MICROFLORAL ASSEMBLAGE FROM SUBATHU SEDIMENTS OF SIMLA HILLS*

S. K. SALUJHA, N. C. SRIVASTAVA[1] and M. S. RAWAT
Research & Training Institute, Oil & Natural Gas Commission, Dehradun

ABSTRACT—The present paper deals with a detailed palynological investigation of the Subathu sediments exposed in Simla hills. A total of 28 genera and 45 species of various spores, pollen grains, hystrichosphaerids and algal remains are recovered along with many indeterminate forms. The microfloral assemblage is indicative of a Lower Eocene age for the Subathu sediments under investigation. Hystrichosphaerids are recorded in good number and indicate the deposition of these sediments to have taken place under shallow marine conditions.

INTRODUCTION

The Subathu sediments are widely distributed along the Himalayan foot-hill zone of Simla and Garhwal as far as Nainital and near Riasi, north of Jammu. These are represented by red, green and grey shales with limestone bands and occasional sandstones. The marine nature of Subathu sediments and the possible source rock characters attracted the attention of Geologists long back, but detailed study of these sediments has been taken up for the first time in the laboratories of Research and Training Institute. In this paper an attempt has been made to study the spores, pollen grains and other associated microfossils of these sediments with a view to evaluate their age and palaeoecology. Earlier to this, some work has also been done by (Mrs.) Mathur (1963, 1964, 1965) wherein have been published short reports on the occurrences of *Pediastrum*, *Botryococcus* and other microflora. Raina (1952) of Geological Survey of India, Chandra *et al.*, (1958), Talukdar *et al.*, (1959), Raiverman *et al.*,(1961) and Chakraborty *et al.*, (1952) of the Oil and Natural Gas Commission have worked out the geological details of the area. Singh (1952), Mandwal (1959) and Datta *et al.*, (1965) have studied the foraminiferal assemblages of Subathu sediments.

MATERIAL AND METHODS

The material for the present study was collected by a party consisting of Dr. A. K. Datta, one of the authors (NCS) and Shri

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1 Present address : N. C. Srivastava, Geology Office, Oil and Natural Gas Commission, Sibsagar (Assam).

B.C. Verma of Research and Training Institute, Dehradun during Jan.–Feb., 1964, along the following sections :

1. Koshalia river, from near Kalka (30° 51′ : 76°56′) upto Dagshai (30°53′ : 77°03′) ;
2. Simla—Kalka road, from west of Dharampur (30°54′ : 77°02′) upto east of Barog (30°53′ : 77°05′) ;
3. West of Khetpal village (30°57′30″ : 67°57′ 30″) to Subathu town (30°59′ : 97°01′) along the stream ;
4. Spot sampling near Kasauli (30°54′ : 76°58′).

The samples were mostly limestones and sandstones with a few green, red and grey shales. A total of 274 samples of palynological interest were macerated and studied. The usual technique of processing the samples with HF, HNO_3 and alkali was adopted and the sporiferous material was separated with heavy liquid (sp. gr., 2.3) floatation. The treatment with acetolysis mixture was carried out as and when necessary. The slides were mounted in glycerine jelly and sealed with either vinyl acetate or lac.

MICROFLORAL ASSEMBLAGE

A good number of spores, pollen grains and hystrichosphaerids along with a couple of algal specimens and some indeterminate forms have been recovered. The overall assemblage consists of 28 genera and 45 species. Most of the microfossil recovery is from grey shales, whereas red and green shales are almost devoid of any microfloral components. The assemblage has been arranged according to the artificial system of classification given by Van der Hammen (1956) and modified by Pierce (1961). Detailed descriptions of the various microfloral types recovered from these sediments and comparisons are given below :

SYSTEMATIC DESCRIPTIONS

Division : SPORITES H. Potonie, 1893

Class : TRILETES (Reinsch) Ibrahim, 1933

Genus : PSILATRILETES V. d. Hammen, 1956

PSILATRILETES SP.

Pl. 3, fig. 6

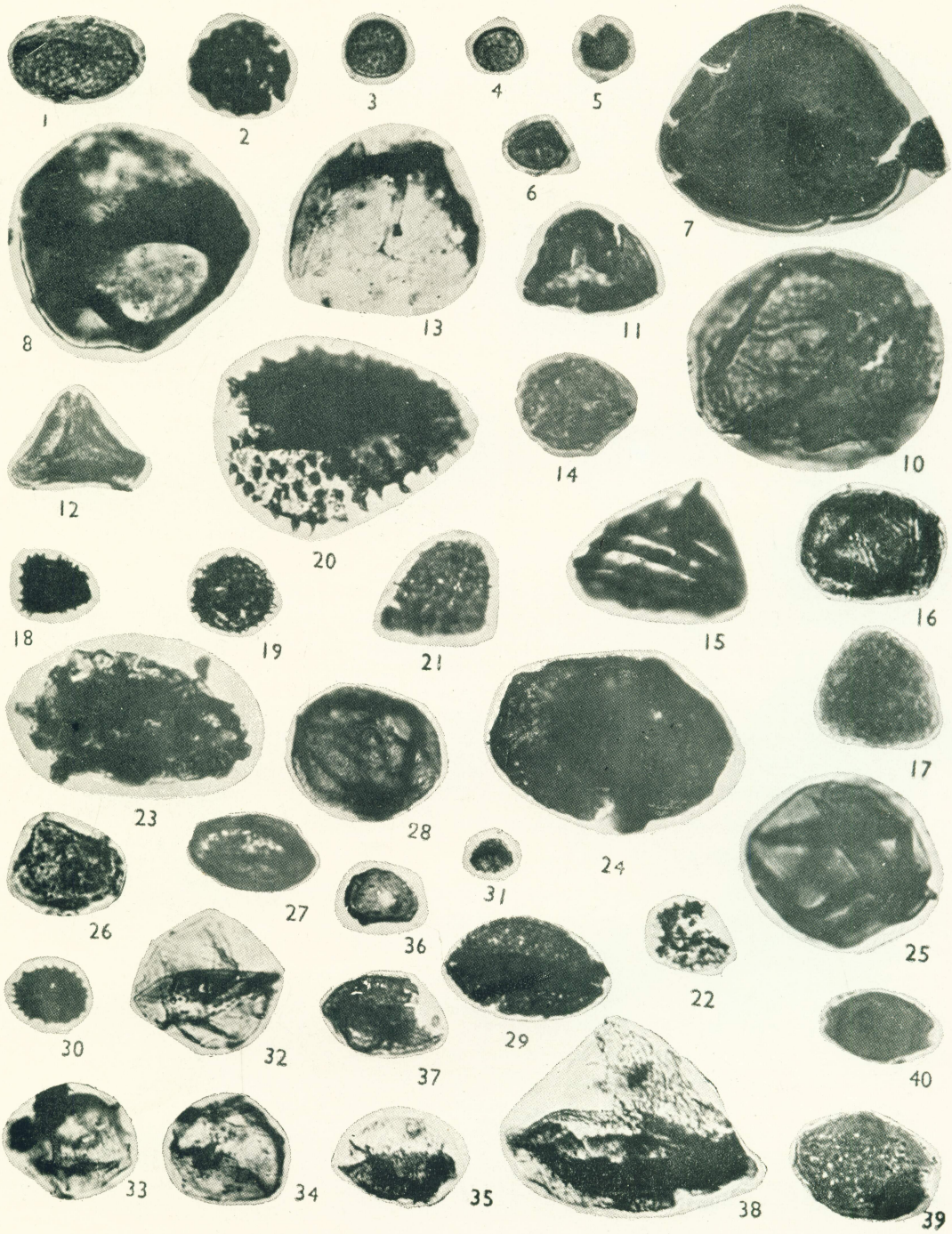
Description—Golden yellow, roundly triangular to subcircular spore. Size ± 18 × 16 μ. Trilete mark faintly visible, rays extending almost upto the equator. Exine less than 1.0 μ thick, psilate.

Comparison—*Trilites* sp., (Chitaley 1951 ; Pl. 13, fig. 5) is bigger in size, has a thinner

EXPLANATION OF PLATE 3

(All magnifications × 500)

1. *Retimonoletes* sp. A ; Photo no. 11/27.2. *Retimonoletes* sp. B ; Photo no. 21/15. 3, 4. *Foveomonoletes minutissimus* sp. nov. Photo nos. 17/24,3/16. 5. *Echimonoletes* sp. Photo no. 17/22. 6. *Psilatriletes* sp. Photo no. 12/9. 7,8. *Psilatriletes lobtus* sp.nov. Photo nos. 12/13, 11/22. 10, 16. *Scabratriletes* sp. A ; Photo nos. 16/3, 5/28. 11. *Scabratriletes* sp. B ; Photo no. 17/26. 12. *Scabratriletes* sp. C ; Photo no. 5/17. 13. *Scabratriletes* sp. D ; Photo no. 20/9. 14. *Retitriletes* sp. Photo no. 11/11. 15. *Striatriletes* sp. Photo no. 21/26. 17. *Verrutriletes* sp. Photo no. 12/16. 18, 19, 30. *Echitriletes densus* sp. nov. Photo nos. 5/29,12/22,5/25. 20. *Echitriletes* sp. A ; Photo no. 5/20. 21. *Echitriletes* sp. B ; Photo no. 17/28. 22. *Echitriletes* sp. C ; Photo no. 20/15. 23. *Bacutriletes* sp. Photo no.5/21. 24. *Punctabivesiculites* sp. Photo no. 14/23. 25. *Psilainaperturites* sp. Photo no. 11/4. 26,27. *Foveoinaperturites longus* sp. nov. Photo nos. 7/9, 5/18. 28, 29, 37. *Verrumonoporites mcaulatus* sp. nov. Photo nos. 21/22, 7/26, 5/3. 31. *Spinainaperturites* sp. Photo no. 13/25, 32, 33, 34, 35. *Psilamonoporites oculatus* sp. nov. Photo nos. 11/26, 15/17, 20/19, 20/16, 36. *Granamonoporites* sp. Photo no. 15/7, 38. *Retimonocolpites* sp. Photo no. 15/15. 39. *Granodiporites* sp. Photo no. 12/18, 40. *Psilodiporites ovatus* sp. nov. Photo no. 13/4.



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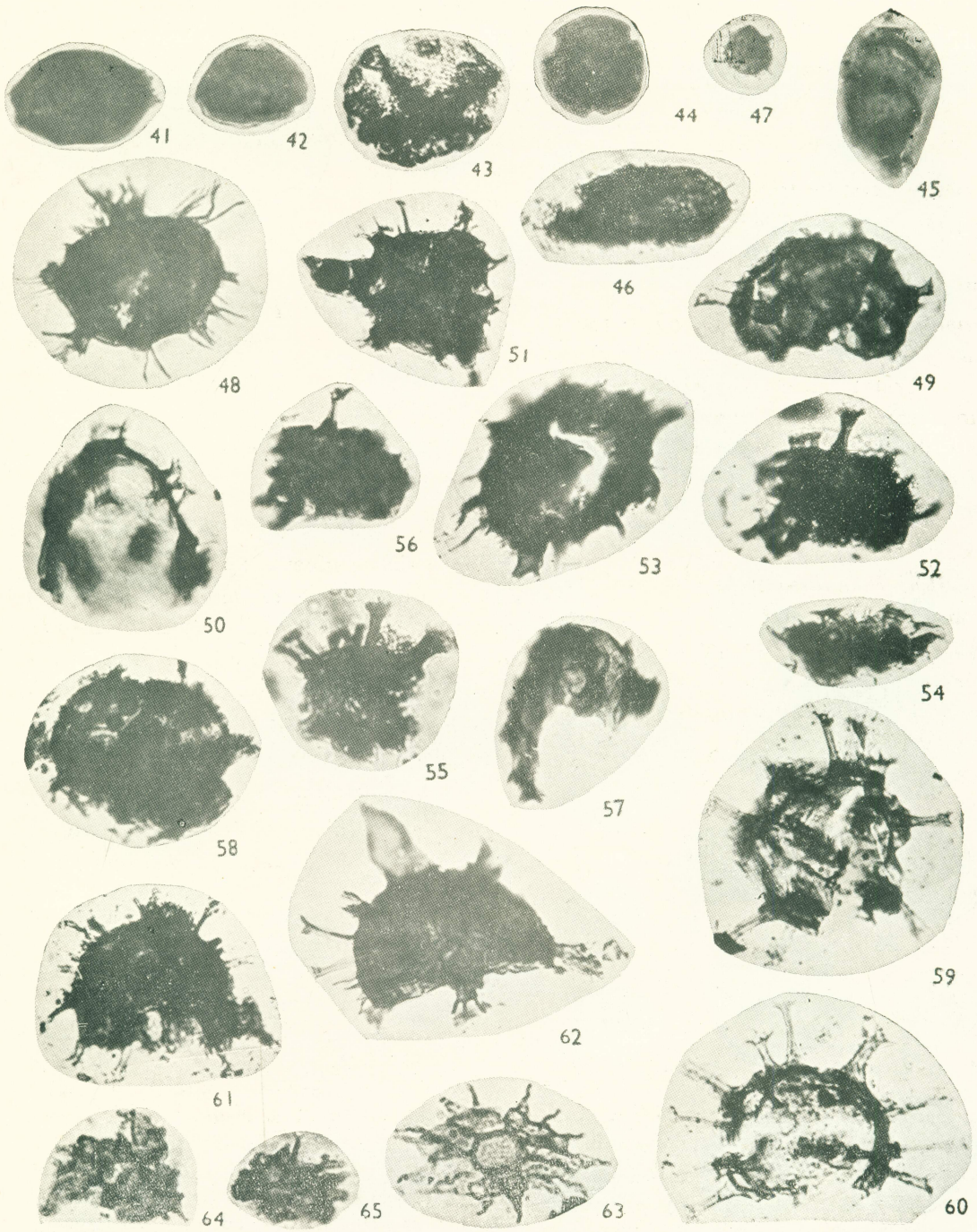

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exine and shorter rays of the trilete mark.

Botanical affinity—Filicinae.

PSILATRILETES LOBATUS sp. nov.
Pl. 3, figs. 7–8

Holotype–Pl. 3, fig. 7.

Diagnosis—Roundly triangular, 51.8-58.8μ; Y-mark seen, rays 1/2-3/4 of spore radius with a distinct labra; exine smooth to faintly punctate.

Description—Light brown, usually roundly triangular. Size range being 51.8-58.8 × 53.2-56 μ. Trilete mark distinct to faintly discernible, rays narrow, sometimes slightly open, extending from half to three-fourth of spore radius ; labra 2-3 μ broad. Exine ± 1.5 μ thick, usually psilate but sometimes faintly punctate.

Comparison—Psilatriletes sp. 4, described by Ghosh and Banerjee (1963; Pl. 1, fig. 15) differs in being bigger in size and in having a thicker exine. *Psilatriletes* sp. B, described by Banerjee (1964 ; Pl.1,fig. 9) comes very close to the present species. Baksi (1962) has recorded *Leiotriletes dehiscensi* (Pl. 1, figs. 1 & 2) which lacks a distinct labra.

Botanical affinity—cf. Filicinae.

Genus: SCABRATRILETES V. d. Hammen, 1956

SCABRATRILETES sp. A
Pl. 3, figs. 10, 16

Description—Golden yellow, variously folded, subcircular spore. Size 62.0–78.2 μ. Trilete mark distinct, rays extending more than half the spore radius. Exine thin, less than 1.0 μ, faintly granulate, grana ± 1 μ in diameter.

Comparison—Chitaley (1951) has recorded a specimen under *Triletes* sp., (Pl. 13, fig. 4) which differs from the present species in being subtriangular in shape with its Y-rays going upto the periphery and in having a smooth exine.

Botanical affinity—Filicinae.

SCABRATRILETES sp. B
Pl. 3, figs. 9, 11

Description—Golden yellow, roundly triangular spore, with almost straight sides. Size 25.5-45 μ. Trilete mark distinct, laesurae open, tapering towards the outer ends, ± 2/3 spore radius long. Exine ± 1.0 μ thick ; granulate, grana coarse and sparse, forming open reticulations.

Comparison—Triletes spm., described and illustrated by Chitaley (1951 ; Pl. 13, fig. 3) resembles with the present species to a great extent.

EXPLANATION OF PLATE 4

(All magnifications × 500)

41. *Psilodiporites ovatus* sp. nov. Photo no. 12/28. 42. *Scabratriporites* sp. Photo no.17/33. 43. *Scabratricolpites* sp. Photo no. 20/25. 44. *Psilatricolporites* sp. Photo no. 20/23 45. *Granateleutosporites* sp. Photo no. 16/28. 46. *Micrhystridium* sp. A ; Photo no. 1/8. 47. *Micrhystridium* sp. B ; Photo no. 13/11. 48. *Multiplicisphaeridium* sp. Photo no. 17/12. 49. *Hystrichosphaera* sp. Photo no. 16/32. 50. *Hystrichosphaeridium* sp. A ; Photo no. 20/27. 51, 52, 55, 62. *Hytrichosphaeridium perifurcatus* sp nov. Photo nos. 1/6, 16/20, 2/16, 3/3. 53. *Hystrichosphaeridium* sp. B ; Photo no. 16/22. 54. *Hystrichosphaeridium* sp. C ; Photo no. 17/7. 56. *Hystrichosphaeridium* sp. D ; Photo no.16/20. 57. *Hystrichosphaeridium* sp. E; Photo no. 17/2. 58. *Hystrichosphaeridum* sp. F; Photo no.1/14. 59, 60. *Hystrichosphaeridium grandis* sp. nov. Photo nos. 4/14,4/12. 61. *Hystrichosphaeridium* sp. *mineralosum* Varma & Dangwal ; Photo no. 11/31. 63, 64, 65. *Pediastrum* cf. *boryanum* (Tup.) Menegh. Photo nos. 12/7, 15/11, 12/30.

Botanical affinity—cf. Filicinae.

SCABRATRILETES sp. C
Pl. 3, fig. 12

Description—Golden yellow, triangular spore with straight to slightly curved sides. Size 34.0 μ. Trilete mark distinct, rays reaching almost up to the equator, inter-ray area thick. Exine finely granulate,grana ± 1 μ in diameter.

Comparison—The present species differs from all the species described earlier in having a thick inter-ray area.

Botanical affinity—*Gleichenia* sp.

SCABRATRILETES sp. D
Pl. 3, fig. 13

Description—Yellow, roundly triangular, measuring 54.0 μ. Trilete mark distinct, rays extending up to 3/4 the radius. Exine ± 1.0 μ thick, granulose, grana sparsely distributed.

Comparison—*Scabratriletes* sp. B (Pl. 3, figs. 9, 11), is smaller in size and has coarser grana forming open reticulations. *Scabratriletes* sp. A (Pl. 3, fig. 10), is subcircular in shape with closely arranged grana. *Scabratriletes* sp. C (Pl. 3, fig. 12), has a thick inter-ray area.

Botanical affinity—cf. Filicinae.

Genus : RETITRILETES Pierce, 1961

RETITRILETES sp.
Pl. 3, fig. 14

Description—Golden yellow, subcircular, measuring 33.0 × 30.2 μ. Mark faintly discernible due to dense ornamentation, rays 1/2-2/3 radius long. Exine thin, reticulate, lumina wide, ± 3.0 μ in diameter, muri narrow, ± 1.5 μ broad.

Comparison—*Retitriletes* sp. 1 (Ghosh & Banerjee, 1963 ; Pl. 2, fig. 25), though having almost the same size as that of the present species, but its laesurae are as much as the radius long and reticulation is comparatively finer. *Retitriletes* sp. 3. (Ghosh & Banerjee, 1963 ; Pl.2,figs. 27, 28), is distinctly triangular in shape and has finer network on the exine.

Botanical affinity—cf. Lycopodiaceae.

Genus : STRIATRILETES V. d. Hammen, 1956

STRIATRILETES sp.
Pl. 3, fig. 15

Description—Golden yellow, roundly triangular spore with straight to slightly curved sides. Size 42.0 × 36.4 μ. Trilete mark not clearly visible. Exine thin, less than 1.0 μ, striate ; striations 2.8–4.2 μ thick, present on both sides of the spore ; gap between two nearest striations being 1.5-2.5 μ.

Comparison—*Striatriletes* sp. 2 (Ghosh & Banerjee 1963 ; Pl. 3, fig. 33) has a thicker exine, a distinct trilete mark and the number of striations is less than in the present species. *Schizeaceaesporites knoxi* (Baksi, 1962 ; Pl. 3, fig. 41) is bigger in size with larger number of striations over it.

Botanical affinity—Schizeaceae (*Mohria* sp.)

Genus : VERRUTRILETES Pierce, 1961

VERRUTRILETES sp.
Pl. 3, fig. 17

Description—Golden yellow, roundly triangular spore, measuring 26.6 μ. Trilete mark distinct, laesurae wide, extending 1/2-3/4 the spore radius. Exine 1.0 μ thick, verrucate, verrucae 3-4 μ broad and ± 1.5 μ long.

Comparison—*Verrutriletes* sp.,. described and illustrated by Ghosh and Banerjee (1963; Pl. 2, figs. 30-31) differs in being bigger in size, in having coarser verrucae and the laesurae extending upto the apices.

Botanical affinity—cf. Hymenophllyaceae.

Genus : ECHITRILETES V. d. Hammen, 1956

ECHITRILETES DENSUS sp. nov.

Pl. 3, figs. 18, 19 & 30

Holotype—Pl. 3, fig. 19.

Diagnosis—Roundly triangular to subcircular, 16.8-29 μ. Y-mark hardly seen, rays 3/4 the grain radius, sometimes more, exine beset with ± 3 μ long spinae.

Description—Golden yellow to light brown, roundly triangular to subspherical spore, measuring 19.6-29 × 16.8-21 μ. Trilete mark faintly discernible due to closely spaced ornamentation, rays narrow, extending 3/4 to full length of spore radius. Exine ± 1.2 μ thick, beset with spinae ; spines 2.5 to 3.5 μ long, broad based and pointed to curved tips distributed evenly all over the surface.

Comparison—The present species differs from *Echitriletes* sp. 1 and 2 (Ghosh & Banerjee 1963 ; Pl. 3, figs. 35, 36) in being smaller in size, with smaller spines and in having a faintly discernible trilete mark.

Botanical affinity—cf. Selaginellaceae.

ECHITRILETES sp. A

Pl. 3, fig. 20

Description—Light brown, roundly triangular grain. Size 70.0 μ. Trilete mark faintly visible, rays ± 2/3 the spore radius long. Exine beset with sharp to blunt tipped spines, spines 3.5-4.0 μ long and ± 2 μ broad at the base, with usually pointed tips.

Comparison—The present species distinguishes from all the other species of *Echitriletes* described so far in having a faint trilete mark and a very prominent exine ornamentation.

Botanical affinity—? Nympheaceae.

ECHITRILETES sp. B

Pl. 3, fig. 21

Description—Golden yellow, roundly triangular to subcircular, measuring 36.0 μ. Trilete mark not clearly visible. Exine covered with sparsely arranged 2-3 μ long, 1.0-1.5 μ broad (at the base) spines.

Comparison—Ghosh and Banerjee (1963) have described *Echitriletes* sp. 1 & 2 (Pl. 3, figs. 35, 36) which differ from the present species in being bigger in size and in having bigger and closely set spines.

Botanical affinity—? Nympheaceae.

ECHITRILETES sp. C

Pl. 3, fig. 22

Description—Golden yellow, broken specimen, presumably subcircular. Size 22 × 18 μ. Trilete mark indistinct. Exine ± 1.0 μ thick, covered with 1.5-2.0 μ long and 1-1.5 μ broad coni with pointed tips.

Comparison—*Echitriletes* sp. A & B (Pl. 3, figs. 20, 21) differ in having bigger spines. *Echitriletes densus* (Pl. 3, figs. 18, 19, 30), though having the same size but the exine is thicker and has closely spaced spines.

Botanical affinity—cf. Nympheaceae.

Genus : BACUTRILETES V. d. Hammen, 1956

BACUTRILETES sp.

Pl. 3, fig. 23

Description—Light brown, folded, presumably subspherical in shape. Size 70 × 38.0 μ. Germinal mark indistinct. Exine ornamented with 4-6 μ long, 2-3 μ broad, sparsely arranged bacula with blunt tips.

Comparison—The present species distinguishes in having a baculate exine.

Botanical affinity—Not known.

Class : MONOLETES Ibrahim, 1933

Genus : RETIMONOLETES Pierce, 1961

RETIMONOLETES sp. A
Pl. 3, fig. 1

Description—Golden yellow, oval, bilaterally symmetrical. Size 30.8 × 19.6 μ. Monolete mark faintly discernible, laesura thin, extending 3/4 the total length or more on proximal face. Exine thin, ± 1.0 μ thick, distinctly reticulate, lumina polygonal, ± 1.5-2.0 μ in diameter; muri ± 0.5 μ thick.

Comparison—Retimonoletes sp. I, described by Ghosh and Banerjee (1963 ; Pl. 1, fig. 7), has a distinct monolete mark and the overall size of the grain is bigger as compared to the present species. *Retimonoletes* sp. 2 & 3 (*loc. cit.*; Pl. 1, figs. 8 & 9) are also bigger in size and have a coarser reticulation.

Botanical affinity—cf. Polypodiaceae.

RETIMONOLETES sp. B
Pl. 3, fig. 2

Description—Light brown, subcircular grain, measuring 21.0 × 14.0 μ. Monolete mark faintly seen, laesura nearly 3/4 the grain radius. Exine ± 1.4 μ thick, reticulate, muri ± 1.5 μ thick, leaving 3-4 μ broad lumina in the centre.

Comparison—Retimonoletes sp. A, differs in having a finer reticulation with thin muri and smaller lumina. *Retimonoletes* sp., (Banerjee 1964 ; Pl. 1, fig. 2) is bigger in size and has comparatively coarser network.

Botanical affinity—cf. Polypodiaceae.

Genus : FOVEOMONOLETES V.d. Hammen, 1956
FOVEOMONOLETES MINUTISSIMUS sp. nov.
Pl. 3, figs. 3-4

Holotype–Pl. 3, fig. 3.

Diagnosis—Subspherical, 14-20 μ ; monolete mark distinct, 3/4 of grain length ; exine foveolate.

Description—Light brown, subspherical sporomorph. Horizontal and vertical dimensions of the grain 15-20 × 14-18 μ. Monolete mark distinct, running over 3/4 the grain length. Exine foveolate, foveola ± 1 μ broad.

Comparison—Monolites spm., described by Chitaley (1957 ; Text-fig. 1-C) is much bigger in size and has a coarser ornamentation.

Botanical affinity—cf. Polypodiaceae.

Genus : ECHIMONOLETES V.d. Hammen, 1956
ECHIMONOLETES sp.
Pl. 3, fig. 5

Description—Golden yellow, subspherical spore ; size 14.0 × 15.0 μ. Monolete mark short, laesura ± 1.0 μ wide, running over 3/4 the total length. Exine ± 1.4 μ thick, echinate, spines 1.5-2.0 μ long, broad at the base and tapering towards the apical ends, distributed uniformly all over the body.

Comparison—Echimonoletes sp., described by Ghosh and Banerjee (1963 ; Pl. 1, fig. 5) differs in being much bigger in size and in having very long and broad spines.

Botanical affinity—cf. Polypodiaceae.

Division : POLLENITES R.Potonié 1931

Class: VESICULATAE Iverson and Troels-Smith,1950

Genus : PUNCTABIVESICULITES Pierce, 1961
PUNCTABIVESICULITES sp.
Pl. 3, fig. 24

Description—Golden yellow, bilateral pollen grain. Size 56.0 × 40.6 μ. Body subcircular, 32.2 × 40.6 μ, body wall distinct, ± 1.0 μ thick, intrapunctate, puncta sparsely distributed. Bladders ± hemispherical, attached laterally on either side of the body. Distally a 9.0 μ wide bladder free area observed.

Comparison—The present species differs from *Saccites* sp. E, (Banerjee, 1964; Pl. 2,

fig. 4) in being bigger in size and in having a finer bladder reticulation.

Botanical affinity—Podocarpaceae.

Class: INAPERTURATAE Iversen & Troels-Simth,1950

Genus : PSILAINAPERTURITES Pierce, 1961

PSILAINAPERTURITES sp.

Pl. 3, fig. 25

Description—Yellow coloured, spherical grain. Size 48.4 × 54.0 μ (in folded condition).. No germinal opening or scar observed. Exine thin, less than 1.0 μ, psilate.

Comparisan—*Foldexina inaperturata* illustrated by Baksi (1962 ; Pl. 1, fig. 16) comes very close to the present species but it lacks a detailed description and a holotype.

Botanical affinity—Not known.

Genus : FOVEOINAPERTURITES Pierce, 1961

FOVEOINAPERTURITES LONGUS sp. nov.

Pl. 3, figs. 26–27

Holotype–Pl. 3. fig. 26.

Diagnosis—Oval to subcircular, 28-42 μ ; without any germinal mark. Exine thick, covered with foveola.

Description—Golden yellow, oval to subspherical grains. Size 28.0-30.8 μ × 29.4-42.0 μ. No germinal mark or scar observed on the body. Exine 1.0-1.5 μ thick ; foveolate, foveola 1-1.5 μ broad. Few irregular folds present on the body.

Comparison—The present species distinguishes in having a foveolate exine, without any germinal mark.

Botanical affinity—Not known.

Genus : SPINAINAPERTURITES Pierce, 1961

SPINAINAPERTURITES sp.

Pl. 3, fig. 31

Description—Golden yellow, subspherical pollen grain. Size 8.4 × 9.5 μ (in folded condition). No germinal aperture seen. Exine less than 1 μ thick ; spinate, spines 2.5-3.0 μ long, ± 1.5 μ broad (at the base), uniformly distributed over the whole exine, A fold running from one end of the grain to the other present.

Comparison—*Foveoinaperturites longus* differs in having a foveolate exine. In *Psilainaperturites* sp., the exine is smooth.

Botanical affinity—Not known.

Class : MONOPORATAE Iverson & Troels-Smith,1950

Genus : PSILAMONOPORITES V. d. Hammen, 1954

PSILAMONOPORITES OCULATUS sp. nov.

Pl. 3, figs. 32, 33, 34, 35.

Holotype—Pl. 3, fig. 32.

Diagnosis—Circular to subcircular, measuring 21-30.8 μ. Monoporate, pore simple, circular to oval. Exine psilate to finely granulose.

Description—Golden yellow, circular to subcircular pollen grains. Size ranging from 25.4-30.8 × 21.0-30.8 μ. Monoporate, pore simple, circular to oval, 1.5-5.6 × 1.5-2.8 μ, psilamarginate encircled by an unsculptured,1.5 to 2.8μ wide margin. Exine ± 1μ thick, usually psilate, sometimes appearing finely granulose. A few irregular folds present on the body.

Comparison—*Monoporites minor* (Chitaley, 1951 ; Text-fig. 8) has a distinctly oval shape with a narrower rim around the pore and is usually devoid of any folds.

Botanical affinity—Graminae.

Genus : GRANAMONOPORITES V. d. Hammen, 1954

GRANAMONOPORITES sp.

Pl. 3, fig. 36

Description—Golden yellow, subspherical pollengrain, measuring 14.0 × 16.8 μ. Pore simple, small, circular, ± 2.0 μ in diameter.

Exine ± 1.0 μ thick, finely granulate, grana ± 1 μ broad.

Comparison—The present species distinguishes in having a distinctly granulose exine.

Botanical affinity—cf. Graminae.

Genus : VERRUMONOPORITES Pierce, 1961

VERRUMONOPORITES MACULATUS sp. nov.

Pl. 3, figs. 28, 29, 37

Holotype–Pl. 3, fig. 28.

Diagnosis—Spherical to subspherical, size 25-52 μ. Monoporate, pore simple, oval, 2.0-2.5 μ × 3-4 μ in size ; exine thin, verrucate.

Description—Golden yellow, variously folded, spherical to subspherical pollen grains. Size 25-52 μ × 22-38 μ (in folded condition). Pore simple, oval, 2.0-2.5 × 3-4 μ, encircled by an unsculptured, 2.5-3.0 μ thick margin. Exine thin, less than 1.0 μ, verrucate, verrucae of varying sizes are closely set.

Comparison—Monoporites spm., recorded by Chitaley (1957 ; Text-fig. 2-1) is small with a thin, smooth wall and germinal pore surrounded by a rim. The specimens illustrated here are bigger in size, have a verrucate exine and the pore is encircled by a wider rim.

Botanical affinity—cf. Graminae.

Class : MONOCOLPATE Iverson & Troels-Smith,1950

Genus : RETIMONOCOLPITES Pierce, 1961

RETIMONOCOLPITES sp.

Pl. 3, fig. 38

Description—Golden yellow, ruptured specimen, presumably subspherical in shape. Size 60.6 × 30.8 μ (in folded condition). Exact nature of colpus not clear but appears to be extending from one end of the grain to other. Exine ± 1.0 μ thick ; reticulate, foveola ± 1.5 μ broad.

Comparison—Monosulcites spinosa described and illustrated by Chitaley (1951 ; Pl. 13, fig. 11), apparently looking similar but differs in having a spinose exine.

Botanical affinity—Palmae.

Class : DIPORITES Van der Hammen, 1954

Genus: GRANODIPORITES Varma and Rawat,1963

GRANODIPORITES sp.

Pl. 3, fig. 39

Description—Light brown, barrel-shaped, bilateral, isopolar pollengrain. Size 33.6 × 25.2 μ. Pores simple, sunken, almost circular, ± 8.5 μ in diameter. Exine ± 1.5 μ thick, granulate, grana ± 1 μ in diameter.

Comparison—Granodiporites erdtmanii (Varma and Rawat, 1963 ; Pl. 1, fig. 13) differs in having bigger pores and grana.

Botanical affinity—Proteaceae.

Genus : PSILODIPORITES Varma and Rawat 1963

PSILODIPORITES OVATUS sp. nov.

Pl. 3, fig. 40 ; Pl. 6, fig. 41

Holotype—Pl. 3, fig. 40.

Diagnosis—Oval, 16.0-32.2 μ. Diporate,

EXPLANATION OF TEXT-FIGURES

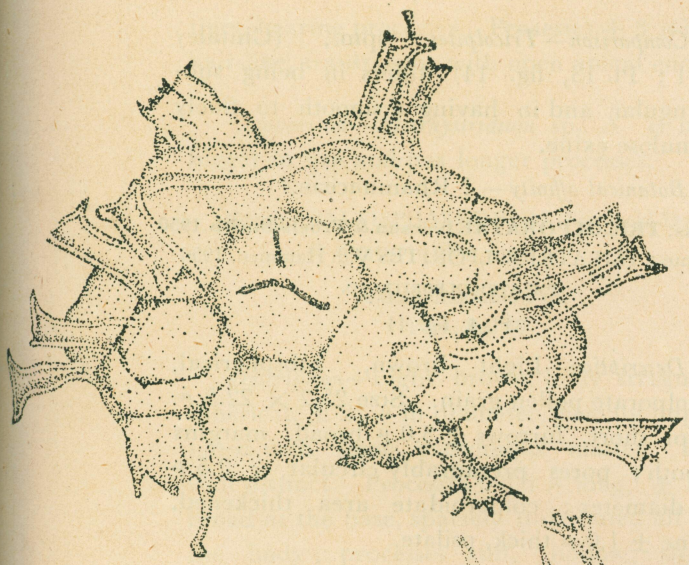
Text-fig. 1. *Hystrichosphaera* sp. Showing body covered with angular fields and bundle of processes arisingfrom angles of these fields.

Text-fig. 2. *Hystrichosphaeridium* sp. A, Showing broad and tubular, bowl like processes with thick, outcurved rims.

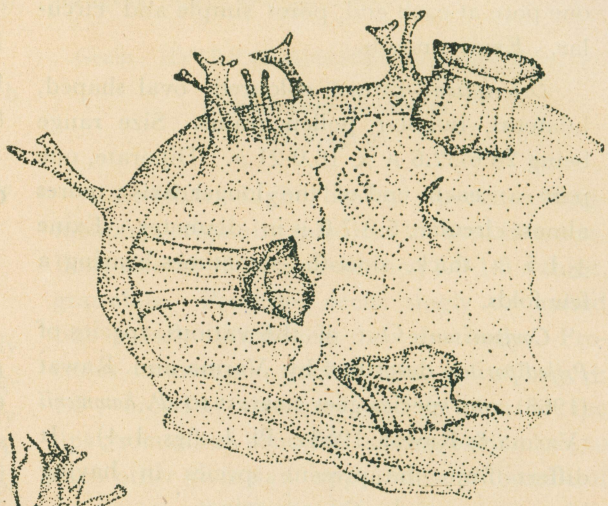
Text-fig. 3. *Hystrichosphaeridium perifurcatus* sp. nov. Showing varied types of processes ; one process with a bulbous base enclosing two rounded bodies separated by a septum. Few such bodies are also seen elsewhere.

Text-fig. 4. *Hystrichosphaeridium* sp. F. Showing the nature of processes and the presence of few dark, rounded bodies.

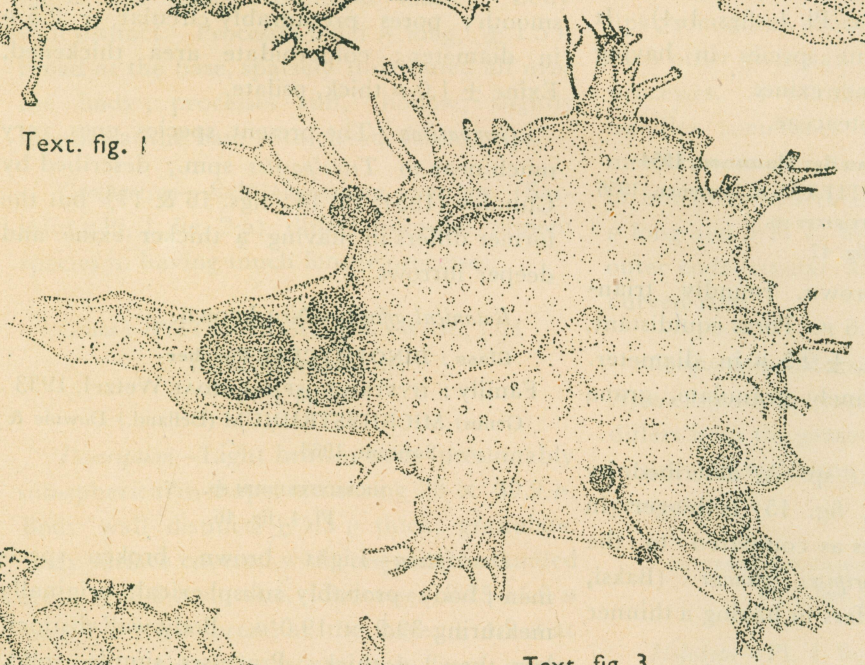
Text-fig. 5. *Pediastrum* cf. *boryanum.*



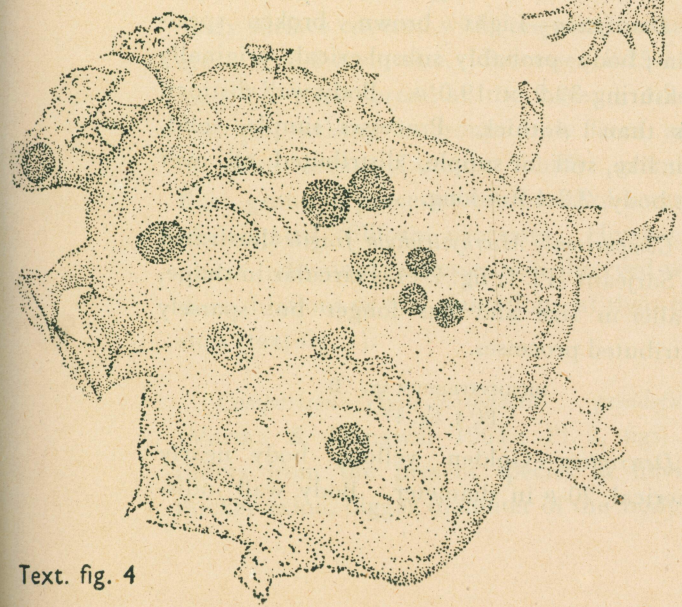
Text. fig. 1



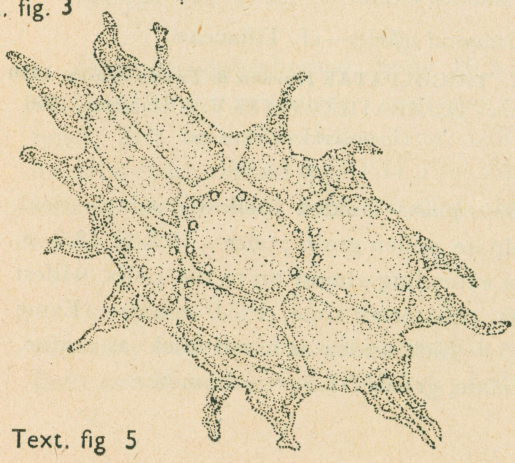
Text. fig. 2



Text. fig. 3



Text. fig. 4



Text. fig 5

one pore at each end, pores simple and circular. Exine smooth.

Description—Brown coloured, oval shaped, bilateral, isopolar pollen grains. Size range being 26.6-32.6 μ × 16.0-21 μ. Diporate, one pore at each end of the longer axis ; pores almost circular, 5.0-7.0 μ in diameter. Exine ± 1.5 μ thick, smooth, sometimes bearing a few folds.

Comparison—Out of the various species of *Psilodiporites* described by Varma and Rawat (1963), our species goes nearest to *P. hammenii* (Varma & Rawat, 1963 ; Pl. 1, figs. 1–4). It differs from the present species in having bigger pores and a thinner exine.

Botanical affinity—Proteaceae.

Class : TRIPORITES Van der Hammen, 1954

Genus : SCABRATRIPORITES V. d. Hammen, 1956

SCABRATRIPORITES sp.

Pl. 4, fig. 42

Description—Light brown, roundly triangular in shape. Size 25.6 μ. Pores equidistant, simple, circular, small, ± 2.5 μ in diameter. Exine ± 1.5 μ thick, finely granulate, grana about 1 μ in diameter.

Comparison—*Triporites* sp. A, described by Banerjee (1964 ; Pl. 2, fig. 15) is bigger in size and has larger pores as compared to the present species. *Triporipites minuta* (Baksi, 1962 ; Pl. 1, fig. 10) differs in having a thinner and smooth exine.

Botanical affinity—cf. Tiliaceae.

Class : TRICOLPATAE Iversen & Troels-Smith, 1950

Genus : SCABRATICOLPITES V. d. Hammen, 1956

SCABRATRICOLPITES sp.

Pl. 4, fig. 43

Description—Golden yellow, subspherical, tricolpate pollen grain ; size 16.8 × 18.2 μ. Colpi extending almost up to the poles, widest at the equatorial zone, ± 7.0 μ wide. Exine ± 1.5 μ thick, sexine as much thick as nexine, granulate, grana 1-1.5 μ in diameter.

Comparison—*Tricolpites* spm., (Chitaley 1951 ; Pl. 13, fig. 14) differs in being subtriangular and in having a smooth to finely granulose exine.

Botanical affinity— ? Rhamnaceae.

Class: TRICOLPORATAE Iverson & Troels-Smith, 1950

Genus : PSILATRICOLPORITES V.d. Hammen, 1956

PSILATRICOLPORITES sp.

Pl. 4, fig. 44

Description—Light brown, subspherical, tricolporate pollen grain. Size 25.2 × 22.5 μ. Colpi short, furrows ± 3.0 μ broad, margins smooth ; pores presumably circular, ± 2.5 μ in diameter ; colporoidate area thickened. Exine ± 1.0 μ thick, psilate.

Comparison—The present species goes very much near to *Tricolporites* spm., described by Chitaley (1951; Pl. 14, figs. 16 & 17) but the former differs in having a thicker exine and deeper furrows.

Botanical affinity—Not known.

Class : DINOPHYCEAE Pascher

Family : HYSTRICHOSPHAERIDAE Wetzel, 1933

Genus: MICRHYSTRIDIUM (Defland.) Downie & Sarjeant, 1963

MICRHYSTRIDIUM sp. A

Pl. 4, fig. 46

Description—Light brown, broken specimen ; body probably subspherical, originally measuring 39.9 × 19.0 μ. Body wall distinct, less than 1 μ thick. Processes simple, solid, hair like, stiff or supple, distributed all over the body, 2.2-4.9 μ long.

Comparison—*Micrhystridium fragile* illustrated by Sarjeant (Pl. 1, fig. 2-e) is circular in shape, smaller in size and has longer but sparsely distributed processes.

MICRHYSTRIDIUM sp. B

Pl. 4, fig. 47

Description—Golden yellow, body nearly spherical, 20 μ in diameter. Body wall indis-

tinct, bearing processes. Processes ± 3 μ long, hair-like, transparent with open apical ends.

Comparison—*Micrhystridium* sp. A is much bigger in size and has longer processes.

Genus : BALTISPHAERIDIUM (Eisenack) Downie & Sarjeant, 1963

BALTISPHAERIDIUM sp.
Pl. 4, fig. 48

Description—Light brown, body irregularly spherical, ± 21 μ in diameter, heavily impregnated with some externuous matter. Body wall distinct. Processes 6-8.5 μ long, ± 1.5 μ broad at the base, sparsely distributed all over the body ; processes stiff, hollow, slightly broader at the base with closed, furcate tips.

Comparison—*Baltisphaeridium lumectum* (Sarjeant ; Pl. 1, fig. 2-a) differs from the present species in having much longer processes.

Genus : HYSTRICHOSPHAERA Wetzel, 1933

HYSTRICHOSPHAERA sp.
Pl. 4, fig. 49

Description—Light brown, body presumably sub-spherical in shape, measuring 28 × 39.9 μ. Body wall distinct, ± 1.5 μ thick, granulate. Body surface covered with angular to rounded areas, ± 8.8 μ in size. Processes 8.25-11.0 μ long, 2.2-4.4 μ broad at the base, ± 4.9 μ at the tips ; arising in groups only from angles of these areas. Lumina faintly granulate. Each group of processes composed of a number of elongated, filiform processes. However, at places individual processes also observed which show dilations or fine furcations at their outer ends (text-fig. 1).

Comparison—*Hystrichosphaera pseudofurcata* (Varma & Dangwal 1964 ; Pl. 2, figs. 7-8) differs from the present species in having a thicker exine, bigger diameter of the body and hanging tips of the processes.

Genus : HYTRICHOSPHAERIDIUM Deflandre, 1937

HYSTRICHOSPHAERIDIUM sp.
Pl. 4, fig. 50

Description—Light brown, specimen fragmentary, originally spherical to oval in shape. Body size 32-45 μ, wall distinct, 1.0-1.5 μ thick, granulate. Processes occur singly or united but sparsely distributed over the body. Processes occurring in singles, thin, ± 6 μ long, ± 1.5 μ broad at the base and ± 4.4 μ at the tips ; sometimes processes arising very close to each other giving an appearance of bundle of processes. A number of such processes or bundles sometimes appear enveloped by a membranous mass to form broad, tubular vase or bowl-like structure (Text-fig. 2), being 4-12 μ long and 5-11 μ broad at the base. Their outer ends circular and open with thick, outcurved rims.

Comparison—Mathur (1963) has described *Hystrichosphaeridium* sp. 3 (Pl. 21, fig. 32) which differs from the present species in being bigger in size and in having tetrafurcating tips of the processes.

HYSTRICHOSPHAERIDIUM PERIFURCATUS sp. nov.
Pl. 4, figs. 51, 52, 55, & 62

Holotype—Pl. 4, fig. 51.

Diagnosis—Subspherical, body 26.5-53.0 μ × 27.0-45.5 μ ; granulose ; processes of two types, first type 7.7-15-0 μ long, stiff with furcated ends ; second type 4-11.5 μ, thin and hollow. A few dark brown bodies observed on the body.

Description—Light brown in colour, originally spherical to subspherical in shape. Body size 26.5-53.0 μ × 27-45.5 μ. Body wall

distinct, thin, ± 0.5 μ thick, granulose. Processes mainly of two types, distributed all over the body, first type of processes 7.7-15.0 μ long, mostly stout, long, stiff, with nearly uniform width, slightly dilated at their apical furcated ends. Stem part of the funnel-like processes (Pl. 4, fig. 52) occasionally showing fibrillar strands. Sometimes processes having bulbous base with one or two dark roundish bodies (Text-fig. 3). Second type of processes 4-11.5 μ, short, thin, stiff and hollow, almost uniformly thick, slightly dilating at their bases and tips. A few dark rounded bodies also seen within the body.

Comparison—Hystrichosphaeridium complex described and illustrated by Varma & Dangwal (1964 ; Pl. 2, figs. 2-3) differ in having only one type of processes whereas in the present species two distinct types of processes are recorded.

Remarks—The dark brown bodies recorded above are very likely to bear some relationship with the mechanism of reproduction in the individual. A somewhat similar analogy is known in Dasycladaceous algae. However, the observation is of great interest as it probably indicates a possible method of reproduction in hystrichosphaerids. These rounded bodies may be of the nature of gametes or zygotes, though an authentic evidence is still not available.

HYSTRICHOSPHAERIDIUM sp. B
Pl. 4, fig. 53

Description—Light brown, body originally spherical, measuring 42.5 × 28.0 μ ; body wall ± 1.5 μ thick, granulate. Processes 6-12 μ long, ± 1.6 μ broad (at the base), distributed all over the body ; processes stiff, broad at the base and gradually narrowing towards their outer open ends ; usually occurring in singles, occasionally in groups of two or more, sometimes fusing completely except at their outer branched ends.

Comparison—Hystrichosphaeridium sp. 4, described by Mathur (1963 ; Pl.21, fig.33), differs 21 in having a thicker and smooth exine.

HYSTRICHOSPHAERIDIUM sp. C
Pl. 4, fig. 54

Description—Brown, specimen broken, body originally appearing to be subcircular, measuring 37.5 × 21.5 μ. Body wall thin, faintly granulate. Processes ± 4.5 μ long, ± 2.7 μ broad (at the base), distributed all over the body. Furcated processes 11.0 μ long and 2·2 μ broad at the base. Processes stiff, hollow with broad conical to hemispherical bases, narrowing sharply towards their outer pointed ends. Sometimes processes branching into three at their outer ends.

Comparison—Apparently similar specimens have been recorded by Varma and Dangwal (1964) as *Hystrichosphaeridium* sp. cf. *H. cornigerum* (Pl. 2, figs. 4-5) in which the body is densely granulate and the processes originating with pyramidal to broad bases.

HYSTRICHOSPHAERIDIUM sp. D
Pl. 4, fig. 56

Description—Light brown, body originally spherical, ± 30.4μ diameter; body wall ± 0.5μ thick, faintly granulate. Processes 3.8-9.3 μ long, ± 2.7 μ broad (at the base), sparsely distributed and deciduous. Processes simple, long and stiff emerging with more or less conical broad bases, the adjoining ones sometimes observed to be connected in their basal region, narrowing towards the tips, occasionally tips furcating.

Comparison—Hystrichosphaeridium sp. 3, illustrated by Mathur (1963 ; Pl. 21, fig. 32), is characterized by having finely foveolate exine, tubular processes with tetrafurcating, recurved

tips. In the present species, the exine is faintly granulate, with simple, long and stiff process which occasionally furcate.

HYSTRICHOSPHAERIDIUM sp. E
Pl. 4, fig. 57

Description—Dark brown, fragmentary, probably oblong to oval in shape. Body size 42.5 × 29.3 μ ; wall ± 0.5 μ thick, granulose. Processes 5.5-14.8 μ long, ± 1.6 μ broad (at the base), distributed sparsely all over the body; processes mostly simple, hollow, filiform, occasionally with broad bases, some processes observed to arise in groups of two. Few dark, rounded bodies, ± 4.5 μ in diameter observed on the body.

Comparison—*Hystrichosphaeridium* sp., illustrated and described by Varma and Dangwal (1964 ; Pl. 2, fig. 6) comes very close to the present species in overall size, size of the processes and exine ornamentation, the only difference is that in the former species processes usually occur in groups of 6-15 and in the later species in groups of 2 only.

Remarks—In the main body are seen quite a few small dark, rounded bodies, from one of them processes similar to those borne by the body are seen to be emerging. There is a great probablity that the enclosed rounded objects may be juvenile bodies of the adult specimen. However, at present, due to insufficient data it only remains a conjecture.

HYSTRICHOSPHAERIDIUM sp.
Pl. 4, fig. 58

Description—Brown, probably spherical. Body diameter ± 37.0 μ, wall thickness and ornamentation not clear due to bad preservation. Processes 5.5-8.3 μ long, 2.2-3.5 μ broad (at the base), sparsely distributed all over the body. Processes simple, long, stiff, hollow with open tips, dilating slightly at their outer ends. Few dark rounded bodies seen on the main body (Text-fig. 4).

Comparison—The specimen illustrated here is badly preserved, thus an exact comparison with any of the known species is difficult.

HYSTRICHOSPHAERIDIUM GRANDIS sp. nov.
Pl. 4, figs. 59-60

Holotype—Pl. 4, fig. 59.

Diagnosis—Spherical, body ± 50.8 μ, distinctly granulose. Processes 7-20 μ long, hollow with open ends and slightly broade bases, usually furcating at the tips.

Description—Golden yellow, originally spherical. Body wall distinct, ± 1.5 μ thick, distinctly granulate, grana ± 1.5μ in diameter. Processes 7-20 μ long, hollow, stiff with open ends and sparsely studded over the body. Processes with slightly broader bases, stems uniformly wide and ending in shallow funnels which are usually dissected.

Comparison—The present species differs from *Hystrichosphaeridium heteracenthum* Defl. & Cook., in having a thinner body exine and the usually furcating tips.

HYSTRICHOSPHAERIDIUM cf. MINERALOSUM
Varma and Dangwal, 1964
Pl. 4, fig. 61

Description—Light brown, probably spherical originally. Body 21-42.0 μ in diameter, wall distinct, 1.0-1.5 μ thick, granulose, grana hardly visible due to dense nature of the body. Processes studded densely all over the body, 8.0-12.5 μ long, simple, hollow, stiff with broad bases extending out with uniform thickness, tips slightly lipped or discoid.

Comparison—Similar processes are known to occur in *Hystrichosphaeridium mineralosum* subspecies *labiatum* and *jekhowskyi* reported by Varma and Dangwal (1964) from the Eocene

horizon of Cambay deep wells. *H. mineralosum* and its subspecies differ from the present specimen in having a prominently mineralized body and more pronounced morphology of the processes. However, as the specimen recovered here shows a close similarity to Cambay forms, they are provisionally referred to as *H.* cf. *mineralosum.*

PEDIASTRUM cf. BORYANUM (Tup.) Menegh.
Pl. 4, figs. 63-65

Description—Golden yellow, coenobium 38-70 μ × 25-44 μ (including processes), cells single-layered. Coenocyte consisting of 8 cells. Central cell roundly triangular, seven-sided, surrounded by seven marginal cells (Text-fig.5). Each cell prominently granulate with distinct, 1.5 μ thick cell wall. Marginal cells irregular in shape. Two processes arising from each of the marginal cells. Processes 14 in number, 7-12 μ long, supple, occasionally broad at the base, gradually tapering towards the tips.

Comparison—Varma & Srivastava (1965) have recorded *Pediastrum delicatites* from the Eocene of Western India. *P. delicatites* differs from the present species in having more number of cells which are separated by triangular perforations. *Pediastrum* cf. *bifidites* recorded by Mathur (1962) from the Subathu formation of Himachal Pradesh has a hexangular central cell with slightly pitted membranes.

INCERTAESEDIS

GRANATELEUTOSPORITES sp.
Pl. 4, fig. 45

Description—Body oblong-clavate, light brown, pedicellate, two celled, slightly constricted at the septum, measuring 25.3 × 13.5 μ (excluding pedicel). Each cell ± globular, measuring ± 13.5 μ in diameter. Body wall distinct, less than 1 μ thick, uniformly thickened except at the apex. Exine finely granulate. Pedicel 7.9 μ long with a slightly bulous base.

Botanical affinity—Fungal spore.

DISCUSSION

As already indicated the microfossil recovery from Subathu sediments consists of a large number of spores, pollen grains, hystrichosphaerids, a couple of algal specimens and some indeterminate forms. For the present investigation, surface samples from four traverses have been studied as mentioned earlier. Three out of the four traverses have very poor spore-pollen content, but the fourth i.e. Koshalia river traverse has yielded a rich microfloral assemblage.

The spore-pollen and microplanktonic assemblage recovered from the Subathu sediments indicates that they (particularly Koshalia river section) were deposited under shallow, marine conditions. The absence of organic debris, cuticles, wood fragments etc., further suggest that the sediments were not brought from long distances. Hence it is most likely that the two types of facies i.e. the green and red have not been brought from different sources and deposited. The absence or poor representation of the microflora in the green and red sediments and its presence in grey shales points towards some chemical and biochemical changes during the deposition of these sediments. It appears most unlikely that the aeroplankton did not settle down in the basin at the time of deposition of the green and red facies.

The absence or extremely low frequency of the conifer pollen is indicative of the fact that the neighbouring land was of a somewhat flat type. The climate, from the absence of conifers and presence of spores and pollen grains belonging to families generally occurring

in warmer climates, must have been subtropical.

The recovery of hystrichosphaerids in the Subathu sediments is of particular interest from the point of oil potentialities. It has been pointed out by Hoffmeister (1960) that the hystrichosphaerids indicate shallow marine deposits and it is well known that the prospects for exploring oil and gas are better in shelf deposits.

The Subathu sediments comprise a huge thickness of over 7000 ft.,out of which the microflora recovered here comes from only a part of this thickness. Thus a precise dating of the rocks from which the microflora is recovered is not possible which is also due to non-availability of spore-pollen complexes from the various stages of the Eocene of India. As it would be too far fetched to make direct correlations with microfloras from far off countries, the authors have restricted comparisons with the published and available unpublished accounts of spores, pollen and microplankton assemblages recovered by Oil and Natural Gas Commission from the wells drilled in Cambay and Ankleshwar in the west and Jalangi well and a few Assam wells in the east. The microfloral assemblage recovered in Subathus is much different as compared to that of the Eocene of eastern India while it indicates similarity with that obtained in the Eocene of Cambay and Ankleshwar. On the other hand the recovery of a few grains of *Proxapertites* sp., similar to that recovered from Lower Eocene horizon of Jalangi well is suggestive of a Lower Eocene age. A finer subdivision in the Lower Eocene, is however, not possible with the existing data on Subathus due to lack of index assemblages from the various stages of the Eocene of India.

ACKNOWLEDGEMENTS

We are grateful to Dr. C.P. Varma, former Senior Scientific Officer for his valuable suggestions during the course of this project. We wish to express our sincere thanks to Dr. D.K. Chandra and (late) Shri G Kohli, former Directors, Shri L. P. Mathur, Director and Prof. N. A. Eremenko, Project Manager for their encouragement and interest in the project. We are thankful to Dr. A. Roy, former Deputy Director. Shri V. V. Sastri Joint Director and Dr. V. R. Rao, Deputy Director (Geology) for their kind help and keen interest envinced in the project. Our thanks are also due to Mr. K. Rehman of Palynology Section, for making the text-figures.

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