, simple, round to oval, 2-4 μm in diameter.

AFFINITIES

The above characters collectively indicate that the fossil belongs to the genus *Albizia* Durazz. The present fossil agrees in all its features with the extant wood of *Albizia lebbek* Benth.

So far only two species of *Albizinium* are known, viz., *A. eolebbekianum* Prakash (1975) and *A. pondicherriensis* Awasthi (1979). The former has been reported from Himachal Pradesh, Burma, Arunachal Pradesh and West Bengal by Prakash (1975), Prakash and Bande (1980), Lakhanpal *et al.* (1981) and Ghosh and Roy (1981) respectively. The latter has been reported from near Pondicherry by Awasthi (1979). Prakash and Barghoorn (1961) described a fossil wood as *Albizia vantagiensis* from the Miocene beds of Columbia Basalt, U.S.A. which has, however, been transferred to *Tetrapleuroxylon* by Müller-Stoll and Mädel (1967, p. 117). In addition, Greguss (1969, pp. 50, 51) described a fossil wood *Albizzioxylon hungaricum* from the Tortonian (Mid-Miocene) of Hungary which he thought to be comparable to the genus *Acacia*. However, due to the occurrence of septate fibres in the fossil he named it as *Albizzioxylon*. As the fibres in *Acacia* woods are non-septate (Pearson & Brown, 1932, p. 438; Metcalfe & Chalk, 1950, p. 485; Ramesh Rao & Purkayastha, 1972, pp. 6, 8, 12), this wood cannot be compared with *Acacia*; obviously it represents the fossil wood of *Albizia*. Since the fossil woods of *Albizia* are now named as *Albizinium* Prakash (1975), the author has taken this opportunity to rename *Albizzioxylon hungaricum* Greguss as *Albizinium hungaricum* (Greguss) comb. nov. Out of the known *Albizinium* species, the present wood shows close similarity with *Albizinium eolebbekianum* Prakash (1975) and hence it is placed under the same.

Albizia lebbek Benth. occurs throughout India, ascending up to 1,200 m in Himalaya and is common in the Andamans (Ramesh Rao & Purkayastha, 1972, p. 36).

Specimen — B.S.I.P. Specimen nos. 36017 and 36018.

Locality — Mothala, about 66 km WWS of Bhuj on the Bhuj-Naliya Road and Dhaneti, 24 km east of Bhuj on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

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*Originally spelt as *Albizzinium* which is now spelt as *Albizinium*.

Albizinium pondicherriensis Awasthi, 1979

Pl. 1, figs 3, 4

This species is represented by a single piece of well preserved petrified wood measuring 30 cm long and 15 cm in diameter.

Topography — *Wood* diffuse-porous (Pl. 1, fig. 3). *Growth rings* delimited by inconspicuous lines of parenchyma and thick-walled fibres. *Vessels* small to large, usually medium, mostly solitary or in multiples of 2-3, rarely in 4, sometimes forming small clusters, evenly distributed, about 3-6 vessels per sq mm, tyloses not seen; empty or filled with gummy material (Pl. 1, fig. 3); round to oval in cross section, t.d. 60-270 μm, r.d. 60-320 μm, wall 4 μm thick; vessel-members 120-300 μm in height with truncated ends; perforations simple; intervessel pits round to oval, about 4-6 μm in diameter, bordered, alternate, vestured. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, mostly aliform to aliform-confluent, aliform extensions moderate (Pl. 1, fig. 3), occasionally enclosing 2(3) vessels; apotracheal parenchyma represented by thin terminal lines of 1-2 cells wide; parenchyma cells polygonal in cross section, thin-walled; crystalliferous strands rare containing solitary crystals in each chamber. *Xylem rays* fine, 1-2 to rarely 3-seriate and 12-32 μm (mostly 20 μm) broad, 10-15 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells, short 3-20 cells or 60-360 μm high (Pl. 1, fig. 4); ray cells thin-walled, tangential height 8-16 μm, radial length 40-120 μm, filled with dark contents. *Fibres* aligned in radial rows, polygonal in shape, 4-6 μm thick, 8-20 μm in diameter, septate, interfibre pits not seen.

AFFINITIES

The anatomical characters enumerated above indicate its similarity with the woods of *Albizia*, particularly *A. amara* Boivin and *A. odoratissima* Benth. In size, shape and number of rays the fossil resembles *Albizia amara* whereas *A. odoratissima* shows closest similarity with the fossil in the size of vessels. Thus, the present fossil combines the characters of both *A. amara* and *A. odoratissima*. The fossil wood is also closely comparable in all its characters (except for some slight differences in the size of vessels which may be due to variation) with the known species *Albizinium pondicherriensis* Awasthi (1979) described from South India near Pondicherry. Hence, it is placed under the same species.

Albizia amara, a moderate sized deciduous tree, occurs in the dry forests of the Indian Peninsula from Khandesh in west to Vishakhapatnam in the east, extending southwards to dry places in the west coast up to 900 m and also in Sri Lanka (Ramesh Rao & Purkayastha, 1972, p. 34). *A. odoratissima* is a large tree distributed throughout India ascending to 1,500 m in the sub-Himalayan tract. It is common in both the dry and deciduous forests of Siwaliks, Ajmer, Mewar and Konkan. Further, it is frequently seen on grasslands and in open forests throughout Travancore up to 900 m (Ramesh Rao & Purkayastha, 1972, pp. 37, 38).

Specimen — B.S.I.P. Specimen no. 36019.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

SUBFAMILY — CAESALPINIACEAE

Genus — *Pahudioxylon* Chowdhury, Ghosh & Kazmi, 1960

Pahudioxylon sahnii Ghosh & Kazmi, 1961

Pl. 3, figs 13, 14

Topography — *Wood* diffuse-porous (Pl. 3, fig. 13). *Growth rings* present, delimited by fine lines of apotracheal parenchyma. *Vessels* small to large (mostly medium), mostly solitary or in multiples of 2-4, evenly distributed, 4-6 per sq mm, occasionally filled with dark contents (Pl. 3, fig. 13), round to oval in cross section, t.d. 60-220 μm, r.d. 40-320 μm, wall about 4 μm thick, vessel members 180-420 μm in height with truncated ends; perforations simple, intervessel pits alternate, oval to slightly elliptical or polygonal, 4-10 μm in diameter, vestured. *Parenchyma* paratracheal, vasicentric, mostly aliform, sometimes aliform-confluent (Pl. 3, fig. 13), apotracheal parenchyma forming narrow lines 1-3 cells in width; parenchyma cells round or oval to elliptical in cross section, 16-32 μm in diameter, 80-140 μm in length, thin-walled, crystalliferous strands occasionally present with several locules containing solitary crystals. *Xylem rays* fine, 1-3 seriate (mostly 2 seriate) or 10-48 μm (usually 20-30 μm) wide, 3-25 cells or 72 to 380 μm (average 240-280 μm) high, 10-13 rays per mm; showing tendency towards storied arrangement (Pl. 3, fig. 14); ray tissue homogeneous; rays homocellular, consisting of procumbent cells (Pl. 3, fig. 14); ray cells thin-walled, 8-20 μm in vertical height. *Fibres* aligned in radial rows, circular or oval to angular in cross section, thick-walled, 8-16 μm in diameter, nonseptate, interfibre pits not seen.

AFFINITIES

The fossil wood shows close similarity with the woods of *Afzelia* Sm. and *Intsia* Thou. (Metcalfe & Chalk, 1950, pp. 476-535; Ramesh Rao & Purkayastha, 1972, pp. 63, 64, 84, 85). These genera are, however, indistinguishable xylotomically.

In 1960, Chowdhury *et al.* established the genus *Pahudioxylon* for the fossil woods showing similarity with that of *Pahudia* Miq. Since *Pahudia* has already been merged with *Afzelia* by Léonard (1950), Prakash (1966a, p. 231) redefined the genus *Pahudioxylon* to include the fossil woods of *Afzelia* and *Intsia*. Prakash *et al.* (1967) listed *Pahudioxylon* species known till then. At present, there are 13 species of *Pahudioxylon* known from the Tertiary of India and abroad. These are *Pahudioxylon bankurensis* Chowdhury *et al.* (1960) from West Bengal; *P. sahnii* Ghosh & Kazmi (1961) from Tripura, Burma, Thailand (Prakash, 1973, 1979a), Pondicherry (Awasthi, 1975b) and Indonesia (Kramer, 1974); *P. arcotense* Navale (1963) from Pondicherry; *P. deomaliense* Prakash (1965) from NEFA; *P. assamicum* Prakash & Tripathi (1975) from Assam and *P. indicum* Prakash (1979b) from Himachal Pradesh. From outside India (in addition to *P. sahnii* mentioned above) are *P. afzelioides* (Boureau) Prakash *et al.* (1967) from the Tertiary of South Anam, Indo-China; *P. irregulare* (Felix) Müller-Stoll & Mädel (1967) from the ?Tertiary of Antigua; *P. pannonicum* (Felix) Müller Stoll & Mädel (1967) from Hungary; *P. kiliani* (Louvet) Prakash *et al.* (1967) from the Tertiary of Algeria; *P. wilkitii* Lemoigne & Beauchamp (1972) from the Miocene of Ethiopia; *P. paracochinchinense* from the Neogene of South Vietnam Vozenin-Sera (1981) and *P. bengalensis* Ghosh & Roy (1982) from the Miocene of West Bengal. Besides, Koeniguer (1973) and Lemoigne *et al.* (1974) described two fossil woods, viz., *Afzelioxylon furoni* and *A. aethiopicum* from the Neogene of Tchad and Ethiopia respectively. These fossils are being renamed as *Pahudioxylon furoni* (Koeniguer) comb. nov. and *P. aethiopicum* (Lemoigne *et al.*) comb. nov. respectively, since all the fossil woods resembling *Afzelia* and *Intsia* are placed under the genus *Pahudioxylon*. It is to be pointed out here that all these species of *Pahudioxylon* need critical re-examination as quite a few are likely to merge into one another. Out of all these, *P. sahnii* shows the closest similarity with the fossil in having mostly 2 seriate rays and also in all other anatomical details. Hence, the present fossil is assigned to it.

The genus *Afzelia* Sm. consists of 14 species distributed in tropical Africa and Asia (Willis, 1973, p. 30), whereas *Intsia* Thou. comprises 9 species found in offshore islands of tropical East Africa, Madagascar and tropical Asia (Willis, 1973, p. 593). In India only *Afzelia bijuga* A. gray [*Intsia bijuga* (Colebr.) O. Ktze.] and *Afzelia retusa* Kurz are found. *Afzelia bijuga* occurs in the tidal forests of Bengal, Andaman islands and Burma while *Afzelia retusa* is found in the coast forests of Sunderbans and the Andamans (Gamble, 1902, p. 280).

Locality — Dhaneti, about 24 km east of Bhuj on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

Pahudioxylon assamicum Prakash & Tripathi, 1975

Pl. 2, figs 11, 12

This species is represented by a large number of fairly well-preserved pieces of silicified woods.

Topography — *Wood* diffuse-porous (Pl. 2, fig. 11). *Growth rings* present, delimited by terminal parenchyma lines, 2-5 per cm

(Pl. 2, fig. 11). *Vessels* small to large, mostly medium, mostly solitary or in multiples of 2-4, occasionally filled with dark contents (Pl. 2, fig. 11), round to oval in cross section, t.d. 64-220 μm, r.d. 70-280 μm, wall about 4 μm thick, vessel members 160-360 μm in height, usually with truncate ends; perforations simple; intervessel pits alternate, oval to slightly elliptical, 4-8 μm in diameter, vestured. *Parenchyma* paratracheal, vasicentric, mostly aliform, sometimes aliform-confluent, apotracheal parenchyma forming narrow lines of 1-3 cells wide (Pl. 2, fig. 11); parenchyma cells round to oval, 12-24 μm in diameter, 80-160 μm in length, thin-walled, crystalliferous strands occasionally present with several locules containing solitary crystals. *Xylem rays* fine to medium, 1-4 seriate (mostly 3 seriate), rarely 4 seriate or 8-72 μm wide (Pl. 2, fig. 12), 2-30 cells or 66-404 μm (average 15-18 cells or 240-320 μm) in height, 5-8 per mm; occasionally showing tendency towards storied arrangement; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 2, fig. 12); ray cells thin-walled, 8-16 μm in vertical height. *Fibres* aligned in radial rows, circular oval or slightly elliptical in cross section, nonlibriform to semilibriform, 8-22 μm in diameter with wide lumen, nonseptate, interfibre pits not seen.

AFFINITIES

The above characters of the fossil wood show that it belongs to *Afzelia-Intsia*. The fossil woods resembling *Afzelia-Intsia* are known by the genus *Pahudioxylon Chowdhury et al.* (1960) and thus the present fossil is also placed under the same. Out of 13 species of this genus known so far (see p. 241), *P. assamicum* Prakash & Tripathi (1975) has been found to be almost identical with the present specimen in all anatomical features, therefore it is placed in the same species.

Specimens — B.S.I.P. Specimen nos. 36020 and 36021.

Localities — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road and Mothala, about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

Genus — *Cynometroxylon* Chowdhury & Ghosh, 1946

*Cynometroxylon holdenii** (Gupta) Prakash & Bande, 1980

Pl. 2, figs 9, 10

1982 *Cynometroxylon indicum* Ghosh & Roy, p. 53, figs. 7-9.

The material consists of a large number of fairly well-preserved pieces of petrified wood.

Topography — *Wood* diffuse-porous (Pl. 2, fig. 9). *Growth rings* discernible but not conspicuous. *Vessels* small to medium, solitary and in radial multiples of 2-5 (mostly 2-3), sometimes forming small clusters, uniformly distributed, 7-9 vessels per sq mm; tyloses absent; vessels sometimes filled with dark contents, oval to elliptic in cross section, t.d. 60-140 μm, r.d. 75-180 μm, thick-walled, 4-8 μm in thickness, vessel-members 160-480 μm in height ending slightly obliquely; perforations simple; intervessel pits small, 4-5 μm in diameter, alternate, bordered, vestured, apertures linear to lenticular. *Parenchyma* abundant, in regular concentric bands, alternating with fibre bands of more or less the same width, undulating, often surrounding the vessels, sometimes bands bifurcating and joining adjacent ones, bands 3-9 cells wide, 4-5 per mm (Pl. 2, fig. 9); parenchyma cells circular to oval in cross section, 12-28 μm in diameter and 60-120 μm in height, nonstoried. *Xylem rays* 1-4 seriate (mostly 2-3), 6-43 cells and 120-750 μm (often 13-20 cells and 270-380 μm) high, 6-12 rays per mm; ray tissue heterogeneous, rays homocellular to mostly heterocellular, consisting of 1-2 marginal rows of upright or squarish cells at one or both the ends and procumbent in the median portion (Pl. 2, fig. 10); ray cells upright to squarish and procumbent, vertical height of upright or squarish cells 30-44 μm and radial length 20-40 μm, vertical height of procumbent cells 16-25 μm and radial length 60-100 μm; crystals rarely seen, dark gummy infiltration present. *Fibres* almost of the same width as alternating parenchyma bands (Pl. 2, fig. 9), polygonal to angular, 6-20 μm in diameter,

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*Prakash and Bande (1980) have spelt the species as *Cynometroxylon holdeni*.

libriform, thick-walled with narrow lumen, 4-6 μm thick, nonseptate, pits not seen.

AFFINITIES

The above characters of the present fossil wood indicate its closest resemblance with the woods of *Cynometra polyandra* Roxb. and *C. ramiflora* Linn. of the family Leguminosae which are anatomically indistinguishable from each other.

The generic name *Cynometroxylon* was first proposed by Chowdhury and Ghosh (1939) to include all the fossil woods of *Cynometra*. Subsequently in 1946, they emended the diagnosis of the genus *Cynometroxylon* to include all the fossil woods of *Cynometra* except *Cynometra alexandri* Wright. Müller-Stoll and Mädel (1967, p. 130) have pointed out that *Cynometra fisheri* Bak. f., *C. hankei* Harms and *C. lujae* De Wild also possess storied arrangement. In addition, *C. hankei* and *C. lujae* possess aliform to confluent parenchyma. Keeping these facts in view they further circumscribed the genus *Cynometroxylon*, which according to them corresponds only with those species of the living *Cynometra* which are anatomically similar to *Cynometra polyandra* Roxb. So far only five species of *Cynometroxylon* are known and these are *C. indicum* Chowdhury & Ghosh (1946), *C. schlagintweitii* Müller-Stoll & Mädel (1967), *C. siwalicus* Trivedi & Ahuja (1978), *C. dakshinense* Navale (1958) and *C. parainaequifolium* Prakash (1979a). However, recently Prakash and Bande (1980) while describing some fossil woods from the Tertiary of Burma reinvestigated the woods of *Dipterocarpoxylon holdenii* Gupta (1935) and found that it belongs to *Cynometroxylon* Chowdhury & Ghosh (1946). Accordingly, they transferred it to *Cynometroxylon* and named *C. holdenii* (Gupta) comb. nov. Since both the woods, *Cynometroxylon holdenii* (Gupta) comb. nov. and *C. indicum* are identical, they considered the latter species as a synonym of the former. In addition, they merged the first three species under the new combination and opined that the fourth does not belong to *Cynometra*. As the present fossil resembles *Cynometroxylon holdenii* Prakash & Bande (1980) in all its characters so it is assigned to the same species. Besides its earlier records (Prakash & Bande, 1980), the species has recently been reported from the Neogene of Kerala Coast and West Bengal (Awasthi & Ahuja, 1982; Ghosh & Roy, 1982).

The genus *Cynometra* Linn. consists of 60 species (Willis, 1973, p. 329) of evergreen trees or shrubs distributed throughout the tropics in the Indo-Malayan region, Phillippines, Australia, Pacific islands, Mexico, Brazil and Africa. Only six species grow in India (Ramesh Rao & Purkayastha, 1972, p. 76) of which *C. cauliflora* Linn. is an introduced species from Malaya. *Cynometra polyandra* is a large evergreen tree found in Cachar, Garo, Lushai and Khasi Hills of Assam in Sylhet and Chittagong. *C. ramiflora* is a small to medium sized tree found in sea coast tidal forests of Sunderbans, South India, Burma, Andamans and Sri Lanka (Gamble, 1902).

Specimens — B.S.I.P. Specimen nos. 36022, 36023 and 36024.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road and Mothala, about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

Genus — **Isoberlinioxylon* Lakhanpal & Prakash, 1970

Isoberlinioxylon congoense Lakhanpal & Prakash, 1970

Pl. 3, figs 15-18

The present description is based on two small pieces of well-preserved woods 10.0 ×2.0 cm and 10.5×3.5 cm in length and diameter respectively.

Topography — *Wood* diffuse-porous (Pl. 3, figs 15, 16). *Growth rings* delimited by narrow lines of parenchyma, smaller vessels and thick-walled fibres (Pl. 3, fig. 16). *Vessels* small to large (mostly medium), solitary or in radial multiples of 2-4 (mostly solitary), evenly distributed, 4-6 per sq mm; tyloses not seen; vessels occasionally filled with dark contents (Pl. 3, figs 15, 16), round to oval in cross section, t.d. 75-225 μm (mostly 135-150 μm), r.d.

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*Lakhanpal and Prakash (1970) have spelt the genus as *Isoberlineoxylon*.

90-225 μm (mostly 180 μm), wall about 4-6 μm thick, vessel members 160-480 μm (often 200-220 μm) in height with truncated ends; perforations simple; intervessel pits alternate to subopposite, 3-6 μm in diameter, vestured. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma abundant, vasicentric, aliform (forming prominent halo around the vessels with very short tangential extensions) to confluent; apotracheal parenchyma scanty, diffuse, occasionally seen as shining whitish cells and forming narrow lines of 1-2 cells wide delimiting the growth rings (Pl. 3, figs 15, 16); parenchyma cells round to oval in cross section, 12-40 μm in diameter, 80-200 μm in height, crystalliferous strands occasionally present with single crystal in each locule. *Xylem rays* fine, 1-3 seriate (3-seriate rarely seen), or 10-36 μm wide, 3-28 cells or 50-450 μm (often 200-220 μm) in height, 5-11 per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells and sometimes with a single marginal row of square or upright cells at one or both the ends (Pl. 3, figs 17, 18), upright ray cells 32-44 μm in vertical height, procumbent cells 8-24 μm in vertical height, radial length could not be measured, cells filled with dark contents. *Fibres* aligned in radial rows, round, oval to polygonal in cross section, walls 4-6 μm thick, 4-16 μm in diameter, probably nonseptate (but sometimes septa-like walls seen*), interfibre pits not seen.

AFFINITIES

The important characters shown by the present fossil wood collectively indicate its affinity with the woods of Leguminosae. From the examination of a large number of thin sections of modern woods of Leguminosae and the published literature and photographs (Pearson & Brown, 1932; Moll & Janssonius, 1914; Metcalfe & Chalk, 1950; Normand, 1950; Lebacq, 1957; Kribs, 1959; Ramesh Rao & Purkayastha, 1972) it was observed that the genus *Isoberlinia* Craib & Stapf. shows the closest similarity with the present fossil and hence it is assigned to the genus *Isoberlinioxylon* Lakhanpal & Prakash (1970). From the published account and photographs of three species of *Isoberlinia*, viz., *I. angolensis* (Welw.) Hoyle & Breman, *I. niembaensis* Duvingn and *I. tomentosa* (Harms) Craib & Stapf. (Lebacq, 1957, pls 79-81) as well as from the thin sections of the first two species available for comparison it was found that the present fossil shows closest resemblance with *I. niembaensis* and *I. angolensis* which are very similar to each other anatomically.

As far as the author is aware, there is only one species of the genus *Isoberlinioxylon*, *I. congoense* described by Lakhanpal and Prakash (1970) from the Miocene of lake Albert, Congo. Except for some minor variable differences the present fossil* resembles in all its xylotomical characters with *Isoberlinioxylon congoense*. Hence, it is placed under the same species.

The genus *Isoberlinia* Craib & Stapf. consists of 6 species which are confined to tropical Africa (Willis, 1973, p. 598). The presence of this genus in India during Pliocene? is important palaeophytogeographically.

Specimens — B.S.I.P. Specimen nos. 36025 and 36026.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

Genus — ***Dialiumoxylon*** **Lemoigne, 1978**

Dialiumoxylon indicum sp. nov.

Pl. 1, figs 5, 6; Pl. 3, fig. 19

The present species is based on a single piece of fairly well-preserved petrified wood.

Topography — *Wood* diffuse-porous (Pl. 1, fig. 5). *Growth rings* not seen. *Vessels* small to medium, solitary as well as in radial multiples of 2-5 (mostly 2-4), rarely more, uniformly distributed, 9-13 vessels per sq mm; tyloses not seen; vessels occasionally filled with gummy material, round to oval in cross section, t.d. 50-140 μm (average

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*Septa-like walls also seen sometimes in thin sections of the modern *Isoberlinia* spp.

*Weakly heterocellular rays observed in the duplicate slide no. RG 2249/3 of *Isoberlinioxylon congoense* Lakhanpal & Prakash and sometimes septa-like walls also seen in the fibres.

80 μm), r.d. 56-160 μm (average 120 μm); perforations simple, vessel-members 160-400 μm in length with truncated ends, storied with parenchyma strands and rays; intervessel pits alternate, bordered, vestured, 4-6 μm in diameter. *Parenchyma* in regular concentric bands alternating with relatively broad fibre bands (Pl. 1, fig. 5); parenchyma bands straight to slightly undulating touching or enclosing the vessels, 4-6 bands per mm, each 2-5 (mostly 2-4) cells wide, *parenchyma strands* storied, 4 cells per strand, cells round to oval in cross section, 12-28 μm in diameter, 60-100 μm long, crystalliferous strands present with solitary crystals in each locule. *Xylem rays* fine, 1-3 seriate (mostly biseriate), 16-40 μm wide, 5-17 cells or 120-360 μm in height, storied (Pl. 1, fig. 6), sometimes irregularly storied, 8-11 rays per mm, ray tissue homogeneous, rays homocellular, consisting of procumbent cells only (Pl. 1, fig. 6; Pl. 3, fig. 19). *Ray cells* 10-24 μm in vertical height, radial length could not be measured, dark infiltration present. *Fibres* forming concentric bands alternating with relatively narrow parenchyma bands (Pl. 1, fig. 6), oval to angular in cross section, 6-10 μm in diameter with narrow lumen, thick-walled, wall about 4 μm thick, nonseptate. *Ripple marks* present, visible due to storied arrangement of vessel-segments, parenchyma strands and rays.

AFFINITIES

The important features of the present fossil are: intervessel pits vestured; parenchyma in regular concentric bands, 2-5 (mostly 2-4) cells wide, touching or enclosing the vessels, alternating with relatively broad fibre bands; rays 1-3 seriate (mostly 2 seriate), homocellular, storied, ripple marks traceable due to storied arrangement of xylem rays, vessel segments and parenchyma strands.

All the aforesaid characters are collectively present in the following leguminous woods: *Alexa* Moq., *Bauhinia* Linn., *Craibia* Harms & Dunn, *Cynometra* Linn., *Dialium* Linn., *Geoffroea* Jacq., *Lonchocarpus* Kunth., *Machaerium* Per., *Millettia* Wight & Arn., *Piscidia* Linn., *Pongamia* Vent., *Pterocarpus* Linn., *Schefflerodendron* Harms and *Swartzia* Schreb.

Out of these, *Bauhinia*, *Lonchocarpus*, *Piscidia* and *Pongamia* differ from the present fossil in having broader parenchyma bands. In *Geoffroea*, *Machaerium* and *Pterocarpus* rays are exclusively uniseriate or only occasionally biseriate. In *Alexa* the frequency of vessels is low which is less than 5 vessels per sq mm. Of the various species of *Cynometra*, only *C. alexandri* Wright shows resemblance with the fossil in having banded parenchyma and storied xylem rays. However, in *Cynometra alexandri* the frequency of vessels is more than in the fossil. Two species of *Millettia*, i.e. *M. pulchra* Kurz and *M. drastica* Welw. ex Baker also show similarity with the fossil in possessing narrow parenchyma bands. The former differs in having homo- to heterocellular rays, much bigger vessels and their lesser frequency whereas the latter differs in having relatively broad and distantly placed parenchyma bands (which quite frequently run without touching the vessels) along with much broad fibre bands and in having vessels quite frequently in clusters. *Craibia affinis* (De Wild) De Wild. which possesses the narrow parenchyma bands differs from the present fossil in having very broad zonate fibrous tissue and frequently parenchyma runs without touching the vessels. *Schefflerodendron usambarense* Harms ex Engl. and *S. gilbertianum* Léonard et Latour though show quite close similarity with the fossil yet differ in having aliform to confluent parenchyma and frequently clustered vessels. Further, the frequency of vessels is more in *Schefflerodendron* than in the fossil. Of the different species of *Swartzia*, *S. fistuloides* Harms, *S. cubensis* (Britton & Wilson) Stanley and *S. bannia* Sandw. show apparent resemblance with the present fossil. *S. fistuloides*, however, differs in having bigger vessels, relatively broad parenchyma bands and short rays. *S. bannia* and *S. cubensis* though show close similarity, yet differs in having occasionally aliform to aliform confluent parenchyma. Moreover, diffuse parenchyma is also present in the former.

The genus *Dialium* agrees with the present fossil in almost all its xylotomical characters. To know the nearest modern equivalent of the fossil, thin sections of the woods of *Dialium*, viz., *Dialium excelsum* Louis ex Steyaert, *D. maingayi* Baker, *D. platysepalum* Baker, *D. laurinum* Baker, *D. travan-*

coricum Bourd. and *Dialium* sp. were examined. In addition, published anatomical descriptions and photographs of the woods of *D. angolense* Welw. ex. Oliv., *D. corbisieri* Staner, *D. excelsum* Louis ex. Steyaert, *D. gossweilerii* Aak. f., *D. pachyphyllum* Harms, *D. pantandrum* Louis ex. Steyaert, *D. zenkeri* Harms (Lebacq, 1957, pls 107-113), *D. dinklagei* Harms, *D. guinense* Willd. (Normand, 1950, p. 118, pl. XLIII; Kribs, 1959, pp. 79-80, fig. 407), *D. indum* Linn. (Moll & Janssonius, 1914, pp. 108-112, fig. 157), *D. cochinchinense* Pierre (Lecomte, 1926, pl. XIX) and *D. travancoricum* Bourd. (Ramesh Rao & Purkayastha, 1972, p. 78, pl. 74, fig. 441) were also consulted. From this it was found that *Dialium angolense*, *D. gossweilerii*, *D. laurinum*, *D. pentandrum*, *Dialium* sp., *D. travancoricum* and *D. zenkeri* show close resemblance with the fossil although the vessels in the present fossil are comparatively smaller.

In 1974, Lemoigne *et al.* described a fossil wood resembling the extant genus *Dialium* from the Miocene beds of Mush Valley, Ethiopia as *Dialioxylon aethiopicum* sp. nov. They did not give any diagnosis of the genus and species. *Dialioxylon aethiopicum*, however, shows superficial resemblance with the modern *Dialium* and differs in having heterogeneous rays (Lemoigne *et al.*, 1974, p. 274, pl. 42, fig. 17), whereas in *Dialium* the rays are homogeneous (Metcalfe & Chalk, 1950, p. 497; Lebacq, 1957, pls 107-113; Kribs, 1959 pp. 79-80; Ramesh Rao & Purkayastha, 1972, p. 14). Hence, *Dialioxylon aethiopicum* Lemoigne *et al.* (1974) cannot be regarded as the fossil wood of *Dialium*.

Again in 1978, Lemoigne described a fossil wood of *Dialium* under a different generic name *Dialiumoxylon* Lakhanpal & Prakash (1970) from the Tertiary of Welkite, Ethiopia. Surprisingly, the author did not mention anything about his earlier created genus *Dialioxylon* Lemoigne *et al.* (1974) though he merged *Leguminoxylon aethiopicum* Lemoigne & Beauchamp (1972) under the genus *Dialiumoxylon*. The genus *Dialiumoxylon* was never created by Lakhanpal and Prakash (1970). Similarly, Trivedi and Misra (1978) also described a fossil wood comparable to *Millettia pulchra* from the Siwalik beds of Uttar Pradesh, India and placed it under the genus *Dialiumoxylon* Prakash (1975). However, Prakash (1975, pp. 203-204) never validly instituted this genus, instead he merely suggested that certain woods may be grouped together under the genus *Dialiumoxylon* while describing a species of *Millettioxylon*. He also did not describe any fossil wood of *Dialium*. Thus, the fossil wood *Dialiumoxylon kalagarhense* Trivedi & Misra (1978) has no valid generic name and as it resembles *Millettia pulchra*, it is transferred to the genus *Millettioxylon* Awasthi (1967) and now named as *Millettioxylon kalagarhense* (Trivedi & Misra) comb. nov. As *Dialiumoxylon aethiopicum* described by Lemoigne (1978) represents the fossil wood of *Dialium* and forms the first record of fossil *Dialium* so the credit of instituting the genus *Dialiumoxylon* goes to Lemoigne. Consequently the genus is named *Dialiumoxylon* Lemoigne (1978) by the author who is also giving its generic diagnosis. The present fossil differs from *D. aethiopicum* mainly in the seriation and height of xylem rays and in the arrangement of parenchyma bands. In *D. aethiopicum* the parenchyma bands are in straight concentric bands and the xylem rays up to 4 seriate (mostly 2-3 seriate) and 200 to 300 μm in height whereas in the present fossil the concentric parenchyma bands are mostly wavy sometimes anastomosing and the xylem rays are 1-3 (mostly 1-2) seriate and 120-360 μm in height. Thus, the present fossil has been assigned to a new species, *Dialiumoxylon indicum* sp. nov.

The genus *Dialium* Linn. consists of 40 species found in the tropics of South America, Africa, Madagascar and Malaysia (Willis, 1973, p. 352). In India, only one species occurs i.e. *D. travancoricum* Bourd. which is found in the forests of South Travancore between 300 to 600 m (Ramesh Rao & Purkayastha, 1972, p. 78).

GENERIC DIAGNOSIS

Dialiumoxylon Lemoigne, 1978

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to large, solitary as well as in multiples of 2-4, rarely more; t.d. 50-200 μm; tyloses wanting. *Parenchyma* in regular concentric lines or narrow bands, alternating with relatively broad fibre bands; bands straight to slightly undulating, often touching or enclosing the vessels, 4-6 bands per mm, each 2-5 cells wide. *Xylem rays* fine, 1-3 seriate (exceptionally 4 seriate), 16-40 μm or more in width, 5-17 cells or 120-360 μm in height, storied, sometimes irregularly storied; 8-14 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only. *Fibres* forming concentric bands alternating with relatively narrow parenchyma bands, thick-walled, nonseptate. *Ripple marks* present due to storied arrangement of vessel segments, parenchyma strands and rays.

Genotype — Dialiumoxylon aethiopicum Lemoigne, 1978.

SPECIFIC DIAGNOSIS

Dialiumoxylon indicum sp. nov.

Vessels small to medium, t.d. 50-140 μm (average 80 μm), r.d. 56-160 μm (average 120 μm), solitary as well as in radial multiples of 2-5 (mostly 2-4), rarely more; 9-13 vessels per sq mm; vessel-members 160-400 μm with truncated ends, storied; perforations simple; intervessel pits 4-6 μm in diameter, tyloses wanting. *Parenchyma* in regular concentric narrow bands, alternating with relatively broad fibre bands, parenchyma bands straight to slightly undulating, often touching or enclosing the vessels, 4-6 bands per mm, each 2-5 (mostly 2-4) cells wide, parenchyma strands storied. *Xylem rays* fine, 1-3 seriate (mostly biseriate), 16-40 μm wide, 5-17 cells or 120-360 μm in height, storied; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only. *Fibres* oval to angular, 6-10 μm in diameter with narrow lumen, thick-walled, wall about 4 μm thick, nonseptate; forming concentric bands alternating with relatively narrow parenchyma bands. *Ripple marks* present, visible due to storied vessel-segments, parenchyma strands and rays.

Holotype — B.S.I.P. Specimen no. 36027.

Locality — Dhaneti, about 24 km east of Bhuj on the Bhuj-Bhachau Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

SUBFAMILY — PAPILIONACEAE

Genus — *Millettioxylon* Awasthi, 1967

Millettioxylon indicum Awasthi, 1967

Pl. 2, figs 7, 8

The material consists of two pieces of silicified wood with fairly good preservation.

Topography — *Wood* diffuse-porous (Pl. 2, fig. 7). *Growth rings* not seen. *Vessels* small to large, mostly medium, solitary or in radial multiples of 2-4, sometimes forming clusters, evenly distributed, 3-6 vessels per sq mm; tyloses not seen; vessels sometimes filled with dark contents, circular to oval in cross section, t.d. 64-224 μm, r.d. 80-288 μm; perforations simple, vessel-members 280-460 μm in length with truncated ends, storied with parenchyma strands and rays; intervessel pits alternate, bordered, vestured, about 4 μm in diameter. *Parenchyma* in regular concentric bands alternating with fibre bands of more or less the same width or of relatively greater width (Pl. 2, fig. 7), bands slightly undulating, sometimes bifurcating and joining the adjoining bands; 4-5 bands per mm; each 3-8 cells wide, parenchyma strands storied, 4 cells per strand; cells round to oval in cross section, 16-28 μm in diameter. *Xylem rays* fine, 1-3 (mostly 2, very rarely 3) seriate or 8-28 μm wide, 3-20 cells or 80-360 μm high, storied, 11-14 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells and sometimes with a single marginal row of square or upright cells at one or both the ends (Pl. 2, fig. 8), upright or square *ray cells* 24-32 μm in vertical height, 36-40 μm in radial length, procumbent cells 12-20 μm in vertical height, 60-100 μm in radial length. *Fibres* forming concentric bands, alternating with parenchyma bands of more or less same width (Pl. 2, fig. 8), circular, oval to angular, in cross section, 8-16 μm in diameter, nonseptate, thick-walled, walls 4-8 μm thick with narrow lumen. *Ripple marks* present, visible due to storied vessel-segments, parenchyma strands and rays.

AFFINITIES

All the above features are collectively seen in a few leguminuous woods, viz., *Bauhinia* Linn., *Craibia* Harms & Dunn, *Cynometra* Linn., *Dialium* Linn., *Lonchocarpus* Kunth., *Millettia* Wight & Arn., *Pongamia* Vent., *Piscidia* Linn., *Schefflerodendron* Harms and *Swartzia* Schreb. Out of these, *Millettia* and *Pongamia* are the only genera which show closest resemblance with the present fossil. A study of a large number of thin sections of the woods of *Millettia* and *Pongamia* revealed that the present fossil shows closest similarity with *Millettia pendula* Benth., *M. prainii* Dunn and *Pongamia glabra* Vent. and the rest of the species can be differentiated on the basis of width of parenchyma bands and rays. As the woods of *Millettia pendula*, *M. prainii* and *Pongamia glabra* are almost similar and difficult to distinguish xylotomically, these have been put together in a single genus *Millettioxylon* Awasthi (1967, 1975a). Consequently, the present wood is assigned to this genus.

So far only six species of *Millettioxylon* are known, viz., *M. indicum* Awasthi (1967, 1975a) from the Cuddalore Series of South India and Upper Tertiary of Thailand (Prakash, 1979a); *M. pongamiensis* Prakash (1975) from the Lower Siwalik of Himachal Pradesh and also from the Tertiary of West Bengal (Bande & Prakash, 1980; Ghosh & Roy, 1981); *M. palaeopulchra* from Mio-Pliocene beds of Deomali, Lakhanpal *et al.* (1981); *M. embergeri* Lemoigne (1978) from the Miocene of Ethiopia; *M. bengalensis* Ghosh & Roy (1979) from Midnapur District, West Bengal; and *M. kalagarhense* (Trivedi & Misra) comb. nov. (see p. 246) from the Mio-Pliocene beds of Kalagarh, Bijnor District, Uttar Pradesh. Out of these, *Millettioxylon indicum* Awasthi shows closest similarity with the present fossil in almost all its characters and hence it is placed under the same species.

Of the two species of *Milletia* with which fossil shows resemblance, *M. pendula* is found in the drier forests of Burma, common in Pegu Yoma, Shweba, Upper Chindwin and Tenasserim while *M. prainii* occurs in the eastern Himalayas in the foot-hills of Sikkim extending a short distance into the plains of North Bengal and also in Assam along the right bank of the river Manas in Goalpara and in the Garo Hills (Ramesh Rao & Purkayastha, 1972, pp. 116-117). The genus *Pongamia* consists of a single species, viz., *P. glabra*, a medium-sized tree, occurs throughout the greater part of India and Burma, chiefly along streams and rivers, being common in the tidal and beach forests and very common in the Andamans. It is also found in Sri Lanka and Malaya extending to North Australia and China (Ramesh Rao & Purkayastha, 1972, p. 122).

Specimens — B.S.I.P. Specimen nos. 36028 and 36029.

Localities — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road and Mothala, about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, district Kachchh, Gujarat.

Horizon — Kankawati Series.

The fossil woods corresponding to *Albizia lebbek*, *A. amara*, *A. odoratissima*, *Isoberlinia* spp. and *Millettia* spp. are the representatives of inland and moist to dry deciduous types of vegetation whereas *Cynometra polyandra* and *Dialium* are the indicators of moist conditions. *Afzelia-bijuga-A. retusa*, *Cynometra ramiflora* and *Pongamia glabra* are denizens of tidal and beach forests.

The occurrence of *Isoberlinia* in the Pliocene? of Kachchh is quite interesting and important palaeophytogeographically, since it provides a strong evidence to the fact that certain African elements did extend into India in the past thereby confirming that this region had been the meeting ground for the western floral elements (African & Arabian) like the present day (Bharucha & Meher-Homji, 1965; Blatter *et al.*, 1929; Chatterjee, 1940, 1962; Puri, 1960; Legris, 1963; Mahabale, 1966).

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REFERENCES

Awasthi, N. (1967). Fossil wood resembling that of *Milletia* from the Tertiary of South India. *Curr. Sci.*, **36** (7): 180.

Awasthi, N. (1975a). *Millettioxylon indicum* Awasthi, a fossil wood of Leguminosae from the Cuddalore Series of South India. *Palaeobotanist*, **22** (1): 47-50.

Awasthi, N. (1975b). Revision of some dicotyledonous woods from the Tertiary of South India. *Palaeobotanist*. **22** (3): 186-191.

Awasthi, N. (1979). Three new leguminous woods from the Cuddalore Series near Pondicherry. *Palaeobotanist*, **26** (2): 157-166.

Awasthi, N. & Ahuja, M. (1982). Investigations of some carbonised woods from the Neogene of Varkala in Kerala Coast. *Geophytology*, **12** (2): 245-259.

Awasthi, N., Guleria, J. S. & Lakhanpal, R. N. (1980). A fossil dicotyledonous wood from the Pliocene beds of Mothala, district Kutch, western India. *Palaeobotanist*, **26** (3): 199-205.

Awasthi, N., Guleria, J. S. & Lakhanpal, R. N. (1982). Two new fossil woods of Sapindaceae from the Tertiary of India. *Palaeobotanist*, **30** (1): 12-21.

Bande, M. B. & Prakash, U. (1980). Fossil woods from the Tertiary of West Bengal, India. *Geophytology*, **10** (1-2): 146-157.

Bharucha, F. R. & Meher-Homji, V. M. (1965). On the floral elements of the semi-arid zones of India and their ecological significance. *New Phytol.*, **64**: 330-342.

Biswas, S. K. & Raju, D. S. N. (1973). The rock-stratigraphic classification of Tertiary sediments of Kutch. *Bull. Oil nat. Gas Commn*, **10** (1-2): 37-45.

Blatter, E., McCann, C. & Sabnis, T. S. (1929). *Flora of the Indus Delta*. Madras.

Chatterjee, D. (1940). Studies on the endemic flora of India and Burma. *Jl R. Asiat. Soc. Beng.*, **5**: 19-67.

Chatterjee, D. (1962). Floristic patterns of Indian vegetation: pp. 32-42 in Maheshwari, P., Johri, B. M. & Vasil, A. K. (eds) — *Proc. Summer School Bot., Darjeeling*.

Chowdhury, K. A. & Ghosh, S. S. (1939). On the anatomy of fossil dicotyledonous wood from Nailalung, Assam. *Proc. 26th Indian Sci. Congr., Lahore*, **3** (Abst.): 127.

Chowdhury, K. A. & Ghosh, S. S. (1946). On the anatomy of *Cynometroxylon indicum* gen. et sp. nov., a fossil dicotyledonous wood from Nailalung, Assam. *Proc. natn. Inst. Sci. India*, **12** (8): 435-447.

Chowdhury, K. A., Ghosh, S. S. & Kazmi, M. H. (1960). *Pahudioxylon bankurensis* gen. et sp. nov. — a fossil wood from the Miocene beds of Bankura District, West Bengal, India. *Proc. natn. Inst. Sci. India*, **26B** (1): 22-28.

Gamble, J. S. (1902). *A Manual of Indian Timbers*. London.

Ghosh, P. K. & Roy, S. K. (1979). A new species of *Millettia* from the Tertiary of West Bengal, India. *Curr. Sci.*, **48** (4): 165-166.

Ghosh, P. K. & Roy, S. K. (1981). Fossil woods of *Millettia* and *Albizzia* from the Tertiary of West Bengal, India. *Curr. Sci.*, **50** (6): 288.

Ghosh, P. K. & Roy, S. K. (1982). Fossil woods of Caesalpinioidae from the Miocene of West Bengal. *Acta Bot. Indica*, **10** (1): 50-55.

Ghosh, S. S. & Kazmi, M. H. (1961). *Pahudioxylon sahnii* sp. nov. — a new fossil record from the Miocene (?) of Tripura. *Sci. Cult.*, **27**: 96-98.

Ghosh, S. S. & Ghosh, A. K. (1959). *Dipterocarpoxylon malvii* sp. nov. — a new fossil record from the Pliocene of Kutch. *Sci. Cult.*, **25**: 328-332.

Greguss, P. (1969). *Tertiary Angiosperm Woods in Hungary*. Budapest.

Guleria, J. S. (1983). Some fossil woods from the Tertiary of Kachchh, western India. *Palaeobotanist*, **31** (2): 109-128.

Guleria, J. S. & Lakhanpal, R. N. (in press). On the occurrence of *Pandanus* from the Eocene of Kutch, western India. *A. K. Ghosh Commemoration Volume*.

Gupta, K. M. (1935). A review of the genus *Dipterocarpoxylon* of Holden, with description of a new species *D. holdeni* from the Irrawady System of Burma. *Proc. Indian Acad. Sci.*, **1** (10): 633-639.

Koeniguer, J. C. (1973). Les bois hétéroxylés de l'oasis de Kirdimi (Tchad). *96e Congr. nat. Soc. Savantes, Toulouse (Sciences)*, **5**: 191-214.

Kramer, K. (1974). Die Tertiären hölzer sudöst-Asiens (unter ausschuss der Dipterocarpaceae). 1. Teil. (The Tertiary woods of south-east Asia (Dipterocarpaceae excluded) Part 1. *Palaeontographica*, **144B**: 45-181.

Kribs, D. A. (1959). *Commercial Foreign Woods on the American Market*. Pennsylvania.

Lakhanpal, R. N. & Guleria, J. S. (1981). Leaf-impressions from the Eocene of Kachchh, western India. *Palaeobotanist*, **28-29**: 353-373.

Lakhanpal, R. N. & Guleria, J. S. (1982). Plant remains from the Miocene of Kachchh, western India. *Palaeobotanist*, **30** (3): 279-296.

Lakhanpal, R. N., Guleria, J. S. & Awasthi, N. (1975). A podocarpaceous wood from the Pliocene of Kutch. *Geophytology*, **5** (2): 172-177.

Lakhanpal, R. N. & Prakash, U. (1970). Cenozoic plants from Congo. I. Fossil woods from the Miocene of lake Albert. *Annls Mus. r. Afr. cent. Sci. Géol.*, Sér. **8**, 64: 1-20.

Lakhanpal, R. N., Prakash, U. & Awasthi, N. (1981). Some more dicotyledonous woods from the Tertiary of Deomali, Arunachal Pradesh, India. *Palaeobotanist*, **27** (3): 232-252.

Lebacq, L. (1957). *Atlas Anatomique des Bois du Congo Belge*. III & IV. Bruxelles.

Lecomte, H. (1926). *Les Bois de l' Indochine*. Paris.

Legris, P. (1963). La Vegetation de l' Inde Ecology et Flore. *Trav. Sect. scient. tech.* **6** *Inst. fr., Pondicherry*.

Lemoigne, Y. (1978). Flores tertiares de la Haute vallee de l' Omo (Ethiopie). *Palaeontographica*, **165B**: 89-157.

Lemoigne, Y. & Beauchamp, J. (1972). Paléoflores tertiaries de la région de Welkite (Ethiopie, Province du Shoa). *Bull. Soc. géol. Fr.*, Ser. 7°, **14**: 336-346.

Lemoigne, Y., Beauchamp, J. & Samuel, E. (1974). Etude paléobotanique des dépots volcaniques d'age Tertiaire des bordures est et ouest due systèms des rifts Ethiopiens. *Geobios*, **7** (3): 267-288.

LÉONARD, J. J. G. (1950). Notes sur les, genres paléotropicans, *Afzelia*, *Intsia* et *Pahudia* (Leguminosae-Caesalpineae) *Reïnwardtia*, **1** (1): 61-66.

MAHABALE, T. S. (1966). Flora of the Deccan: past and present. Presidential address, Botany Section. *Proc. 53rd Indian Sci. Congr., Chandigarh*, Pt. II: 121-151.

METCALFE, C. R. & CHALK, L. (1950). *Anatomy of the Dicotyledons*. **I & II**. Oxford.

MOLL, J. W. & JANSSONIUS, H. H. (1914). *Mikrographie des Holzes der auf Jawa Verkommenden Baumartrn*. **III**. Leiden.

MÜLLER-STOLL, W. R. & MÄDEL, E. (1967). Die fossilen Leguminosae hölzer. Eine revision der mit Leguminosen vergleichenen fossilen hölzer und beschreibungen älterer und neuer arten. *Palaeontographica*, **119B**: 95-174.

NAVALE, G. K. B. (1959). Occurrence of fossil *Cynometra* from the Cuddalore Series near Pondicherry, India. *Palaeobotanist*, **7** (1): 6-11.

NAVALE, G. K. B. (1963). Fossil woods of Leguminosae from Tertiary beds of Cuddalore Series near Pondicherry, India. *Palaeobotanist*, **11** (1-2): 54-65.

NORMAND, D. (1950). *Atlas des Bois de la Côte de'Ivoire*. I, II & III. Nogent-Sur-Marne (Seine) — France.

PEARSON, R. S. & BROWN, H. P. (1932). *Commercial Timbers of India*. **I & II**. Calcutta.

PRAKASH, U. (1965). *Pahudioxylon deomaliense* sp. nov., a new fossil wood from the Tertiary of eastern India. *Curr. Sci.*, **34** (14): 433-434.

PRAKASH, U. (1966a). Some fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist*, **14** (1-3): 223-235.

PRAKASH, U. (1973). Fossil woods from the Tertiary of Burma. *Palaeobotanist*, **20** (1): 48-70.

PRAKASH, U. (1975). Fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Palaeobotanist*, **22** (3): 192-210.

PRAKASH, U. (1979a). Fossil dicotyledonous woods from the Tertiary of Thailand. *Palaeobotanist*, **26** (1): 50-62.

PRAKASH, U. (1979b). Some more fossil woods from the Lower Siwalik beds of Himachal Pradesh, India. *Himalayan Geol.*, **8** (1): 61-81.

PRAKASH, U. & BANDE, M. B. (1980). Some more fossil woods from the Tertiary of Burma. *Palaeobotanist*, **26** (3): 261-278.

PRAKASH, U. & BARGHOORN, E. S. (1961). Miocene fossil woods from the Columbia Basalts of Central Washington. *J. Arnold Arbor.*, **42** (2): 165-203.

PRAKASH, U., BOUREAU, E. & LOUVET, P. (1967). Les plans ligneux convergents et la nomenclature de bois de Légumineuses Tertiaries du Sahara et d'Asie. *Taxon*, **16**: 505-509.

PRAKASH, U. & TRIPATHI, P. P. (1975). Fossil dicotyledonous woods from the Tertiary of eastern India. *Palaeobotanist*, **22** (1): 51-62.

PURI, G. S. (1960). *Indian Forest Ecology*. I. Oxford Book and Stationery Co., New De'hi.

RAMESH RAO, K. R. & PURKAYASTHA, S. K. (1972). *Indian Woods*. **III**. Delhi.

TRIVEDI, B. S. & AHUJA, M. (1978). *Cynometroxylon siwalicus* n. sp. from the Siwalik Range. *Curr. Sci.*, **47** (17): 638-639.

TRIVEDI, B. S. & MISRA, J. P. (1978). *Dialiumoxylon kalagarhense* n. sp. from the Mio-Pliocene of Kalagarh, U.P., India. *Indian J. Bot.*, **1** (1-2): 57-60.

VOZENIN-SERRA, C. (1981). Les structures ligneuses Neogenes du plateau de Di Linh (Sud-Vietnam). *Palaeontographica*, **177B** : 136-161.

WILLIS, J. C. (1973). *A Dictionary of the Flowering Plants and Ferns*. Cambridge.

EXPLANATION OF PLATES

PLATE 1

Albizinium eolebbekianum Prakash, 1975

1. Cross section showing the nature and distribution of vessels, parenchyma and fibres. × 40. Slide no. 6661.
2. Tangential longitudinal section showing the nature and distribution of rays and fibres. × 120. Slide no. 6662.

Albizinium pondicherriensis Awasthi, 1979

3. Cross section showing the nature and distribution of vessels and parenchyma. × 15. Slide no. 6663.
4. Tangential longitudinal section showing the nature and distribution of rays and septate fibres. × 120. Slide no. 6664.

Dialiumoxylon indicum sp. nov.

5. Cross section showing narrow bands of parenchyma and distribution of vessels. × 50. Slide no. 6674.
6. Tangential longitudinal section showing storied vessel-segments, parenchyma strands and rays. × 100. Slide no. 6675.

PLATE 2

Millettioxylon indicum Awasthi, 1967

7. Cross section showing the nature and distribution of vessels, parenchyma and fibres. × 30. Slide no. 6677.
8. Tangential longitudinal section showing the nature of rays and their storied arrangement. × 120. Slide no. 6678.

Cynometroxylon holdenii (Gupta) Prakash & Bande, 1980

9. Cross section showing the nature and distribution of vessels, parenchyma and fibres. × 32. Slide no. 6669.
10. Tangential longitudinal section showing heterocellular rays. × 120. Slide no. 6670.

Pahudioxylon assamicum Prakash & Tripathi, 1975

11. Cross section showing growth ring and distribution of vessels, parenchyma and rays. × 32. Slide no. 6667.
12. Tangential longitudinal section showing the nature and distribution of rays and their storied tendency. × 120. Slide no. 6668.

PLATE 3

Pahudioxylon sahnii Ghosh & Kazmi, 1961

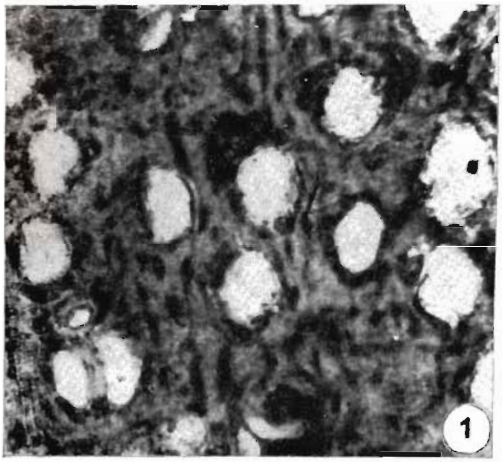
13. Cross section showing growth ring, nature and distribution of vessels and parenchyma. × 35. Slide no. 6665.
14. Tangential longitudinal section showing the nature and distribution of rays and their storied tendency. × 140. Slide no. 6666.

Isoberlinioxylon congoense Lakhanpal & Prakash, 1970

15. Cross section at low magnification showing the nature and distribution of vessels and parenchyma. × 10. Slide no. 6671.
16. A portion of cross section magnified to show the growth ring, nature and distribution of vessels and parenchyma. × 30. Slide no. 6671.
17. Tangential longitudinal section showing nature and distribution of rays. × 95. Slide no. 6672.
18. Radial longitudinal section showing homogeneous rays. × 120. Slide no. 6673.

Dialiumoxylon indicum sp. nov.

19. Radial longitudinal section showing homogeneous rays. × 100. Slide no. 6676.



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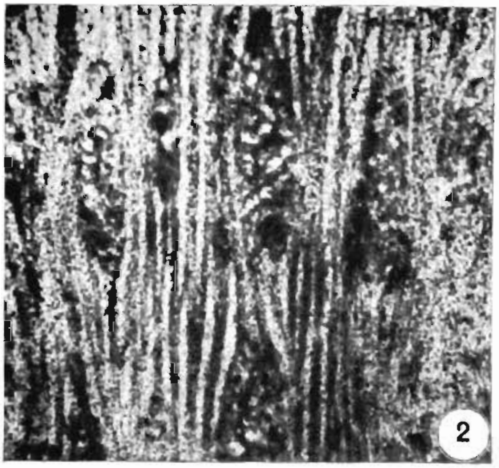

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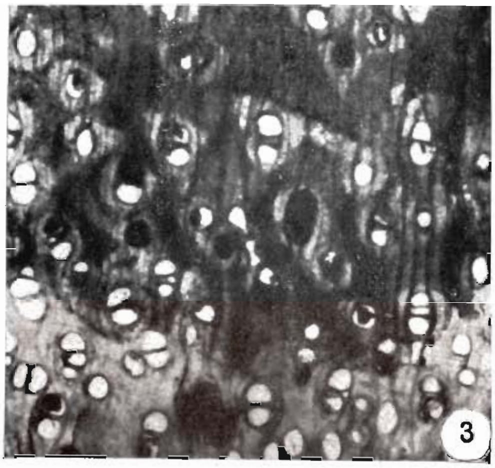

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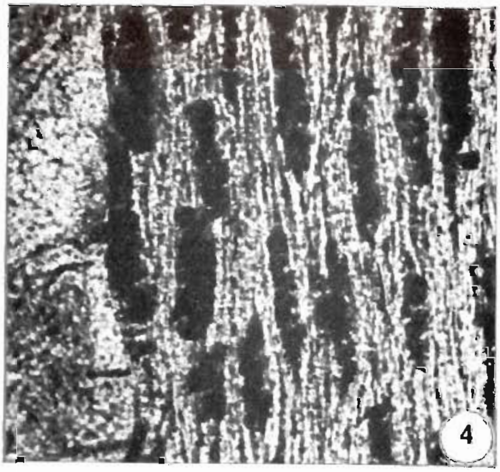

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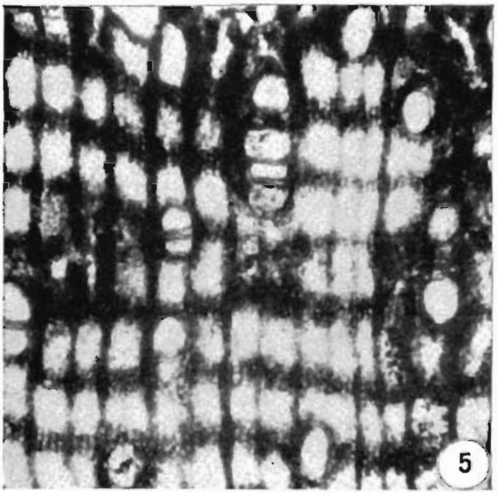

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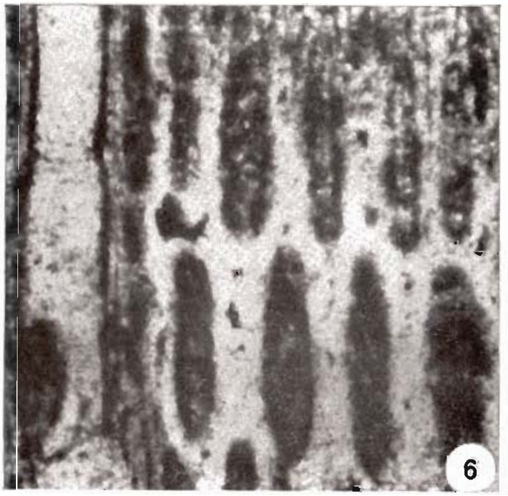

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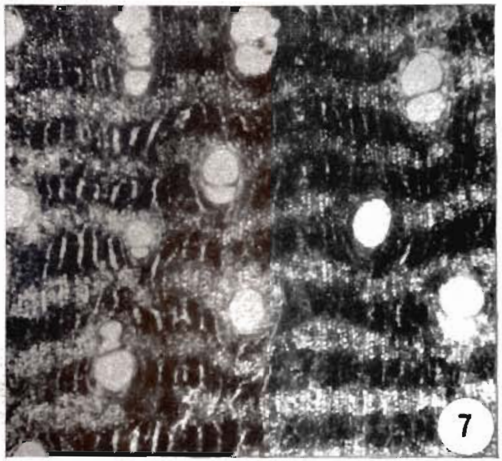
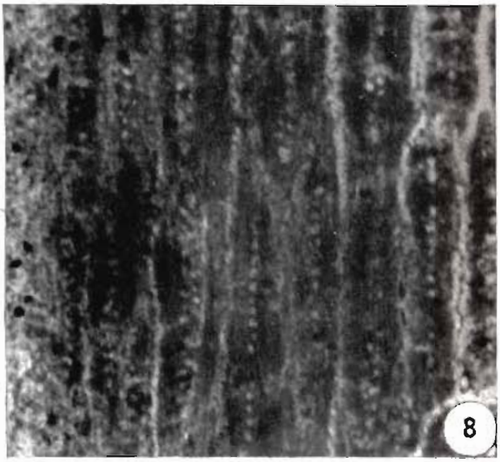
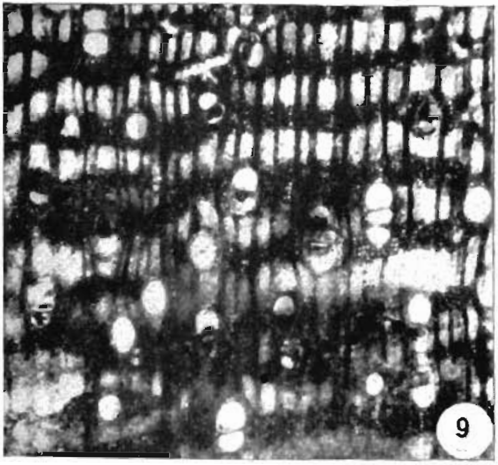
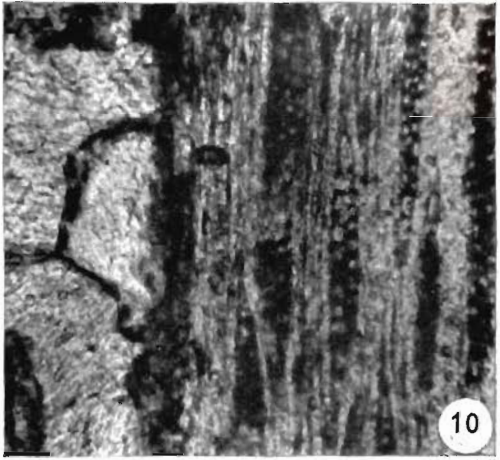
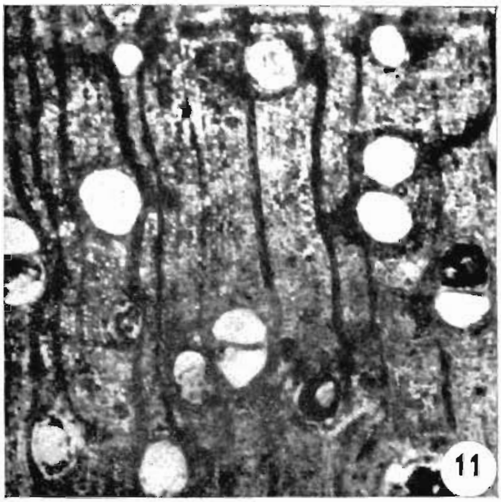
PLATE 1











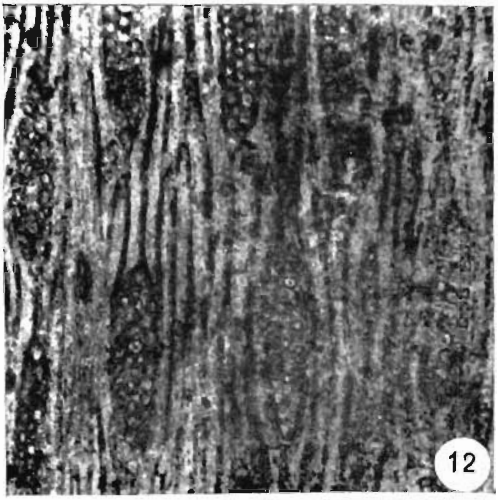
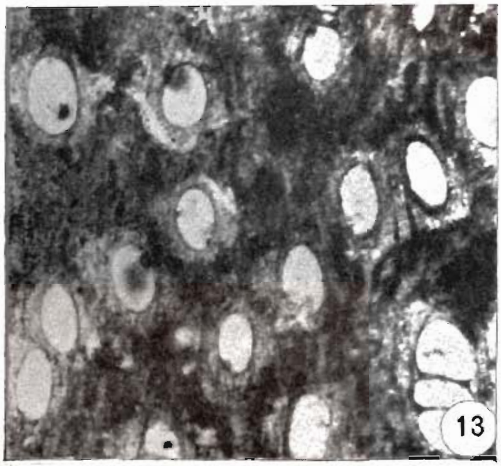
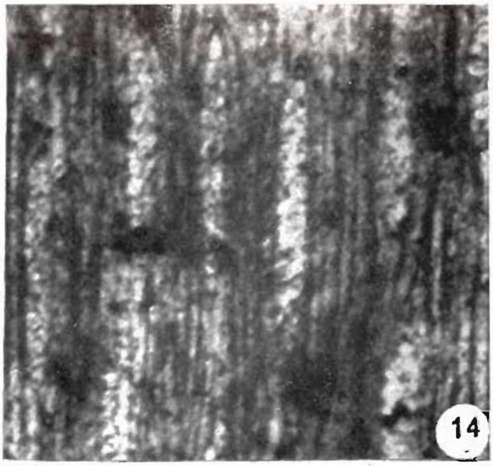
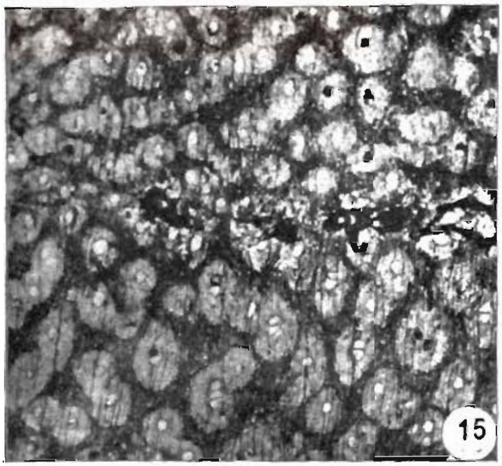
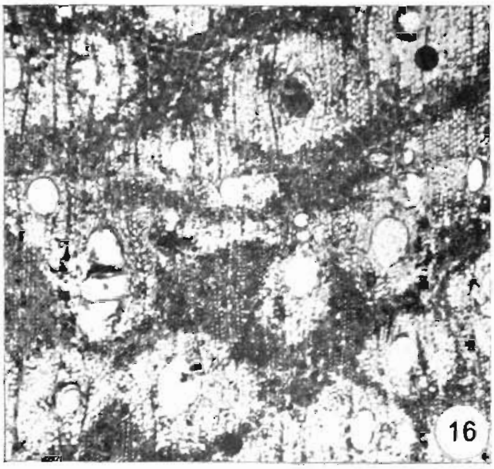


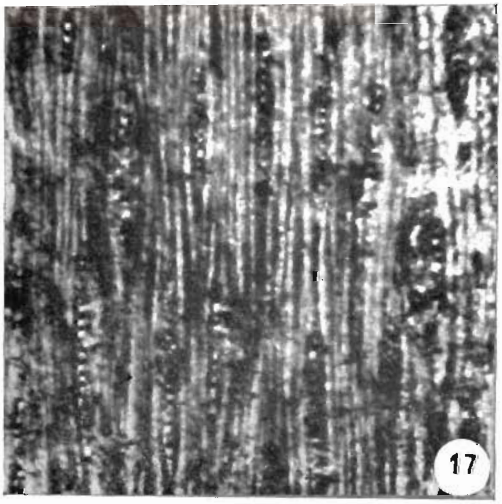
PLATE 2

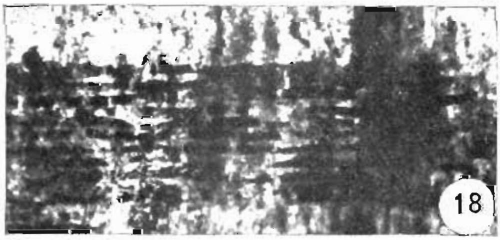












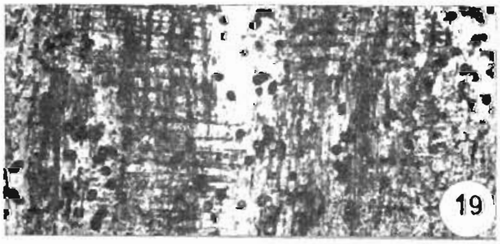


Plate 3

The Palaeobotanist, 31(3): 255-262, 1984.

INDIA: THE ORIGINAL HOMELAND OF *CERATOPTERIS* BRONGNIART (PARKERIACEAE)

R. K. KAR

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

ABSTRACT

The spores of *Ceratopteris* Brongniart (known as *Striatriletes* in fossil state) have been studied in detail and it has been found that this spore was recorded for the first time from the Middle-Upper Eocene in Kachchh, Meghalaya and Assam. In Venezuela, Caribbean islands, Nigeria and Malayasia, *Striatriletes* started its occurrence in the Lower Oligocene. It has also been presumed that (a) *Ceratopteris* evolved in India during Middle-Upper Eocene when it was near the equator and enjoying tropical climate; (b) the genus migrated from western coast of India towards equatorial Africa and then crossed the Atlantic Ocean to reach tropical Americas; (c) *Ceratopteris* migrated to Malayasia through north-east India and from there it reached to tropical Australia. Further, it has been suggested that the dominance of *Ceratopteris* spores in Oligocene-Miocene sediments of India, Venezuela, Caribbean islands, Nigeria and Malayasia is indicative of a big palaeogeographical province which may be called as *Ceratopteris* or *Striatriletes* province.

Key-words — *Ceratopteris*, Parkeriaceae, Pteridophytes, Palaeobiogeography (India).

सारांश

सिराटॉप्टेरिस ब्रोंगनिआ (पार्केरिएसी) की उद्भवभूमि : भारत – रंजीत कुमार कर

आश्मिक रूप में स्ट्रयाट्राइलिटीज़ के नाम से विदित सिराटॉप्टेरिस ब्रोंगनिआ के बीजाणुओं के विस्तृत अध्ययन से यह प्रेक्षित किया गया है कि मध्य-उपरि आदिनूतन काल में यह बीजाणु कच्छ, मेघालय एवं असम से सर्वप्रथम अभिलिखित किया गया था। वेनेज़ुएला, करीबीयन द्वीपसमूह, नाइजीरिया एवं मलेशिया में यह अधरि अल्पनूतन काल में मिलता है। यह भी अनुमान किया गया है कि (अ) मध्य-उपरि आदिनूतन युग में जब भारत भूमध्य रेखा के समीप था तथा यहाँ उष्णकटिबंधीय जलवायु विद्यमान थी, सिराटॉप्टेरिस का विकास हुआ था; (आ) भारत के पश्चिमी तट से भूमध्यरेखीय अफ्रीका की ओर इस वंश का अभिगमन हुआ, तत्पश्चात् उष्णकटिबंधीय अमेरिका तक पहुँचने के लिए यह अटलाँटिक महासागर को पार कर गया; (इ) सिराटॉप्टेरिस का उत्तर-पूर्व भारत से अभिगमन हुआ जहाँ से यह उष्णकटिबंधीय ऑस्ट्रेलिआ पहुँच गया। इसके अतिरिक्त यह भी प्रस्तावित किया गया है कि भारत, वेनेज़ुएला, करीबीयन द्वीपसमूह, नाइजीरिया एवं मलेशिया के अल्पनूतन-मध्यनूतन काल में सिराटॉप्टेरिस के बीजाणुओं की बाहुल्यता से एक बृहत् पुराभौगोलिक प्रदेश की उपस्थिति व्यक्त होती है जिसे कि सिराटॉप्टेरिस अथवा स्ट्रयाट्राइलिटीज़ प्रदेश की संज्ञा दी जा सकती है।

INDIA has been called by Whitmore (1981) as 'Noah's Ark' drifting northwards and covering a distance of roughly 5,000 km. The rate of drifting was, however, not uniform though it is generally assumed that at times it was more rapid than any other continent so far known. Johnson, Powell and Veevers (1976) calculated that to cover such a long distance India might have travelled at the rate of 35-175 mm per year.

The scientists of the deep sea drifting expedition thought that the clue of relative and changing position of India and Australia might lie in the ocean floor between them comprising Bengal fan, central Indian basin, Ninety east ridge, and Wharton basin. McKenzie and Sclater (1971) detected prominent east-west magnetic anomalies in the Bengal fan and central Indian basin which constrain the position of India relative to Antarctica. The Ninety east ridge, in the opinion of McKenzie and Sclater (1971), marks a transform fault along which India migrated northward during the late Cretaceous and early Tertiary.

The wandering nature of India was no doubt deadly on some species but it also provided the unique opportunity to others to evolve and flourish. On its way, India might have also populated by other plants which were not indigenous to the soil. Of course, it would be very difficult to detect which plants were original and which were induced. Longwell (1963) observed that Nature's methods of distributing animals and plants are devious, some of them almost incredible. We may reckon as " vanishingly small " the probability that certain living forms can be transplanted between widely separated lands but by giving a million years or more a tiny probability may suffice. Otherwise it would be difficult to explain the presence of many tiny forms found indigenous or isolated in Pacific islands, thousands of miles away from their closest relatives or continents.

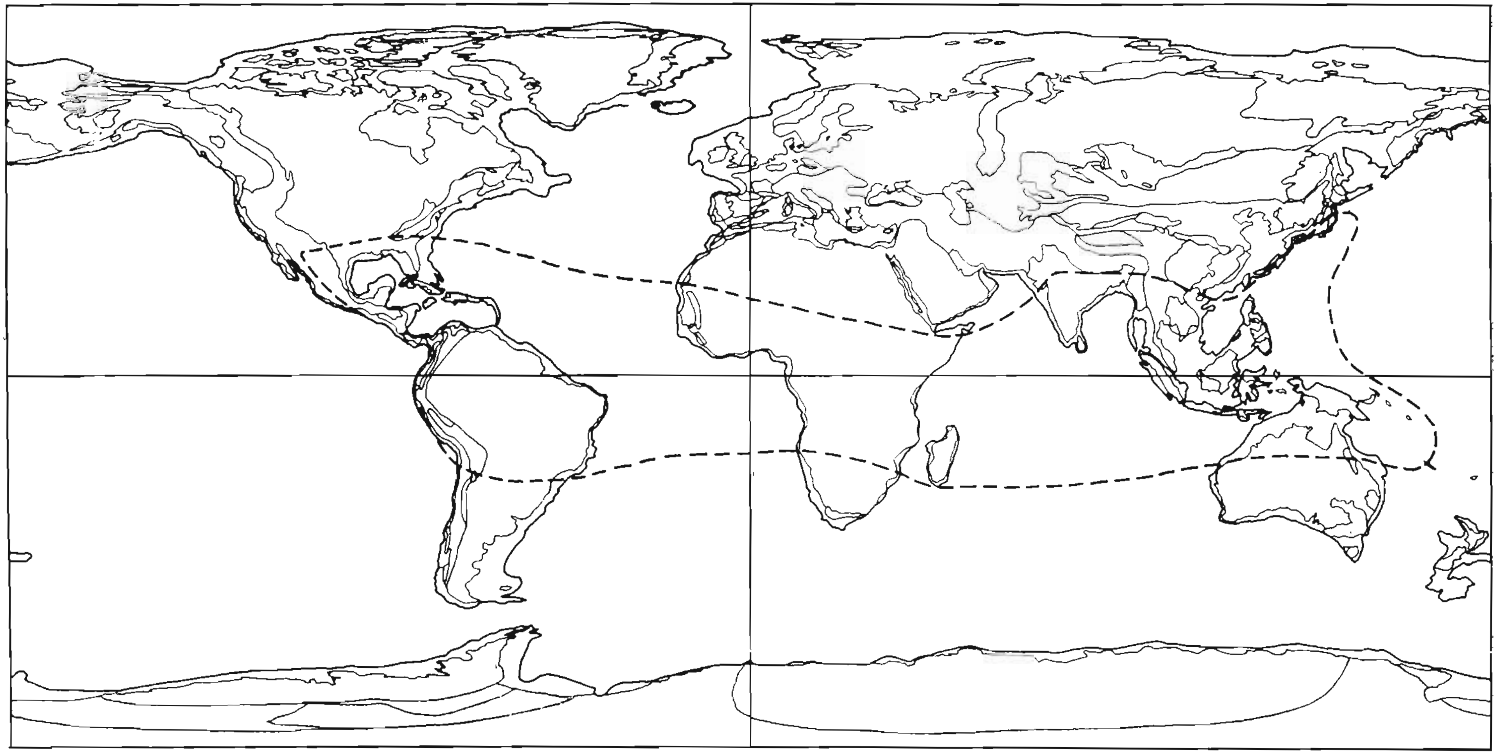
The water fern genus *Ceratopteris* Brongniart of the family Parkeriaceae may be considered here in this context. *Ceratopteris* is only genus of the family and one of the very few annual and aquatic ferns with exceptionally unstable sporangium wall. This genus is characterized by aquatic or subaquatic annuals with short, erect, rhizome bearing a few scattered small scales; stipes are green, fleshy with numerous vascular bundles. Fronds are moderate sized, pinnately decompound, broad, glabrous, soft, herbaceous and dimorphic. Sterile fronds are with broad lobes, ovate or triangular, pinnate or bipinnatified and often viviparous. Fertile fronds are larger, finely dissected with longer and narrower pinnules than the sterile. Venation of the fronds are reticulate. Sporangia are sessile or subsessile, seriate along the veins, large and occupying the entire surface, protected by continuous inflexed leaf margins. Annulus comprises 30-70 broad, thickened cells.

Ceratopteris pteridoides according to Copeland (1974) is a typical floating fern with inflated stipes which supply necessary buoyancy, able to root or grow on mud and can not exist elsewhere. The roots are freely produced from the lower surface of stipes to absorb the nutrients and to provide additional buoyancy. It is the only fern, so far known, ever grown as a food crop by the natives.

Hooker and Baker (1868) noted the occurrence of *Ceratopteris* throughout the tropics in quiet water from Mexico and West Indies southward in Brazil and up to Florida in North America and in Asia from Punjab southwards up to tropical Australia, in Madagascar, Angola, west tropical Africa and particularly in Nigeria. It also occurs in Japan (Text-fig. 1).

In India, this genus (Chowdhury, 1973), is found in Dehradun and Haldwani in Uttar Pradesh, Gujarat except Kachchh, Maharashtra, Goa, Kerala, Tamil Nadu, Orissa, Bihar, West Bengal and Assam. He is of the opinion that there are about seven species of this genus of which two are found in the orient, one in Africa and three in tropical America. Lloyd (1972), on the other hand, after examining the extensive herbarium material opines that the genus *Ceratopteris* can be divided into four species based solely on morphological characters. These include *C. richardii*, found in Africa and tropical region of America, *C. pteridoides* of South and North America, *C. cornuta* distributed from Africa to northern Australia and *C. thalictroides*, a highly polymorphic species of circum-tropical distribution. According to him the important diagnostic characters include spore number per sporangium, annulus cell number, spore size, floating or rooting habit, stipe width, shape and dissection of sterile fronds, and frequency of vegetative budding. Out of them *C. richardii* is the most distinct and uniform species and has only 16 spores per sporangium and they may be up to 150 μm in size. The remaining three species have 32 spores per sporangium. Llyod (1972) thinks that *C. thalictroides* is the most diverse morphologically and probably polytypic. Distinct populations of this species occur in Japan, Surinam and Central America.

The spores of *Ceratopteris* are very characteristic and can be easily identified in the dispersed condition. They are generally subtriangular-subcircular in shape with rounded apices and straight to slightly convex interapical margin. The trilete rays are generally distinct, uniformly broad and extend half to three-fourth radius. Exine costate, costae appear as bands, running



TEXT-FIG. 1 — Showing the present day distribution of *Ceratopteris* Brong. (Parkeriaceae).

more or less parallel to each other in one inter-radial area and its corresponding distal side. Generally one set of costae is found in each inter-radial area on the proximal side; they may arise on proximal side parallel to the trilete rays or at the ray ends. Three corresponding sets of costae on the distal side may also be juxtaposed on the distal polar region leaving a triangular area in between them.

No other spores have similar features and this is also true in the spores of *Anemia* and *Mohria* which also have costate trilete spores. But the spores of *Anemia* and *Mohria* have two distinct sets of costae on proximal and distal surfaces (Kar, 1979).

The fossil spores of *Ceratopteris* are known as *Striatriletes* van der Hammen emend. Kar (1979). Germeraad, Hopping and Muller (1968) instituted *Magnastriatites* also to accommodate this type of spores. But according to Kar (1979) *Magnastriatites* is nothing but a junior synonym of *Striatriletes*. The genus *Cicatricosisporites* Potonié & Gelletich (1933) also resembles *Striatriletes* in the presence of costae. The costae in *Cicatricosisporites*, however, are restricted either to proximal or distal side and run parallel to each other.

The spores assignable to *Striatriletes* have been reported from India by Meyer (1958), Baksi (1962, 1965), Biswas (1962), Banerjee (1964), Banerjee, Misra and Koshal (1973), Ghosh, Jacob and Lukose (1964), Sah and Dutta (1968), Salujha, Kindra and Rehman (1972, 1974), Nandi (1975), Kar (1979), Kar and Saxena (1981), Kar and Jain (1981) and others.

Germeraad, Hopping and Muller (1968) had the unique opportunity to work out surface and subsurface mateial of Caribbean region, Venezuela, Nigeria and Malayasia for number of years. They reported the occurrence of fossil spores of *Ceratopteris* from the Lower Oligocene to Pliocene from Caribbean, Nigeria and Borneo. They observed that the source areas of this species are the alluvial plain and swamps near the coast. *Ceratopteris* grows in these regions as a small acquatic fern in shallow water, on the margin of lakes and river banks. This environment is liable to rapid local facies changes and is distinctly marked in the pronounced quantitative fluctuation in past coastal sediments. In marine sediments, Germeraad, Hopping and Muller (1968) found the spores of *Ceratopteris* much rarer. They are, however, found in good quantities both in the shelf and geosynclinal facies of north-eastern India. Germeraad, Hopping and Muller (1968) remarked that the frequency of *Ceratopteris* spores in the Neogene of all the pantropical areas and their absence in the older Palaeogene and Cretaceous deposits indicate that the present day pantropical distribution of *Ceratopteris* may date only from the mid-Tertiary. They, however, observed that this is in contrast to the isolated systematic position and specialized morphology of the genus which is assumed to be of great antiquity. Its origin may have been local but as no ancestral forms are found this problem remains unsolved.

Copeland (1947) noted the extraordinary instability of the sporangium wall in *Ceratopteris* which has no parallel in other group of ferns. He remarked that the most probable affinity of *Ceratopteris* is to the Cheilanthes Group. If this supposition is true then the sporangium is to be regarded as degenerate, to the limit that in *C. pteridoides* it is rather a structureless sack holding the spores together. Copeland (1947) did not think *Ceratopteris* as primitive. The costate spores according to him recall those of *Orthiopteris*. He further observed that the degeneration of sporangial structure in *Ceratopteris* has taken it beyond easy inclusion in any family but there is no doubt that it has derived from some other families.

Whatever might be the origin of *Ceratopteris*, its subsequent development and dispersal in wide areas aound tropical-subtropical countries throughout the world in a comparatively small span of time is very striking. According to Croizat (1952) ferns and fern allies can be divided into two elements: (a) that had associated with the angiosperms from the beginning, and (b) which had not associated so but later absorbed within the angiospermous floras. The former overtops the latter because the former travelled with angiosperms which were themselves Antarctic. He also observed that non-angiospermous dispersal ought to be studied in a special manner because so far the origin of these plants are concerned they are in the dimmest night of the ages.

But the case of *Ceratopteris* is entirely different; it is even younger than the angiosperms and within roughly 50 million years it has spread its tentacles all over the world in the tropics. It is a matter of great palaeogeographical importance to decipher its original home and subsequent dispersal in both old and new worlds. In trying to explain the distribution of vegetable species and the paths they have followed, a better result may be attained by studying the ways in which they spread at the present time than by setting up hypotheses of tremendous convulsion of nature which can neither be proved or disproved (vide Willie in Croizat, 1952). Croizat (1952) also thought that dispersal being older, it is dispersal phenomenon that gives a clue to the maps that are relevant in the case and not the other way round. He also remarked that faulty thinking in fundamentals is beyond doubt responsible for 90 per cent of the difficulties in modern biogeography. The literature conclusively shows that dispersal cannot be approached constructively in any other way but with a good understanding of its magnitude in time and space.

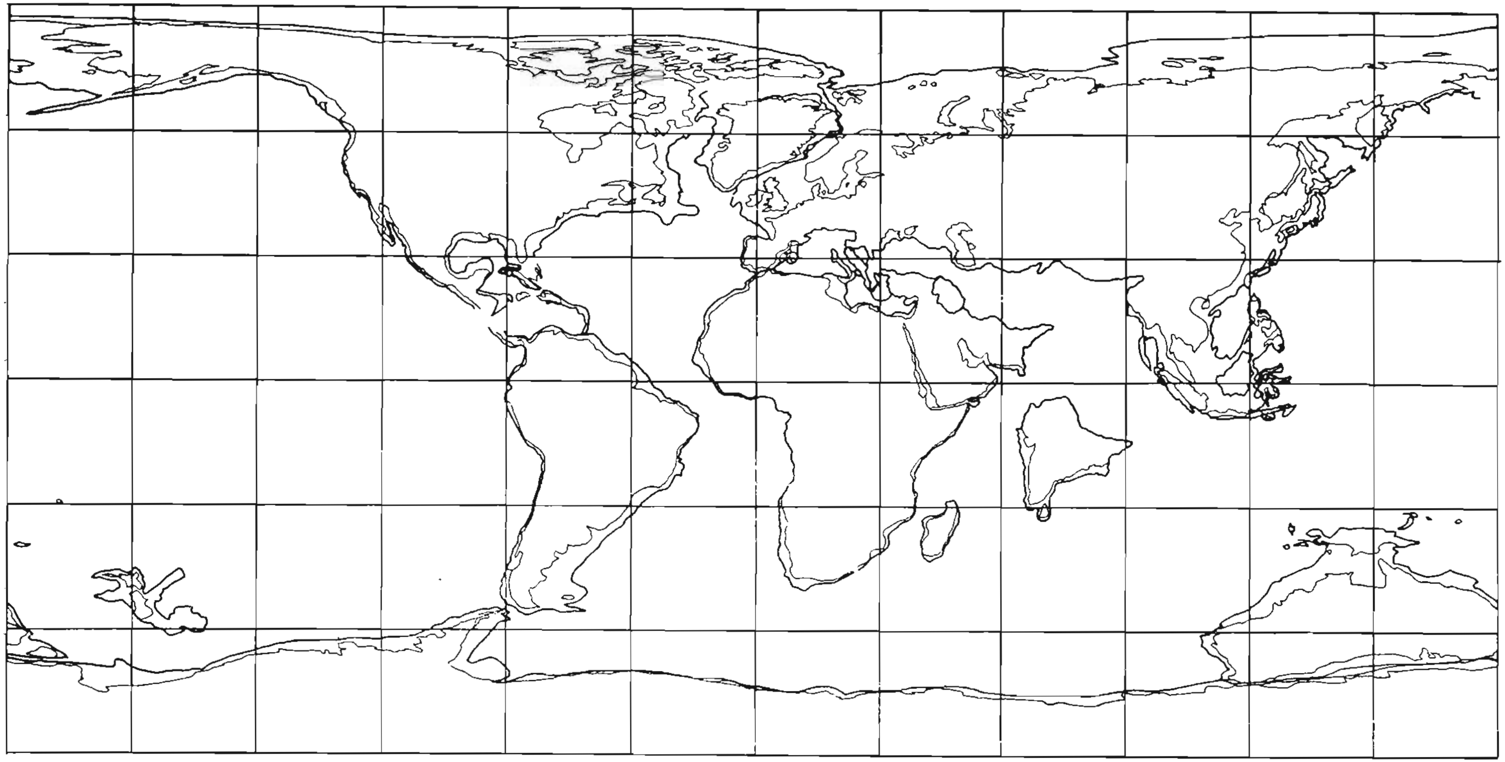
Thanks to the peculiar spore morphology of *Ceratopteris* and its association with potential oil bearing sedimentary rocks, the fossil history of this genus is quite precisely known. Germeraad, Hopping and Muller (1968) proposed several pantropical palynological zones of which *Proxapertites operculatus* Zone is the oldest and is probably Senonian in age. The next is the *Monoporites annulatus* Zone and the third in ascending order is *Verrucatosporites usmensis* Zone. In the latter zone there is sporadic occurrence of *Cicatricosisporites dorogensis* Potonié & Gelletich (1933) in the Caribbean area and in Paz del Rio section in Colombia.

In the presence of smaller foraminifera: *Globigerina ampliapertura*, *G. ciperoensis*, *Globorotalia opina opina* and *G. kugleri* in the Carribbean area the age of the overlying *Cicatricosisporites dorogensis* Zone may be assigned to Oligocene. In Nigeria, the same age is indicated by the presence of *Globigerina ciperoensis*, *G. ciperoensis angulisuturalis* and *Globorotalia kugleri*. It may be mentioned here that Trivedi, Ambwani and Kar (1981) has already pointed out that the specimen illustrated by Germeraad, Hopping and Muller (1968, pl. 2, fig. 2) as *Cicatricosisporites dorogensis* Potonié & Gelletich (1933) may not belong to *Cicatricosisporites* but to *Malayaeaspora* Trivedi, Ambwani & Kar (1981).

The next overlying *Magnastriatites howardi* Zone is marked by the first appearance of *Magnastriatites howardii*. As has been stated earlier, Kar (1979) made *Magnastriatites* as a junior synonym of *Striatriletes* van der Hammen emend. Kar (1979). According to Germeraad, Hopping and Muller (1968), in Paz Del Rio Section, Colombia and Benin West-1, Nigeria, the boundary is sharply defined. The age of this zone starts from the Lower Oligocene in Caribbean, Nigeria and Borneo and continues up to Pliocene.

In India, the history of the fossil spores of *Ceratopteris*, viz., *Striatriletes* is, however, different. Kar and Saxena (1981) worked out a bore-core near Rataria, southern Kachchh, Gujarat where they recorded *Striatriletes susannae* van der Hammen emend. Kar (1979) and *Striatriletes multicostatus* Kar & Saxena (1981) from the bore-core along with *Cheilanthoidspora enigmata*, *C. monoleta*, *Couperipollis kutchensis*, *Tricolpites reticulatus*, *Lakiapollis ovatus*, *Hystrichosphaeridium tubiferum*, *Oligosphaeridium complex*, *Cordosphaeridium gracilis* and *Hystrichokolpoma eisenacki*. On the basis of this palynological assemblage, Kar and Saxena (1981) assigned a Middle to Upper Eocene age. It may be pointed out here that there is no exposures of Upper Eocene rocks in Kachchh and thus a Middle Eocene age for the bore-core seems to be appropriate.

The palynological investigation of the Tertiary sediments in north-eastern India worked out by Baksi (1962, 1965, 1973), Biswas (1962), Sah and Dutta (1966, 1968), Dutta and Sah (1970), Banerjee and Misra (1972), Salujha, Kindra and Rehman (1972, 1974), Sein and Sah (1974), and others revealed that *Ceratopteris* spores occur for the first time in the Kopili Formation (Upper Eocene). On the basis of this spore, Sein and Sah (1975) demarcated the Middle Eocene (Sylhet Limestone) from the Upper Eocene. The percentage of this spore is further increased in Oligocene represented by the Barail Group in both shelf and geosynclinal sediments. In Miocene, this spore is equally abundant but gradually declines in Pliocene.



TEXT-FIG. 2 — Cylindrical equidistant map of the world (after Smith, Hurley & Briden, 1981) during Palaeocene. Note the position of India and its nearness to the east coast of Africa.

From the above information, it becomes apparent that the oldest fossil record of *Ceratopteris* spore is from the Middle-Upper Eocene in India while in Malayasia, Venezuela, Nigeria and Carribbean it starts from the Oligocene. In this context, the relative position of India during Eocene with reference to Africa, Malayasia and Australia may provide a new vista of knowledge hitherto unconsidered.

Smith and Briden (1977) and Smith, Hurley and Briden (1981) published a series of maps showing the wandering continents and their relative position from one another. They did not profess these maps without errors but certainly provide the basic position of the continents to formulate some hypotheses. They have also not shown the microcontinental islands in the oceans.

About 60 million years ago during Palaeocene they have placed India in the cylindrical equidistant map projection below the equator. The western coast of India was almost running parallel to the eastern coast of Africa and Madagascar was comparatively closely placed. India in this position was ideally placed for the propagation of *Ceratopteris* because it was almost in the realm of tropical zone. The modern distribution of *Ceratopteris* bespeaks with eloquence its love for the tropical subtropical climate. At that time Kachchh was nearer to equator than Assam and was also nearest to the eastern coast of Africa (Text-fig. 2).

Approximately about 40 million years ago during the Upper Eocene as shown in the cylindrical equidistant map by Smith, Hurley and Briden (1981), major part of India had already crossed the equator. The north-eastern India was almost in touch with Malayasia though north India was still quite away from the mainland of Laurasia.

During Lower Miocene about 20 million years ago, as depicted by Smith, Hurley and Briden (1981), the southern most tip of India has already passed equator and land connection between India and Laurasia firmly established.

Considering the wandering nature of India and its relative position in relation to other continents during Tertiary, it may be envisaged that during Middle-Upper Eocene *Ceratopteris* evolved in India. From the western coast of India, the genus migrated towards equatorial Africa and from there to tropical region of North and South America by crossing the Atlantic Ocean. The north-east India, particularly Assam also played an important role to disperse *Ceratopteris* in Malayasia and tropical Australia. Madagascar was perhaps populated through Africa and Japan through Malayasia.

As is well known that *Ceratopteris* is a herbaceous water fern which can survive only in fresh water, of warm climates. How could such a small plant disperse so quickly and how it could cross the Atlantic and other oceans are matters of speculation. Even if it is admitted that the Atlantic Ocean was not so wide during the Upper Eocene, it has to be assumed that the plant must have possessed a very effective means of dispersal. The credit perhaps goes to the robustly built costate spores for this. The spores might have travelled long distances with the help of favourable winds and water currents. Besides, some water fowls might have been instrumental in dispersing the adhering sticky spores into far off places. It would be no wonder if some birds also swallowed the spores along with mud and the undigested spores later came out to germinate in new places.

The overwhelming dominance of *Ceratopteris* spores in Oligocene and Miocene sediments of India and also its regular occurrence in similar sediments of Caribbean, Nigeria and Malayasia makes it a big palaeogeographical province which may be called as *Ceratopteris* or *Striatriletes* province.

REFERENCES

BAKSI, S. K. (1962). Palynological investigation of Simsang River Tertiaries, South Shillong Front, Assam. *Bull. geol. Soc. India*, **26**: 1-21.

BAKSI, S. K. (1965). Stratigraphy of Barail Series in southern part of Shillong Plateau, Assam, India. *Bull. Am. Assoc. Petr. Geol.*, **49** (12): 2282-2288.

BAKSI, S. K. (1973). Significant pollen taxa in the stratigraphical analysis of the Tertiary sediments of Assam. *Proc. Autumn School organized by B.S.I.P. at Kodaikanal Sept.* : 502-515.

BANERJEE, D. (1964). A note on the microflora from Surma (Miocene) of Garo Hills, Assam. *Bull. geol. min. metall. Soc. India*, **29**: 1-8.

BANERJEE, D. & MISRA, C. M. (1972). Hystrichosphaerids in the Tertiary formations of Assam and Tripura. *Proc. Sem. Palaeopalynol. Indian Stratigr. Calcutta, 1971*: 207-211.

BANERJEE, D., MISRA, C. M. & KOSHAL, V. N. (1973). Palynology of the Tertiary subcrops of Upper Assam. *Palaeobotanist*, **20** (1): 1-6.

BISWAS, B. (1962). Stratigraphy of the Mahadeo, Langpar, Cherra and Tura formations, Assam, India. *Bull. geol. Min. metall. Soc. India*, **25**: 1-48.

CHOWDHURY, N. P. (1973). *The Pteridophyte Flora of the Upper Gangetic Plain.* Navayug Traders, New Delhi.

COPELAND, E. B. (1947). *Genera filicum.* Waltham, U.S.A.

CROIZAT, L. (1952). *Manual of Phytogeography.* Uitgeverij-Junk, The Hague.

GERMERAAD, J. H., HOPPING, C. A. & MULLER, J. (1968). Palynology of Tertiary sediments from tropical areas. *Rev. Palaeobot. Palynol.*, **6** (344): 189-348.

GHOSH, A. K., JACOB, A. & LUKOSE, N. G. (1964). On the spores of Parkeriaceae and Schizaeaceae from India. *Bull. bot. Soc. Bengal*, **17** (1 & 2): 23-28.

HOOKER, W. J. & BAKER, J. G. (1868). *Synopsis Filicum or a Synopsis of all known ferns.* London.

JOHNSON, B. D., POWELL, C. M. & VEEVERS, J. J. (1976). Spreading history of the eastern Indian Ocean and greater India's northward flight from Antarctica and Australia. *Bull. geol. Soc. Am.*, **87**: 1560-1566.

KAR, R. K. (1979). Palynological fossils from the Oligocene sediments and their biostratigraphy in the district of Kutch, western India. *Palaeobotanist*, **26** (1): 16-45.

KAR, R. K. & JAIN, K. P. (1981). Palynology of Neogene sediments around Quilon and Varkala, Kerala coast, South India-2. Spores and pollen grains. *Palaeobotanist*, **27** (2): 113-131.

KAR, R. K. & SAXENA, R. K. (1981). Palynological investigation of a bore-core near Rataria, southern Kutch, Gujarat. *Geophytology*, **11** (2): 103-124.

LLOYD, R. M. (1972). Species delineation in the genus *Ceratopteris* (Parkeriaceae)-Abstract. *Am. J. Bot.*, **59**: 676.

LONGWELL, C. R. (1963). My estimate of the continental drift concept in: *Continental drift a symposium, Hobart, Tasmania*: 1-12.

McKENZIE, D. & SCLATER, J. G. (1971). The evolution of Indian Ocean since the late Cretaceous. *J. geophys. Res. astr. Soc.*, **25**: 437-528.

MEYER, B. L. (1958). Palynological investigations of some samples from Nahorkatiya, Assam. *J. palaeont. Soc. India*, **5** (3): 156-157.

NANDI, B. (1975). Palynostratigraphy of the Siwalik Group of Punjab. *Him. Geol.*, **5**: 411-424.

POTONIÉ, R. & GELLETICH, J. (1933). Ueber Pteridophyten-Sporen einer eocänen Braunkohle aus Dorog in Ungarn. *Sber. Ges. naturf. Freunde Berl.*: 517-526.

SAH, S. C. D. & DUTTA, S. K. (1966). Palynostratigraphy of the Tertiary sedimentary formations of Assam: 2. Stratigraphic significance of spores and pollen in the Tertiary succession of Assam. *Palaeobotanist*, **16** (2): 177-195.

SALUJHA, S. K., KINDRA, G. S. & REHMAN, K. (1972). Palynology of the South Shillong Front Part-1: The Palaeogene of Garo Hills. *Proc. Sem. Palaeopalynol. Indian Stratigr. Calcutta, 1971*: 265-292.

SALUJHA, S. K., KINDRA, G. S. & REHMAN, K. (1974). Palynology of the South Shillong Front, Part-II. The Palaeogenes of Khasi and Jaintia Hills. *Palaeobotanist*, **21** (3): 267-284.

SEIN, M. K. & SAH, S. C. D. (1974). Palynological demarcation of the Eocene-Oligocene sediments in the Jowai-Badarpur road section, Assam. *Symp. Stratigr. Palynol., Calcutta, 1971*: 99-105.

SMITH, A. G. & BRIDEN, J. C. (1977). *Mesozoic and Cenozoic Palaeocontinental Maps.* Cambridge Univ. Press, Cambridge.

SMITH, A. G., HURLEY, A. M. & BRIDEN, J. C. (1981). *Phanerozoic Palaeocontinental World Maps.* Cambridge Univ. Press, Cambridge.

TRIVEDI, B. S., AMBWANI, K. & KAR, R. K. (1981). *Malayaeaspora costata* gen. et sp. nov. from the Tertiary coal of Malaya. *Curr. Sci.*, **50** (20): 910-911.

TRIVEDI, B. S., AMBWANI, K. & KAR, R. K. (1983). Palynological studies on the Tertiary coal from Malaya with comments on its age. *J. Indian bot. Soc.*

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PALYNOLOGICAL DATING OF JHINGURDAH SEAM, SINGRAULI COALFIELD: A REAPPRAISAL

R. S. TIWARI & SURESH C. SRIVASTAVA

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

ABSTRACT

A re-examination of the mioflora of the thickest coal seam of India, the Jhingurdah seam in Singrauli coalfield, Madhya Pradesh, has shown the presence of the genera *Indospora*, *Gondisporites*, *Densoisporites*, *Kendosporites*, *Thymospora*, *Corisaccites*, *Guttulapollenites*, *Lunatisporites* and *Falcisporites* associated with a striated-disaccate-rich assemblage. The mioflora is closely comparable with the known Raniganj miofloras. The presence of the genera *Lophotriletes*, *Brevitriletes*, *Latosporites*, *Barakarites*, *Parastriopollenites* and *Scheuringipollenites* indicates a partial continuity of the older biozones into the younger one.

Key-words — Palynology, Mioflora, Jhingurdah Seam, Singrauli Coalfield (India).

साराँश

सिंगरौली कोयला-क्षेत्र के झिगुरदाह स्तर का परागाणविक कालनिर्धारण : एक समालोचना – राम शंकर तिवारी एव सुरेश चन्द्र श्रीवास्तव

मध्य प्रदेश के सिंगरौली कोयला-क्षेत्र में विद्यमान भारत के सबसे मोटे कोयले के झिगुरदाह स्तर के सूक्ष्मवनस्पतिजात के पुन: अध्ययन से रेखीय-द्विकोष्ठीय तत्वों से भरपूर एक समुच्चय से सहयुक्त इन्डोस्पोरा, गोन्डिस्पोराइटिस, डेन्सोस्पोराइटिस, कैन्डोस्पोराइटिस, थाइमोस्पोरा, कोरिसेक्काइटिस, गुटुलापोलिनाइटिस, ल्यूनाटिस्पोराइटिस एवं फालसीस्पोराइटिस नामक वंशों की उपस्थिति व्यक्त हुई है। यह सूक्ष्मवनस्पतिजात रानीगंज से विदित सूक्ष्मवनस्पतिजातों से घनिष्ठ तुलनीय है। लोफ़ोट्राइलिटीज़, ब्रेविट्राइलिटीज़, लाटोस्पोराइटिस, बराकाराइटिस, पैरास्ट्रिओपोलिनाइटिस एवं श्यौरिन्गिपोलिनाइटिस नामक वंशों की उपस्थिति से अधिक आयु वाले जैवमंडलों की कम आयु वाले जैवमंडलों में आंशिक निरन्तरता व्यक्त होती है।

INTRODUCTION

THE Lower Gondwana sediments representing Talchir, Barakar, Barren Measures and Raniganj formations are well developed in the Singrauli Coalfield (Latitude 23° 47′ to 24° 12′N & longitude 81° 45′ to 82° 48′E). The Barakar Formation is overlain by the Barren Measure Formation which is about 125 m in thickness having coarse-grained to gritty ferruginous, yellow sandstones. Above the latter, the 400 m thick Raniganj Formation contains fine to coarse-grained felspathic sandstones, white and grey clays with ferruginous bands, carbonaceous shale and coal seams. The Jhingurdah seam (164 m) belongs to the last formation (late Permian; for detailed geological information see Ahmad, 1955; Basu, 1965). However, Bharadwaj and Sinha (1969a) reported that the Jhingurdah coal deposit contains a more or less uniform mioflora having a closer resemblance with the Upper Barakar miofloras. Their conclusion is based upon the prominence of the following genera:

Non-striate disaccate — *Scheuringipollenites*, *Ibisporites*, *Vesicaspora*.

Striate-disaccate — *Faunipollenites*, *Striatopodocarpites*.

Apiculate trilete — *Cyclogranisporites*, *Lophotriletes*, *Brevitriletes*, *Horriditriletes*.

Quantitatively, the above three groups of spores and pollen grains range from 20-30 per cent each (Tiwari, 1971; histogram 2). All the more, certain miospore taxa, characteristic of the Raniganj Formation, e.g. *Indospora*, *Gondisporites*, *Thymospora* and *Densipollenites* were reported to be absent (or rarely present) in the Jhingurdah seam by Bharadwaj and Sinha (1969a) which further supported their contention that this seam contains a mioflora closely comparable to the Barakar miofloras.

Does this palynoflora really belongs to the Barakar age ? Recent data on palynology of the Indian Lower Gondwana have provided a wider basis for understanding the lateral and vertical variations of palynofloras. A synthesis of Barakar palynofloras (Tiwari, 1974) has further brought out some new trends of variations in different basins. In view of these data, *vis-a-vis* the existing discrepancy in geological and palynological observations, Dr Bharadwaj (personal communication) suggested a reinvestigation of the Jhingurdah seam pollen-spore assemblage and the present work is a sequel to the same.

INVESTIGATIONS

In all, 15 compound samples were prepared from Bore-hole NCSJ-4, out of which each sample represents the coaly and shaly zones separately. The following list gives the present sample numbers as JH-1 to JH-15 and the corresponding sample numbers given by Bharadwaj and Sinha (1969a; text-fig. 1; histogram 1).

PRESENT SAMPLE NO.	CORRESPONDING SAMPLE NOS. OF BHARADWAJ AND SINHA (1969a)	DEPTH FROM THE SURFACE IN METERS	LITHOLOGY
JH-1	1 to 12	9.15-22.46	Coal
JH-2	13 to 14	22.46-24.30	Coaly shale and coal
JH-3	15 to 57	24.80-63.95	Coal
JH-4	58 to 66	63.95-75.80	Shale
JH-5	67	73.80-75.34	Coal and thin shale band
JH-6	68 to 70	75.34-78.22	Shaly coal and coal
JH-7	71 to 73	78.22-81.80	Coal
JH-8	74	81.80-83.35	Coaly shale
JH-9	75 to 83	83.35-92.75	Coal
JH-10	84 to 92	92.75-98.45	Mainly shale with thin coal
JH-11	93 to 112	138.50-147.56	Thin coal and shale bands
JH-12	113 to 121	147.56-154.62	Mainly coal with thin shale
JH-13	122	161.48-161.98	Coal
JH-14	123 to 125	161.98-163.43	Shale
JH-15	126	163.43-164.31	Coal

Two hundred specimens were counted at generic level. Sample nos. JH-7, 11, 14 and 15 did not yield enough miospores and hence were left from the quantitative considerations. Several slides from each sample were also thoroughly scanned to record rare species. The analysis revealed the presence of 44 miospore genera. Their frequency has been given in Table 1 and a diagrammatic representation of the quantitatively important taxa is shown in Histogram 1.

GENERIC DEVIATION

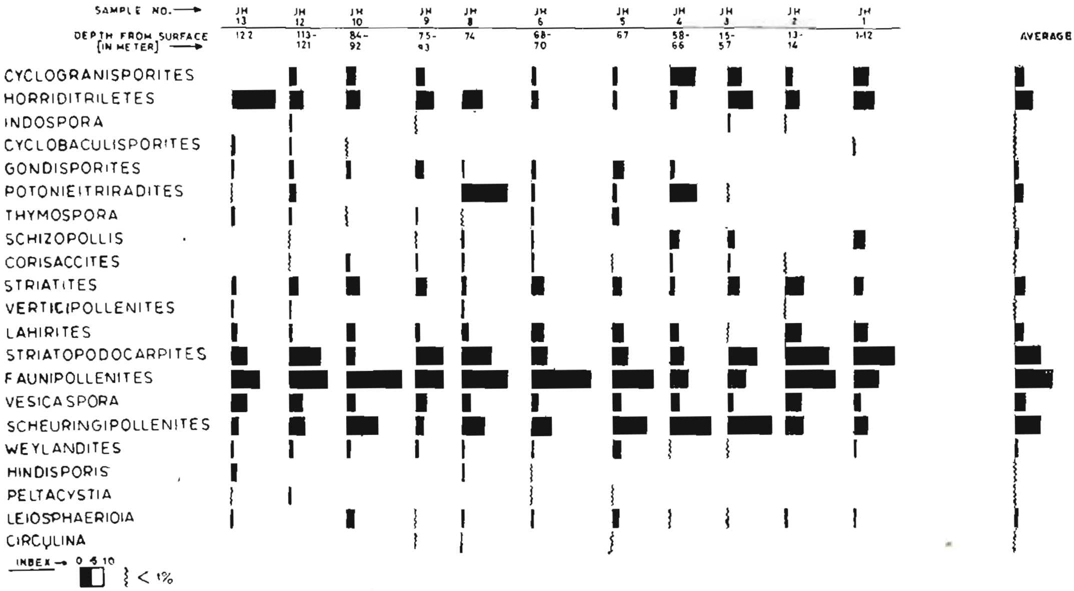
Qualitative — The following genera, found by us, were not recorded by Bharadwaj and Sinha (1969, 1969a) and Sinha (1969, 1972): *Guttulapollenites*, *Corisaccites*,, *Densoisporites*, *Kendosporites*, *Falcisporites*, *Lunatisporites* and *Hindipollenites*. This record of these genera is qualitatively important.

Quantitative — Histogram 2 given by Bharadwaj and Sinha (1969a) suggests that *Scheuringipollenites* records a general dominance in the lower-half of the coal seam, while *Faunipollenites* remains subdominant. In the upper-half of the coal seam a reverse trend was present; on an average, the nonstriate-disaccate genera (*Scheuringipollenites*, *Ibisporites*) and striate-disaccate genera (*Faunipollenites*, *Striatopodocarpites*) almost balance each other in frequency, although the former group has a little edge over the latter.

The present study shows (Histogram 1) that nonstriate-disaccate and striate-disaccate genera are represented in almost a ratio of 3:4. The striate-disaccate group of pollen, in general, dominates the spectrum from bottom up to the top of the coal seam, while nonstriate-disaccates remain subdominant. The zonate-cingulate miospores occur persistently almost in all the samples which were earlier recorded as rare. The dominance of striate-disaccates suggests a younger aspect than what has been suggested earlier for this coal seam. Also, the occurrence of cingulate-zonate triletes in significant percentages (*Potonieitriradites*— 20% in sample no. 8) has not been reported earlier from the Barakar Formation. The break-up of the dominant, sub-dominant, common and rare genera as found in the present

TABLE 1 — SHOWING PERCENTAGE DISTRIBUTION OF MIOSPORES IN BORE-HOLE NO. NCSJ-4, JHINGURDAH SEAM, MOHER BLOCK, SINGRAULI COALFIELD

MIOSPORE GENERA / SAMPLE NOS. JH	13	12	10	9	8	6	5	4	3	2	1	AVERAGE
DEPTH IN METER	122	113-121	84-92	75-83	74	68-70	67	58-66	15-57	13-14	1-12	
Leiotriletes	1.0	2.0	0.5	2.0	1.0	0.5	2.0	1.0	2.0	—	—	1.1
Callumispora	1.0	—	—	—	—	—	—	—	—	—	—	0.1
Cyclogranisporites	—	3.0	4.0	4.0	—	2.0	2.0	11.0	6.0	3.0	6.5	3.7
Lophotriletes	1.0	—	1.5	0.5	1.0	0.5	0.5	2.0	1.0	—	2.0	0.9
Brevitriletes	1.5	4.0	1.5	1.0	0.5	2.0	0.5	0.5	0.5	1.0	2.0	1.4
Horriditriletes	19.0	6.0	6.0	8.0	9.0	3.0	2.0	3.0	11.0	6.0	9.0	7.4
Microbaculispora	3.0	3.0	—	—	—	—	—	0.5	—	—	—	0.6
Indospora	—	1.0	—	0.5	—	—	—	—	1.0	0.5	—	0.3
Cyclobaculisporites	1.5	1.0	0.5	—	—	—	—	—	—	—	0.5	0.3
Microfoveolatispora	2.5	1.0	—	5.0	1.0	1.0	2.0	3.0	2.0	—	0.5	1.6
Gondisporites	1.0	2.0	2.0	3.5	1.0	2.0	5.0	2.0	—	—	—	1.6
Potonieitriradites	0.5	3.0	—	—	20.0	1.5	2.0	12.0	0.5	—	—	3.6
Latosporites	10.5	5.0	1.0	8.0	1.0	3.0	4.0	3.0	2.0	1.5	4.0	4.0
Thymospora	1.5	1.0	0.5	1.0	0.5	1.0	3.0	—	—	—	—	0.7
Parasaccites	—	1.0	0.5	0.5	—	1.0	—	—	—	—	—	0.2
Tuberisaccites	1.0	—	—	—	—	—	—	—	—	—	—	0.09
Barakarites	1.0	—	—	—	—	—	1.0	0.5	0.5	—	—	0.1
Striomonosaccites	—	—	—	—	—	—	—	0.5	—	—	—	0.04
Cuneatisporites	1.5	0.5	—	1.0	1.0	—	—	0.5	2.0	0.5	1.0	0.7
Platysaccus	3.0	1.0	4.0	6.0	2.0	4.0	6.0	6.0	8.0	4.0	9.0	4.8
Schizopollis	—	0.5	—	0.5	1.0	1.0	—	4.0	3.0	—	5.0	1.4
Corisaccites	—	0.5	1.5	1.0	1.0	1.0	0.5	1.0	1.0	0.5	—	0.8
Striatites	2.0	4.0	6.0	5.0	2.0	5.5	4.0	2.0	5.0	8.0	4.0	4.3
Primuspollenites	1.5	4.0	4.0	4.0	2.0	2.0	1.5	2.0	4.0	2.0	3.0	2.7
Rhizomaspora	—	1.0	2.0	—	—	—	—	—	—	—	—	0.3
Verticipollenites	1.0	1.0	—	—	1.0	—	—	—	—	0.5	—	0.3
Lahirites	2.5	1.5	4.0	2.0	3.0	5.5	5.0	4.0	0.5	7.0	6.0	3.7
Hindipollenites	0.5	1.0	—	0.5	1.0	—	—	—	—	1.0	—	0.4
Striatopodocarpites	7.0	14.0	4.0	12.0	13.0	7.0	7.0	6.0	13.0	19.0	18.0	11.0
Faunipollenites	12.5	17.0	24.0	13.0	20.0	26.0	18.0	8.0	8.0	22.0	11.0	16.2
Crescentipollenites	1.0	—	—	—	—	—	—	—	0.5	1.0	1.0	0.3
Illinites	0.5	—	1.0	0.5	0.5	—	—	—	0.5	—	—	0.3
Vesicaspora	7.0	6.0	4.0	5.0	4.0	3.0	4.0	4.0	2.5	7.0	3.0	4.5
Scheuringipollenites	3.5	7.0	14.0	3.5	10.0	19.0	15.0	18.0	19.0	8.0	6.0	11.1
Ibisporites	2.5	4.0	4.0	7.0	—	5.0	6.0	4.0	4.5	6.0	4.0	4.2
Weylandites	1.0	2.0	2.0	1.5	1.0	1.0	4.0	0.5	0.5	—	1.0	1.2
Pilasporites	2.5	1.0	3.0	1.5	1.0	1.0	1.0	0.5	—	—	2.0	1.2
Hindisporis	2.5	—	—	—	1.0	0.5	—	—	—	—	—	0.4
Balmeella	1.0	—	1.0	—	—	—	—	—	—	—	—	0.2
Peltacystia	0.5	1.0	—	—	—	0.5	0.5	—	—	—	—	0.2
Leiosphaeridia	1.0	—	3.5	0.5	1.0	1.0	3.0	0.5	0.5	1.0	1.0	1.2
Spongocystia	0.5	—	—	1.0	—	0.5	—	—	—	—	—	0.2
Circulina	—	—	—	0.5	0.5	—	0.5	—	—	—	—	0.1
Striasulcites	—	—	—	—	—	—	—	—	—	0.5	0.5	0.1



Histogram 1 — Percentage frequency of important miospore genera through various levels in the Jhingurdah Seam.

analysis is given below (mean of the percentage is given in parenthesis):

1. Dominant:
   Faunipollenites 8-26% (16.2%)
2. Subdominant:
   Striatopodocarpites 4-19% (11%)
   Scheuringipollenites 3.5-19% (11.1%)
   Horriditriletes 2-19% (7.4%)
3. Common:
   Platysaccus 1-9— (4.8%)
   Vesicaspora 2.5-7% (4.5%)
   Striatites 2-8% (4.3%)
   Ibisporites 2.5-7% (4.2%)
   Latosporites 1-10.5% (4.0%)
   Lahirites 0.5-7% (3.7%)
   Potonieitriradites 0-20% (3.6%)
   Primuspollenites 1.5-4% (2.7%)
4. Rare:
   a. Between 1 and 2 per cent
   Leiotriletes, *Brevitriletes*, *Microfoveolatispora*, *Verrucosisporites*, *Gondisporites*, *Corisaccites*, *Falcisporites*, *Guttulapollenites*, *Schizopollis*, *Weylandites*, *Pilasporites*, *Leiosphaeridia*.
   b. Less than 1 per cent:
   Callumispora, *Lophotriletes*, *Microbaculispora*, *Indospora*, *Kendosporites*, *Cyclobaculisporites*, *Thymospora*, *Parasaccites*, *Cuneatisporites*, *Rhizomaspora*, *Verticipollenites*, *Crescentipollenites*, *Lunatisporites*, *Hindipollenites*, *Illinites*, *Hindisporis*, *Balmeela*, *Peltacystia*, *Spongocystia*, *Circulina* and *Striasulcites*.

The above listed miospores can be segregated into 10 groups. The mean percentage frequencies of these groups are as follows:

MIOSPORE GROUPS	MEAN PERCENTAGES
Apiculates triletes	15.0
Varitriletes	2.5
Zonate cingulates	5.2
Monoletes	3.7
Monosaccates (girdling type)	0.5
Striate-disaccates	38.5
Reticuloid striate-disaccates	2.9
Nonstriate-disaccates	27.0
Monocolpates	1.3
Alete and others	3.4

MIOFLORAL COMPARISONS

Succession in Singrauli Coalfield — As it has been stated earlier, the Jhingurdah seam, the youngest seam of the Coalfield, overlies the Barren Measures which in its turn overlie the Barakar containing Panipahari, Khadia,

TABLE 2 — SHOWING PERCENTAGE OF VARIOUS MIOSPORE GROUPS IN JHINGURDAH SEAM, SINGRAULI COALFIELD, INDIA

MIOSPORE GROUPS	SAMPLE NOS. JH/ 13 DEPTH IN METER 122	12 113-121	10 84-92	9 75-83	8 74	6 68-70	5 67	4 58-66	3 15-57	2 13-14	1 1-12	AVERAGE
Apiculate triletes	25.0	16.0	14.0	15.5	11.5	8.0	7.0	17.5	20.5	10.0	20.0	15.0
Varitriletes	5.5	5.0	—	5.5	1.0	1.0	2.0	3.5	3.0	0.5	0.5	2.5
Zonate triletes	1.5	5.0	2.0	3.5	21.0	3.0	7.0	14.5	0.5	—	—	5.2
Monoletes	12.0	6.0	1.5	9.0	1.5	4.0	7.0	3.0	2.0	1.5	4.0	3.7
Monosaccates	1.0	1.0	0.5	0.5	—	1.0	1.0	0.5	0.5	—	—	0.5
Nonstriate-disaccates	18.0	18.5	27.0	23.0	17.5	31.0	31.0	32.5	36.5	25.5	23.0	27.0
Striate-disaccates	26.5	39.5	39.5	34.0	42.0	46.0	35.0	25.0	32.0	59.0	45.0	38.5
Reticuloid disaccates	1.5	5.0	6.0	4.0	2.0	2.0	1.0	2.0	4.0	2.0	3.0	2.9
Colpates	1.0	2.0	2.0	1.5	1.0	1.0	4.0	0.5	0.5	—	1.0	1.3
Aletes	8.0	2.0	7.5	3.5	2.5	3.0	5.0	1.0	0.5	1.5	3.5	3.4

Purewa, Turra and Kota coal seams in descending order. The palynoflora of the Barren Measures of this area as well as Panipahari and Khadia seams is not known. There is, therefore, a gap in palynological information between the Purewa seam and Jhingurdah seam.

The mioflora of Purewa seam is typical of the Middle Barakar in having *Scheuringipollenites* as the dominant genus. The striate-disaccates are not prominent while the apiculate triletes are significant in this seam (Tiwari, 1969). The Jhingurdah seam, on the other hand, contains striate-disaccate as dominant group. *Scheuringipollenites* declines to more than half of its representation as compared to its position in Purewa seam. Khadia and Panipahari seams, successively overlying the Purewa seam, belong to the Upper Barakar Formation (also Basu, 1965) as they are conformably overlain by the Barren Measure Formation.

Miofloristic transgressions — It is now well established that the nonstriate-disaccate genera (e.g. *Scheuringipollenites*, *Ibisporites*, etc.) are dominant in the Middle Barakar mioflora. They decline in the Upper Barakar where the striate-disaccate genera rise to become almost the dominant elements (Tiwari, 1974). The Upper Barakar mioflora, therefore, is the beginning of "striate-disaccate phase" which continues through Barren Measures to the Raniganj mioflora. Broadly speaking, the striate-disaccate dominant phase transgresses the lithostratigraphic horizons and cuts across three formations, i.e. Upper Barakar, Barren Measures and Raniganj.

Obviously, the palynological differentiation of these stages poses certain problems. In such a discrimination, particularly of isolated cases, the older or the younger affinity of the spore-pollen assemblage has to be carefully determined and the general evolutionary level of mioflora in question has to be ascertained. Normally, the quantitative incidences decide the relative position of any mioflora but in the case where such differentiations are difficult, certain subtle qualitative indicators are very useful.

In case of Jhingurdah seam, the genera *Faunipollenites*, *Striatopodocarpites*, *Scheuringipollenites* and *Horriditriletes* contribute about 45 per cent of the mioflora. As such, there is an apparent resemblance of this mioflora with that of the Upper Barakar mioflora but the presence of *Indospora*, *Gondisporites*, *Thymospora*, *Kendosporites*, *Guttulapollenites*, *Corisaccites*, *Falcisporites*, *Lunatisporites* and *Verticipollenites* rules out its being equivalent to the Barren Measures mioflora. Although in all other Raniganj miofloras the striate-disaccate dominance is much more pronounced than what we find in the Jhingurdah seam, yet the general resemblance between the two is quite convincing. It could, however, be possible that in the Singrauli Coalfield the process of vertical variation was relatively slow. In other words, a partial transgression of palynozone seems to have taken place. Nevertheless, in the tendency of qualitative and quantitative behaviour, the Jhingurdah mioflora corresponds more closely with those miofloras which are known from the Raniganj Formation and this result also corroborates the lithological observations.

CONCLUSION

The foregoing account indicates that the resemblance of the mioflora in Jhingurdah coal seam with that of the Barakar mioflora is apparent rather than real and shows a tendency of the influence of older biozone into the younger lithostratigraphic zone with a somewhat less-than-expected change. The Raniganj-affiliation of the Jhingurdah seam is, however, supported by qualitatively important miospore genera in its assemblage. The indications of an older age are absent. Thus, the palynological study supports the stratigraphical position of the Jhingurdah seam to be homotaxial with the Raniganj Formation.

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REFERENCES

AHMAD, F. (1955). The Singrauli Coalfield. *Indian Minerals*, **9** (4): 318.

BASU, A. (1965). General geology of the north eastern part of the Singrauli Coalfield, M.P. *Q. Jl geol. Min. metall. Soc. India*, **37** (1): 29-34.

BHARADWAJ, D. C. & SINHA, V. (1969). Some new miospores from Lower Gondwana coals, pp. 7-16 in H. Santapau *et al.* (eds) — *J. Sen Memorial Vol.* Bot. Soc. Bengal, Calcutta.

BHARADWAJ, D. C. & SINHA, V. (1969a). Sporological succession and age of Jhingurdah Seam, Singrauli Coalfield, M.P., India. *Palaeobotanist*, **17** (3): 275-287.

SINHA, V. (1969). Some "Acritarchs" and other microfossils from Barakar Stage of Lower Gondwanas, India. *Palaeobotanist*, **17** (3): 326-331.

SINHA, V. (1972). Sporae dispersae from Jhingurdah Seam, Singrauli Coalfield (M.P.), India. *Palaeobotanist*, **19** (2): 175-201.

TIWARI, R. S. (1969). Sporological succession in Purewa seam, Singrauli Coalfield (M.P.), pp. 93-100 in H. Santapau *et al.* (eds) — *J. Sen Memorial Vol.* Bot. Soc. Bengal, Calcutta.

TIWARI, R. S. (1971). Sporological succession in Kota and Turra seams, Singrauli Coalfield (M.P.), India. *Palaeobotanist*, **18** (3): 264-269.

TIWARI, R. S. (1974). Inter-relationships of the palynofloras in Barakar Stage (Lower Gondwana), India. *Geophytology*, **4** (2): 111-129.

EXPLANATION OF PLATE

(All magnifications. × 500)

1. *Lunatisporites* (Lesch.) Bharad., 1974; slide no. 6660.
2. *Lueckisporites* Pot. & Kl., 1954; slide no. 6660.
3. *Vitreisporites* (Lesch.) Janson., 1962; slide no. 6657.
4. *Corisaccites* Venkat. & Kar, 1966; slide no. 6657.
5. *Guttulapollenites* (Goubin) Venkat. & Kar, 1967; slide no. 6656.
6. *Lueckisporites* Pot. & Kl., 1954; slide no. 6655.
7. *Kendosporites* (Sal.) Surange & Chandra, 1975; slide no. 6660.
8. *Indospora* Bharad., 1962; slide no. 6660.
9. *Microbaculispora* Bharad., 1962; slide no. 6652.
10. *Gondisporites* Bharad., 1962; slide no. 6660.
11. *Weylandites* Bharad. & Sriv., 1969; slide no. 6658.
12. *Verrucosisporites* (Ibr.) Smith *et al.*, 1964; slide no. 6660.
13. *Falcisporites* (Lesch.) Kl., 1963; slide no. 6659.
14. *Distriatites* Bharad., 1962; slide no. 6654.
15. *Hindipollenites* Bharad., 1962; slide no. 6653.

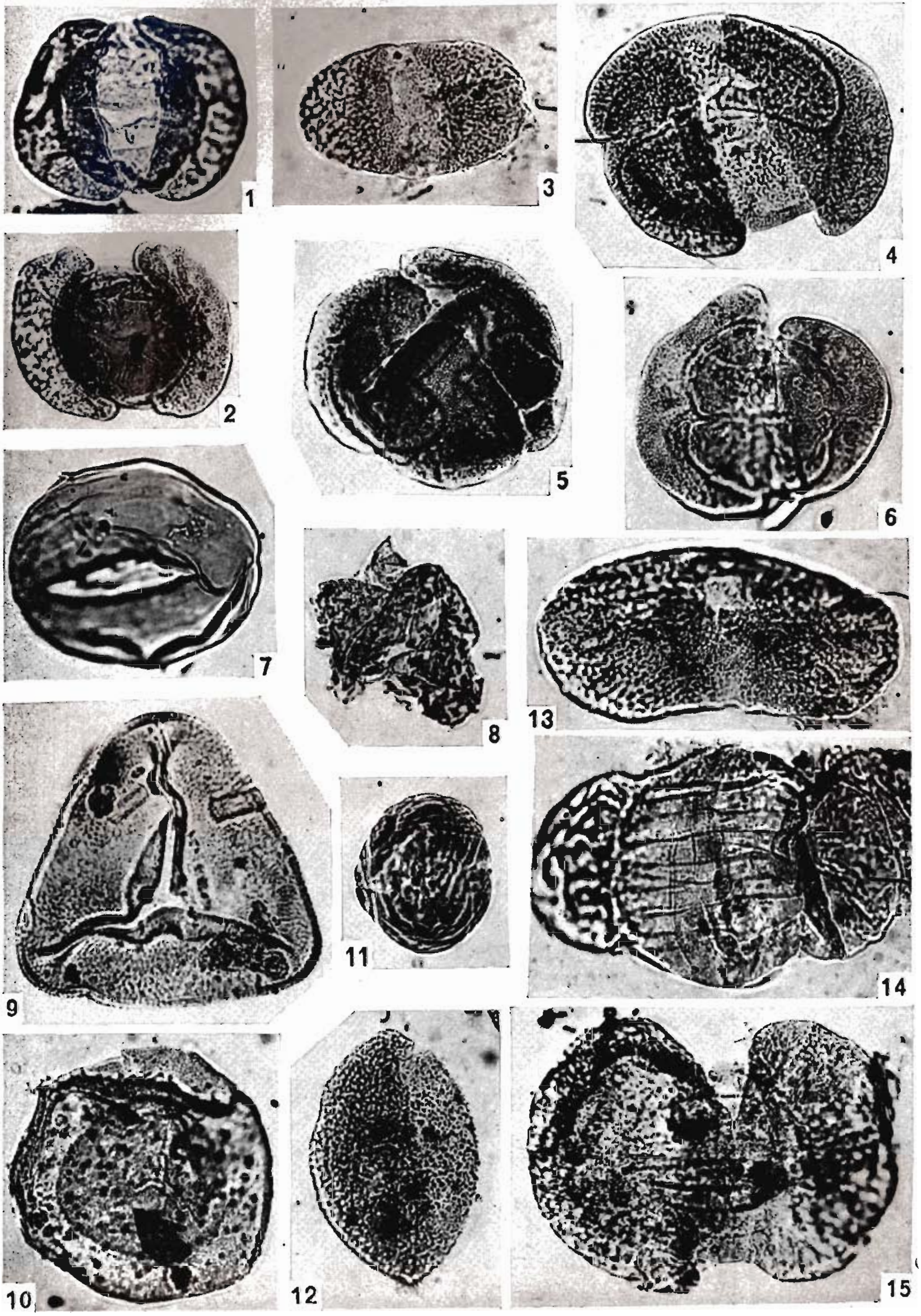

PLATE 1