

ABSTRACT

Ten species (five new) and three subspecies (all new) of the family Hystrichosphaeridae, and a new monotypic genus, Mathurosphaera, of uncertain affinity are described from the Cambay Basin of western India. The forms considered here are restricted to Oligocene and Eocene horizons only. Most of these organisms have been used successfully as index fossils to demarcate the pre-Miocene horizons.

Tertiary hystrichosphaerids from India

C. P. VARMA AND A. K. DANGWAL

Oil and Natural Gas Commission
Dehra Dun, India

INTRODUCTION

While we were making a palynological study of samples from the sections penetrated by some deep wells in the Cambay Basin of western India for age assignment, palaeoecology and correlation of the various rock units, hystrichosphaerids were observed in the slides prepared for pollen and spore study. Since then these microfossils have also been observed to occur in wells of the Anklesvar Basin and adjoining basins, and also in other parts of India. The most interesting feature in the Cambay and Anklesvar Basins of northern Bombay State has been an almost complete restriction of the family Hystrichosphaeridae to the pre-Miocene horizons of the Tertiary (although the overlying sediments are also marine) except for the very few species which have also been recorded in the Miocene. From the present study it would be premature to draw any conclusions regarding the stratigraphic distribution of the species interregionally. However, it has become abundantly clear from the studies made so far in the Anklesvar and Cambay Basins that there must have been a major ecological change in the planktonic environment at the close of the Oligocene Epoch which resulted in the local extinction or emigration of the hystrichosphaerids. This idea is gaining strength as more and more wells are studied in the western region. In the present short paper, which was read at the International Conference on Palynology, Tucson, Arizona, U. S. A., in April, 1962, the authors have confined themselves to the morphological descriptions of some easily distinguishable types out of a large number and variety of hystrichosphaerids recovered from the Cambay Basin only.

In the text, C.D.W. stands for Cambay Deep Well, and the following interval indicates the depth in meters of the cutting from which the specimen under consideration was recovered. Location of the specimen on the slide is indicated by the coordinates on the Wild microscope with the label conventionally on the right side. The slides are deposited in the Palynology Section of the Oil and Natural Gas Commission at Dehra Dun, India.

SYSTEMATIC DESCRIPTIONS

Order HYSTRICHOSPHAERIDEA

Family HYSTRICHOSPHAERIDAE

Genus HYSTRICHOSPHAERIDIUM Deflandre, 1937

Hystrichosphaeridium cambayense Varma and Dangwal,
new species

Plate 1, figures 1-2

Diagnosis: Body spherical to somewhat angularly rounded, the angularity most probably attained during fossilisation. Body wall well defined, up to 3μ thick. Body densely granulate, processes rising from the body surface in groups or coalesced bundles situated at fair distances from each other. These groups of processes show a granulation similar to that seen on the body. Observed thickness of the bundles varies from 9 to 30μ . Individual processes united almost throughout their length, sometimes even in an anastomosing manner. Processes simple or sometimes with slightly bifurcated tips.

Measurements: Diameter of body ca. $44-70\mu$, length of processes ca. $15-30\mu$.

Comparison: At first sight the most closely comparable species appears to be *H. inodes* Klumpp, but the details of *H. cambayense* are so widely different that they warrant its designation as a new species.

Holotype: Slide no. H-2, 95.4:31.2 Wild (plate 1, figure 1).

Type locality: Western India, Cambay Basin, C.D.W. no. 1, 1580-85 m.

Hystrichosphaeridium sp. cf. *H. polytrichum* Valensi
Plate 1, figures 3-4

cf. *Hystrichosphaeridium polytrichum* VALENSI, 1947, Acad. Sci. France, C.R., vol. 225, no. 18, p. 817, text-fig. 4.

Description: Body somewhat spherical, light-brown in color. Body wall mostly granulate, sometimes psilate to

faintly granulate. Processes studded all over the body. They are simple, hollow, and mostly stiff, but a few supple ones could also be observed occasionally. Processes arise out of the body with slightly broadened bases and gradually narrow towards the tips, where their hollow nature may be clearly observed.

Measurements: Diameter of body ca. 35–70 μ ; length of processes ca. 10–18 μ .

Comparison: Individuals show closest resemblance to *H. hirsutum* and *H. polytrichum*, but the Indian specimens differ in details of the body and processes. However, for the present the species is compared to *H. polytrichum*, with which it shows greater similarities in organisation.

Illustrated specimen: Slide no. H-2, 100.8:28.8 Wild.

Occurrence: Western India, Cambay Basin, C.D.W. no. 1, 1580–85 m.

Hystrichosphaeridium heteracanthum
Deflandre and Cookson subsp. *sparsiprocessum*
Varma and Dangwal, new subspecies
Plate 1, figure 7

Diagnosis: Body spherical to hemispherical, brown and densely granulate. Body wall thin but clearly observed. Processes occurring singly and sparsely studded all over the body. Each process is stiff, usually unbranched, hollow, with tip ending abruptly. Tip part not observed in most cases, probably due to secondary breakage. Sometimes two or more processes appear to coalesce at the base but dissociate near the tip, giving a falsely furcate appearance.

Measurements: Diameter of body ca. 39–65 μ ; length of processes ca. 15–20 μ .

Comparison: The fossil is closely similar to *H. heteracanthum* Deflandre and Cookson, but the detailed differences, along with the sparsity of the processes, show it to be a distinct subspecies.

Holotype: Slide no. H-3; 98:27.8 Wild (plate 1, figure 7).

Type locality: Western India, Cambay Basin, C.D.W. no. 2, 1523–26 m.

Hystrichosphaeridium perplexum Varma and Dangwal,
new species
Plate 1, figures 5–6

Diagnosis: Body spherical to oblong, dark-brown in color. Body wall distinctly seen, about 2 μ thick, psilate to granulate. Processes of light color, studded densely all over the body, long, hollow, supple, flexuous, and characteristically tangled with one another into a confused interwoven mass. Tips mostly broken.

Measurements: Diameter of body ca. 42–54 μ ; length of processes ca. 19.5 μ and more.

Comparison: At first sight it seems similar to *H. polytrichum* Valensi, but its processes are long, supple, filiform and interwoven, whereas in *H. polytrichum* the processes are straight and bristle-like, and not in the form of a confused interwoven mass. *H. polytrichum* also differs in other minor details.

Holotype: Slide no. H-4, 107.7:38.9 Wild (plate 1, figure 5).

Type locality: Western India, Cambay Basin, C.D.W. no. 9, 1475–80 m.

Hystrichosphaeridium mineralosum
Varma and Dangwal, new species
Plate 1, figures 8–9

Diagnosis: Body usually spherical, sometimes oval to irregular, granular, giving a characteristic appearance of an aggregation of mineral particles. Body wall usually concealed, rarely seen to be thin. Processes radiating from all over the body, small, transparent, very difficult to observe under magnifications of low power. Body comparatively darker. Processes simple, spinelike or hairlike, solid or hollow, unbranched, generally stiff and seldom supple. Some show a rather broad base. The shafts of the processes narrow slightly towards the blunt tips. Tips of the processes of some individuals show labiate, discoidal or cup-shaped structures. Individuals showing these minor variations have been classified by the authors as subspecies of *H. mineralosum*.

Measurement: Diameter of body ca. 30–45 μ ; length of processes ca. 7.8–15.6 μ .

Comparison: At first sight one would detect a resemblance to *H. centrocarpum* Deflandre and Cookson, but on detailed comparison one finds that the Australian species has a bigger body and shows major differences in the organisation of the body, wall and processes, hence our specimens have to be treated as a new species.

Holotype: Slide no. H-6, 94.7:31.5 Wild (plate 1, figure 9).

Type locality: Western India, Cambay Basin, C.D.W. no. 1, 1560–65 m.

Hystrichosphaeridium mineralosum subsp. *labiatum*
Varma and Dangwal, new subspecies
Plate 1, figures 10–11

Diagnosis: Body originally spherical, densely granulate, looking somewhat like an aggregation of mineral matter as in *H. mineralosum* s. s., dark-brown in color. Body wall is concealed. Processes hollow, straight, unbranched, stiff to slightly supple, and radiating from all over the body at moderate distances from each other. Bases of the processes broad, the upper part of the processes narrowing down very slightly towards the tips, which are open and have a thickened liplike structure all round.

Measurement: Diameter of body ca. 39 μ ; length of processes ca. 7.8 μ .

HYSTRICHOSPHAERIDS FROM INDIA

Comparison: Essentially these forms belong to *H. mineralosum*. The lipped processes of this subspecies are quite distinct from any other noted in the present study.

Holotype: Slide no. H-7, 106:34.3 Wild (plate 1, figure 10).

Type locality: Western India, Cambay Basin, C.D.W. no. 14, 1500–05 m.

Hystrichosphaeridium mineralosum subsp. *jekhowskyi*
Varma and Dangwal, new subspecies
Plate 1, figure 12; plate 2, figure 1

Diagnosis: Body originally spherical, granulate, light-brown in color. Body wall is concealed. Processes of still lighter color projecting densely from all over the body, hollow, stiff and thin (occasionally, supple processes also seen). Tips of the processes slightly broadened, ending in flat or hollowed discs.

Measurements: Diameter of body ca. 30–50 μ ; length of processes ca. 10–17 μ .

Comparison: This subspecies is essentially like *H. mineralosum* but differs from the typical subspecies in having processes almost uniform in diameter from base to tip. The tips end in small discoidal structures when complete, whereas the tips of *H. mineralosum* s. s. are hairlike or digitate.

Remarks: The new subspecies has been named after Mr. B. de Jekhowsky of the Institut Français du Pétrole, Paris.

Holotype: Slide no. H-8, 91.5:26.6 Wild (plate 2, figure 1).

Type locality: Western India, Cambay Basin, C.D.W. no. 15, 1575–80 m.

Hystrichosphaeridium complex (White)
Plate 2, figures 2–3

Xanthidium tubiferum complex WHITE, 1842, Microsc. Soc. London, Trans., vol. 1, p. 83, pl. 8, fig. 10.

Hystrichosphaeridium elegantulum LEJEUNE-CARPENTIER, 1940, Soc. Géol. Belg., Ann., vol. 63, nos. 5–6, p. B 222, text-figs. 11–12.

Hystrichosphaeridium complex (White). — DEFLANDRE, 1946, Soc. Géol. France, C.R., 1946, no. 7, p. 111.

Description: Body spherical, light-brown, prominently granulate, and fragile. Body wall distinct, composed of two layers about 3 μ thick. Processes not many, placed distantly from each other all over the body, hollow, arising from the body with widened bases, continuing straight with nearly uniform diameter, and ending in funnel-like structures with the margins often hanging down. Sometimes these funnel margins appear to have furcating projections.

Measurements: Diameter of body ca. 70 μ (based on only one individual); length of processes ca. 19.5 μ .

Comparison: At first sight this form invites comparison with *H. alcornu*, *H. recurvatum*, *H. tubiferum* and *H. complex*. One of the processes shown in plate 2, figure 3 gives some indication of being angular at the tip, but, on closer observation, it is also found to have a tubular cross section and to have attained this angularity as an accident of preservation. Even in this single case, the angularity is not sharp. In detailed comparison, this form tallies best with *H. complex*, where it could be included among the numerous variations of that species.

Illustrated specimen: Slide no. H-11, 94:43.6 Wild (plate 2, figure 2).

Occurrence: Western India, Cambay Basin, C.D.W. no. 2, 1526–29 m.

Hystrichosphaeridium sp. cf. *H. cornigerum* (Wetzel)
Plate 2, figures 4–5

cf. *Hystrichosphaera cornigera* WETZEL, 1933, Palaeontographica, vol. 78, Abt. A, p. 39, pl. 5, fig. 6.

Description: Body originally spherical to oval, sometimes deformed during preservation, densely granulate. Body wall thin, sometimes concealed. Body and processes light-brown. Processes originating from all over the body at moderate distances from one another, mostly with pyramidal to broad bases. Each process extending outwards with a uniform thickness, rarely hairlike, and as a rule furcating towards the tip into two, three or more branches. Processes hollow, mostly stiff. One extraordinarily long process shown in plate 2, figure 4 either displays a peculiar type of branching or has been ripped partly off.

Measurements: Diameter of body ca. 25–35 μ ; length of processes ca. 7.8–19.5 μ .

Comparison: The individuals illustrated here are very similar to *H. cornigerum*, with which they are compared, but due to lack of better-preserved specimens the exact identity can not be established.

Illustrated specimen: Slide no. H-12, 94:38 Wild (plate 2, figure 5).

Occurrence: Western India, Cambay Basin, C.D.W. no. 2, 1590–95 m.

Hystrichosphaeridium sp. cf. *H. ferox* Deflandre
Plate 2, figure 6

cf. *Hystrichosphaeridium ferox* DEFLANDRE, 1937, Ann. Pal., vol. 26, p. 24, pl. 14, figs. 3–4.

Description: Body originally spherical and densely granulate. Body wall clear, 1–2.5 μ thick. Processes hollow, simple, mostly stiff, occurring over the body usually in groups of 6 to 15, each group projecting from a specialised cushionlike structure which is slightly thicker than the rest of the body. Interspaces between the individual processes of the group are densely granulate (perhaps composed of coalescing? membrane) similar to the main body.

Measurement: Diameter of body ca. 54.6μ ; length of processes ca. $4-12\mu$.

Comparison: Only one individual of this type has so far been noticed in the wells studied. The closest relationship is with *H. ferox* Deflandre, with which it is compared. A number of characters showing slight differences may be considered as minor variations of *H. ferox*.

Illustrated specimen: Slide no. H-13, 91:41.6 Wild (plate 2, figure 6).

Occurrence: Western India, Cambay Basin, C.D.W. no. 14, 1500-05 m.

Genus HYSTRICHOSPHAERA Wetzel, 1933

Hystrichosphaera pseudofurcata Varma and Dangwal,
new species
Plate 2, figures 7-8

Diagnosis: Body spherical, smooth to granulate. Body wall distinct, about 3μ thick. All over the body are

seen a few, big, roundish to angular, 5- to 7-sided, platelike structures (size $15-25\mu$) characteristic of *Hystrichosphaera* species. Generally, from the angles of these plates arise one or more processes which coalesce with one another, forming a sort of bundle. Tips of the processes in each bundle hang down sideways giving a false appearance of branching.

Measurement: Diameter of body ca. $45-60\mu$; length of processes ca. 11.7μ .

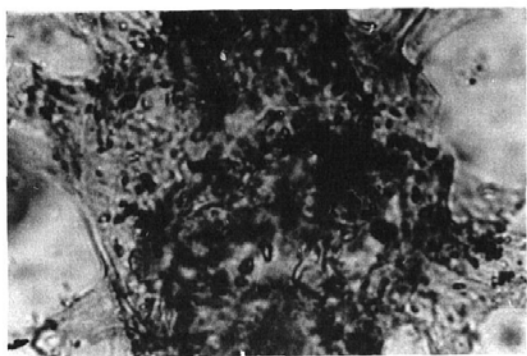
Comparison: At first sight the specimens resemble *Hystrichosphaera furcata*, but a detailed comparison shows marked difference in the size of the body, in the organisation of the plates, and in the processes, which do not have true furcations.

Holotype: Slide no. H-5, 92.2:36.5 Wild (plate 2, figure 7).

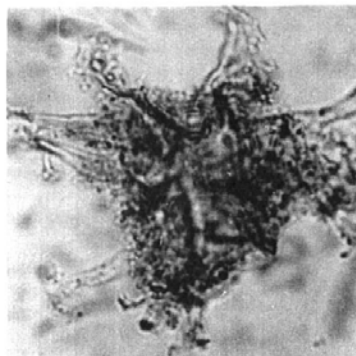
Type locality: Western India, Cambay Basin, C.D.W. no. 1, 1580-85 m.

PLATE 1

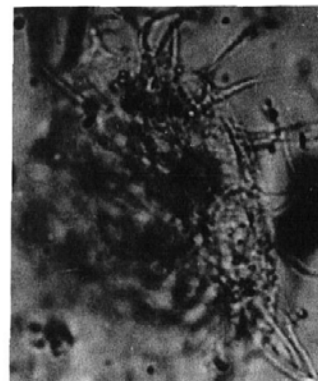
- 1-2 *Hystrichosphaeridium cambayense* Varma and Dangwal, n. sp.
1, part of the holotype enlarged to show the thick and granulated wall and to illustrate how the individual processes coalesce to form bundles of unequal width, $\times 1000$; 2, paratype, an uncommon individual showing a somewhat angular and granulated body with a few bundles of processes, $\times 500$.
- 3-4 *Hystrichosphaeridium* sp. cf. *H. polytrichum* Valensi
3, surface view, only partly in focus, bringing out the granulate structure of the wall and the filiform processes, $\times 1000$; 4, part of the same specimen shown in figure 3 to illustrate the hollow nature of the processes, $\times 1000$.
- 5-6 *Hystrichosphaeridium perplexum* Varma and Dangwal, n. sp.
5, holotype, complete individual showing the characteristically tangled mass of long and supple processes, $\times 500$; 6, part of the holotype illustrated in figure 5, enlarged to show more clearly the filiform and tangled nature of the processes and the thick body wall, $\times 1000$.
- 7 *Hystrichosphaeridium heteracanthum* Deflandre and Cookson subsp. *sparsiprocessum* Varma and Dangwal, n. subsp.
Holotype, showing the sparsity of the processes, $\times 500$. One process appears to be bifurcated, but actually two adjoining processes have coalesced for a greater part of their length, although they are separate at the base and the tip.
- 8-9 *Hystrichosphaeridium mineralosum* Varma and Dangwal, n. sp.
8, paratype, with a somewhat angular body of mineralised appearance, showing the broadened bases and the blunt tips of the processes, $\times 1000$; 9, holotype, showing a spherical, granular body with the characteristic appearance of an aggregation of mineral particles, and the hairlike, thin, stiff processes all over the body, $\times 1000$.
- 10-11 *Hystrichosphaeridium mineralosum* subsp. *labiatum* Varma and Dangwal, n. subsp.
10, holotype, focused upon so as to show the characteristic body with a few processes whose tips end in thickened liplike structures, $\times 1000$; 11, holotype, in a different focus to show processes with lipped ends, $\times 1000$.
- 12 *Hystrichosphaeridium mineralosum* subsp. *jekhowskyi* Varma and Dangwal, n. subsp.
Paratype, showing a characteristic body and the tangled mass of supple processes with discoid tips, $\times 1000$.



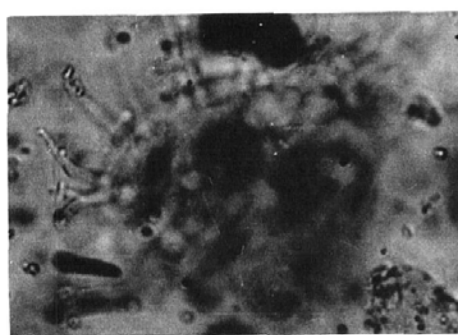
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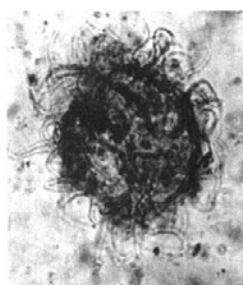
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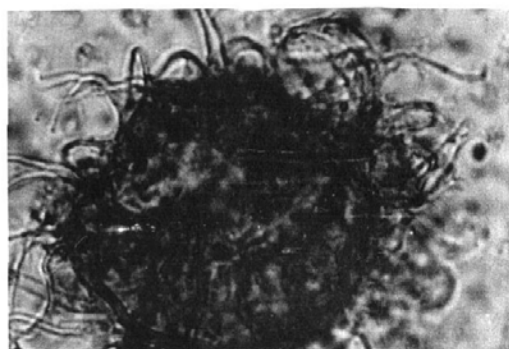
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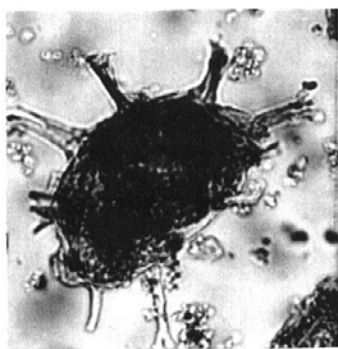
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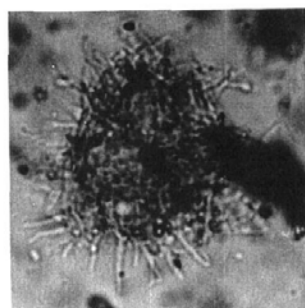
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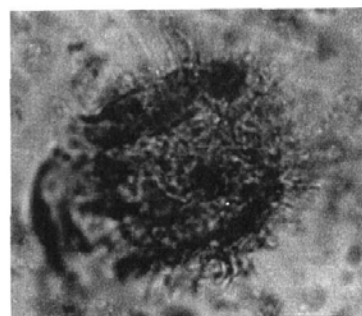
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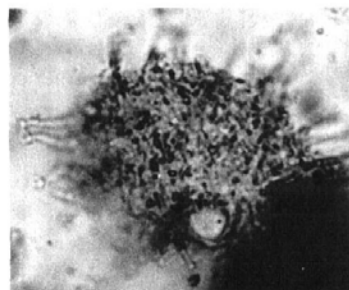
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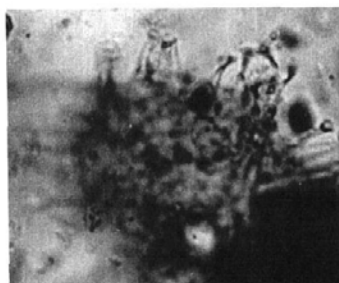
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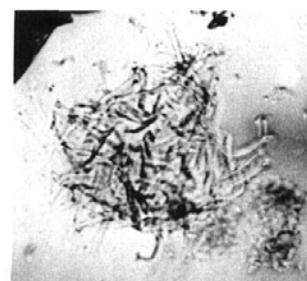
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Genus *TENUA* Eisenack, 1958*Tenua taugourdeau* Varma and Dangwal, new species
Plate 2, figure 9

Diagnosis: Body originally spherical to oblong, incomplete due to the breakage of the pole cap. Body wall prominently granulate, sometimes weak, fairly thick, about 2.5μ in the specimen illustrated. Processes arise from all over the body rather sparsely, start with a somewhat broad base and extend outwards as hollow structures of uniform thickness or narrow towards the tip in the form of fingers or bluntly ending spines. The tips are occasionally broken, but, when preserved, they are closed and some times also show slight (?) overgrowth hanging downwards. Processes mostly stiff, rarely supple.

Measurements: Diameter of body ca. $55\mu \times 50\mu$; length of processes ca. 7.8μ .

Comparison: The pole cap is often missing from the body, as seen in the figure illustrated, a feature of *T. hystrix* Eisenack, but the present species differs from *T. hystrix* in having a smaller body and in the shape of the spinelike processes, which are also more sparsely studded.

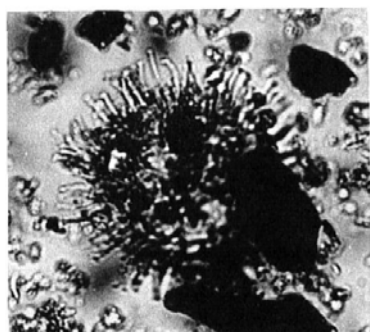
Remarks: The new species has been named after Mr. Phillip Taugourdeau of the Institut Français du Pétrole, Paris.

Holotype: Slide no. H-9, 96:41.6 Wild (Plate 2, figure 9).

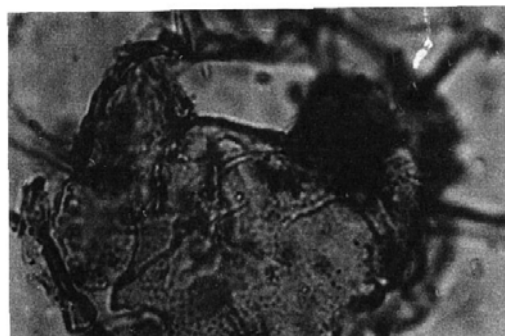
Type locality: Western India, Cambay Basin, C.D.W. no. 9, 1475-80 m.

PLATE 2

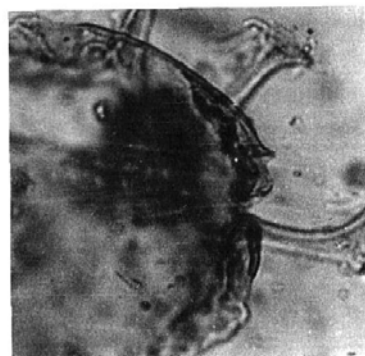
- 1 *Hystrichosphaeridium mineralosum* subsp. *jekhowskyi* Varma and Dangwal, n. subsp.
Holotype, showing the body typical of the species and the processes with discoid tips of the subspecies *jekhowskyi*, which are straighter than in the paratype (plate 1, figure 12) and project radially all over the body, $\times 1000$.
- 2-3 *Hystrichosphaeridium complex* (White)
2, part of a specimen showing the prominent granulations, the thick wall and the sparsely arranged processes, $\times 1000$; 3, same specimen in different focus to show the two-layered body wall and the funnel-like tips of the processes, $\times 1000$.
- 4-5 *Hystrichosphaeridium* sp. cf. *H. cornigerum* (Wetzel)
4, broken specimen with one extraordinarily long process which has taken this unusual shape most probably due to having been ripped partly off, $\times 1000$; 5, a specimen with an oval body and branching processes, $\times 1000$.
- 6 *Hystrichosphaeridium* sp. cf. *H. ferox* Deflandre
Specimen showing the spherical, granulate body and the body wall clearly, $\times 1000$. At the top right of the photo a number of processes have been focused upon to show their hollow structure and tendency to group.
- 7-8 *Hystrichosphaera pseudofurcata* Varma and Dangwal, n. sp.
7, holotype, showing a spherical body, the body wall, and the processes arising from the angles of the polygonal platelike areas, $\times 1000$; 8, holotype in different focus to show the granulations and the polygonal platelike areas, $\times 1000$.
- 9 *Tenua taugourdeau* Varma and Dangwal, n. sp.
Holotype, showing the granulate, oblong body with a missing pole cap, the thick body wall, and the short spinelike processes set rather sparsely, $\times 1000$.
- 10 *Tenua hystricella* Eisenack
Specimen showing a roundish oval body, thickly studded with short, hollow, spinelike processes, and, on the side of the body in focus, a demarcated area which may represent vestiges of the pole cap, $\times 1000$.
- 11-12 *Mathurosphaera rajivi* Varma and Dangwal, n. sp.
11, holotype, focused upon so as to show the granulate body, densely covered all over by thin, hairlike processes, $\times 500$; 12, holotype in different focus to show the polygonal fields, $\times 500$.



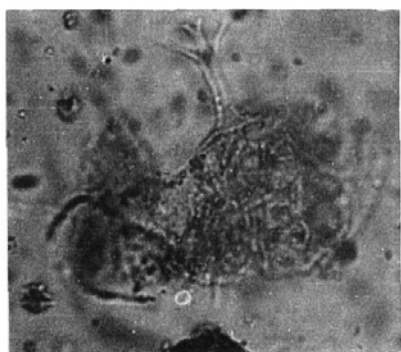
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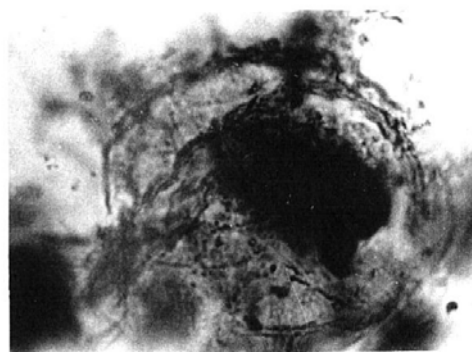
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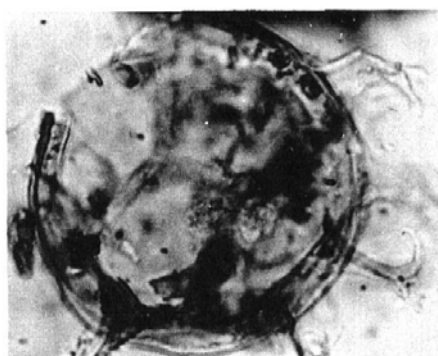
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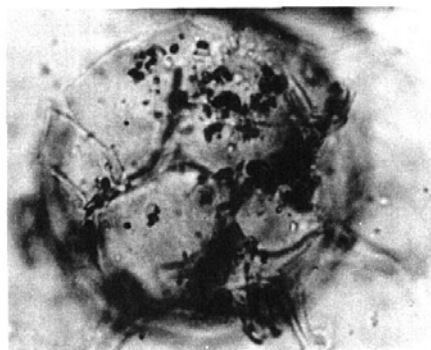
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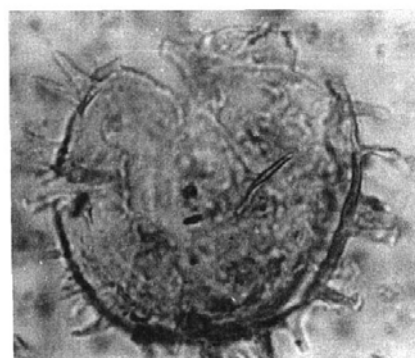
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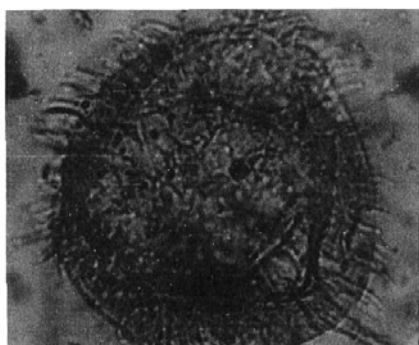
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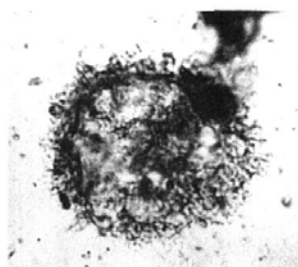
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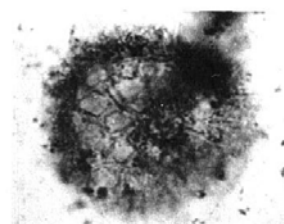
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Tenua hystricella Eisenack
Plate 2, figure 10

Tenua hystricella EISENACK, 1958, Neues Jahrb. Geol. Pal., vol. 106, p. 411, pl. 23, figs. 5-7.

Description: Body oval. Body wall about 1μ thick. Processes hairlike, closely spaced, and radiating from all over the body. Extensions of the spinelike processes tend to fuse and form some wormlike lines on the surface of the body, a characteristic feature seen in the holotype of the species.

Measurement: Diameter of body ca. $54.6 \times 35.1\mu$; length of processes ca. 7.8μ .

Comparison: This form is closely similar to *T. hystricella* in its shape, wall characters and the characteristic feature of the spinelike processes and their fusion, but is smaller in size.

Illustrated specimen: Slide no. H-10, 98.5:27.7 Wild (plate 2, figure 10).

Occurrence: Western India, Cambay Basin, C.D.W. no. 9, 1475-80 m.

Genus *Mathurosphaera* Varma and Dangwal,
new genus

Diagnosis: Body usually spherical, covered with rounded to angular (mostly pentagonal or hexagonal) fields without raised marginal ledges; processes originating freely from all over the body.

Type species: *Mathurosphaera rajivi* Varma and Dangwal, n. sp.

Comparison: This genus is peculiar in having pentagonal to hexagonal fields all over the body like *Hystrichosphaera* but without any girdle-like structure, and at the same time being studded with very fine, simple, hairlike, solid processes. It shows resemblance to another genus, *Cymatiosphaera* Wetzel, as emended by Deflandre, in having a spherical, granulated body, and in having the external surface divided into polygonal fields, but differs remarkably in not having these polygonal fields bordered by raised ledges (the most characteristic feature of the new genus) and in having numerous, small, solid, hairlike, translucent processes arising from all over the body. The peculiar combination of processes, which are characteristically present in the family Hystrichosphaeridae, and the pentagonal to hexagonal fields, comparable to those of *Cymatiosphaera*, belonging to the family Pterospermopsidae, provide the genus with a distinctive position. But the paucity of individuals and species stands in the way of giving at present any clear-cut family affinities of this genus.

Remarks: This genus has been named after Mr. L. P. Mathur, a member of the Oil and Natural Gas Commission, Dehra Dun, India. It has been described from a single specimen recovered from Cambay Deep Well no. 15 in the uppermost Oligocene. It has also been noticed recently in the Oligocene of Akholjuni Deep Well no. 1, drilled in an adjoining structure.

Mathurosphaera rajivi Varma and Dangwal,
new species

Plate 2, figures 11-12

Diagnosis: Body spherical, light-brown in color, densely granulate, covered with mostly pentagonal or hexagonal fields (4- to 6-sided, occasionally roundish) about $5.6-11\mu$ wide. Fields prominent on the surface but their angular boundaries are not raised as in *Cymatiosphaera*. Processes originating from all over the body. Each process is light-colored, simple, solid, somewhat hairlike, stiff or supple.

Measurements: Diameter of body ca. 45μ ; length of processes ca. $7.8-11.7\mu$.

Remarks: The species is named in dedication to the memory of the late Rajiv Varma, the 11-months-old son of the senior author, whose death occurred while this work was in progress.

Holotype: Slide no. H-14, 101.2:29.2 Wild (plate 2, figures 11-12).

Type locality: Western India, Cambay Basin, C.D.W. no. 15, 1525-30 m.

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