ALGAL AND FUNGAL MICROFOSSILS FROM MATANOMADH FORMATION (PALAEOCENE), KUTCH, INDIA

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ABSTRACT

Algal and fungal microfossils recovered from the type area of Matanomadh Formation (Palaeocene), in the district of Kutch, Gujarat have been described. The assemblage comprises 20 genera and 27 species. Out of these, 10 genera and 13 species belong to algae and 10 genera and 14 species belong to fungi. Of the algae, *Leioplanktona* gen. nov. and *Matanomadhia* gen. nov. are quite common. Amongst the fungi, *Phragmothyrites* (Edw.) emend., *Notothyrites* Cook. (1947) and *Inapertusporites* (v.d.Ham.) Els. (1968) are frequently found.

Microthyriacites Cook. (1947), *Callimothallus* Dil. (1965), *Microthallites* Dil. (1965) and *Pseudosphaerialites* Venk. & Kar (1969b) have been regarded here as junior synonyms of *Phragmothyrites* (Edw.) emended here.

The present assemblage has been compared with the known algal and fungal assemblages from the Tertiaries of India. It has been inferred on the good percentage of microthyriaceous fungi that during Palaeocene, Matanomadh and the adjacent regions were having a tropical and humid climate favouring a luxuriant vegetation of pteridophytes and angiosperms.

INTRODUCTION

THE records of the algal and fungal remains from the Tertiary rocks in Kutch are meagre. Vimal (1953) recorded *Botryococcus* from the Eocene rocks of Kutch. Mathur (1963) while describing spores and pollen grains from the Lower Eocene gypseous shales from Western Kutch also illustrated a few hystrichosphaerids. Mathur in 1972, again reported some nannoplanktons from the Kuar Bet, Pachham Island, Kutch. Varma and Rawat (1963) described fungal spores from Western and Eastern India including Gujarat and also emphasized on their stratigraphic value. Pant and Mamgain (1969) mentioned the occurrence of nannofossils in Eocene-Oligocene deposits from the various localities in Kutch while reporting their presence from different lithologies ranging in age from Jurassic-Oligocene in India. Venkatachala and Kar (1969b) described in detail a few genera of microthyriaceous ascostromata from the Lower Eocene sediments.

From the above data, it becomes apparent that most of the algal and fungal remains from Kutch have been described mostly from the Eocene sediments. There is no authentic published record of any algal or fungal fossils from the Palaeocene of this region.

The Matanomadh Formation represents the Palaeocene in Kutch and the present paper deals with the algal and fungal remains recovered from this formation in the type area. The material was collected from the two measured sections near the village Matanomadh. The position of the exposures and the lithology of these sections are given below (Map no. 1).

The samples were collected from all the rock types. But mostly the tuffaceous and carbonaceous shales yielded a rich palynological assemblage comprising pteridophytic spores, angiospermic and gymnospermic pollen grains and algal and fungal remains. For maceration the following procedure was followed:

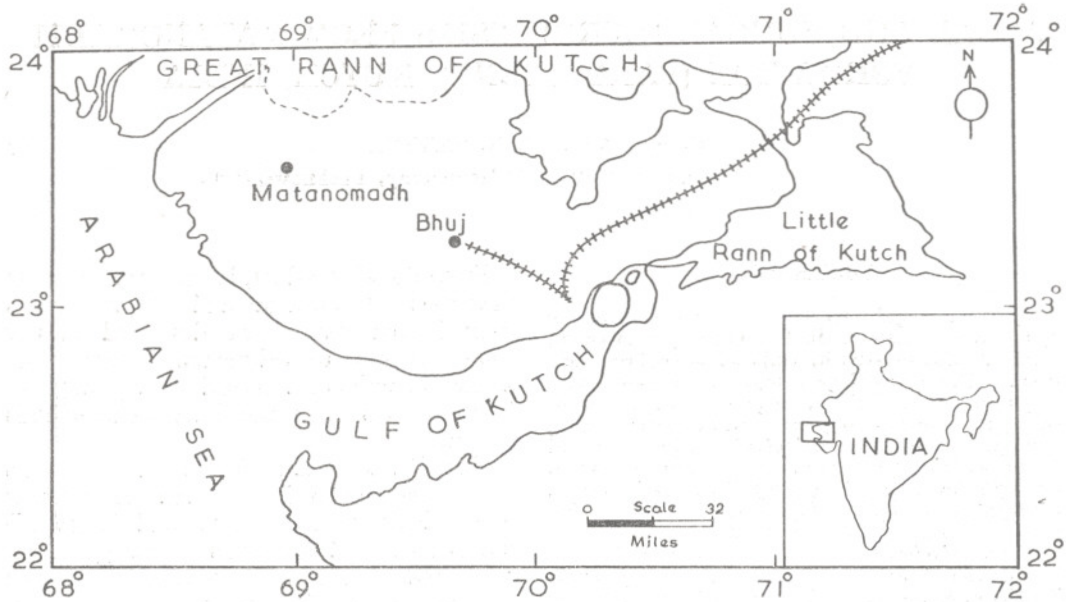
10-15 grams of rock samples were kept in nitric acid in case of carbonaceous shales and in hydrofluoric acid in case of tuffaceous shales and mottled clays for 3 to 5 days or till it was digested. The material was then washed several times and treated with 5 per cent potassium hydroxide solution for about 5 minutes. The material was then washed again and dried on the cover glass with polyvinyl alcohol and mounted in canada balsam. The rock samples and slides have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION

ALGAE

Genus — *Botryococcus* Kutz., 1849
***Botryococcus palanaensis* Sah & Kar, 1974**

Genus — *Tetraporina* (Naum.) Naum., 1950
***Tetraporina apora* Sah & Kar, 1974**



Map no. 1 — Showing the location of the type area of Matanomadh Formation.

SECTION No. 1

Stratigraphic section exposed along a nala cutting near Bhuj-Lakhpat Road, east of the village Matanomadh

6.	Red ferruginous lateritic sandstone	.... 10 ft.
5.	Mottled variegated clay	.... 21 ft.
4.	Gritty sandstone with tuffaceous bands	.... 28 ft.
3.	Carbonaceous shale with tuffaceous bands having leaf impressions	.... 6 ft.
2.	Gritty sandstone with tuffaceous shale bands	.... 20 ft.

UNCONFORMITY

1. Laterite

SECTION No. 2

Stratigraphic section exposed along a nala cutting south of section no. 1

13.	Recent deposits	.... 1½ ft.
12.	Red ferruginous sandstone	.... 2 ft.
11.	Grey shale	.... 1½ ft.
10.	Red sandstone with embedded clay nodules	.... 4 ft.
9.	Grey shale	.... ½ ft.
8.	Violet sandstone with embedded clay nodules	.... 1 ft.
7.	Grey carbonaceous tuffaceous shale rich in sulphur	.... 12 ft.
6.	White-red sandstone with clay nodules	.... 12 ft.
5.	Mottled clay	.... 2 ft.
4.	Grey shale	.... 8 ft.
3.	Red sandstone mixed with grey shale	.... 1 ft.
2.	Gritty sandstone	.... 6 ft.
1.	Lignitic shale	.... 4 ft.

Genus — *Cephalia* Sah & Kar, 1974
***Cephalia globata* Sah & Kar, 1974**
Genus — *Octaplata* Sah & Kar, 1974
***Octaplata rotunda* Sah & Kar, 1974**

Pl. 4, fig. 50

Remarks — The specimen figured here as *Octaplata rotunda* Sah & Kar (1974) exhibits more or less same shape and size. But the plates are less developed in the present specimen.

Genus — *Palanaea* Sah & Kar, 1974
***Palanaea granulosa* Sah & Kar, 1974**

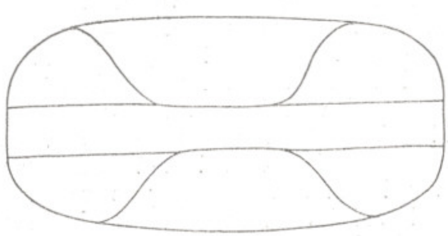
Palanaea laevigata Sah & Kar, 1974

Pl. 2, figs. 15a-15b

Remarks — Sah and Kar (1974) instituted the genus *Palanaea* to accommodate tabular, rectangular microplanktons with laevigate-granulose and warty walls from the Palana lignites, Rajasthan. They, however, did not mention about the number of plates in the specimens. In the present material, some well preserved specimens referable to *P. laevigata* Sah & Kar (1974) were found. They possess on one side, one longitudinal plate in middle extending from one end to other. This plate is associated with on each lateral side by a long plate which falls short at both ends where the longitudinal plate is accompanied by a smaller plate on each side. The tabulation on the other side of the specimens is, however, not clear (Text-fig. 1).

Genus — *Cryptosphaera* Sah & Kar, 1974
***Cryptosphaera valvata* Sah & Kar, 1974**

Remarks — This species is rare in the present preparation and the specimens do not exhibit, much variations in the number of chambers as recorded by Sah and Kar (1974).



TEXT-FIG. 1 — Showing the plate system in *Palanaea laevigata* Sah & Kar.

Genus — *Cornplanktona* Sah & Kar, 1974
***Cornplanktona unicorna* Sah & Kar, 1974**

Remarks — Specimens with one appendage have only been observed. Inner cavity is well defined but the inner body is absent in most of the specimens.

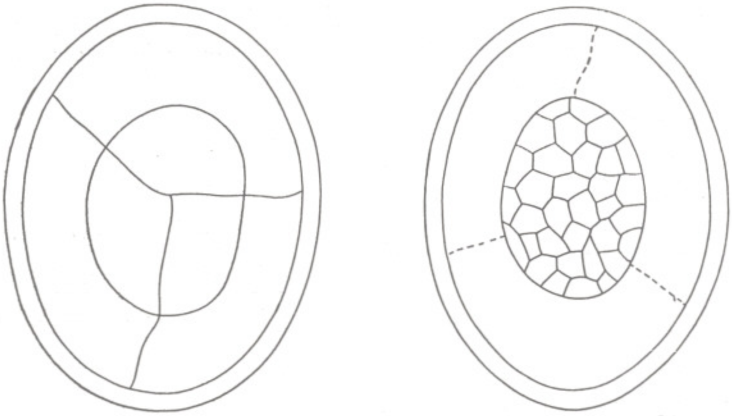
Genus — *Leioplanktona* gen. nov.

Type Species — Leioplanktona madhensis sp. nov.

Diagnosis — Microplankton oval-subcircular, outer wall made up of three plates, they join in middle to form a pseudotrilete mark as found mostly in cryptogamic spores. Operculum oval-subcircular, made up of many small square-rhomboid plates. Plates on outer wall as well as on operculum may not be discernible in some specimens. Wall generally smooth but may be sculptured in some.

Description — Overall shape generally oval-subcircular but may also be irregular in some specimens. Plates on outer wall mostly traceable, in a few specimens only one or two may be distinct. Size range 34-92 μ. Operculum in most cases conforms with overall shape of microplanktons. It is made up of many small plates to provide pseudoreticulate pattern. Outer wall up to 12 μ thick, in some specimens it may be unequally thick; wall when ornamented is found bedecked with grana and verrucae, they are mostly mixed but in some they may be either only granulose or verrucose (Text-fig. 2).

Comparison — Psilosphaera Sah & Kar (1974) resembles the present genus in subcircular-oval shape and operculum; but the former is conspicuous by its absence of traceable plates on the outer wall and also on the operculum. Besides the outer wall in *Psilosphaera* is made up of several concentric layers. *Cryptosphaera* Sah & Kar (1974) is generally many chambered and the operculum is built by a solitary plate. *Octaplata* also instituted by Sah & Kar (1974) has eight plates on the outer wall and hence is readily distinguished from the present genus.



TEXT-FIG. 2 — Showing the organization and plate system in *Leioplanktona* gen. nov. 2a — showing the arrangement of 3 plates. 2b — showing the smaller plates on the operculum.

Leioplanktona madhensis sp. nov.
Pl. 1, figs. 1-4

1974 — Microplankton type 1 Sah & Kar, p. 181, pl. 4, fig. 94.

Holotype — Pl. 1, fig. 1, size 49×40 μ. Slide no. 4766/15.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Microplankton oval-subcircular, 35-87 μ. Outer wall consists of three plates joined together in middle to form pseudotrilete mark. Operculum distinct, oval-subcircular, made up of many small square-rhomboid plates. Plates on outer wall and also on operculum may not be discernible in some specimens. Outer wall up to 12 μ thick, smooth.

Leioplanktona verrucosa sp. nov.
Pl. 1, figs. 5-6

Holotype — Pl. 1, fig. 5, size 72×58 μ. Slide no. 4770/24.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Microplankton oval, subcircular or slightly irregular in outline, 42-92 μ. Outer wall made up of three plates, joined together in middle region. Operculum distinct, oval-subcircular, made up of many plates. Plates may not be traceable in some specimens. Outer wall 4-12 μ thick, sculptured with grana and verrucae, found generally interspersed with each other.

Comparison — *Leioplanktona madhensis* approximates the present species in shape and general organization but is easily distinguished by its smooth outer wall.

Genus — *Spinasphaera* gen. nov.

Type Species — *Spinasphaera robusta* sp. nov.

Diagnosis — Solitary microplankton circular-subcircular in shape but generally a few-many are grouped together forming various shapes. No definite plate system is observed. Outer wall bedecked with very closely placed, robustly built spines. An opening near margin is seen in some specimens.

Description — Microplankton reddish brown in colour, 18-69 μ; solitary microplankton is rarely observed, microplanktons are so solidly grouped together that the individual ones are hardly traceable. Outer wall up to 3 μ thick, it is almost completely hidden by spines, spines up to 8 μ long. Very much juxtaposed and seem to be arranged radially. Opening is rarely observed and its nature can also be hardly ascertained.

Comparison — *Baltisphaeridium* (Els.) Down. & Sarj. (1963) resembles rather closely *Spinasphaera* in circular-subcircular shape and presence of spiny processes. The present genus is, however, distinguished by its very closely placed spines allowing no room in between them and presence of an opening near margin. Besides, *Baltisphaeridium* is always found as individual specimens whereas the present one is mostly found in groups. *Oligosphaeridium* Dav. & Will. (1966), *Achomosphaera* Evitt (1963), *Hystrichosphaera* (Wet.) Dav. & Will. (1966) and *Hystrichosphaeridium* (Defl.) Dav. & Will. (1966) are all distinguished from *Spinasphaera* proposed here by their possession of definite archaeopyle and number of processes. *Polysphaeridium* Dav. & Will. (1966) is also distinguished by its presence of apical archaeopyle and less number of processes.

Spinasphaera robusta sp. nov.

Pl. 1, figs. 7-10

Holotype — Pl. 1, fig. 7, size 44×42 μ. Slide no. 4772/3.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Individual microplankton circular-subcircular, 18-69 μ, generally grouped together to loose individual entity. Outer wall up to 3 μ thick, hardly observed due to spines, spines up to 8 μ long, very closely placed and strongly built. An opening near margin sometimes observed in some specimens.

Genus — *Matanomadhia* gen. nov.

Type Species — *Matanomadhia indica* sp. nov.

Diagnosis — Microplankton elliptical-oval in shape, median girdle distinct or indistinct on one or both sides. On one side, few longitudinal plate generally observed, they may or may not be interconnected with smaller plates; on other side many rectangular-rhomboid plates are present. Outer wall mostly smooth, no definite opening is found.

Description — Microplankton generally elliptical in overall shape but may also be oval, size range 67-235×52-137 μ. Median girdle found distinctly only in few specimens. Longitudinal plates look like grooves and mostly extend from one end to other, their number varies from 1-6, sometimes they are branched and connected with each other, in others they run parallel and interconnecting plates are not traceable. In some specimens, no longitudinal plates could be traced and only a few transverse plates could be deciphered. The other side of microplankton is made up mostly of many small plates. On one side of girdle 10 plates could be counted in one specimen (pl. 1, fig. 11a); on the other moiety, transverse plates are not so well developed and instead, a few longer plates are observed. Outer wall up to 4 μ thick, generally smooth but in a few specimens it may be intrastructured (Text-fig. 3).

Comparison — *Leioplanktona* is subcircular-circular in shape and is made up of three plates only. It has also distinct operculum which is made up of number of plates. *Palanaea* Sah & Kar (1974) resembles the present genus in elliptical-rectangular shape and in the presence of longitudinal plates; but is distinguished by the absence of median girdle and transverse plates connecting the longitudinal ones.

Derivation of Name — The genus has been instituted after the Matanomadh Formation.

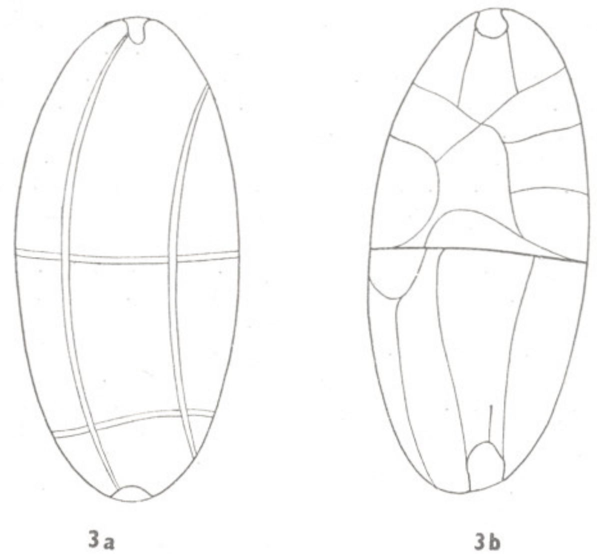
Matanomadhia indica sp. nov.

Pl. 1, figs. 11a-11b

Holotype — Pl. 1, figs. 11a-11b, size 209×120 μ. Slide no. 4776/3.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Microplankton elliptical-oval in shape, 110-220×60-150 μ; median girdle generally decipherable; on one side, few longitudinal plates are mostly traceable, they may be unbranched or branched and may be connected to each other by means of rectangular-rhomboid plates. On other side, longitudinal plates generally absent and many plates of ± rectangular-rhomboid shapes are observed. On the holotype, 10 plates could be counted at one side of the girdle, on other specimens, plates are not so distinct and only a few plates could be traced.



TEXT-FIG. 3 — Showing the organization and plate system in *Matanomadhia* gen. nov. 3a — showing the longitudinal plates. 3b — showing the smaller plates on the other side.

Matanomadhia ovata sp. nov.

Pl. 2, figs 12a-14; Pl. 4, figs. 41-42

Holotype — Pl. 2, figs. 12a-12b, size 109×78 μ. Slide no. 4777/19.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Microplankton mostly oval, 58-126 μ, median girdle not traceable in most specimens. Longitudinal plates look like grooves extending from one end to other, they are distinct at least on one side and interconnected with each other to form ± rectangular-rhomboid plates. On other side, many plates are generally observed, they are also ± squarish-rhomboid in shape. Outer wall smooth.

Comparison — *Matanomadhia indica* closely resembles *M. ovata* in general organization but the latter is differentiated by its oval shape and in the absence of median girdle.

Matanomadhia sp.

Pl. 4, fig. 40

Description — Microplankton oval, 134×68 μ, no median girdle could be deciphered, longitudinal plates also not traceable, two transverse plates are, however, present; they are interconnected to each other by means of another plate. Besides, 3 or 4 minor plates are also observed at one end. Outer wall strongly microfoveolate.

Comparison - The species described here is distinguished from *Matanomadhia indica* and *M. ovata* in the absence of median girdle and longitudinal plates. The present species is also conspicuous by the presence of microfoveolate outer wall.

cf. *Matanomadhia* sp.

Pl. 2, fig. 19

Description — Microplankton oval, 108×64 μ. On one side, a median plate divides the organism into two unequal halves. On other side, three plates are visible. Wall is about 3 μ thick, translucent, slightly protruding at two ends; inside the wall there are rod like bacular structures.

Remarks — The specimen comes closer to *Matanomadhia* in the presence of oval shape and a median girdle. But it differs in having an intrabacular outer wall which is slightly projected at two ends.

Microplankton type — 1

Pl. 2, fig. 16

Description — Subcircular-circular microplankton, 48-74 μ. Inner region dense, dark brown, conforming overall shape. In some specimens, it constitutes minute, unicellular bodies; in others, only a dense mass having some oil globules are seen. The central mass is encircled either by a translucent or a light brown sheath.

Microplankton type — 2
Pl. 2, fig. 17

Description — Microplankton oval-elliptical in shape, 67-121 × 31-79 μ, inner mass oval-elliptical, dark brown and generally have many oil globules. Central mass generally surrounded by a translucent-light brown sheath.

Remarks — Microplankton type-1 resembles the present specimens in general organization but is differentiated by its subcircular-circular shape.

Microplankton type — 3
Pl. 2, figs. 18a-18b

Description — Microplankton oval, 70 × 54 μ. On one view, it shows 4 irregular plates, while on the other, it has 4 rectangular plates; these plates fall short at one margin and are accompanied by 3 or 4 smaller plates. Operculum seems to be intact and subcircular in outline.

Remarks — No microplankton genera are closely comparable to this type. Only a solitary specimen has been recorded in the present material and so nothing is known about its variations.

Microplankton type — 4
Pl. 4, figs. 48-49

Description — Microplanktons oval, 60-76 μ; a tubular cavity present. Outer wall laevigate-sculptured.

Remarks — The tubular cavity present in the specimens distinguishes it from the other microplankton types described here (Text-fig. 4).

TEXT-FIG. 4 — Showing the organization in Microplankton type — 4.

Algal filament — type 1
Pl. 3, fig. 39

Description — Filaments broken, unbranched, 15-29 celled, septa distinct, parallel to one another, wall up to 1·5 μ thick. Individual cells mostly rectangular and more or less of same size.

Remarks — The general appearance of the filament resembles green and blue green algae; but further affinity up to family level can not be traced.

FUNGI

Genus — *Phragmothyrites* (Edw.) emend.

Type Species — Phragmothyrites eocaenica (Edw.) emend.

1942 — *Phycopeltis microthyrioides* Kirch., pp. 177, 201, figs. 1-5, 7, 8.
1947 — *Microthyriacites* Cook., pp. 210-211, pl. 13, figs. 17-19; pl. 14, figs. 20, 21.
1965 — *Callimothallus* Dil., pp. 13-15, pl. 5, figs. 37-42; pl. 6, figs. 43-46; pl. 7, figs. 47-55.
1965 — *Microthallites* Dil., pp. 16-17, pl. 10, figs. 83-85; pl. 12, figs. 92, 95, 96.
1969 — *Pseudosphaerialites* Venk. & Kar., pp. 180-181, pl. 1, figs. 6, 7.

Remarks — Microthyriaceous and allied fungal remains have been described from the various Tertiary sediments in wide geographical regions (Edwards, 1922; Potonié, 1934; Potonié & Venitz, 1934; Thiergart, 1940; Kirchheimer, 1942; Wilson & Webster, 1946; Cookson, 1947; Hunger, 1953; Maàcz & Simoncsics, 1956; Neuy-Stolz, 1958; Rao, 1959; Raukopf, 1959; Kedves, 1960; Graham, 1962; Dilcher, 1965; Sah, 1967; Venkatachala & Kar, 1969b; Jain & Gupta, 1970; Kar, Singh & Sah, 1972; Ramanujam & Rao, 1973; Jain, 1974 and others).

Edwards (1922) described in details a few microthyriaceous ascostromata from the Lower Eocene interbasaltic beds of Mull, Scotland. He found these discoid bodies on some coniferous leaves and instituted the genus *Phragmothyrites* to accommodate these fossil forms whose exact position is uncertain but which appear to be closely related to the extant genus *Phragmothyrium*. The specimens which he described are up to 165 μ in size, radiate, nonostiolate, dimidiate and without any free mycelium. He designated *Phragmothyrites eocaenica* as the type species of the genus. He, however, did not designate any holotype for the species.

Kirchheimer (1942) described some microthyriaceous epiphyllous fungi as *Phycopeltis microthyrioides* from the Oligocene brown coals of Germany. It may be mentioned here that *Phycopeltis* is an algal genus and it has many apparent resemblance to microthyriaceous ascostromata. Dilcher (1965) has already pointed out that the specimens described by Kirchheimer (1942) are really the remains of epiphyllous, microthyriaceous fungi.

Cookson (1947) proposed the genus *Microthyriacites* for the radiate dimidiate, ascostromata with unknown ascospores. This genus has already been put as a junior synonym of *Phragmothyrites* by Sah (1967). Venkatachala and Kar (1969b) opined that of the three species described by Cookson (1947), *Microthyriacites grandis* and *Microthyriacites* sp. very closely resemble *Phragmothyrites* while *M. fimbriatus* is distinguished from *Phragmothyrites* by its large size and presence of dark strongly built, thick walled radiating hyphae in the middle region. In the present material, many microthyriaceous ascostromata have been studied with wide variation and it seems that this species can also be accommodated in the genus *Phragmothyrites*.

Dilcher (1965) described many hitherto unknown fungal fossil forms from the Eocene deposits in Western Tennessee, USA. He instituted two new genera, viz., *Callimothallus* and *Microthallites* for the microthyriaceous ascostromata. He defined *Callimothallus* as, " no free hyphae. Stroma round, radiate, astomate, no central dehiscence, individual cells may possess single pore. Spores undetermined". For the genus *Microthallites* he proposed: " stroma radiate, more or less round, lacks free hyphae, ostiolate or non-ostiolate. Spores unknown".

It is apparent from the above generic diagnoses that the two genera hardly differ from one another except that in *Callimothallus* " individual cells may possess single pore". The tone of uncertainty in the author's diagnosis bespeaks with eloquence that this character alone can not be taken as criterion to distinguish the said two genera.

It has already been stated that Edwards (1922) did not designate any holotype for *Phragmothyrites eocaenica*, the type species of the genus. He, however, illustrated a number of specimens of the same. Of these, fig. no. 4 of pl. 8 shows a few pores scattered throughout the ascostromata. In fig. no. 2 of pl. 8, the pores are not conspicuous but it seems that a few are also present. So Dilcher's claim that " *Callimothallus* is the only genus in the Microthyriaceae which is multiporate " (Dilcher, 1965, p. 15) seems to be ill-founded. Besides, his transfer of fig. nos. 5-6 of pl. 8 of Edwards (1922) to young forms (germlings) of microthyriaceous fungi does not invalidate the genus *Phragmothyrites*. Edwards (1922) also referred them as stigmocysts which are unicellular, hyphopodia with more or less circular shape and deeply crenulate margin. The other specimens figured by Edwards (pl. 8, figs. 1, 4) are very much similar to the specimens included by Dilcher (1965) under *Callimothallus* Dil. (1965, pl. 5, figs. 37-42; pl. 6, figs. 43-46; pl. 7, figs. 47-55) and *Microthallites* Dil. (1965, pl. 10, figs. 83-85; pl. 12, figs. 92, 95-96). Since the genus *Phragmothyrites* has been validly published before *Microthyriacites* Cook. (1947), *Callimothallus* Dil. (1965), *Microthallites* Dil. (1965) and *Pseudosphaerialites* Venk. & Kar (1969b) so it has got nomenclatural priority over these genera. The genus *Phragmothyrites* has, however, not been systematically diagnosed by Edwards (1922). He also did not emphasize some characters of taxonomic importance. For these reasons, *Phragmothyrites* has been emended here as follows: no free hyphae, ascostromata subcircular-circular, dimidiate, nonostiolate; hyphae radially arranged, interconnected to form pseudoparenchymatous cells; central cells ± squarish-subcircular, outer cells elongated, may be setose at margin and thickened. Cells with or without pore, generally cells in middle region are more porate than outer ones.

Phragmothyrites eocaenica (Edw.) emend

Pl. 3, fig. 20

1947 — *Microthyriacites grandis* Cook., p. 211, pl. 14, figs. 20-21.
1947 — *Microthyriacites* sp. Cook., p. 211, pl. 13, figs. 18-19.
1965 — *Callimothallus pertusus* Dil., pp. 13-14, pl. 5, figs. 37-42; pl. 6, figs. 43-46; pl. 7, figs. 47-55.
1969b — *Pseudosphaerialites senii* Venk. & Kar, p. 181, pl. 1, figs. 6-7.
1972 — *Callimothallus* sp. cf. *C. pertusus* Dil.: Kar, Singh & Sah, p. 151, pl. 2, fig. 21.
1973 — *Callimothallus pertusus* Dil., Raman. & Rao, p. 205, pl. 2, figs. 15-18.

Lectotype — Edwards, 1922, pl. 8, fig. 3.

Type Locality — Interbasaltic beds of Mull (Lower Eocene), Scotland.

Emended Diagnosis — Ascostromata subcircular-circular, no free hyphae observed, dimidiate, nonostiolate, hyphae radially arranged and interconnected with each other to form mostly one celled thick pseudoparenchymatous cells. Cells in middle region are less elongated than marginal ones; cell walls ± uniformly thick throughout or marginal cells thicker and setose. Pores generally present or sometimes absent, cells uniporate, central cells generally more porate than outer ones.

Phragmothyrites fimbriatus (Cook.) comb. nov.

1947 — *Microthyriacites fimbriatus* Cook., p. 211, pl. 13, fig. 17.

Holotype — Cookson, 1947, pl. 13, fig. 17.

Diagnosis & Description — See Cookson, 1947, p. 211.

Phragmothyrites lutosus (Dil.) comb. nov.

1965 — *Microthallites lutosus* Dil., p. 16, pl. 10, figs. 83-85.

Holotype — Dilcher, 1965, pl. 10, figs. 84-85.

Diagnosis & Description — See Dilcher, 1965, p. 16.

Phragmothyrites quilonensis (Jain & Gupta) comb. nov.

1970 — *Callimothallus quilonensis* Jain & Gupta, p. 180, pl. 1, figs. 15, 16.

Holotype — Jain & Gupta, 1970, pl. 1, figs. 15, 16.

Diagnosis & Description — See Jain & Gupta, 1970, p. 180.

Genus — *Notothyrites* Cook, 1947

Type Species — *Notothyrites setiferus* Cook., 1947.

Notothyrites setiferus Cook., 1947

Pl. 3, fig. 21; Pl. 4, fig. 43

Description — Ascostromata generally subcircular, dimidiate, ostiolate, cells around ostiole thick walled and generally few celled thick. Hyphae radially arranged, interconnected to form pseudoparenchymatous cells, outer cells one layered thick, elongated and nonporate.

Notothyrites amorphus sp. nov.

Pl. 4, figs. 44, 45

Holotype — Pl. 4, fig. 44, size 59×53 μ. Slide no. 4784/6.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Ascostromata mostly subcircular, $45\text{-}105 \times 40\text{-}98$ μ, dimidiate, ostiolate, ostiole surrounded by a wall of few celled thick. Hyphae radially arranged but do not anastomose to form distinct pseudoparenchymatous cells.

Comparison — The present species is distinguished from *Notothyrites setiferus* Cook. (1947), *N. airensis* Cook. (1947) and *N. denticulatus* Raman. & Rao (1973) by its absence of distinct pseudoparenchymatous cells.

Notothyrites sp. cf. *N. amorphus* sp. nov.

Pl. 4, fig. 46

Description — Ascostromata elliptical, large, 223×118 μ, ostiolate, ostiole distinct, surrounded by a thin but a few celled thick wall. Hyphae not individually distinguishable, pseudoparenchymatous cells are also not conspicuous.

Remarks — The specimen described here resembles *Notothyrites amorphus* in the absence of distinct pseudoparenchymatous cells but is differentiated by its large size. Besides, the wall surrounded the ostiole in the present specimen is also thinner in comparison to *N. amorphus*.

cf. *Notothyrites* sp.

Pl. 3, fig. 22

Description — Ascostromata subcircular, 140×118 μ, dimidiate, ostiolate, ostiole not surrounded by a thick wall made up of few layers of cells; hyphae radially arranged, anastomose to form pseudoparenchymatous cells, cells 2-6 μ in size.

Remarks — The ostiole in *Notothyrites* Cook. (1947) is surrounded by a few celled thick wall. The present specimen is devoid of any such wall. Hence, the said specimen has only been compared with *Notothyrites*.

Genus — *Inapertusporites* (v.d.Ham.) Els., 1968

Type Species — *Inapertusporites typicus* v.d. Ham., 1954

Remarks — van der Hammen (1954) referred and described the nonaperturate fungal spores as *Inapertusporites*. Elsik (1968) emended the genus and wrote it as *Inapertisporites*. The original name proposed by van der Hammen (1954) is retained here.

Inapertusporites kedvesii Els., 1968

Pl. 3, fig. 23; Pl. 4, fig. 47

Description — Subcircular-circular fungal spores, 27-72 μ, inaperturate. Spore wall up to 1 μ thick, irregularly folded.

Inapertusporites sp.

Pl. 3, fig. 24

Description — Spores spindle shaped, 30-82×8-21 μ, inaperturate, usually nonseptate. spore wall less than 1 μ thick, generally folded along longitudinal axis.

Comparison — The present species is distingnished from *Inapertusporites kedvesii* Els. (1968) by its spindle shape.

Genus — *Pluricellaesporites* (v.d.Ham.) Els., 1968

Type Species — *Pluricellaesporites typicus* v.d. Ham., 1954.

Pluricellaesporites planus Triv. & Verma., 1969

Pl. 3, figs. 25-26

Description — Spores elliptical with unequally broad ends, penta- to octacellate. Pore at broader end, small but distinct. Septa thick, cells slightly bigger in middle region. Spore wall less than 1 μ thick, laevigate.

Genus — *Dicellaesporites* Els., 1968

Type Species — *Dicellaesporites popovii* Els., 1968.

Dicellaesporites popovii Els., 1968

Pl. 3, fig. 27

Description — Bicellate, elliptical-oval fungal spores, 39-48×19-28 μ; inaperturate. Septa distinct, spore wall 1 μ thick, laevigate.

Dicellaesporites minutus sp. nov.

Pl. 3, fig. 28

Holotype — Pl. 3, fig. 28, size 27×18 μ. Slide no. 4791/10.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Spores bicellate, oval, 23-33×7-12 μ; inaperturate, septa distinct, individual cells ± same in size and shape. Spore wall up to 1·5 μ thick, laevigate.

Comparison — *Dicellaesporites popovii* Els. (1968), the type species of the genus, shows similarity with the present species in shape and general organization. *D. minutus* proposed here is, however, distinguished by its smaller size range.

Genus — *Multicellaesporites* Els., 1968

Type Species — *Multicellaesporites nortonii* Els., 1968.

Multicellaesporites elsikii sp. nov.

Pl. 3, figs. 29-30

Holotype — Pl. 3, fig. 29, size 64×21 μ. Slide no. 4792/14.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Spores ± elliptical, generally pentacellate but may vary from tetra- to hexacellate, 49-68×16-27 μ; inaperturate, septa clear, individual cells ± of same size, spore wall up to 1 μ thick, psilate.

Comparison — *Multicellaesporites nortonii* Els. (1968) is fusiform and the middle cells are bigger in size; whereas the present species is elliptical in shape and the cells are more or less of same size.

Genus — *Monoporisporites* (v.d.Ham.) Els., 1968

Type Species — *Monoporisporites minutus* v.d. Ham., 1954.

Monoporisporites stoverii Els., 1968

Pl. 4, fig. 51

Description — Spore subcircular, 29 μ, monoporate, pore distinct, slightly protruding, wall about 1·5 μ thick, laevigate.

Genus — *Diporisporites* (v.d.Ham.) Els., 1968

Type Species — *Diporisporites elongatus* v.d. Ham., 1954.

Diporisporites elongatus v. d. Ham., 1954

Pl. 3, figs. 31-32

Description — Spore unicellular, diporate, elliptical, 39-72×19-43 μ. Pore distinct, pore margin not thickened, exine laevigate, minutely folded.

Diporisporites anklesvarensis (Var. & Raw.) Els., 1968

Pl. 3, fig. 33

Remarks — Varma and Rawat (1963) instituted *Foveodiporites* to accommodate diporate pollen grains with foveolate exine from the Tertiary deposits of India. They designated *Foveodiporites anklesvarensis* as the type species of the genus. Elsik (1968) transferred this species to *Diporisporites* as *D. anklesvarensis* (Var. & Raw.) Els.

The specimens studied in the present preparation referable to *D. anklesvarensis* have punctate exine, pore margin at each end is denser and thickened. In some specimens, the pore seems to be slightly protruding.

Genus — *Diporicellaesporites* Els., 1968

Type Species — *Diporicellaesporites stacyi* Els., 1968.

Diporicellaesporites stacyi Els., 1968

Pl. 3, fig. 34

Description — Tetracellate, laevigate, diporate fungal spores, 38-61×17-25 μ. One pore at each end, pore distinct, margin slightly thickened, sometimes protruding. Septa well developed, thickened, spore wall up to 2 μ thick.

Diporicellaesporites pluricellus sp. nov.

Pl. 3, figs. 35-36

1963 — *Diporicellaesporites* (?) sp. Elsik, p. 279, pl. 3, fig. 12.

1972 — *Diporicellaesporites* sp. Kar, Singh & Sah, p. 152, pl. 2, fig. 27.

Holotype — Pl. 3, fig. 35, size 96×28 μ. Slide no. 4791/12.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Spores generally eight celled but number may vary from seven to eleven, 67-94×19-38 μ, ± elliptical in shape. One pore at each margin, pore well developed, sometimes may be slightly protruding. Spore wall up to 2·5 μ thick, psilate. Septa distinct, straight or slightly curved, cells are bigger in size in middle region.

Comparison —*Diporicellaesporites stacyi* Els. (1968) comes near to the present species in shape and laevigate spore wall. But *D. stacyi* is only 4 celled whereas the present species has 7-11 cells.

Genus—*Involutisporonites* (Clar.) Els., 1968

Type Species — *Involutisporonites wilcoxii* Els., 1968.

Involutisporonites kutchensis sp. nov.

Pl. 3, figs. 37-38

1959 — Rao, p. 46, pl. 1, fig. 13.
1972 — *Involutisporonites* sp. Kar, Singh & Sah, p. 152, pl. 2, fig. 28.

Holotype — Pl. 3, fig. 37, size $77 \times 72\ \mu$. Slide no. 4795/3.

Type Locality — Matanomadh, Matanomadh Formation (Palaeocene), Kutch, Gujarat.

Diagnosis — Coiled, laevigate, generally monoporate fungal spores. Cells on central region darker with thicker wall and rhomboid-squarish shape, outer cells thinner but longer in size to form rectangular shape.

Comparison — *Involutisporonites wilcoxii* Els. (1968) resembles the present species in general organization but the latter is distinguished by its presence of comparatively smaller cells in middle as well as in outer region. *Involutisporonites* (?) sp. also described by Elsik (1968) is only tetracellate and has also thickened rim around the pore.

DISCUSSION

General Consideration — The algal and fungal elements described here comprise 20 genera and 27 species. Of them, 10 genera and 13 species belong to algal and the rest 10 genera and 14 species show fungal affinities. Comparatively speaking, fungal bodies are more common than the algal ones in the assemblage. Among the fungi, microthyriaceous ascostromata are found in abundance. Their dimidiate nature and absence of free mycelium indicate their complete dependence on the leaves of the host plants.

No microthyriaceous ascostromata have been found in direct contact with the cuticle in the present preparation. The fungal elements are, however, found in slides richly populated by *Dandotiaspora* Sah, Kar & Singh (1971) and *Couperipollis* Venkatachala & Kar (1969a). *Dandotiaspora* shows unmistakable relationship to pteridophytes while, *Couperipollis* is supposed to be related to Palmae. The pteridophytes, speaking in general, are comparatively immune to the fungal attack than the angiosperms. Moreover, the abundance of epiphyllous, microthyriaceous fungi in different Tertiary sediments from varied geographical regions, perhaps indicates its close relationship with the angiosperms. The fungi like algae are found from the very old sediments but it is only in the Tertiary, in association with the angiospermic evolution, they flourished and diversified. So, in all probability, the microthyriaceous remains described here were parasites on the leaves of angiosperm.

The present day microthyriaceous fungi are also found parasites mostly on the angiospermic leaves though Edwards (1922) and Dilcher (1965) also found them on conifers. This strengthens the supposition that the fossil ones were also parasites on angiosperm.

In India, Pande and Patwardhan (1967) recorded the occurrence of a new species of *Maublancia*, viz., *M. indica* of Microthyriaceae on the leaves of *Eugenia jambolana* Lamk. belonging to the family Myrtaceae. Patwardhan, Joshi and Mhaskar (1974) also reported *Asteridiella linocieriae* Hansf. (1956) of Microthyriaceae on the young seedlings of *Olea dioica* Roxb. of Oleaceae from South India.

The extant microthyriaceous epiphyllous fungi are found mostly in tropical region. The abundance of epiphyllous fungi in the present material perhaps points out a humid, tropical climate during the time of deposition.

Comparison with Other Assemblages — Venkatachala and Kar (1969b) reported the fungal remains from the Naredi Formation (=Laki Stage) of Kutch. They described *Phragmothyrites* Edw. (1922), *Pseudosphaerialites* Venk. & Kar (1969b) and *Sphaerialites* Venk. & Kar (1969b). Out of these, *Pseudosphaerialites* has already been treated here as a junior synonym of *Phragmothyrites*.

The fungal remains described here are more diversified and also consists of fungal hyphae and spores besides disc like microthyriaceous ascostromata.

The hystrichosphaerids illustrated by Mathur (1963) also from the Naredi Formation are conspicuous by their absence in the assemblage described here. Perhaps, the condition of deposition was different and that is why they show different algal elements.

The algal and fungal assemblage described from the Tertiary sediments of Palana, Rajasthan, by Sah and Kar (1974) comprises 9 genera and 16 species of algal and 3 genera and 4 species of fungal remains. Of the algae, 7 genera and 8 species are common to both the assemblages. They are: *Botryococcus palanaensis* Sah & Kar (1974), *Tetraporina apora* Sah & Kar (1974), *Cephalia globata* Sah & Kar (1974), *Octaplata rotunda* Sah & Kar (1974), *Palanaea granulosa* Sah & Kar (1974), *P. laevigata* Sah & Kar (1974), *Cryptosphaera valvata* Sah & Kar (1974) and *Cornplanktona unicorna* Sah & Kar (1974).

Mention may, however, be made here that the species listed above are very poorly represented in the present material. But the rest algal genera instituted here, viz., *Leioplanktona*, *Spinasphaera* and *Matanomadhia* are quite common in the assemblage.

Amongst the fungal remains from Palana, the following genera and species are also found in Matanomadh Formation: *Inapertusporites kedvesii* Els. (1968), *Dicellaesporites* Els. (1968) and *Phragmothyrites* Edw. (1922) emend. But *Phragmothyrites*, which is very common in the present assemblage, is meagrely represented in Palana. Besides, *Notothyrites* Cook. (1947), *Diporisporites* (v.d. Ham.) Els. (1968), *Dicellaesporites* Els. (1968) *Multicellaesporites* Els. (1968), *Diporicellaesporites* Els. (1968) and *Involutisporonites* (Clar.) Els. (1968) are also occasionally found in the present assemblage.

It is interesting to note that not a single fossil microplankton described from the Langpar Formation of Therriaghat (Upper Cretaceous), South Shillong Plateau, Assam by Sah, Kar and Singh (1970) is found in the present assemblage.

Kar, Singh and Sah (1972) described algal and fungal remains from the Tura Formation (Palaeocene-Lower Eocene) of Garo hills, Assam. Of the 7 algal genera reported by them, none is found in Matanomadh. Amongst the 8 fungal genera, *Phragmothyrites* Edw. (1922) emend., *Notothyrites* Cook. (1947), *Pluricellaesporites* (v. d. Ham.) Els. (1968), *Diporicellaesporites* Els. (1968) and *Involutisporonites* (Clar.) Els. (1968) are present in both the assemblages. *Cucurbitariaceites* Kar, Singh & Sah (1972) and *Parmathyrites* Jain & Gupta (1970) are, however, absent in the Matanomadh assemblage. Besides these differences, the fungal elements in both the assemblages are quite similar to each other.

Ramanujam (1963a, 1963b) and Ramanujam and Rao (1973) described some microthyriaceous fungi from the Miocene lignites of South India. They also found *Phragmothyrites* and *Notothyrites* in the Miocene lignites. But the fungal assemblage described by them can be easily distinguished from the present one by the presence of *Asterina eocenica* Dil. (1965), *Asterothyrites* sp., *Euthyrites keralensis* Raman. & Rao (1973) and *Plochmopeltinites cooksonii* Raman. & Rao (1973).

CONCLUSION

From the above discussion, it becomes apparent that the algal assemblage found in Matanomadh Formation is somewhat similar to that of Palana algal assemblage described by Sah and Kar (1974). But the fungal elements show more resemblance to Tura assemblage described by Kar, Singh and Sah (1972) than any other known assemblages. As the algal elements generally indicate the internal environment of the basin during the time of deposition, so it seems that both Palana and Matanomadh assemblages were deposited in more or less similar type of environment.

The abundance of microthyriaceous fungi, on the other hand, indicates that during Palaeocene, Matanomadh and the adjacent regions were enjoying a tropical and humid climate resulting a luxuriant vegetation of pteridophytes and angiosperms upon which the epiphyllous fungi flourished.

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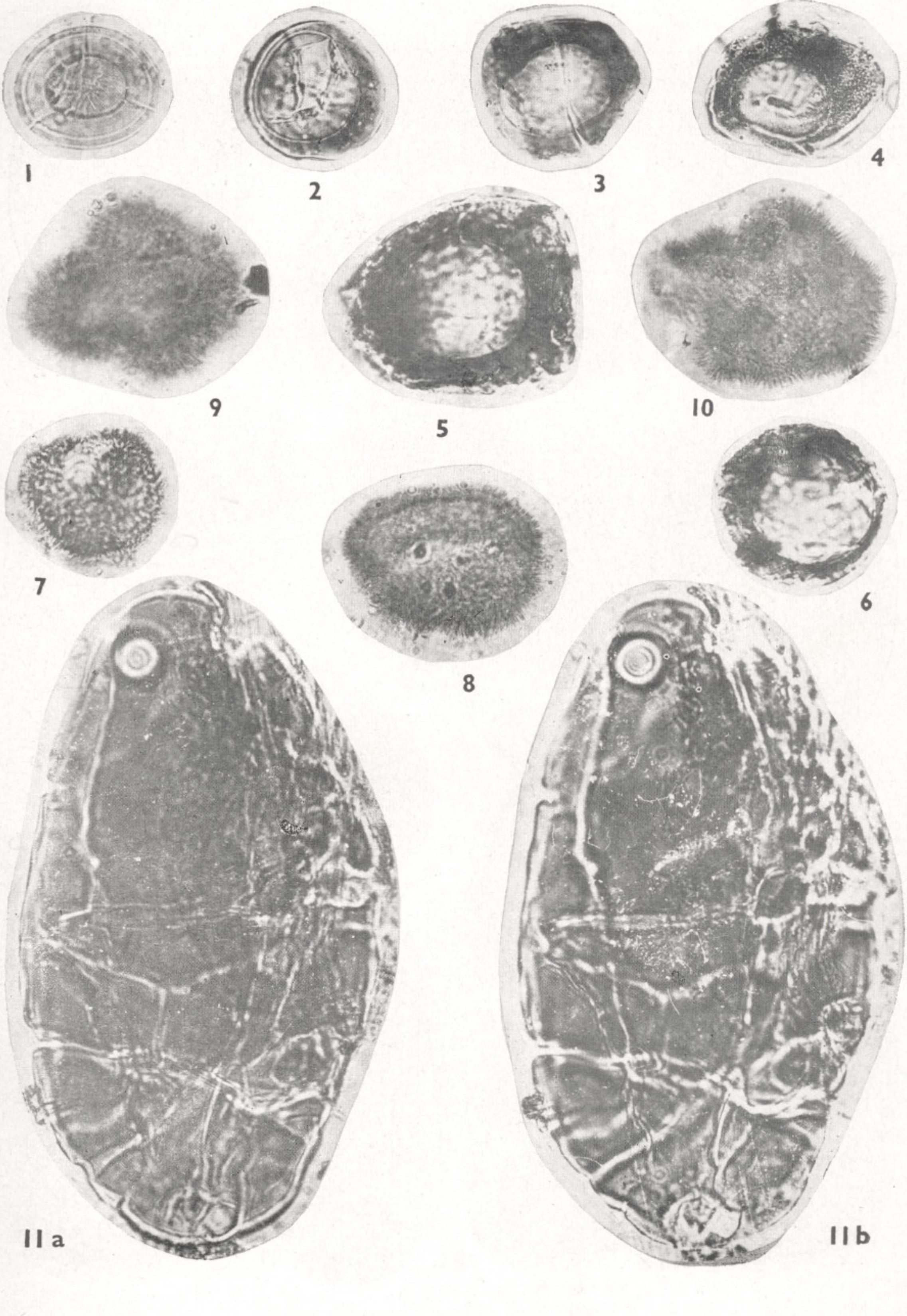
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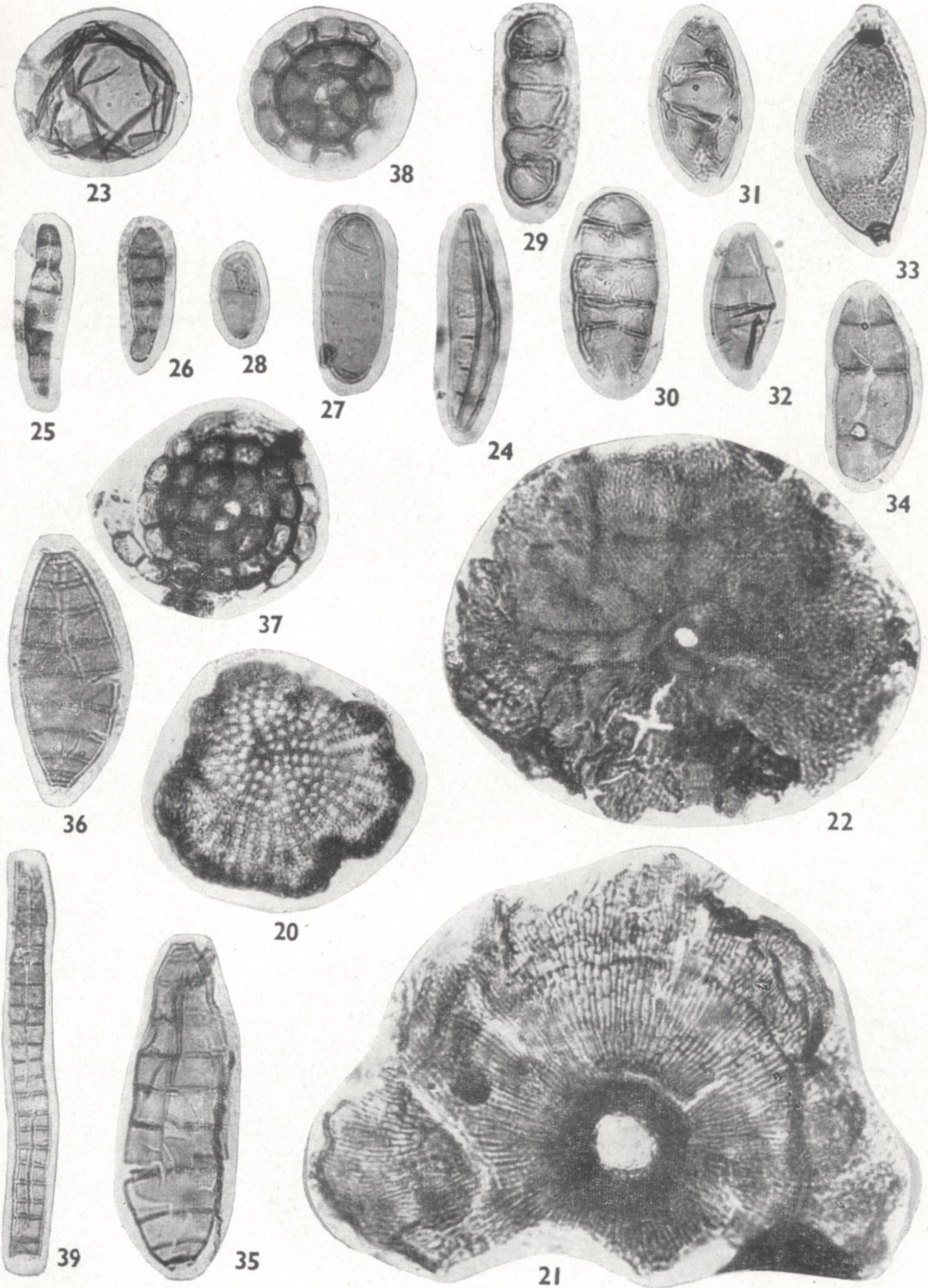
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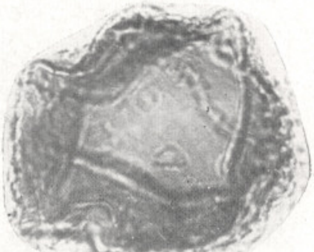

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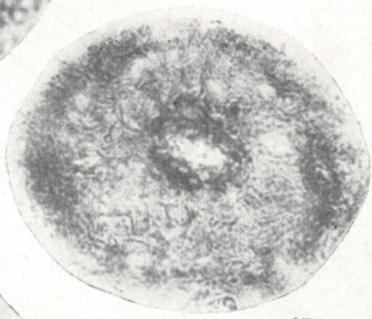

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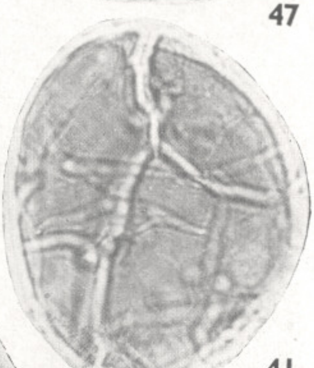

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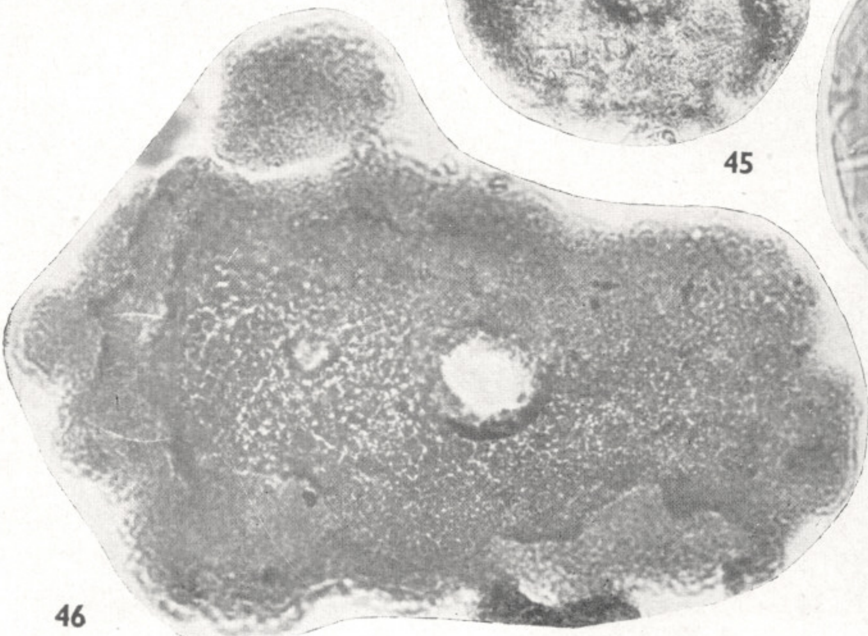

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EXPLANATION OF PLATES

(All photomicrographs are enlarged *ca.* × 500 unless otherwise mentioned)

PLATE 1

1-4. *Leioplanktona madhensis* gen. et sp. nov. Slide nos. 4766/15-(1338), 4767/8-(1338), 4768/1-(1338), 4769/22-(1338).

5-6. *Leioplanktona verrucosa* sp. nov. Slide nos. 4770/24-(1338), 4771/7-(1338).

7-10. *Spinasphaera robusta* gen. et sp. nov. Slide nos. 4772/3-(1338), 4773/5-(1338), 4774/3-(1338), 4775/10-(1338).

11a-11b. *Matanomadhia indica* gen. et sp. nov. Slide no. 4776/3-(1338).

PLATE 2

12a-14. *Matanomadhia ovata* sp. nov. Slide nos. 4777/19-(1338), 4778/6-(1338), 4776/9-(1338).

15a-15b. *Palanaea laevigata* Sah & Kar. Slide no. 4779/3-(1338).

16. Microplankton type-1. Slide no. 4780/19-(1338).

17. Microplankton type-2. Slide no. 4781/4-(1338).

18a-18b. Microplankton type-3. Slide no. 4782/10-(1338).

19. cf. *Matanomadhia* sp. Slide no. 4783/2-(1338).

PLATE 3

20. *Phragmothyrites eocaenica* (Edw.) emend. Slide no. 4784/12-(1338).

21. *Notothyrites setiferus* Cook. Slide no. 4785/13-(1338).

22. cf. *Notothyrites* sp. Slide no. 4786/2-(1338).

23. *Inapertusporites kedvesii* Els. Slide no. 4787/16-(1338).

24. *Inapertusporites* sp. Slide no. 4788/1-(1338).

25-26. *Pluricellaesporites planus* Triv. & Verma. Slide nos. 4789/6-(1338), 4790/2-(1338).

27. *Dicellaesporites popovii* Els. Slide no. 4766/1-(1338).

28. *Dicellaesporites minutus* sp. nov. Slide no. 4791/10-(1338).

29-30. *Multicellaesporites elsikii* sp. nov. Slide nos. 4792/14-(1338), 4766/13-(1338).

31-32. *Diporisporites elongatus* v.d. Ham. Slide nos. 4789/2-(1338), 4793/7-(1338).

33. *Diporisporites anklesvarensis* (Var. & Raw.) Els. Slide no. 4794/17-(1338).

34. *Diporicellaesporites stacyi* Els. Slide no. 4793/4-(1338).

35-36. *Diporicellaesporites pluricellus* sp. nov. Slide nos. 4791/12-(1338), 4794/15-(1338).

37-38. *Involutisporonites kutchensis* sp. nov. Slide nos. 4795/3-(1338), 4796/15-(1338).

39. Algal filament type-1. Slide no. 4797/5-(1338).

PLATE 4

40. *Matanomadhia* sp. Slide no. 4798/31-(1338).

41-42. *Matanomadhia ovata* sp. nov. Slide nos. 4776/4-(1338), 4783/1-(1338).

43. *Notothyrites setiferus* Cook. Slide no. 4785/12-(1338).

44-45. *Notothyrites amorphus* sp. nov. Slide nos. 4784/6-(1338), 4791/17-(1338).

46. *Notothyrites* sp. cf. *N. amorphus* sp. nov. Slide no. 4799/1-(1338).

47. *Inapertusporites kedvesii* Els. Slide no. 4776/2-(1338).

48-49. Microplankton type-4. Slide nos. 4800/2-(1338), 4801/10-(1338).

50. *Octaplata rotunda* Sah & Kar. Slide no. 4775/11-(1338).

51. *Monoporisporites stoverii* Els. Slide no. 4784/2-(1338).