ON SOME MICROTHYRIACEOUS FUNGI FROM A TERTIARY LIGNITE OF SOUTH INDIA*

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ABSTRACT

The paper deals with some well preserved remains of fruit bodies of the microthyriaceous fungi recovered from the Upper Tertiary (U. Miocene) Warkalli lignite of Kerala state. *Notothyrites, Callimothallus, Asterina, Euthyrites* and *Plochmopeltinites* represent the common taxa in the material examined. The following are the species recorded, viz. *Notothyrites setiferus, N. airensis, N. denticulatus* sp. nov., *Callimothallus pertusus, C. raoi* sp. nov., *Asterina eocenica, Asterothyrites* sp., *Euthyrites keralensis* sp. nov., and *Plochmopeltinites cooksonii* sp. nov. Numerous germlings of microthyriaceous fungi have also been encountered in the lignite samples.

The common occurrence of diverse types of microthyriaceous fungi in the Warkalli deposits clearly points toward the tropical humid climate in Kerala during the Upper Tertiary period. The paper also discusses briefly the geological history of the microthyriaceous fungi.

INTRODUCTION

STUDIES on fossil fungi in India have been few and far between despite the common occurrence of fungal spores, fruit bodies and mycelial shreds along with diverse type of spores of petridophytes and pollen grains and cuticles of higher plants in various Tertiary lignites and carbonaceous clays. Rao (1958) provided for the first time a systematic study of a few microthyriaceous fungi from the Upper Tertiary lignites of South Arcot and Warkalli areas in South India. Ramanujam (1963a) recorded a few well-preserved fruit bodies referable to Asterinae and *Euthyrites* of Microthyriaceae from the South Arcot lignite. The same year he (Ramanujam, 1963b) reported briefly the occurrence of *Notothyrites* of Microthyriaceae and *Plochmopeltinites* of Micropeltaceae from the South Arcot lignite. During the more recent years Venkatachala and Kar (1969), and Jain and Gupta (1970) have investigated the epiphyllous microthyriaceous fungi from the Early Tertiary deposits of Kutch and Late Tertiary carbonaceous clays of Kerala respectively.

In the course of an examination of the macerated detritus of some lignite samples from the Warkalli Formation (Miocene) in Kerala State of South India, the authors have come across numerous well-preserved discoid fruit bodies with a more or less distinct radial pattern along with diverse spores, pollen grains and leaf cuticles. Some of these fruit bodies are found epiphyllous on some shreds of angiosperm leaves. These fruit bodies show remarkable resemblances to the ascomata or thyriothecia of the microthyriaceous fungi of the order Hemisphaeriales of Ascomycetes. A number of ascomata recovered are found to be different from the ones known previously from the Indian Tertiary deposits. The present contribution deals with a study of some of the more commonly encountered forms of these fungi.

MATERIAL AND METHODS

The material consists of lignite samples (W.L.S. 1-3) of the Warkalli formation from near Warkalli in Kerala State. The lignite samples were partially crushed and treated first with dilute HF to remove silica if any. They were then treated with concentrated HNO_3 for 12 hours. The macerated residue was then repeatedly washed in distilled water and kept in 5% KOH for about 10 minutes. To reduce the percentage of spores and pollen grains of vascular plants and to increase relatively the concentration of fungal spores and fruit bodies KOH treatment was prolonged deliberately for many hours with certain samples of the macerated detritus. A number of slides have been made with Canada balsam, Glycerine and Glycerine-Jelly. The lignite samples and the prepared slides are in the palaeobotanical collection of the senior author at the Dept. of Botany, Osmania University, Hyderabad.

SYSTEMATIC DESCRIPTION

The fruit bodies reported in this paper are all referred to either Microthyriaceae or

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Micropeltaceae of the order Hemisphaeriales. Forms characterized by superficial, more or less flat, dimidate ascomata with a distinct radial construction of hyphae have been included in Microthyriaceae, and those with a plechtenchymatous structure consisting of highly sinuous hyphae, in Micropeltaceae. Asci and ascospores which provide diagnostic criteria in the identification of living taxa could not be observed in the thyriothecia, although a number of *sporae dispersae* possibly referable to microthyriaceous fungi could be found in the macerated detritus. Hence, various morphological characters of the ascomata such as the presence or absence of free mycelium associated with the fruit bodies, nature of ostiole and its border, presence or absence of setae and such other processes, occurrence of pores in the cells etc., have been taken into consideration for the identification of various taxa.

Germlings of Microthyriaceous Fungi

Pl. 1, Figs. 1-3

Numerous germlings showing a number of developmental stages of microthyriaceous fungi have been observed in all the samples studied. While these germlings may have developed into various mature forms, there is, however, no way of referring them to any specific taxon. Hence no attempt has been made to refer the germlings to any of the ascomata described in the present paper.

In extremely small, immature germlings which are irregularly rounded the walls show marginal thickenings at certain local areas. Invaginations of the walls are found in slightly larger germlings. These invaginations appear to have been formed by the differential growth of the germling margin. At this stage the germlings are of various irregular shapes. Germlings which appear to be older than the above show the presence of a group of more or less centrally placed cells surrounded by one or two rows of peripheral cells. The peripheral cells of some of the germlings show regular forking. Jain and Gupta (1970) recently reported more or less similar germlings from a Miocene carbonaceous clay near Quilon in Kerala State.

Family — Microthyriaceae
Sub-family — Microthyreae

Genus — *Notothyrites* Cookson 1947

N. setiferus Cookson 1947

Pl. 1, Figs. 4-6

Description — Free mycelium absent. Ascomata flattened, dimidate, rounded with faintly crenate margin, 80-100 μ in diam. Cells of radiating hyphae interconnected; cells towards ostiole border squarish, peripheral cells rectangular. Tangential walls of peripheral cells thickened. Fruit bodies ostiolate, ostiole 20-30 μ in diam., bordered by 2-4 layers of thick-walled dark-brown, narrow-lumened cells. Setiferous, setae 5-7, seen on cells bordering ostiole, non-septae, thick-walled towards base, thinner-walled apically. Setae 12 μ long brownish, tapering to more or less pointed tip, base 5 μ broad, tip 2·5 μ broad.

Comments — Fruit bodies of this type are found commonly in our slides; some of them are found to be aligned laterally so that the setae could be seen prominently (Fig. 6). The South Indian specimens agree in all important respects with the specimens described from the Oligo-Miocene of Australia (Cookson, 1947). *N. nayudii* reported from the South Arcot lignite (Ramanujam, 1963b) shows only two setae consistently. *N. padappakarensis* described recently from the Miocene of Quilon area, Kerala (Jain & Gupta, 1970) differs from *N. setiferus* in having small papillae on the cells bordering the ostiole.

N. denticulatus sp. nov.

Pl. 1, Figs. 7, 8

Diagnosis — Free mycellium lacking. Ascomata discoid, dimidate, rounded, margin smooth, rigid; 69-81 μ in diam. Ostiolate, ostiole centric, 10-15 μ in diam., elevated on slightly raised border. Ostiole border 3·4 layered, cells dark brown, thick-walled rounded to flattened, lumina narrow. Marginal cells of ascomata 5-16 μ × 3·8-6·5 μ, tangential walls thickened. Cells between ostiole border and ascomata periphery squarish to rectangular, with thickened tangential walls; 4-7 conical, teeth-like (denticular) processes protruding into ostiole

cavity from inner layer of border. Denticular processes 3-5 μ long, 4 or 5 μ broad basally, tip blunt or subacute often slightly reflexed.

Comments — The possession of denticular processes projecting into the ostiole cavity is the diagnostic feature of this species. *Notothyrites setiferus* and *N. neyvelii* are characterized by the possession of typical setae which are bristle like and longer and hence easily distinguishable from the short denticular processes of the present specimens (Cookson, 1947; Ramanujam, 1963b). *N. padappakarensis* (Jain & Gupta, 1970) in the possession of papillae confined to the outer marginal cells of the ostiole border is also quite different from *N. denticulatus*. Specimens of *N. denticulatus* are encountered frequently in the samples of the lignite examined.

Locality — Warkalli.

Geological Age — Upper Miocene.

Holotype — Pl. 1, Fig. 7, Slide: WLS-100; Co-ordinates: 17·8×80·8, Size: 70 μ.

Paratype — WLS 1-2, Pl. 1, Fig. 8; Co-ordinates: 13·7×85·3.

N. airensis Cookson 1947

Pl. 1, Fig. 9

Description — Free mycelium lacking. Ascomata flattened, dimidate, rounded, margin thin membraneous, smooth or faintly wavy; 55-75 μ in diam., distinctly elevated on conical border, ostiole border 3-5 layered, cells at border flattened, dark brown, thick-walled, lumina very narrow. Cells away from ostiole border cubical to rectangular, 3·75-6·25 μ × 2·5-3·75 μ.

Comments — The glabrous ascomata with a narrow ostiole and thin-walled almost membraneous peripheral margin compare favourably with *N. airensis* from the Oligo-Miocene of Australia (Cookson, 1947); hence included under the same species. Only a few specimens of *N. airensis* have been found in our preparations.

Callimothallus Dilcher 65

C. pertusus Dilcher 1965

P. 2, Figs. 15-18

Description — Free mycelium lacking ascomata (stromata) discoid, rounded to occasionally oval, 35-100 μ in diam., margin crenate or almost entire. Central cells of stroma crowded, small, 2·5-4 μ in diam., irregularly angled or cubical, darker in colour than other cells. Distinctly radial rows of cells extend outward from central cells; cells in radial rows 3-10 μ × 2·5-5 μ, rectangular to almost squarish, light coloured. Most of central cells and radiating cells conspicuously porate, pore single in each cell, 1-2 μ in diam., confined to proximal ends of cells in most of cells, but randomly situated in central cells.

Comments — But for their slightly smaller size these South Indian fruit bodies agree very well with *Callimothallus pertusus* described originally from the Eocene of Tennessee in USA (Dilcher, 1965). None of the many specimens examined showed the presence of any dehiscence. This is a fairly common type in our slides. *Callimothallus quilonensis* described from the Miocene of Quilon area in Kerala, South India (Jain & Gupta, 1970) can be distinguished from *C. pertusus* in having pores confined only to the peripheral cells of the stroma. But for the minutely papillose nature of the stromal margin, *Pseudosphaerialites* recently described from the Laki Stage (Eocene) of Kutch (Venkatachala & Kar, 1969) appears to agree with the generic circumscription of *Callimothallus*. The illustrations of *Pseudosphaerialites* given by Venkatachala and Kar (1969, Pl. 1, Figs. 6, 7) resemble very much Dilcher's *Callimothallus* in the possession of smaller, darker, irregularly angled central cells, from which radiate larger rectangular cells and in possessing distinct pores confined to the proximal ends of the radiating cells.

Callimothallus raoi sp. nov.

Pl. 3, Figs. 19, 20; Text-fig. 1

Diagnosis — Free mycelium lacking, Ascomata discoid, rounded, margin entire; 55-75 μ in diam. Central part consists of irregular cavity with ragged margin, 5 or 6 layers of cells around central cavity smaller, 1·25-3 μ in diam., darker, thick-walled, irregularly angled than cells of rest of fruit body. Cells nearer periphery in radiating pattern, light-coloured, thinner-walled, slightly larger than former, rectangular, 2·5-6 μ × 2-4 μ. Only few cells in central and peripheral regions porate, pore

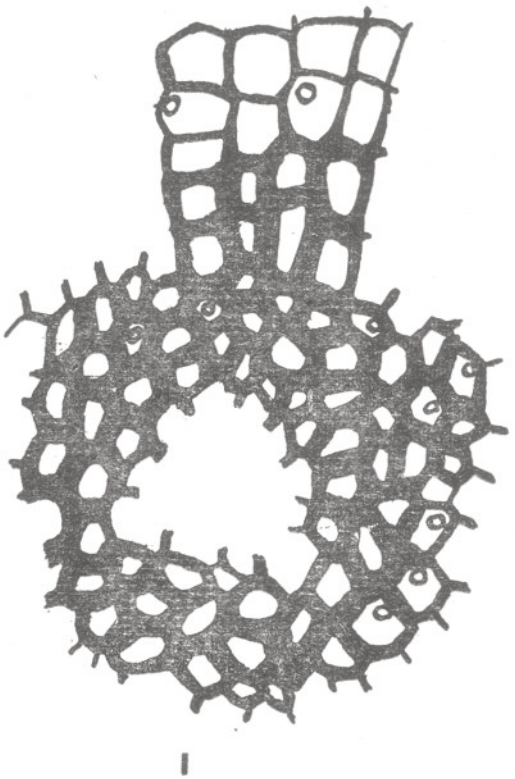
single 1-1·5 μ usually distal in peripheral cells, central to proximal in central thick-walled cells.

Comments — In the possession of a few layers of thick-walled cells towards the centre of fruit body, and only a few porate cells, the above described specimens differ from *Callimothallus pertusus*. To these differences may be added the presence of an irregular central cavity in the former. From the look of this cavity it appears as if it had resulted from the disorganization of some central cells of the ascomata. We are, however, not quite sure whether this is a regular feature of this species. We have treated this species under *Callimothallus* because of the presence of pores in some cells of the fruit body. The species has been named after Prof. A. R. Rao, who gave a systematic account of some microthyriaceous fungi for the first time from India.

Locality — Warkalli, South India.

Geological Age — Upper Miocene. Slide: WLS_1 87; Co-ordinates: 18·3×84·3, Size: 55 μ in diam.

Holotype — Pl. 3, Figs. 19, 20; Text-fig. 1.



TEXT-FIG. 1 — *Callimothallus raoi* sp. nov. Note the central cavity and the few cells of the stroma with pores (only part of fruit body shown). × 1250.

Sub-family — Asterineae

Genus — *Asterina* Levéille 1845

A. eocenica Dilcher 1965

Pl. 3, Fig. 21

Description — Free mycelium present but not profuse. Ascomata rounded small, 31-46 μ in diam., margin smooth or slightly wavy. Hyphae associated with ascomata non-hyphopodiate, 2·5 μ thick. Non-ostiolate, central cells thin-walled, cubical to irregularly angled, 2·5-3·75 μ × 2-3 μ, peripheral cells elongated, 2·75-7·5 μ long, forked or entire at outer margin.

Comments — Only a few specimens of this type are found in our slides. These closely resemble the smaller type of ascomata described by Dilcher (1965) from the Eocene of Tennessee, U.S.A.

***Asterothyrites* Cookson 1947**

Asterothyrites sp.

Pl. 3, Fig. 24

Description — Ascomata irregular, slightly lobed, central part non-ostiolate, raised, dark-brown, periphery almost colourless; 115-135 μ in diam., composed of slightly flexuous, thick-walled radiating hyphae; central cells 4 or 5 small, dark-brown cubical or irregularly angled, extremely thick-walled with narrow lumina, rest of ascomatal cells excepting marginal cells light-brown, usually rectangular; marginal cells very much elongated, 6·5-12 μ long, thin-walled almost colourless. Margin irregular, locally flexuous, and irregularly folded. Free hyphae dark to light-brown, somewhat sinuous, non-hyphopodiate, 1·5-2·5 μ thick. Mode of dehiscence not known.

Comments — The South Indian *Asterothyrites* sp. resembles *A. sinuatus* and *A. delicatissimus* described from Australia (Cookson, 1947) in its size, but is distinguishable from these in the possession of very much elongated, thin-walled marginal cells, and a group of 4 or 5 small extremely

thick-walled dark-brown central cells. *A. tennesseensis* from the Eocene of Tenneessee, USA (Dilcher, 1965) is more or less round with much shorter marginal cells than in our specimens. Further, information regarding the nature of central group of cells is not known with the American species as this zone was not found preserved in this species. As only two specimens of *Asterothyrites* type described above have been found in our slides, we have refrained giving any specific name to this type.

Genus — *Euthyrites* Cookson 1947

E. keralensis sp. nov.

Pl. 1, Figs. 10, 11; Pl. 2, Figs. 12-14

Diagnosis — Mycelium superficial, ascomata linear, elliptical to oblong, ends rounded or flattened, lateral margins uneven. Ascomata 125-350 μ × 60-100 μ, dehiscing by a longitudinal slit (7-13 μ broad); cells radiating from mid-vertical line, square to rectangular, 2·5-8 μ × 2·5-3·75 μ, thick-walled, brownish to dark-brown. Mycelial hyphae radiating mostly from lateral marginal cells, usually flexuous, 2·5-3·75 μ thick, hyphopodiate, hyphopodia small, peg-like.

Comments — Linear, radiate type of fruit bodies have been recovered commonly from all the lignite samples studied. The South Indian ascomata differ from *Euthyrites oleinites* described from the Upper Tertiary of Australia (Cookson, 1947) in the possession of flexuous, hyphopodiate mycelial hyphae, and in being smaller. The mycelial hyphae in *E. oleinites* are straight, rigid and non-hyphopodiate. The affinities of *E. keralensis* seem to be with species of the modern *Lembosia*. A number of *E. keralensis* ascomata have been found perched on some unidentifiable angiospermic leaf cuticles. The specific name is after Kerala State from where these fruit bodies have been recorded.

Locality — Warkalli.

Geological Age — Upper Miocene.

Holotype — Pl. 1, Fig. 10; Pl. 2; Figs. 12, 13; Slide: WLS_1-85; Co-ordinates: 12·1 ×79·0; Size 210×110 μ.

Paratype — Pl. 2, Fig. 14, Slide:WLS 102; Co-ordinates: 24·6×87·5.

Family — Micropeltaceae
Sub- family — Plochmopeltineae

Genus — *Plochmopeltinites* Cookson 1947

P. cooksonii sp. nov.

Pl. 3, Figs. 22, 23

Diagnosis — Ascomata superficial, discoid, rounded, brown to reddish brown, 65-166 μ in diam., ostiolate, ostiole 10-18·5 μ in diam., irregular in shape, more or less centric, border dense, slightly raised, of dark-brown thick-walled irregular cells, covering membrane of ascomata plechtenchymatous consisting of extremely sinuous, irregularly branched hyphae; hyphal cells 4-18 μ long, considerably thick-walled (3·5-6 μ) excepting cells of peripheral layer. Margin of fruit body not entire, formed of thin-walled membraneous peripheral cells. Free hyphae at times extending from marginal cells of ascomata wavy.

Comments — In the possession of considerably thick-walled cells forming the bulk of the plechtenchymatous covering, the absence of an entire margin and the irregular ostiole the species under report is disguishable from *Plochmopeltinites masoni* described from the Upper Tertiary of Australia (Cookson, 1947) and *P. ratnami* reported from the South Arcot lignite, Madras (Ramanujam, 1963b). The species has been named in honour of Dr. Isabel Cookson, as *P. cooksonii*. It is frequently met with in the lignite samples studied.

Locality — Warkalli.

Geological Age — Upper Miocene.

Holotype — Pl. 3, Figs. 22, 23; Slide: WLS_1-44; Co-ordinates: 17·2×79·0, Size: 130 μ.

DISCUSSION

Including the present study epiphyllous fossil fungi referable to Microthyriaceae and Micropeltaceae are now known from India from the Upper Miocene South Arcot lignite of Madras State (Rao, 1958; Ramanujam, 1963a, b). Intertrappean beds of Madhya Pradesh (Chitaley, 1957); Lower Tertiary sediments of Assam (Baksi, 1962), Kutch (Venkatachala and Kar, 1969), and Upper

Tertiary (Miocene) deposits of Kerala (Rao, 1958, Jain & Gupta, 1970). In addition to these records, Jacob & Jacob (1953) mentioned the occurrence of Trichopeltaceae on some angiosperm leaf cuticles of the South Arcot lignite of Madras State. The following taxa have so far been recovered from the Upper Tertiary lignites and carbonaceous clays of South India, viz., various species of *Microthyriacites, Parmathyrites indicus, Notothyrites padappakarensis, N. setiferus, N. airensis, N. denticulatus, Paramicrothallites menonii, Phragmothyrites* cf. *P. eocaenicus, Callimothallus quilonensis, C. pertusus, C. raoi, Asterina eocaenica, Asterothyrites* sp., *Euthyrites keralensis* and *Plochmopeltinites cooksonii.* Taxa recorded from the Eocene of Kutch are *Sphaerialites ovatus, Pseudosphaerialites senii* and *Phragmothyrites* sp. cf. *P. eocaenicus.* In all these cases we have no knowledge of the ascospores produced. However, a number of ascospore types possibly referable to the microthyriaceous ascomata are commonly found in the macerals. Unless these *sporae dispersae* are found within the fruit bodies there is no way of determining their exact affinities.

Modern microthyriaceous fungi are known to infect both coniferous as well as angiospermous leaves. The fossil taxa referable to these fungi have also been discovered on coniferous as well as angiospermous (dicotyledonous) leaves (Edwards, 1922, Cookson, 1947; Popov, 1960; Dilcher, 1965). No coniferous remains have been discovered so far in any of the South Indian lignites, while angiospermic remains in the form of leaves, woods and pollen grains however, are known abundantly from these lignites. This obviously indicates that the epiphyllous microthyriaceous fungi recovered from these Upper Tertiary lignites depended entirely on the then angiosperm foliage only.

From outside India microthyriaceous fungi have been recorded from the Eocene of Scotland (Edwards, 1922), Eocene to Miocene of Germany (Kräusel, 1920, 1950; Potonié, 1934, 1951; Tilgner, 1954), Pliocene of Minnesota, USA (Rosendahl, 1943), Oligo-Miocene of Australia and Newzealand (Cookson, 1947), Lower Miocene of Silesia, Poland (Macko, 1957), Oligocene of Russia (Popov, 1960), Tertiary of South Africa (Thiergart, Frantz & Raukopf, 1963), Palaeocene and Eocene of USA (Elsik, 1968; Dilcher, 1963, 1965), Upper Tertiary (Neogene) of Congo (Sah, 1967) and Late Tertiary of British Columbia, Canada (Martin and Rouse, 1965) etc. For a complete list of foreign records of microthyriaceous fungi reference may be made to the papers of Popov (1960) and Dilcher (1965).

The distribution of the microthyriaceous fungi during the Tertiary period, according to the available data, appears to be global as evidenced by their occurrence in Scotland, Germany, Sicily, East Europe, Western Siberia, Sumatra, Australia, Newzealand, Kerguelen Island, USA, Western Canada, South Africa, and India. At present, these fungi are most abundant in humid tropical to semitropical areas of the world with high rainfall. It is generally believed that more than the temperature, the factors promoting the rapid spread of these fungi are the rainfall and humidity. Some of the members like plochmopeltineae of Micropeltaceae appear to have enjoyed wider distribution during the Tertiary period compared to their present distribution (Cookson, 1947). The common occurrence of microthyriaceous fungi in the lignites from near Warkalli and carbonaceous clays of the Quilon area, indicates that the climate of the Miocene epoch in Kerala was of the warm humid tropical type. The present day climate of Kerala State is more or less of the same kind.

The oldest known epiphyllous fungi referable to Microthyriaceae have been reported from the Upper Cretaceous Laramie coal of South Park, Colarado, USA (see Dilcher, 1965). No Pre-Cretaceous microthyriaceous fungi are known to date. Dilcher (1965) visualized the origin of these fungi during Early or Middle Mesozoic Era. We, however, tend to believe that the origin of microthyriaceous fungi as the available data indicate could not probably be earlier than the Lower Cretaceous period. A number of these fungi already attained near modernity in their structural organization, by as early as palaeocene-Eocene times (Elsik, 1968; Dilcher, 1965).

The presumable origin of the microthyriaceous fungi in the Lower Cretaceous times when taken in conjunction with their modern aspect by the Palaeocene-Eocene times, appears to be a clear indication of the fast pace of their evolutionary progress, once these fungi appeared. As the Cretaceous period represents the crucial age for the rise and rapid spread or radiation of

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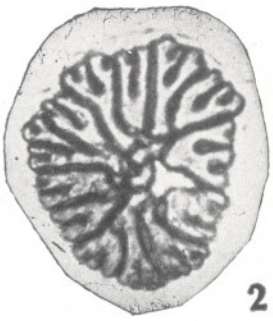

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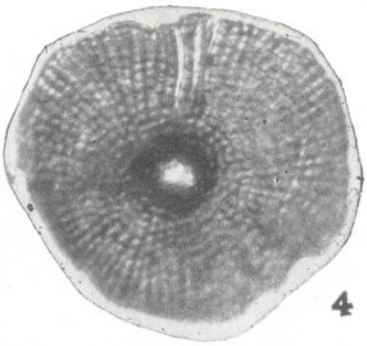

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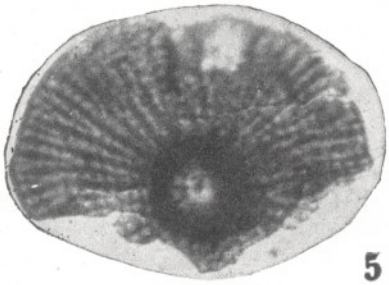

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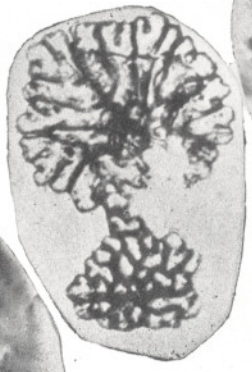

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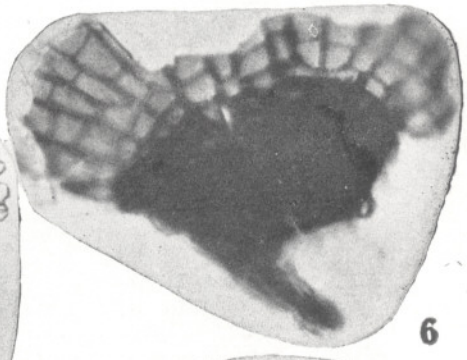

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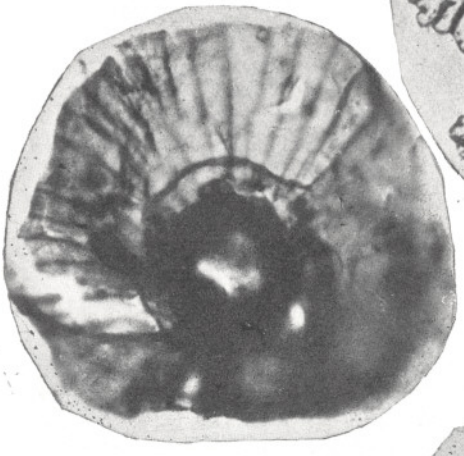

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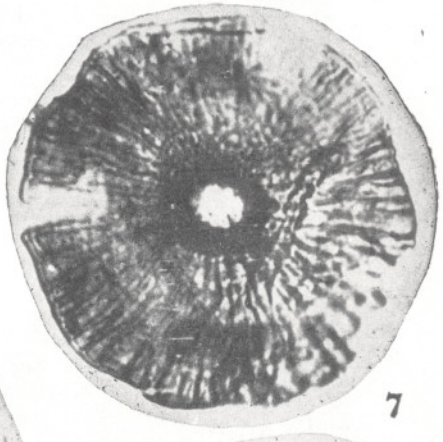

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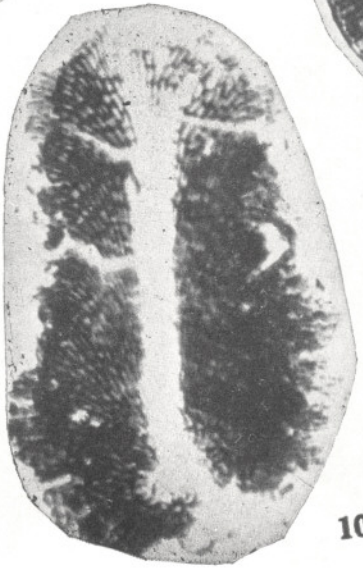

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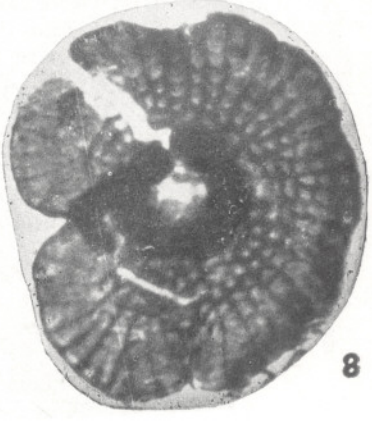

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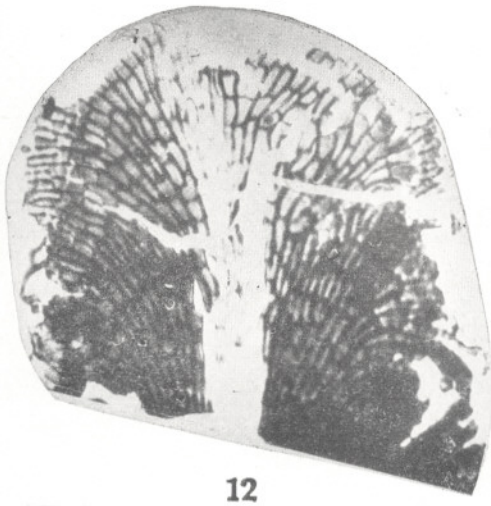

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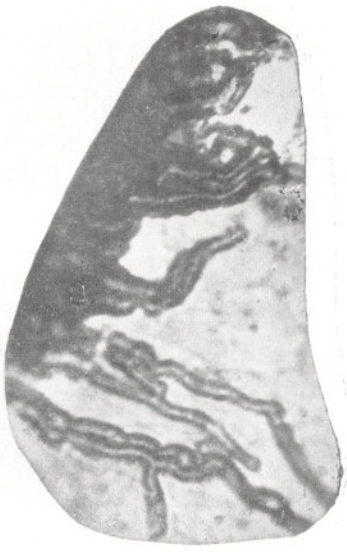

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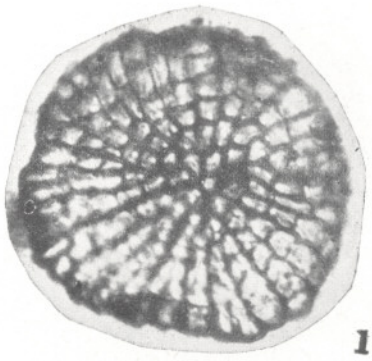

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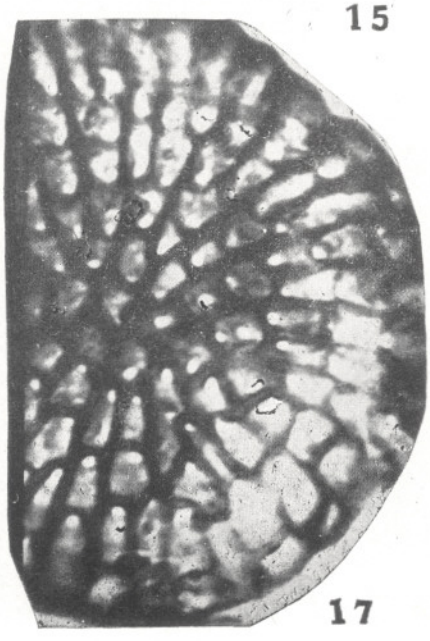

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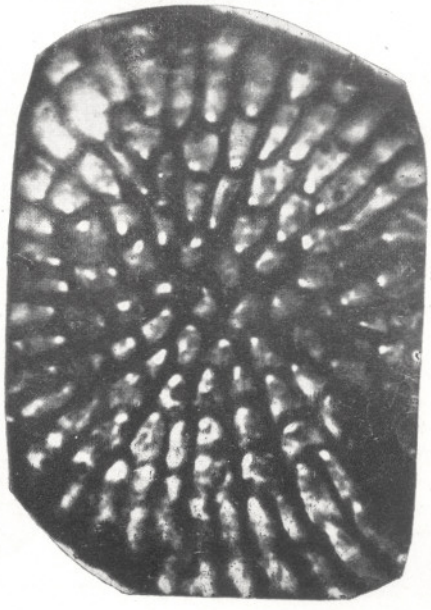

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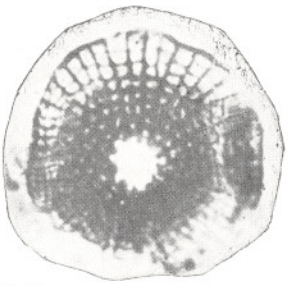

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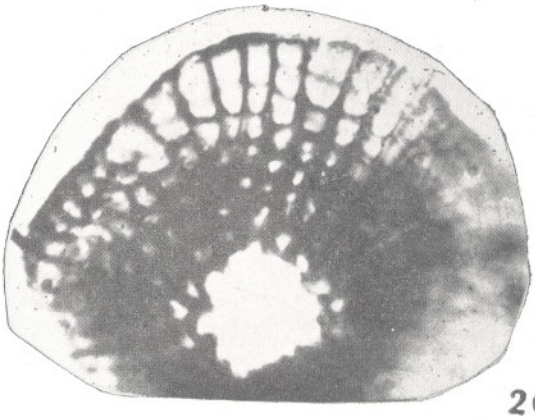

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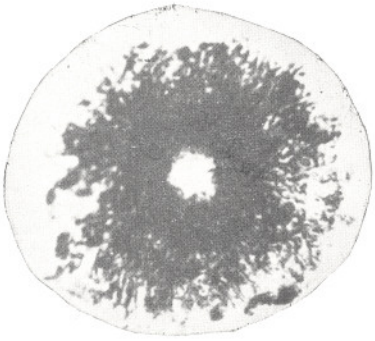

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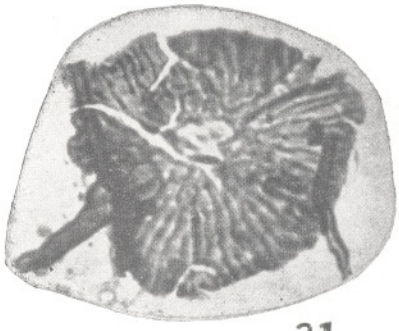

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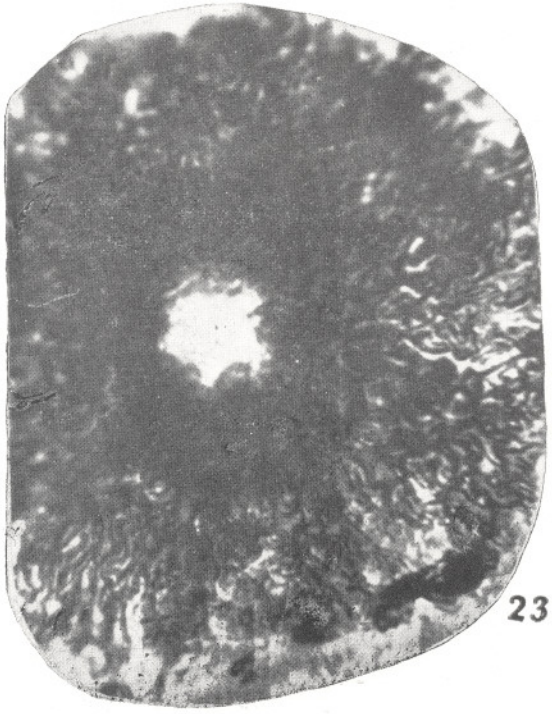

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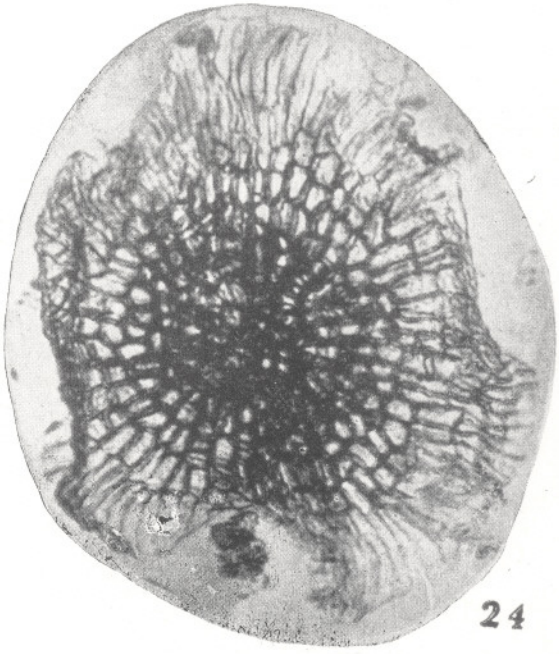

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angiosperms, we fully endorse Dilcher's opinion that, for their evolutionary progress and geographical spread the microthyriaceous fungi may have depended upon the then newly appeared angiosperms.

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EXPLANATION OF PLATES

PLATE 1

1-3. Germlings of microthyriaceous fungi × 1100.
4, 5. *Nothyrites setiferus*. Note the nature of ostiole borner and setae. × 450.
6. *N. setiferus*, enlarged to show prominent setae. × 1100.
7. *N. denticulatus* sp. nov. (Holotype). × 700.
8. *N. denticulatus* (Paratype). × 700.
9. *N. airensis*. × 900....
10. *Euthyrites keralensis* sp. nov. (Holotype). × 300.
11. *E. keralensis*. × 300.

PLATE 2

12. *Euthyrites keralensis*. Upper part of Holo type enlarged. × 700.
13. *E. keralensis*. Free mycelial hyphae of Holotype further magnified to show their hypho podiate nature. × 1100.
14. An elliptical fruit body of *E. keralensis* (Paratype). × 300.
15, 16. *Callimothallus pertusus*. Note the two different shapes of the ascomata. × 700.
17, 18. *C. pertusus* enlarged to show the central group of irregularly angled cells and pore position in each cell. × 1350.

PLATE 3

19. *Callimothallus raoi* sp. nov. (Holotype). × 700.
20. *C. raoi*, Part of above specimen enlarged. Note thick-walled cells around central cavity and presence of pores only in a few cells. × 1350.
21. *Asterina eocenica*. × 700.
22. *Plochmopeltinites cooksonii* sp. nov. (Holo type). × 350.
23. *P. cooksonii*, Part of Holotype enlarged. × 1350.
24. *Asterothyrites* sp. × 700.