

HYSTRICHOSPHERES FROM THE SILURIAN WENLOCK SHALE OF ENGLAND

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ABSTRACT. Hystrichospheres from samples taken at a single locality and horizon in the Wenlock Shale of Wenlock Edge are described. The assemblage includes thirty-three species and varieties of *Baltisphaeridium*, *Michystridium*, *Veryhachium*, *Cymatiosphaera*, *Pterospermopsis*, *Pulvinosphaeridium*, *Leiofusa*, *Leiosphaeridia*, and *Tasmanites*, of which fourteen are new. It most closely resembles an assemblage from the Wenlock of the Montagne Noire.

INTRODUCTION

HYSTRICHOSPHERES are small microscopic organisms having a more or less spherical body usually composed of yellow-brown organic matter. The organic substance of which they are composed may be similar to cutin or sporonin, but this is not certain. Usually the body carries spines or branched processes of various sorts. Hystrichospheres resemble desmid spores in shape, and have been so described by Ehrenberg (1838), Bashnagel (1942), and Timofiev (1956). They appear, however, to be exclusively marine, and were thought by Deflandre (1947) and Eisenack (1954*b*) to be members of the marine plankton whose precise affinities were uncertain.

Hystrichospheres have now been described from a considerable number of localities and horizons in the Lower Palaeozoic. The localities, however, are widely scattered and frequently their stratigraphical position is ambiguous. Consequently an assessment of the stratigraphical value of these microfossils requires a systematic study of their vertical distribution to be carried out in a restricted area, preferably where the age of the rock is determined by other fossil evidence. Because of the absence of metamorphism, and the well-documented stratigraphy, the Shropshire region appears to be most suitable for this study. It is also the type area for a number of stratigraphical divisions of the Lower Palaeozoic. A number of horizons have yielded assemblages of hystrichospheres, sometimes in great abundance, but so far only one from the Tremadocian (Downie 1958) has been described.

There will be described in this paper some of the most commonly occurring hystrichospheres in the Wenlock Shale of Wenlock Edge and this will subsequently form the basis of a fuller account of the distribution of the hystrichospheres within the Wenlock Shale. All the forms described here come from the same locality, an exposure in the lane about 70 yards east of Eaton Church, below Wenlock Edge. The horizon lies about 250 feet below the Wenlock Limestone and can be traced continuously into the Middle Coalbrookdale Beds about five miles to the north-east. These beds belong to the zone of *C. lundgrenni* (Pocock *et al.* 1938).

[*Palaeontology*, Vol. 2, Part 1, 1959, pp. 56-71, pls. 10-12.]

The rocks yielding the hystrichospheres were slightly calcareous greenish-grey mudstones with an irregular fracture. Marine macrofossils were common. Thin sections showed the rocks to be composed of a clay matrix with sporadic mica and calcite grains, together with abundant quartz about 15μ in diameter and a few grains of pyrite. The content of organic matter, determined by combustion, was only 1.7 per cent. by weight and the only organic matter visible in thin section was small fragments of chitin and a little bituminous matter diffused in the matrix. No hystrichospheres were visible.

Treatment of material. Three rock samples (WS/A, WS/2a, WS/2b) were collected from points a foot or two apart. A few grammes from each were taken separately, crushed to about pea-size, and dissolved in hydrochloric acid. After decanting the liquid the resulting sludge was heated in hydrofluoric acid for about 48 hours. The residue then consisted of a fine-grained black deposit. When this was washed free from acid, drops were mounted in glycerine jelly for examination under the microscope. Rock sample WS/A was broken into four pieces, each of which was treated separately, so that altogether six independent preparations were made from this horizon. They showed no significant differences in the composition of the hystrichosphere assemblages and it is thought that the total assemblage represents fairly accurately what actually occurs in the Wenlock Shale at this locality. The table (p. 69) summarizes the six assemblages.

Two of the preparations (WS/Ac, WS/Ad) were split after treatment with hydrofluoric acid and one part was put in fuming nitric acid for a few minutes. This treatment had a violent effect. All the remaining clay particles and many of the smaller microfossils, notably *Veryhachium tetraëdron*, disappeared from preparation WS/Ac leaving a concentration of large forms like *Baltisphaeridium digitatum* and thick-walled forms like *Cymatiosphaera pavimenta*. The other preparation, WS/Ad, was treated for a slightly longer time and almost everything was destroyed except very thick-walled forms like *Tasmanites* (see table, p. 69).

All the preparations are now in the collections of the Department of Geology, University of Sheffield. Figured and type material will be deposited in the Geological Survey and Museum, London, the registration numbers of which are quoted.

Abundance of hystrichospheres. The number of hystrichospheres present in the preparations shows that they were not particularly abundant in the rock. There were probably between 1,000 and 10,000 in each cubic centimetre. Similar numbers of microplankton have been recorded in marine sediments by Valensi (1953) from Jurassic flints and Downie (1957) from the Kimeridge Clay. Much greater numbers were found in the Shineton Shales (Downie 1958).

Altogether several thousand individuals were examined, but a large number were unidentifiable and are not included in the figures given on the table. Several distinctive types have been omitted because of their rarity.

Previous research. The only hystrichospheres previously recorded from the British Silurian are *Baltisphaeridium polygonale* and *B. digitatum* from the Wenlock Limestone of Dudley (Eisenack 1954a). They have, however, been recorded from the Silurian of the Baltic (Eisenack 1954a; 1955), Bohemia (Eisenack 1934; 1958a), southern France (Deflandre 1945), Brittany (Deunff 1954a), and North America (White 1862; Fisher 1953).

SYSTEMATIC DESCRIPTIONS

Order HYSTRICHOSPHAERIDEA Eisenack 1938

Family HYSTRICHOSPHAERIDAE O. Wetzel 1933, emend. Deflandre 1937

Genus BALTISPHAERIDIUM Eisenack 1958b

Type species by original designation: *Hystrichosphaeridium longispinosum* (Eisenack), Ordovician, Baltic.

Diagnosis. A genus of hystrichospheres with round or oval body, surface not divided into fields, carrying more or less numerous, well-separated, hollow processes closed at the end. Processes generally similar, may or may not branch.

Baltisphaeridium longispinosum (Eisenack)

Plate 10, figs. 1, 2, 6

Ovum hispidum longispinosum Eisenack 1931, pl. 5, figs. 6-17.

Hystrichosphaeridium longispinosum Eisenack 1938, pl. 1, figs. 1-9.

Hystrichosphaeridium longispinosum Eisenack 1951, pl. 1, figs. 1-6.

Diagnosis. A species of *Baltisphaeridium* with a more or less spherical test, processes longer than the radius, less than about twenty-five in number.

Occurrence. Shineton Shales, Shropshire (Downie 1958); Ordovician, Baltic regions (Eisenack 1931; 1938; 1951); Ordovician, Rheinischer Schiefer Gebirge (Eisenack 1939); Ordovician, Bohemia (Eisenack 1948); Caradocian, Wales (Lewis 1940); Middle Silurian, Niagara, U.S.A. (Fisher 1953).

Remarks. In redescribing this species Eisenack (1951) emphasized the variation in the size and shape of the processes. Only two of the forms he illustrated appear in the Wenlock Shale. One, comprising about two-thirds of the number present, measures about 30μ in diameter, with a matt yellow test surface and broad processes often constricted at their base (Pl. 10, figs. 1, 2). It resembles a form illustrated by Eisenack (1951, pl. 1, fig. 6). The second type present is smaller, diameter about 20μ , the test surface is smooth yellow-green and the processes narrow and cylindrical. It resembles the holotype but is smaller.

Apart from Fisher (1953) this is the only record of *B. longispinosum* from the Silurian. The forms illustrated by Fisher resemble the variety more common in the Wenlock Shale. Eisenack (1939) considered this species to be characteristic of the Ordovician but it is clear that some varieties at least range into the Upper Silurian.

Baltisphaeridium brevispinosum (Eisenack)

Ovum hispidum brevispinosum Eisenack 1931, pl. 5, figs. 3-5.

Diagnosis. A species of *Baltisphaeridium* with a more or less spherical test, processes shorter than the radius, less than about twenty-five in number (in optical section), merging with test at their bases, distal ends rounded.

Baltisphaeridium brevispinosum var. *nanum* Deflandre

Plate 10, fig. 9

Diagnosis. A small variety of *B. brevispinosum*, diameter about 25 μ , processes relatively few, less than twenty in optical section.

Occurrence. Wenlock, France (Deflandre 1945); Middle Devonian, Brittany (Deunff 1954b).

Baltisphaeridium brevispinosum var. *wenlockensis* nov.

Plate 10, fig. 4

Holotype. Mik(P)27001.

Diagnosis. A small variety of *H. brevispinosum*, diameter about 25 μ , processes relatively numerous, about twenty-five in optical section.

Description. The diameter ranged from 16 to 32 μ , the mode being 24 μ . The number of processes ranged from sixteen to thirty-six, the mode being twenty-four, and their length ranged from 20 to 80 per cent. of the test diameter, most of them being shorter than the radius.

Remarks. This variety is distinguished from the typical form by its smaller size and from *H. brevispinosum* var. *nanum* by the greater number of processes. This is one of the most common forms in this assemblage.

Baltisphaeridium brevispinosum var. *granuliferum* nov.

Plate 10, fig. 5

Holotype. Mik(P)22001.

Diagnosis. A small variety of *B. brevispinosum* with relatively numerous processes, the test surface ornamented with small granules 1 μ apart.

Remarks. This variety resembles *B. brevispinosum* var. *wenlockensis* except for its granular surface. It is less common, only eight specimens being found.

Baltisphaeridium ramusculosum (Deflandre)

Plate 11, fig. 13

Hystrichosphaeridium ramusculosum Deflandre 1942, figs. 2-6.

Hystrichosphaeridium ramusculosum Deflandre 1945, pl. 1, figs. 8-16.

Diagnosis. A species of *Baltisphaeridium* with rounded test, processes usually 50 to 100 per cent. of test diameter, test diameter about 20 μ or less, processes branch distally, irregularly, small branches also on trunk of processes. Some processes may be simple.

Occurrence. Wenlock, France (Deflandre 1945); Middle Devonian, Brittany (Deunff 1954b).

Remarks. Specimens from Shropshire measured 11 to 21 μ in diameter, process length being 60 to 90 per cent. of diameter, number of processes in optical section from seven to fourteen.

Baltisphaeridium eoplanktonicum (Eisenack)

Plate 10, fig. 3

Hystriosphæridium eoplanktonicum Eisenack 1955, pl. 4, fig. 14.

Diagnosis. A species of *Baltisphaeridium* with rounded test, diameter about 20 μ , a few long processes irregularly branching at the tips.

Occurrence. Upper Ludlow, Estonia.

Remarks. Specimens from Shropshire measured 16 to 25 μ in diameter, the process length varied from 100 to 150 per cent. of the diameter; the number of processes was usually four, but five and six were found. According to Eisenack the species belongs to the *B. longispinosum* group, but it also resembles *B. ramusculosum* from which it is distinguished by the smaller number and greater length of the processes.

Baltisphaeridium microspinosum (Eisenack)

Plate 10, fig. 10

Hystriosphæridium microspinosum Eisenack 1954a, pl. 1, fig. 8.

Diagnosis. A species of *Baltisphaeridium*, test spherical, diameter about 60 μ , processes closely spaced, spines short 1.5 μ long.

Occurrence. Upper Llandovery, Estonia.

Remarks. The specimens from Shropshire ranged in size from 48 to 80 μ , the processes from 2 to 4 per cent. of the diameter. Eisenack's single specimen had processes 2.5 per cent. of the diameter in length. *H. cf. microspinosum* from the Upper Ludlow of Estonia (Eisenack 1955) had processes measuring 5 per cent. of the test diameter, but was otherwise similar to the type.

Baltisphaeridium cf. meson (Eisenack)

Plate 10, fig. 8

Hystriosphæridium intermedium Eisenack 1954a, figs. 3-4, pl. 1, figs. 3, 9.

Hystriosphæridium meson Eisenack 1955.

Diagnosis. A species of *Baltisphaeridium* with spherical test, diameter about 60 μ , processes well spaced, forked or simple, spikes at tips.

Occurrence. Upper Llandovery, Estonia.

Remarks. *B. meson* from the Llandovery is intermediate in form between its contemporaries *B. brevifurcatum* (Eisenack), most processes of which bifurcate, and *B. oligofurcatum* (Eisenack), with only a few branching. The specimens from the Wenlock Shale

have a few, but indeterminable number of, bifurcating processes. They resemble *B. meson* but are smaller, with diameter 35 to 42 μ . The number of processes in optical section varied from twenty to forty.

Baltisphaeridium robustispinosum sp. nov.

Plate 10, fig. 7

Holotype. Mik(P)9002.

Diagnosis. A species of *Baltisphaeridium* with more or less spherical test, diameter about 30 μ , processes about 10 μ , stout, 4 μ wide at base, 10 to 15 μ apart, about seven seen at circumference, surface of processes granular, terminated by a short hair, sometimes broken.

Remarks. This species does not closely resemble any other.

Genus MICRHYSTRIDIUM Deflandre 1937

Type species by original designation: *Hystrichosphaera inconspicua* Deflandre, Upper Cretaceous, France.

Diagnosis. A genus of hystrichospheres, more or less spherical, diameter generally less than 20 μ .

Micrhystridium stellatum Deflandre

Plate 11, figs. 11, 14

Micrhystridium stellatum Deflandre 1942, figs. 7-8.

Micrhystridium stellatum Deflandre 1945, pl. 3, figs. 16-19.

Diagnosis. A species of *Micrhystridium*, test tending to be polygonal, spines strong, simple, straight or slightly curving, length greater than radius, few in number, about a dozen. Test diameter 11-16 μ .

Occurrence. Wenlock, France (Deflandre 1945), Middle Devonian, France (Deunff 1954b), Bajocian, France (Valensi 1953).

Remarks. Test diameter ranged from 9 to 24 μ , process-length from 60 to 120 per cent. of diameter, processes numbered from five to fourteen in optical section. They conform closely in all respects to the typical Wenlock material. The Devonian forms have more numerous, shorter spines. The rare specimens in the Bajocian may be derived.

Micrhystridium stellatum var. *inflatum* var. nov.

Plate 11, fig. 12

Holotype. Mik(P)14002.

Diagnosis. A variety of *M. stellatum* with a spherical inflated test.

Remarks. Diameter 15 to 16 μ , process-length 110 to 130 per cent. of test diameter, number in optical section six to eight. This form could be confused with small individuals of *B. longispinosum*.

Micrhystridium eatonensis sp. nov.

Plate 11, fig. 15

Holotype. Mik(P)15001.*Diagnosis.* A species of *Micrhystridium*, walls 1.5μ thick, red-brown colour usually. Processes stout, 1.5μ long, 1μ apart, tips mostly pointed, a few bifurcate.*Remarks.* Diameter varied from 12 to 22μ . This species resembles *B. microspinosum* Eisenack but is less than half the diameter, the spines also are relatively longer and more widely spaced in *M. eatonensis*.

Genus VERYHACHIUM Deunff 1954d

Type species by original designation: *Hystrichosphaeridium trisulcum* Deunff, Upper Ordovician, France.*Diagnosis.* A genus of hystrichospheres, test shape determined by the number of processes, globose only when a single process is present; processes few (one to eight), long pointed, often curved; body size 10 to 40μ usually.*Veryhachium tetraëdron* Deunff*Occurrence.* Middle Devonian, Canada.*Remarks.* Deunff (1954c) gives no diagnosis or description of this species. The illustration shows it to be tetrahedral, the body measuring 36μ across, the processes, four in number, also measure about 36μ . The test surface appears to be granular.*Veryhachium tetraëdron* var. *wenlockium* var. nov.

Plate 12, figs. 9, 11

Holotype. Mik(P)23001. *Paratype.* Mik(P)24001.*Diagnosis.* A small variety of *V. tetraëdron*, with a smooth test surface and relatively longer processes.*Description.* The size of the test varies from 6 to 27μ , the shape is always tetrahedral, the walls always smooth, yellow-green in colour. The processes range in length from 100 to nearly 500 per cent. of the test diameter.*Remarks.* This is one of the commonest hystrichospheres in the Wenlock Shale. It is consistently smaller than the typical Devonian members of the species.*Veryhachium rhomboidium* sp. nov.

Plate 12, fig. 10

Holotype. Mik(P)21001.*Diagnosis.* Test rhomboidal, surface smooth, walls moderately thick, test size 16 to 23μ ; processes, four or six, arising at corners of the test, simple spines, length 50 to 100 per cent. of test size.

Remarks. This species resembles *V. minutum* Downie but is larger, thicker walled, and has narrower processes. It does not have the long curving processes of *V. staurateroides* Deflandre or *V. crucistellatum* Deunff, nor the broad conical processes of *V. oligospinosum* (Eisenack). The *Hystrichosphaeridium* sp. figured by Fisher (1953, pl. 7, fig. 11) from the Middle Silurian of New York, could belong to this species, but has rather long processes.

Genus CYMATIOSPHAERA O. Wetzel 1933, emend. Deflandre 1954

Type species by original designation: *Cymatiosphaera radiata* O. Wetzel, Upper Cretaceous, Germany.

Diagnosis. Spherical or ellipsoidal tests of brownish organic matter, surface divided into polygonal fields by membranes perpendicular to test surface, no equatorial girdle, no spines.

Cymatiosphaera octoplana sp. nov.

Plate 11, fig. 2

Holotype. Mik(P)17001.

Diagnosis. A species of *Cymatiosphaera*, lemon-yellow colour, test surface granular, divided into eight rectangular, more or less equal sized, areas by membranes about one-third of the diameter in height, height of membrane varies giving a rectangular outline, test diameter about 30 μ .

Remarks. This species closely resembles *C. cubus* Deunff (1954c), with which it is associated. *C. cubus*, however, has only six rectangular fields. The extra partitions are usually easily seen but in certain views separation of the species may be difficult.

Cymatiosphaera pavimenta (Deflandre)

Plate 11, figs. 8, 9

Michystridium pavementum Deflandre 1945, pl. 3, figs. 20, 21.

Diagnosis. Test spherical, diameter 10 to 20 μ , walls thick, colour generally deep red-brown, partitions 20 to 40 per cent. of test diameter in height, polygonal fields 5 to 10 μ across, pillars formed where partitions join, nine to fourteen seen around circumference.

Occurrence. Wenlock, France.

Remarks. Deflandre established the species on the basis of two poorly preserved specimens, and it has not been recorded since. His description has been fully confirmed.

Cymatiosphaera wenlockia sp. nov.

Plate 11, fig. 4

Holotype. Mik(P)7002.

Diagnosis. A species of *Cymatiosphaera*, diameter 18 to 35 μ , walls moderately thick,

partitions 15 to 20 per cent. of test diameter, polygonal fields 10 to 20 μ across, number variable, always more than eight.

Remarks. This species resembles *C. canadensis* from the Middle Devonian (Deunff 1954c) but is smaller with higher crests and smaller polygonal fields.

Genus PULVINOSPHAERIDIUM Eisenack 1954a, emend. Deunff 1954d

Type species by original designation: *P. pulvinellum* Eisenack, Llandovery, Baltic.

Diagnosis. Hystrichospheres processes of which are broad off-shoots from the central body, no definite boundary between the two; processes with blunt rounded terminations.

Pulvinosphaeridium oligoprojectum sp. nov.

Plate 10, fig. 12; Plate 12, fig. 12

Holotype. Mik(P)12002. *Paratype.* Mik(P)16001.

Diagnosis. Hollow test, walls thin, yellow-brown, surface matt, five broad hollow rounded processes unite to form the ill-defined body, overall size 150 to 250 μ .

Remarks. This species resembles *P. pulvinellum* in size and general appearance, but *P. pulvinellum* has its four projections in the same plane. The only example of *P. oligoprojectum* in the Wenlock Shale with four projections was tetrahedral. *P. oligoprojectum* strongly resembles the 'bodies of unknown affinity' figured by Eisenack (especially 1951, pl. 3, figs. 15 and 16).

Family PTEROSPERMOPSIDAE Eisenack 1954b

Genus PTEROSPERMOPSIS W. Wetzel 1952

Pterospermopsis cf. *onondagaensis* Deunff

Plate 12, fig. 8

Diagnosis. A spherical capsule of organic matter, diameter 12 μ , with equatorial flange of thinner organic matter, flange width 50 to 60 per cent. of capsule diameter.

Occurrence. Middle Devonian, Canada (Deunff 1955).

Remarks. The specimens of *Pterospermopsis* found in the Wenlock Shales had capsules ranging in diameter from 15 to 35 μ , and are therefore a little larger than the Devonian form. The flange is a little narrower, usually being about 40 per cent. of the diameter in width. Deunff does not indicate the range of variation shown by Devonian forms.

Family LEIOFUSIDAE Eisenack 1938

Genus LEIOFUSA Eisenack 1938

Type species by original designation: *Leiofusa fusiformis* (Eisenack), Lower Palaeozoic, Baltic.

Diagnosis. Oval or fusiform, hollow test, membrane smooth.

Leiofusa filifera sp. nov.

Plate 11, figs. 6, 7

Holotype. Mik(P)10001.

Diagnosis. A species of *Leiofusa* with the ends drawn out to form long hollow threads, body about one-third of total length, body width about one-quarter of its length.

Remarks. The overall length varied from 30 to 350 μ , it is possible that the small examples (30 to 90 μ) form a distinct species with a mode about 70 μ , but until a greater number of specimens are available it would be unsafe to separate it. *L. filifera* differs from *L. fusiformis* by having a shorter body, the ratio of body to total length being one-third compared with seven-tenths.

Leiofusa tumida sp. nov.

Plate 11, fig. 5

Holotype. Mik(P)28001.

Diagnosis. A species of *Leiofusa* with long terminal processes and rounded central body, overall length about 110 μ .

Remarks. The central body is much more inflated than in *L. filifera* (ratio of width to length being 0.66 to 0.9), but otherwise the species is similar, each processes being about one-third of the total length.

Family LEIOSPHAERIDAE Eisenack 1954b

Genus LEIOSPHAERIDIA Eisenack 1958a

Type species by original designation: *Leiosphaeridia baltica* Eisenack, Lower Palaeozoic, Baltic.

Diagnosis. Hollow more or less spherical test, often folded by subsequent compression, walls of waxy, yellow to red-brown organic substance, without visible pores.

Remarks. A very large number of specimens were found, apparently belonging to a number of species. But in a genus with so few variable characters species are not easy to distinguish (Eisenack 1958a, p. 4). Only the most important groups are dealt with here.

Leiosphaeridia wenlockia sp. nov.

Plate 12, figs. 2-4

Holotype. Mik(P)13003.

Diagnosis. A species of *Leiosphaeridia*, diameter 20 to 50 μ , distinct mode at 30 μ , walls yellow, 1 μ thick, smooth, waxy.

Remarks. Over 1,000 were observed, but it is uncertain just how many, for it overlaps with other species at the upper and lower ends of its size range. It closely resembles *L. baltica* but is smaller, the genotype measuring 80 to 140 μ . It is also smaller than *L. microcystis* (Eisenack) of the Upper Silurian (57 to 72 μ), but *L. cf. microcystis* (Deflandre 1945) from the Wenlock of France may belong to *L. wenlockia*.

Leiosphaeridia cf. *microcystis* (Eisenack)

Plate 12, fig. 1

Diagnosis. A species of *Leiosphaeridia*, diameter about 65 μ , range 57 to 72 μ .

Occurrence. Ordovician and Silurian, Baltic (Eisenack 1938); Upper Silurian, Baltic (Eisenack 1958a).

Remarks. A number of specimens of *Leiosphaeridia* were found, ranging in size from 40

EXPLANATION OF PLATE 10

- Figs. 1, 2, 6. *Baltisphaeridium longispinosum* (Eisenack). 1, Mik(P)14001, an example of the common form with broad processes. 2, Mik(P)20001, a smaller individual of the same type. 3, Mik(P)29001, a small form with narrow cylindrical processes.
 Fig. 3. *Baltisphaeridium eoplanktonicum* (Eisenack), Mik(P)26001.
 Fig. 4. *Baltisphaeridium brevispinosum* var. *wenlockensis* nov., Mik(P)27001, holotype.
 Fig. 5. *Baltisphaeridium brevispinosum* var. *granuliferum* nov., Mik(P)22001, holotype.
 Fig. 7. *Baltisphaeridium robustispinosum* sp. nov., Mik(P)9002, holotype.
 Fig. 8. *Baltisphaeridium* cf. *meson* (Eisenack), Mik(P)6002.
 Fig. 9. *Baltisphaeridium brevispinosum* var. *nanum* Deflandre, Mik(P)9001.
 Fig. 10. *Baltisphaeridium microspinosum* (Eisenack), Mik(P)6001.
 Fig. 11. *Veryhachium* cf. *balticum* (Eisenack), Mik(P)19002.
 Fig. 12. *Pulvinosphaeridium oligoprojectum* sp. nov., Mik(P)12002, holotype.
 All figures are $\times 500$.

EXPLANATION OF PLATE 11

- Fig. 1. *Baltisphaeridium digitatum* (Eisenack), Mik(P)12001.
 Fig. 2. *Cymatiosphaera octoplana* sp. nov., Mik(P)17001, holotype.
 Fig. 3. *Cymatiosphaera cubus* Deunff, Mik(P)26002.
 Fig. 4. *Cymatiosphaera wenlockia* sp. nov., Mik(P)7002, holotype.
 Fig. 5. *Leiofusa tumida* sp. nov., Mik(P)28001, holotype.
 Figs. 6, 7. *Leiofusa filifera*. 6, Mik(P)25001, small specimen. 7, Mik(P)10001, holotype.
 Figs. 8, 9. *Cymatiosphaera pavimenta* (Deflandre). 8, Mik(P)13001. 9, Mik(P)13002.
 Fig. 10. *Veryhachium bulbiferum* (Deflandre), Mik(P)19001.
 Figs. 11, 14. *Micrhystridium stellatum* Deflandre. 11, Mik(P)7001. 14, Mik(P)18001.
 Fig. 12. *Micrhystridium stellatum* var. *inflatum* var. nov., Mik(P)14002.
 Fig. 13. *Baltisphaeridium ramusculosum* (Deflandre), Mik(P)8001.
 Fig. 15. *Micrhystridium eatonensis* sp. nov., Mik(P)15001.
 All figures are $\times 500$.

EXPLANATION OF PLATE 12

- Fig. 1. *Leiosphaeridia* cf. *microcystis* (Eisenack), Mik(P)14003.
 Figs. 2-4. *Leiosphaeridia wenlockia* sp. nov. 2, Mik(P)13003, holotype. 3, Mik(P)14004, specimen with a pylom. 4, Mik(P)5003, specimen with wrinkled surface and pyrite grains within, a common habit.
 Fig. 5. *Tasmanites medius* (Eisenack), Mik(P)5002.
 Fig. 6. *Tasmanites* cf. *medius* (Eisenack), Mik(P)18002.
 Fig. 7. *Veryhachium trispinosum* (Eisenack), Mik(P)11001.
 Fig. 8. *Pterospermopsis* cf. *onondagaensis* Deunff, Mik(P)5001.
 Figs. 9, 11. *Veryhachium tetraëdron* var. *wenlockium* nov. 9, Mik(P)23001, holotype. 11, Mik(P)24001, paratype.
 Fig. 10. *Veryhachium rhomboidium* sp. nov., Mik(P)21001, holotype.
 Fig. 12. *Pulvinosphaeridium oligoprojectum* sp. nov., Mik(P)16001, paratype.
 All figures are $\times 500$.

to 60μ , which were distinguished from *L. wenlockia* by their slightly larger size, thicker (2 to 3μ) walls and darker yellow or reddish-brown colour. They resemble *L. microcystis* but are slightly smaller in size.

Genus *TASMANITES* Newton 1875, emend. Eisenack 1958a

Type species by original designation: *Tasmanites punctatus* Newton, Permian, Australia.

Diagnosis. Hollow spherical test, wall relatively thick, of yellow to dark-brown colour, radial pores occur but seldom penetrate the whole wall, most often opening outwards.

Tasmanites medius (Eisenack)

Plate 12, fig. 5

Tasmanites medius Eisenack 1958a, p. 6.

Diagnosis. A species of *Tasmanites*, diameter a little over 100μ , wall thickness 25 per cent. of radius, surface smooth, pores occasional, wall not layered, colour yellow to reddish-brown.

Occurrence. Ordovician to Upper Silurian, Baltic (Eisenack 1955).

Remarks. This is the first record from the Wenlock. The diameter ranged from 120 to 150μ , and the walls from 14 to 16μ in thickness.

Tasmanites cf. *medius* (Eisenack)

Plate 12, fig. 6

Remarks. Some specimens differed from the typical form of *T. medius* by having a slightly smaller diameter (60 to 100μ) and relatively thinner walls (6 to 10μ). No transitional forms have been found and the two groups appear to be quite distinct. The smaller forms have therefore been separated from *T. medius*.

OTHER SPECIES IN THE ASSEMBLAGE

A number of other species were present. Little need be said about them except to record their presence and previously recorded occurrences.

Baltisphaeridium digitatum (Eisenack), Pl. 11, fig. 1, has been recorded from the Wenlock of the Montagne Noire (Deflandre 1945) and the Llandovery and Wenlock of the Baltic by Eisenack (1951) who also noted it in the Wenlock of Dudley.

Michystridium imitatum Deflandre has previously been recorded only from the Wenlock of the Montagne Noire by Deflandre (1945).

Michystridium parinconspicuum Deflandre has been found in the Wenlock of the Montagne Noire (Deflandre 1945) and in the Middle Silurian of New York State (Fisher 1953). The specimens in the shale from Wenlock Edge appear to have somewhat thinner tests than those figured by Deflandre.

Michystridium is also represented by a number of small forms with long processes

and thin walls. Since they may be small individuals of *Baltisphaeridium longispinosum* it is not proposed to give them a name here.

Veryhachium bulbiferum (Deflandre), Pl. 11, fig. 10, has previously only been recorded from the Wenlock of the Montagne Noire (Deflandre 1945).

Veryhachium cf. *balticum* (Eisenack), Pl. 10, fig. 11, is a form resembling Eisenack's (1951) species from the Ordovician of the Baltic, but is smaller with thinner walls.

Veryhachium trispinosum (Eisenack), Pl. 12, fig. 7, is found in considerable numbers in this assemblage, ranging in size from 8 to 50 μ , with processes from 50 to 200 per cent. of the test size. Possibly more than one species is represented. *V. trispinosum* has been recorded from the Ordovician of the Baltic (Eisenack 1938), Bohemia (Eisenack 1948), Rheinischer Schiefer Gebirge (Eisenack 1939), the Middle Devonian of Brittany (Deunff 1954b), and probably from the Middle Silurian of New York (Fisher 1953, figs. 8, 10; Bashnagel 1942, pl. 1, figs. 6, 7). A similar species, *V. geometricum*, described by Deflandre (1945) from the Wenlock of France, has not been observed.

Cymatiosphaera cubus Deunff, Pl. 11, fig. 3. The only previous record of this species is from the Middle Devonian of Canada (Deunff 1954c). The specimens in the Wenlock Shale range in size from 12 to 35 μ , excluding the membranes.

Cymatiosphaera prismatica Deunff has previously only been recorded from the Middle Devonian of Canada (Deunff 1954c).

CONCLUSIONS

The examination of about 3,000 hystrichospheres from a restricted horizon in the Wenlock Shales has yielded more than thirty-three different forms. Fourteen of these are new. Of the other forms present, ten have been previously described from the Wenlock. They are: *B. brevispinosum* var. *nanum*, *B. digitatum*, *B. ramusculosum*, *M. stellatum*, *M. imitatum*, *M. parinconspicuum*, *C. pavimenta*, *V. bulbiferum*, *L. microcystis* and *T. medius*. In addition *B. meson* and *B. microspinosum* were previously known only from the Upper Llandovery, and *B. eoplanktonicum* was previously recorded only from the Ludlow.

The remaining forms show links with the Devonian on the one hand and the Ordovician on the other. The species previously known only from the Devonian are *C. cubus*, *C. prismatica*, and *P. onondagaensis*. The Ordovician species are *B. longispinosum* and possibly *V. balticum*. One species, *V. trispinosum*, had been recorded previously from the Ordovician and Devonian, but not from the Wenlock.

The assemblage from Wenlock most closely resembles that described by Deflandre from the Wenlock of the Montagne Noire in south France. Of the fourteen forms noted by Deflandre, nine are found in Shropshire. The Wenlock Shales also have a number of forms in common with Estonia. However, no Wenlock assemblage from there has been described so the closest comparison is with the Upper Llandovery (Eisenack 1954a), which has three species in common (excluding leiospheres), and the Ludlow (Eisenack 1955) with three species in common (including leiospheres).

There are even species in common with North America, two from the Middle Devonian of Canada and two from the Middle Silurian of New York.

These observations clearly demonstrate the wide distribution of the hystrichospheres and suggest at the same time that they may have some limited stratigraphical value.

TABLE
DISTRIBUTION OF HYSTRICHOSPHERES IN SIX PREPARATIONS OF WENLOCK SHALE

	Percentage in preparation						Total no.
	WS/Aa	AS/Ab	WS/Ac†	WS/Ad	WS/2a	WS/2b	
HYSTRICHOSPHERES:							
<i>B. longispinosum</i> (Eisenack)	8.5	16.7	13.0	6.0	3.0	18.9	49
<i>B. brevispinosum</i> var. <i>nanum</i> (Deflandre)	0.4	..	..	..	0.6	..	2
var. <i>wenlockensis</i> nov.	11.0	16.7	2.4	12.1	13.6	13.5	66
var. <i>granuliferum</i> nov.	1.3	..	..	2.4	3.6	..	8
<i>B. ramusculosum</i> (Deflandre)	3.4	..	..	7.2	1.8	5.4	19
<i>B. eoplanktonicum</i> (Eisenack)	3.0	..	2.4	9.6	1.2	2.7	20
<i>B. microspinosum</i> (Eisenack)	2.5	..	..	1.2	0.6	..	8
<i>B. digitatum</i> (Eisenack)	..	..	3.5	..	..	..	3
<i>B. meson</i> (Eisenack)	0.8	..	..	1.2	..	2.7	4
<i>B. robustispinosum</i> sp. nov.	0.4	..	..	..	0.6	..	2
<i>M. stellatum</i> Deflandre	11.4	16.7	5.9	9.6	4.3	2.7	49
<i>M. stellatum</i> var. <i>inflatum</i> nov.	0.4	..	2.4	2.4	3.6	..	8
<i>M. parinconspicuum</i> Deflandre	3.8	33.2	10.6	..	7.4	..	32
<i>M. imitatum</i> Deflandre	0.4	..	..	1.2	..	..	2
<i>M. eatonensis</i> sp. nov.	..	..	14.2	..	1.2	..	14
<i>V. bulbiferum</i> (Deflandre)	0.4	..	..	1.2	..	..	2
<i>V. cf. balticum</i> (Eisenack)	..	..	..	1.2	..	..	1
<i>V. tetraëdron</i> var. <i>wenlockium</i> nov.	25.4	..	4.7	19.3	41.3	16.2	144
<i>V. rhomboidium</i> sp. nov.	0.4	..	..	2.4	0.6	2.7	5
<i>V. trispinosum</i> (Eisenack)	3.0	..	..	3.6	5.5	8.1	22
<i>C. cubus</i> Deunff	2.1	..	..	3.6	0.6	..	9
<i>C. octoplana</i> sp. nov.	2.5	..	..	1.2	..	2.7	8
<i>C. prismatica</i> Deunff	0.4	..	1.2	..	0.6	..	3
<i>C. pavimenta</i> (Deflandre)	0.8	..	13.0	1.2	..	..	14
<i>C. wenlockia</i> sp. nov.	1.3	..	2.4	1.2	..	2.7	7
<i>P. oligoprojectum</i> sp. nov.	..	..	8.3	1.2	..	..	8
<i>Pr. cf. onondagaensis</i> Deunff	1.2	..	1.2	..	1.2	..	6
<i>L. filifera</i> sp. nov.	4.7	16.7	..	7.2	3.7	10.8	28
<i>L. tumida</i> sp. nov.	..	..	..	..	..	8.1	3
Other identifiable forms (excluding leiospheres)	10.5	..	14.8	3.8	5.0	2.8	65
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	609
LEIOSPHERES:							
<i>L. wenlockia</i> sp. nov.	62.2	60.9	42.6	68.0	53.3	66.7	1,202
<i>L. cf. microcystis</i> (Eisenack)	1.2	..	2.7	3.6	1.4	2.1	37
<i>T. medius</i> (Eisenack)	0.3	..	..	1.8	0.3	1.4	12
<i>T. cf. medius</i> (Eisenack)	0.6	..	1.6	1.5	..	0.7	15
Other leiosphere species	11.2	13.0	61.7	0.4	1.3	0.4	129
Hystrichospheres (excluding leiospheres)	24.5	26.1	46.4	24.7	43.7	28.7	609
Total per cent.	100.0	100.0	100.0	100.0	100.0	100.0	..
Total number	961	23	183	337	371	129	2,004

† Treated with fuming nitric acid.

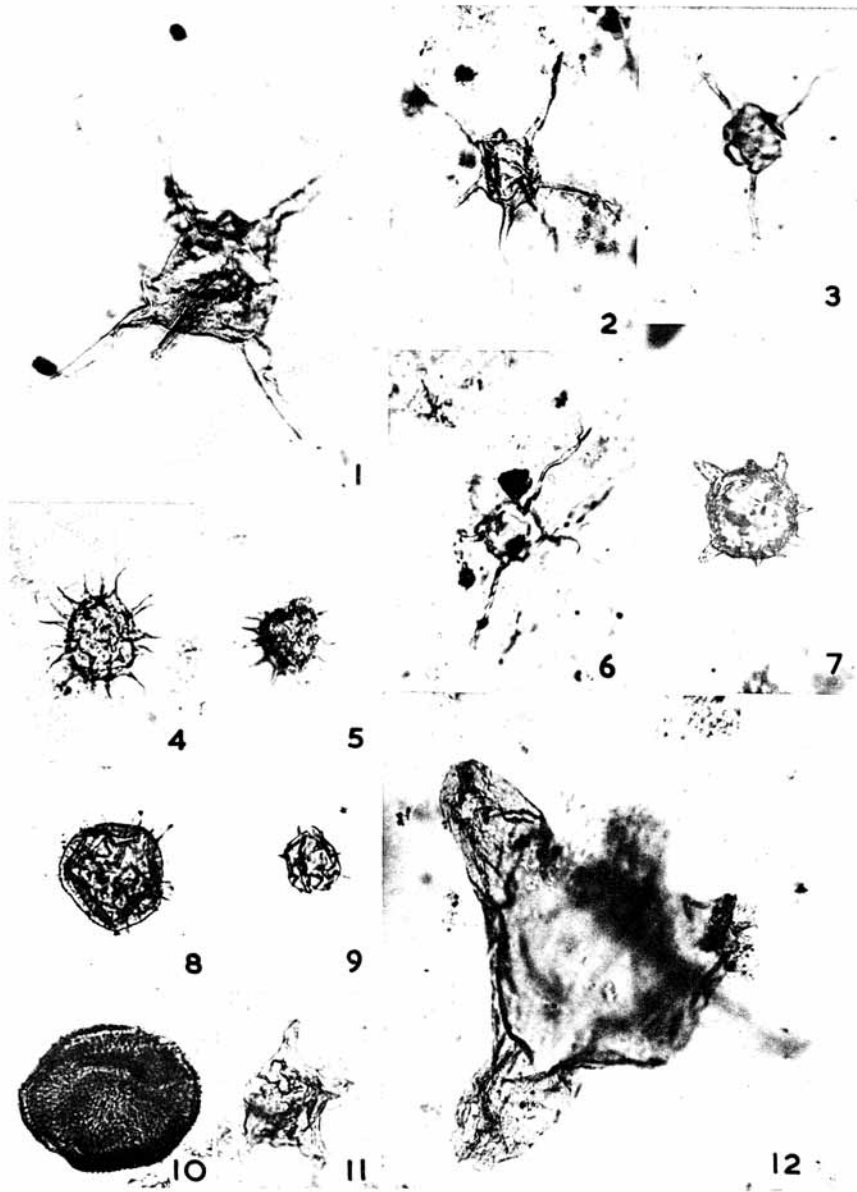
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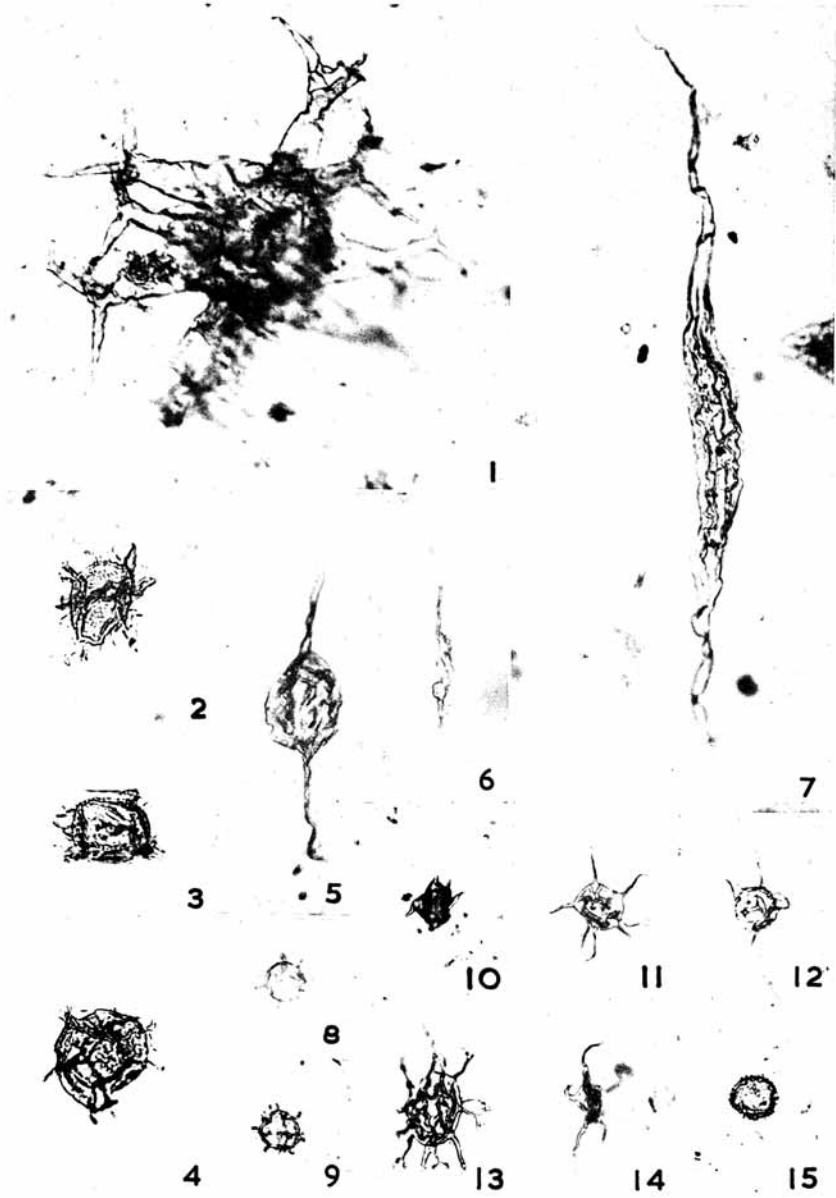
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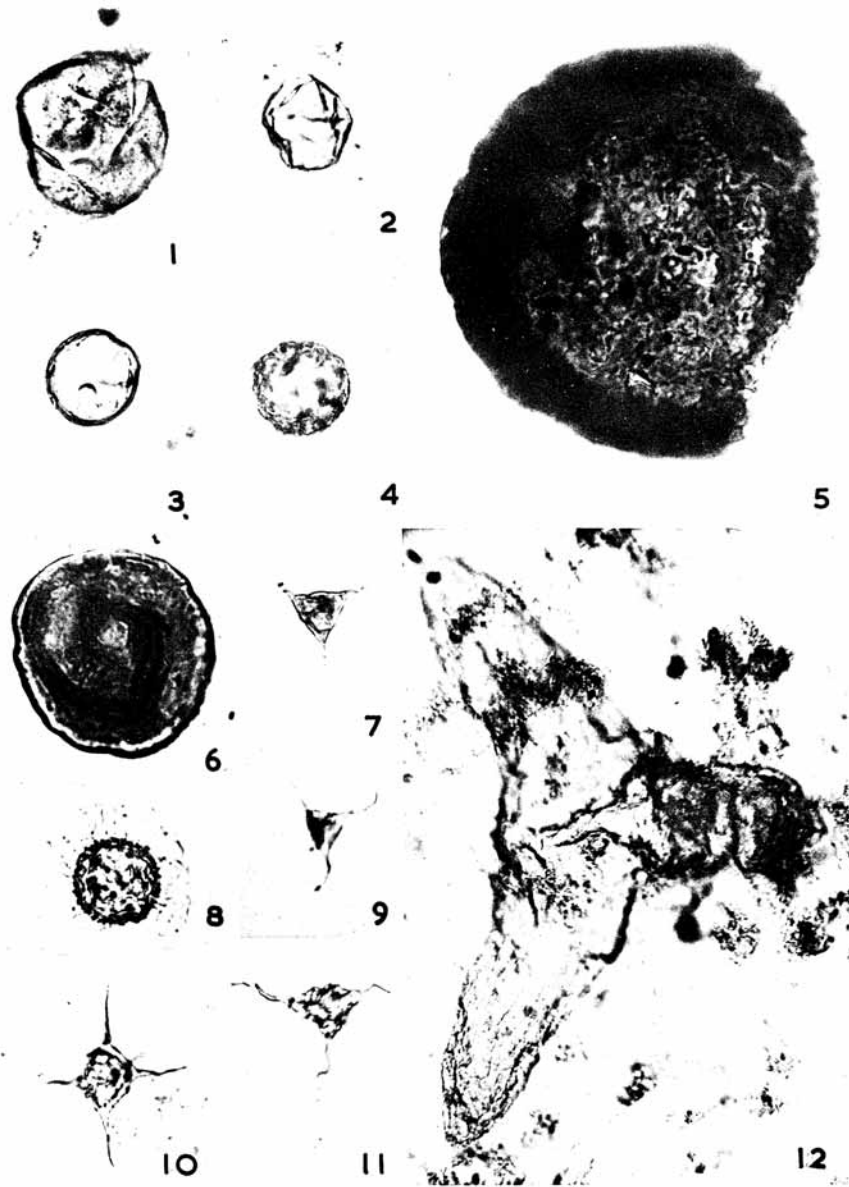
Manuscript received 16 November 1958



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