PERMIAN HYSTRICHOSPHERES FROM BRITAIN

by DAVID WALL and CHARLES DOWNIE

ABSTRACT. Hystrichospheres are described from the Permian of Britain for the first time and are allocated to four genera and eleven species, two of which are new. Closest comparison is with other Permian assemblages but many of the hystrichospheres present appear to be virtually indistinguishable from forms known to occur in beds ranging from the Ordovician to the Eocene in age.

LARGE numbers of small hystrichospheres have recently been found in the Lower Permian Marls of Yorkshire. Hitherto, Permian hystrichospheres have only been recorded from Yugoslavia and the Sahara (Jekhowsky 1961) and from North America (Wilson 1960), although Triassic hystrichospheres have been described from Switzerland (Brosius and Bitterli 1961) and the Soviet Arctic (Kara-Murza 1957). Wilson, however, only described a single specimen, so that comparison is mainly with Jekhowsky's material. His published descriptions are restricted to a number of forms allocated to the genus *Veryhachium* and do not cover the variety of types found in the British assemblages, which belong to eleven species representing the genera *Baltisphaeridium*, *Micrhystridium*, *Veryhachium*, and *Leiofusa*.

The material was prepared according to the standard procedure for the recovery of acid-insoluble microfossils (Funkhauser and Evitt 1959); pollen and spores account for about 30 per cent. of the fossil assemblage.

Location of the samples. Sample A was collected in the Ashfield Brick Pit, Conisbrough, Yorkshire (Grid Ref. 514983), from the Lower Permian (Bed J of Gilligan 1918) and consisted of a grey marl.

Sample B came from the Ash Hill Borehole, near Sykehouse, Yorkshire (Grid. Ref. 621161) from the Lower Permian Marl at a depth of 1,006 feet.

All the specimens described are now in the collection of the Micropalaeontology Laboratory of the Department of Geology, University of Sheffield.

GENERAL CHARACTER OF THE HYSTRICHOSPHERE ASSEMBLAGE

The hystrichosphere assemblage as a whole is characterized by the small size of the individuals present. Their average size is about 15 μ and even the species of *Baltisphaeridium* present does not exceed 25 μ in test diameter.

Another feature is the variability of the hystrichospheres. Apart from four distinctive species, readily separated from each other and the remainder, all the hystrichospheres form a plexus of morphological variation transgressing the boundary between *Micrhystridium* and *Veryhachium* and including forms morphologically identical or akin to seven described species. The modal forms in this plexus must certainly be identified as *Veryhachium? irregulare* Jekhowsky and the group as a whole is referred to here as the '*V. ? irregulare*' complex (text-fig. 1*a–z*).

The problems of taxonomy raised by the variation within this plexus cannot be dismissed simply by uniting all the forms in a single species. To do so would cause con-

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siderable confusion since homoeomorphs of many previously named species occur and the diagnoses of two genera would have to be altered in such a way as to make them largely inseparable. Furthermore, it is considered desirable to retain several specific names for the morphotypes present since it is known that similar variable groups occur at other horizons, but with an emphasis on different morphotypes.

To adapt a 'natural' classification in these circumstances would lead to confusion and the identification of single specimens or small assemblages would require prior knowledge of their geological age. It has therefore been the policy of the authors to accept the species already described as morphological entities and to identify with them, all forms having identical or closely similar shapes, irrespective of age or of gradations into other forms.

Minor variations in morphology, for example, in spine length, rigidity of spines, breadth of spine bases, have been given consideration and where it has been thought that these form an insufficient basis on which to erect new species, the specimens have been described as *formae* within the species. Species are distinguished on the basis of more obvious characters such as the number of spines and the shape of the test.

The authors would have preferred a system of classification more closely adjusted to the biological facts and have tried to restrict the number of these artificial species and *formae* to the minimum.

MICRHYSTRIDIUM AND VERYHACHIUM

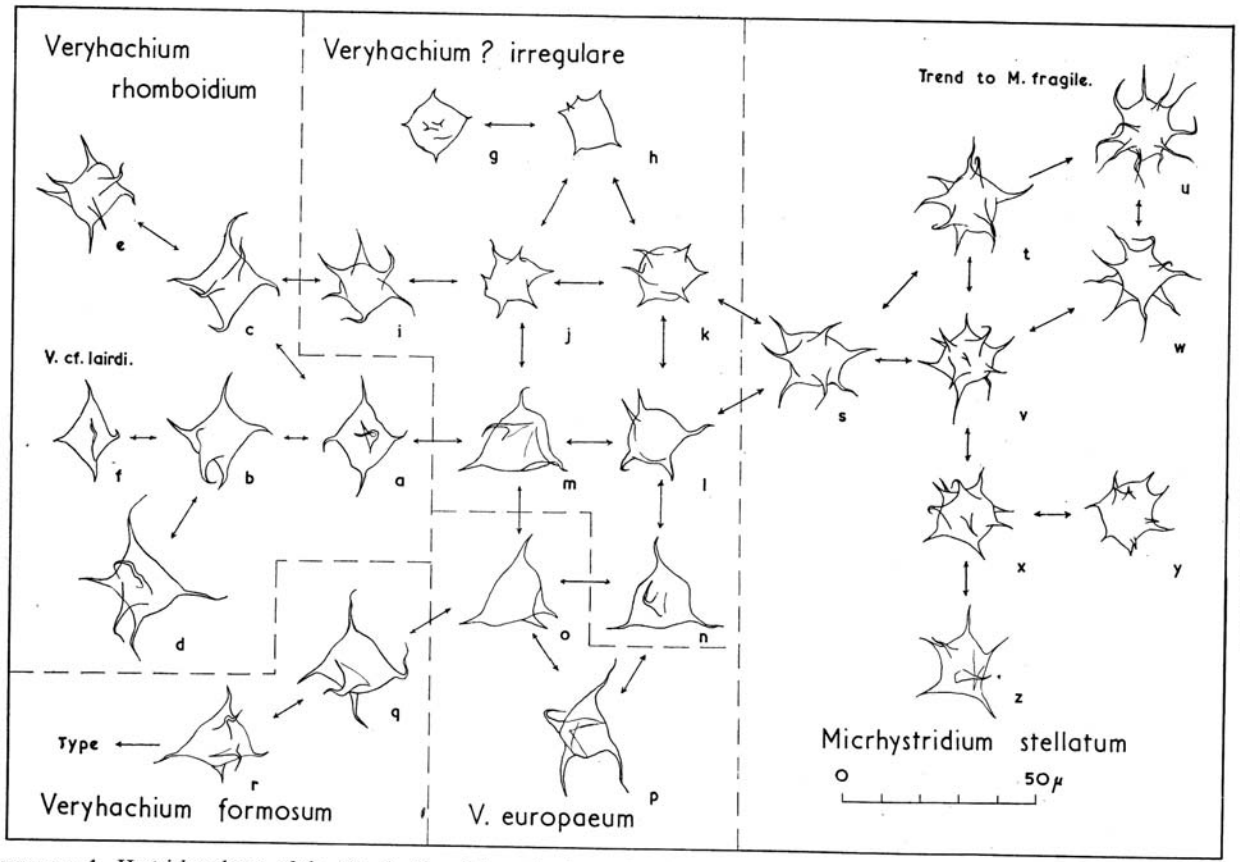
The '*V. ? irregulare*' complex includes at one extreme forms with only four processes and a polygonal test, which generally would be considered typical members of the genus *Veryhachium*; at the other extreme are small spherical hystrichospheres with as many as twenty spines, which would indubitably be placed in *Micrhystridium* by most authors. It would cause confusion to place the plexus entirely within one or other of these genera and therefore an arbitrary distinction has been made between the two.

The basis of this distinction has been the original definition of *Veryhachium* by Deunff (1945*b*), emended by the transfer of *Veryhachium monocanthum* by Downie (1960). The genus includes species with non-globose tests with three to eight spines. Some authors (Staplin, 1961) have subsequently included forms with sixteen processes, but this is not justified, although occasionally it may be necessary to include a specimen with nine or ten spines if the additional spines are 'adventitious' and do not alter the normal test shape of the species possessing eight or less spines.

In the '*V. ? irregulare*' complex the gradation between *Veryhachium* and *Micrhystridium* involves both an increase in spine number and a transition towards a globose shape. Distinction between the two genera is based on the definition of *Veryhachium* given above, so that within this genus are included forms with polygonal and subpolygonal tests with eight or less spines and a few individuals with markedly polygonal tests and additional 'adventitious' spines. *Micrhystridium* embraces that part of the complex with globose and subspherical tests generally with seven or more spines.

The systematic importance of small spines

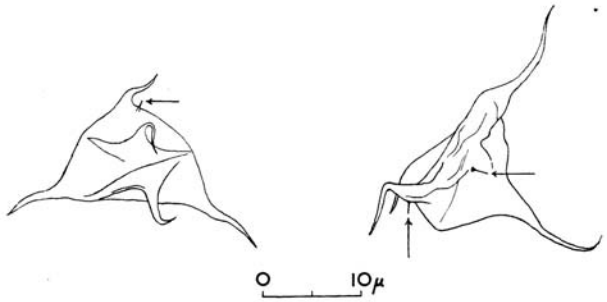
Certain specimens of *Veryhachium* occuring in the Permian have very small processes, 1 to 3 microns in length, in addition to the normal spines (text-fig. 2; Pl. 114, fig. 12).



TEXT-FIG. 1. Hystrichospheres of the '*Veryhachium ? irregulare*' complex from the British Permian. *a–e*, *V. rhomboidium*. *a*, Forma 1. *b*, *c*, Forma 2. *d*, Forma 3. *e*, Forma 4. *f*, *V.* cf. *lairdi*. *g–n*, *Veryhachium ? irregulare*. *g*, *h*, Forma 1. *i–k*, Forma *subhexaedron*. *l*, *m*, Forma *irregulare*. *n*, Forma *subtetraedron*. *o–p*, *V. europaeum*. *o*, Forma 1. *p*, Forma 2. *q–r*, *V. formosum*, *q*, Forma 1. *r*, Forma 2. *s–z*, *Micrhystridium stellatum*. *s*, Forma 6. *t*, Forma 2. *u*, Forma 3. *v*, Forma *stellatum*. *w*, Form similar to forma 5 but with less-expanded spine bases. *x*, Form transitional between forma *stellatum* and *z*. Forma 1. *y*, Forma 4.

These small processes, which appear to be solid, are situated on the faces of the polygonal tests, either centrally or close to the main spine bases; as many as three may be present on an individual specimen.

Staplin (1961), in describing *Veryhachium* cf. *trispinosum*, noted a minute structure (presumably spinous) interpreted as a flagellar sheath. The small spines on our Permian forms cannot be interpreted in this way, for there may be up to three on an individual and their distribution on the test is random. It is considered more likely that they are underdeveloped processes. Examination of a large number of individuals shows that



TEXT-FIG. 2. *Veryhachium sp.*, with small spines in addition to larger processes (examples from sample A).

some variation in spine length occurs in all specimens, and although a complete gradation in size between the small spines and the larger is not always obvious, separation of small and large spines is very subjective.

Forms of Micrhystridium *in the* 'V.? irregulare' *complex*

All the forms of *Micrhystridium* within the complex are attributed to *M. stellatum* Deflandre, but often show slight differences from the typical Silurian material in spine length and shape. The forms described by Deflandre have globose to rather polygonal tests bearing about twelve spines, more than 50 per cent. of the diameter in length; their bases expand only slightly where they join the test. Other Silurian material described by Downie (1959) indicates that the number of spines may be as few as five in optical section and the spine length ranges from 60 to 120 per cent. of the test diameter.

Of the twelve specimens of *M. stellatum* illustrated by Stockmans and Willière (1960, pls. 1, 2), examples occur resembling both the Silurian and Permian material. Valensi (1953) and Sarjeant (1959, 1960, 1961) have also described forms of *M. stellatum* from the Jurassic of France and Britain. These are indeed similar to the Palaeozoic fossils but their spine-bases tend to be more expanded and to taper uniformly towards the tip (Sarjeant, 1959, p. 341).

In the Permian assemblage dealt with here, globose, subpolygonal, and polygonal forms occur, some of which, having expanded spine bases tapering gradually distally, are almost identical with the Jurassic forms, while others having more constricted spine bases and tapering more rapidly proximally, closely resemble the Devonian and Silurian specimens. In addition, there is a trend towards shortening of the spines and the relative length may be as low as one-third of the test diameter.

Globular forms of *M. stellatum* and polygonal forms with relatively numerous spines occurring in the Permian may also closely resemble the Mesozoic species *Micrhystridium fragile* Deflandre. Both species have spines equivalent in length and number to each other and *M. fragile* may tend to develop a polygonal test, for example those figured by Valensi (1953, pl. 5, fig. 4). The only criterion left which can usefully serve to separate the two species is the nature of the spines. *M. stellatum* possesses relatively rigid spines with expanded bases while *M. fragile* has more delicate spines without expanded bases (Valensi 1953, p. 43). Separation of the two species becomes artificial to some extent, especially in some Jurassic strata, but on this basis the Permian forms must be regarded as belonging to *M. stellatum* since their spine bases are always expanded even if the spines are not always rigid. Forms directly comparable with the holotype of *M. fragile* (Deflandre 1947, fig. 13) were not found in the Permian assemblages.

Forms of Veryhachium *in the* 'V.? irregulare' *complex*

The remainder of the plexus consists of polygonal and subpolygonal forms, generally with four to six spines. The subpolygonal forms here have recently been described from the Permo-Trias by Jekhowsky (1961) as *Veryhachium? irregulare*. Of the four *formae* he described, three occur in the Yorkshire Permian, only *forma pirula* being absent. The doubt expressed by Jekhowsky in attributing these forms to *Veryhachium* is understandable, since they are transitional in form to *Micrhystridium*, but in view of the distinction between the two genera discussed earlier, this question is not pursued any further here. Complete transition also occurs between the subglobular forms of *V.? irregulare* and polygonal forms with four to six spines allocated to other species of *Veryhachium*.

With respect to the test shape of the polygonal forms, two basic series can be distinguished, one being octagonal, the other tetrahedral. Members of the first series typically have six spines projecting from their apices, but may have any number from four to nine. The second series typically has four spines but may occasionally have as many as eight spines without losing their basic tetrahedral shape.

The typical octagonal forms are very similar to *Veryhachium rhomboidium* Downie from the Silurian and may be considered as homoeomorphs of the latter. In view of their basic similarity in shape the Permian forms are allocated to this species. There are, however, slight differences which are expressed by the recognition of three new *formae*. These are not named here, but if it is subsequently found desirable to name them, this can readily be done. However, if any other new hystrichospheres are found (referable to a species within the complex) it is hoped they will be named as *formae* and not as new species based on obscure and unstated differences which might confuse morphological relationships and render identification almost impossible. It is not, however, implied that the naming of all species of microplankton should be based on such arbitrary morphological distinctions. The system applied here is considered a temporary expedient in this difficult group of hystrichospheres.

A few forms with five spines (three of which lie in an 'equatorial' region and the other two at the poles) also occur and appear to be morphologically transitional between *V. rhomboidium* and forms resembling *V. lairdi* Deunff from the Caradocian of Brittany. The latter species is characterized by four spines arranged at the apices of a rectangular or rhomboidal pad; a Permian form with four spines is compared with this species.

The typically tetrahedral forms of the second series resemble two previously recorded species in shape and spine number. These are *Veryhachium tetraëdron* Deunff and a morphologically similar but smaller species, *V. europaeum* Stockmans and Willière. The former species name was introduced by Deunff (1954*a*, fig. 9, p. 1065) for hystrichospheres occurring in the Devonian of Canada. No description accompanied or preceded his illustration and the species name is therefore illegitimate (Article 32, International Rules of Botanical Nomenclature). *V. tetraëdron* var. *wenlockia* Downie 1959 must also be illegitimate (Article 42, loc. cit.). The Permian forms are allocated to the legitimate species *V. europaeum* and two new *formae* are distinguished. *V. tetraëdron* var. *wenlockia* is renamed as *V. europaeum* Stockmans and Will. var. *wenlockianum* var. nov.

The remainder of the second series retains the basic tetrahedral shape but the four apical spines are augmented by processes arising from the test faces. These specimens are allocated to *V. formosum* Stockmans and Will. because of their great similarity to the Devonian species but two slightly distinct Permian *formae* are recognized. There may be up to four additional spines present bringing the total number to eight, but the test remains triangular in outline.

V. ? riburgense f. *regulare* Brosius and Bitterli from the Trias of Switzerland is to be regarded as a closely related member of this series, transitional between *V. ? riburgense* f. *irregulare* and *V. formosum*, but differing from the latter species by its inflated test and shorter spines. *V. ? riburgense* f. *irregulare* is similar to *V. ? irregulare* but has more spines.

Some forms appear to be intermediate between the octahedral and tetrahedral series, in which case their classification becomes difficult. However, in most cases these forms appear to be identifiable as specimens of *V. formosum* that have been slightly distorted during fossilization. Plate 114, fig. 7 illustrates a typical example whose outline comprises two equal and straight sides and a third longer, convex side. Since the outline is not four-sided as in *V. rhomboidium* or *V. lairdi* the specimen is allocated to *V. formosum*.

Comparison of the assemblages

A comparison of the proportional distribution of hystrichospheres in samples A and B (Table 1) reveals a considerable difference in their composition. Sample A is dominated by *V. ? irregulare*, *V. europaeum* forma 1, and *V. reductum* while *B. deblispinum* sp. nov., *V. flagelliferum* sp. nov., and *M. stellatum* dominate sample B. The prominent forms in one sample are uncommon or absent in the other.

A precise stratigraphical correlation of the two samples is not possible, but both occur within the Lower Permian Marl, which is relatively restricted in thickness (maximum 20 feet) in south Yorkshire. It is probable that the assemblages differ due to lateral rather than vertical changes in the fossil composition of the horizon. The Conisbrough assemblage (sample A) is possibly representative of a facies nearer shore since the pollen content is twice that of sample B, taken approximately 13 miles to the NNE. Furthermore, its hystrichospheres are always small subpolygonal or polygonal forms with small spires only a few microns in length, compared with the more inflated and longer-spined forms encountered in sample B; this interpretation is in agreement with other geological information.

TABLE 1. Proportional distribution of hystrichosphere species in two samples from the British Permian.

List of species	Percentage in preparation Sample B	Sample A
Baltisphaeridium debilispinum sp. nov.	50·2	..
Micrhystridium recurvatum Valensi	0·4	..
Veryhachium flagelliferum sp. nov.	13·4	..
Veryhachium reductum (Deunff) Jekh.	1·1	7·8
Leiofusa jurassica Cookson. and Eis.	0·4	..
Micrhystridium stellatum f. *stellatum*	4·0	..
M. stellatum forma 1	6·1	0·9
M. stellatum forma 2	1·9	..
M. stellatum forma 3	1·6	..
M. stellatum forma 4	1·9	0·5
M. stellatum forma 6	2·8	..
V. irregulare f. *subhexaedron*	1·1	18·2
V. irregulare f. *subtetraedron*	0·4	2·7
V. irregulare f. *irregulare*	1·1	17·3
V. irregulare forma 1	0·4	12·3
V. rhomboidium forma 1	1·1	5·0
V. rhomboidium forma 2	0·4	..
V. rhomboidium forma 3	4·0	0·5
V. rhomboidium forma 4	1·9	0·5
V. cf. *lairdi*	..	0·5
V. europaeum forma 1	1·8	18·2
V. europaeum forma 2	..	4·1
V. formosum forma 1	2·1	7·8
V. formosum forma 2	1·9	3·7
Total percentage	100·0	100·0
Number of Hystrichospheres	277	219
Number of pollen grains	73	140
Total number of specimens counted	350	359

COMPARISON WITH OTHER ASSEMBLAGES

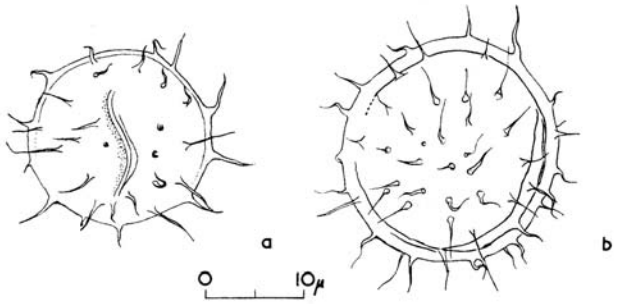
The hystrichospheres in sample A correspond most closely to those described by Jekhowsky (1961) from the Permo-Trias of Africa and Europe, although they are generally less inflated. The dominant species in sample B are new, but comparison may be possible when details of various Micrhystridia briefly mentioned by Jekhowsky become available. The Permian specimen from Oklahoma described by Wilson (1960) as *Hystrichosphaeridium sp.* is quite different from any seen in the British Permian.

Some Devonian species of *Veryhachium* and *Micrhystridium* illustrated by Stockmans and Willière (1960) are also very like the British Permian forms, but the Devonian assemblage is richer in species and the genera *Polyedryxium* and *Cymatiosphaera*, absent in the Yorkshire assemblages, also occur. Most of the Devonian hystrichospheres described by Staplin (1961) from Alberta also differ considerably from those in the Permian, but *Veryhachium brevitrispinosum* Staplin and *V.* sp. cf. *H. trispinosum* closely resemble *V. reductum* Jekhowsky, and *V. sedecimspinosum* Staplin resembles *M. stellatum* (forma 1 below). *V. reductum* also occurs in Carboniferous marine shales from Britain (personal communication, Mr. F. Spode) and north-west Spain (personal communication, Dr. R. Neves).

The assemblage described by Brosius and Bitterli (1961) from the Trias of Switzerland comprises hystrichospheres very similar in overall morphological characteristics to the Permian forms. However, detailed comparison reveals that all the species described apart from *V. reductum* differ in some respect from the Yorkshire specimens. Additional work is necessary to prove whether or not these distinctions are always valid.

Most of the British Permian hystrichospheres persist into the Lower Jurassic and somewhat similar assemblages dominate the British Lias. Within the Middle and Upper Jurassic, however, the small forms of *Veryhachium* apparently become very rare or are entirely absent with the incoming of more complex hystrichospheres and dinoflagellates (Valensi, 1953; Sarjeant, 1959).

The assemblage is therefore composed mostly of long-ranging species, which differ only slightly in the *formae* present from counterparts in earlier and later horizons. It is noteworthy in the absence of the larger, more distinctive forms that commonly occur in the Lower Palaeozoic and Mesozoic. Whether this is characteristic of the environment or of the time is not yet known.



TEXT-FIG. 3*a*, *b*. *Baltisphaeridium debilispinum* sp. nov. *a*, Holotype PB/11 91·0 32·7. *b*, Paratype, with maximum number of spines and marginal folding of the test wall; single mount. (Both specimens from sample B.)

SYSTEMATIC DESCRIPTIONS

Order HYSTRICHOSPHAERIDEA Eisenack
Section 1. Hystrichospheres excluding the '*V. ? irregulare*' complex
Family HYSTRICHOSPHAERIDAE O. Wetzel 1933
Genus BALTISPHAERIDIUM Eisenack 1958

Baltisphaeridium debilispinum sp. nov.

Plate 112, figs. 1, 2; text-fig. 3*a*, *b*

Holotype. Slide PB/11, 91·0 32·7. Plate 112, fig. 2. Diameter 18 μ.

Diagnosis. Test spherical, smooth, relatively thick-walled; spines slender, straight or curved, with conical bases 1 μ in diameter; number of spines twenty to fifty, length 20 to 25 per cent. of the test diameter, sometimes up to 50 per cent.

Dimensions. Test diameter 16 (22) 25 μ; test wall 1 to 2 μ thick (fifty specimens measured).

Description. The thickness of the test wall is approximately 10 per cent. of the diameter and the inner margin is frequently visible as a distinct line under the microscope. The wall often folds. The spine bases are circular, 1 to 2 μ wide, but taper abruptly to form slender processes which do not appear to communicate with the test lumen. Smaller specimens tend to possess a thicker wall and fewer spines, while larger forms have relatively shorter spines and a thicker wall.

Comments. In sample B this form is abundant. *B. debilispinum* differs from *B. ehrenbergi* Defl. in that the latter is larger and possesses more numerous and longer spines and from *B. ehrenbergi* Defl. var., *brevispinosum* Sarjeant by possessing less numerous and weaker spines. *Micrhystridium* aff. *fragile* Defl. 1947 described by Brosius and Bitterli (1961) is similar but lacks the conical spine bases and relatively thick wall.

Since the test size exceeds 20 μ in the majority of cases, this species is allocated to *Baltisphaeridium* but smaller examples are common.

Genus MICRHYSTRIDIUM Deflandre 1937

Micrhystridium recurvatum Valensi 1953

Several specimens of *M. recurvatum* were recorded from the Ash Hill Borehole (sample B). They correspond closely to *M. recurvatum* f. *reducta* Valensi from the Bathonian of France.

Genus VERYHACHIUM Deunff 1954

Emended diagnosis. A genus of hystrichospheres with three to eight spines; shape of the test more or less determined by the number of spines present.

Remarks. According to the original diagnosis of *Veryhachium* (Deunff 1954*b*) the number of spines present varies from one to eight. Downie (1960) created a new genus, *Deunffia*, to accommodate small hystrichospheres with only one spine, and transferred *V. monocanthum* Deunff to this genus. Hystrichospheres possessing only two spines usually belong to the genera *Leiofusa* Eisenack 1938, or *Domasia* Downie 1960, according to whether the spines are situated at opposite poles or are both at one pole respectively. In this manner, the actual lower limit for the number of spines present in the genus *Veryhachium* can be regarded as three. The upper limit for the spine number has in some cases been raised to include forms with nine spines when other characters justify their inclusion in *Veryhachium*.

EXPLANATION OF PLATE 112

All figures × 1,000.

Figs. 1, 2. *Baltisphaeridium debilispinum* sp. nov. 1, Paratype; single mount. Sample B. 2, Holotype; PB/11, 91·0 32·7. Sample B.

Figs. 3–5. *Veryhachium flagelliferum* sp. nov. 3, Holotype; PB/11, 91·4 24·7. 4, 5, Paratypes; PB/11. All from sample B.

Fig. 6. *Leiofusa jurassica* Cookson and Eisenack. Sample B.

Figs. 7–9. *Veryhachium reductum* (Deunff) Jekh. 7, Forma *trispinoides*, sample B. 8, F. *reductum*; sample A. 9, F. *breve*; sample A.

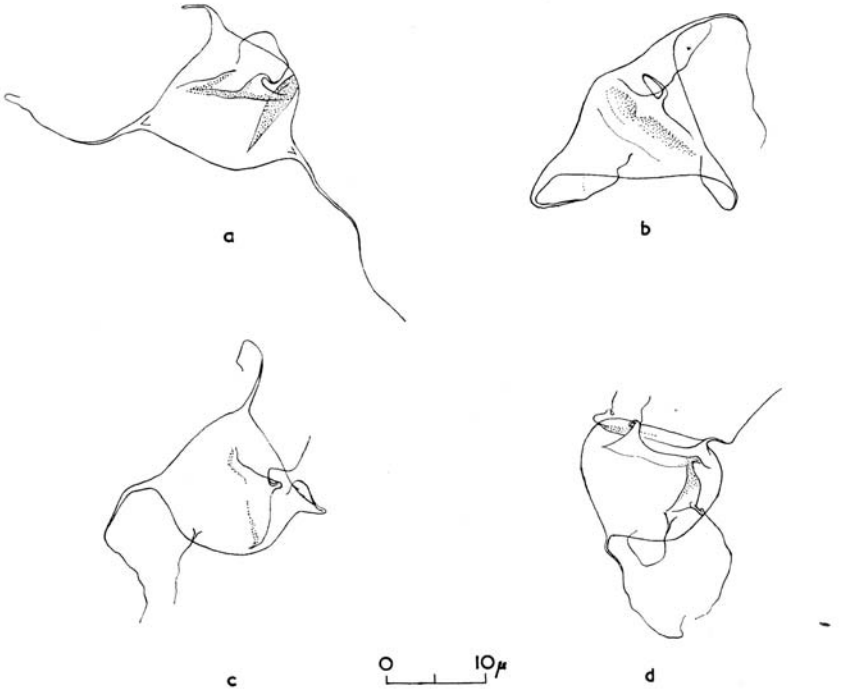
Figs. 10–12. *Micrhystridium stellatum* Defl. .10, Forma *stellatum*. 11, Forma 1. 12, Transitional form between f. *stellatum* and forma 1. All from sample B.

Veryhachium flagelliferum sp. nov.

Plate 112, figs. 3–5; text-figs. 4*a–d*

Holotype. Slide PB/11, 91·4 24·7. Plate 112, fig. 3. Test 16 μ.

Diagnosis. Test triangular to subglobose in outline, rarely with straight sides, bearing four to six long, flagellae-like processes whose length exceeds the test dimensions.



TEXT-FIG. 4*a–d*. *Veryhachium flagelliferum* sp. nov. *a*, Holotype, PB/11 91·4 24·7. *b–d*, Paratypes showing variation in test shape and spine number (specimens from sample B, slide PB/11, 82·5 30·7 77·1 29·3, 75·2 32·4).

Dimensions. Test 14 (16) 18 μ; spines over 24 μ (twenty specimens measured).

Description. The test is smooth, thin-walled, subtetrahedral if only four spines are present but subglobose when bearing five or six spines. The spines have restricted bases, 1 to 2 μ wide, but for the most of their length they are extremely fine and flexuous and only visible at higher magnifications. They are usually colourless.

Comparisons. The long, fine processes are a readily distinguishable feature distinct from other forms resembling *V. flagelliferum* in shape. It differs from *V. trisulcum* Deunff by possessing four to six spines and it has a smaller test.

Veryhachium reductum (Deunff 1959) Jekhowsky 1961

Plate 112, figs. 7–9

1958 *Veryhachium trisulcum* var. *reductum* Deunff.
1961 *Veryhachium brevitrispinosum* Staplin.

Discussion. The three *formae* distinguished by Jekhowsky 1961 can be recognized in the British Permian. In the authors' opinion, *Veryhachium brevitrispinosum* Staplin (1961, pl. 49, fig. 1) is synonymous with *V. reductum* f. *breve* Jekhowsky (1961, pl. 2, figs. 38–44), which is senior.

Family LEIOFUSIDAE Eisenack 1938
Genus LEIOFUSA Eisenack 1938
Leiofusa jurassica Cookson and Eisenack 1957

Plate 112, fig. 6

Description. Test fusiform, 61 μ overall, central body about $32 \times 15 \mu$. Spines approximately half of the maximum test dimension, bases narrow, gradually merging with the test.

Remarks. This hystrichosphere is relatively rare in the Permian samples examined. It is apparently identical with the holotype figured by Cookson and Eisenack 1957 (pl. 10, fig. 4) from the Upper Jurassic of Western Australia.

Section 2. Hystrichospheres of the '*V. ? irregulare*' complex
Family HYSTRICHOSPHAERIDAE O. Wetzel 1933
Genus MICRHYSTRIDIUM Deflandre 1937
Micrhystridium stellatum Deflandre 1945

Diagnosis. Test more or less globose, 11 to 16 μ without the spines, often tending to be polygonal and bearing approximately a dozen strong simple spines whose length exceeds the test radius.

Remarks. The variation in morphology of this species has been discussed earlier. British Permian forms vary in size (for the test alone) from 11 to 17 μ and in spine number from six to sixteen. The spine length may be equivalent to only one-third of the test size or equal to it. Several morphotypes are recognizable in the British Permian.

Forma *stellatum* (Pl. 112, fig. 10; text-fig. 1*v*). Test subpolygonal, both straight and rounded sides occur in each individual; spine bases enlarged but separated, length greater than the text radius. This morphotype closely resembles the holotype (Deflandre 1942, fig. 7).

EXPLANATION OF PLATE 113

All figures $\times 1{,}000$.

Figs. 1–5. *Micrhystridium stellatum.* 1, Forma 2. 2, Forma 3. 3, Forma 4. 4, Form similar to typical forma 4, but with less expanded spine bases. 5, Forma 6. All from sample B.

Figs. 6–8. *V. ? irregulare* Jekh. 6, F. *subhexaedron.* 7, F. *subtetraedron*; sample B. 8, Forma 1; sample A.

Figs. 9–12. *V. rhomboidium* Downie. 9, Forma 1. 10, Forma 2. 11, Forma 2. 12, Forma 3. All from sample B.

Forma 1 (Pl. 112, fig. 11; text-fig. 1*z*). Test polygonal, sides straight, spine bases enlarged but separated (see Deflandre 1942, fig. 8).

Forma 2 (Pl. 113, fig. 1; text-fig. 1*t*). Test almost completely rounded, spine length greater than the radius, spine bases considerably enlarged but separated.

Forma 3 (Pl. 113, fig. 2; text-fig. 1*u*). Test polygonal or subpolygonal, spine bases only slightly enlarged, spines equal to the test diameter in length, more or less flexuous and relatively numerous (more than twelve). This morphotype closely resembles examples of *M. fragile* having subpolygonal tests but differs by its expanded spine bases.

Forma 4 (Pl. 113, fig. 3, text-fig. 1*y*). Test shape variable, spine length approximately one-third of the test diameter, bases expanded. This *forma* differs from *Micrhystridium sydus* Valensi by being larger and having expanded spine bases and in the latter respect it also differs from *M. parinconspicuum* Defl. It differs from *M. inconspicuum* Defl. as described by Brosius and Bitterli, 1961 (p. 40) by possessing fewer spines.

Forma 5. Test polygonal, subpolygonal, spine bases greatly expanded, almost touching, test outline concave between spines. Typical examples of this morphotype are absent in the British Permian but they are mentioned here because of their importance in comparison of Mesozoic and Palaeozoic *formae*. They appear to be restricted to the Mesozoic and have been figured by Sarjeant (1959, fig. 7*c*; 1961, fig. 8*d*) and Valensi (1953, fig. 27). The specimen figured here (Pl. 113, fig. 4) resembles the Mesozoic specimens but has less expanded spine bases.

Forma 6 (Pl. 113, fig. 5; text-fig. 1*s*). Test polygonal or rounded, bearing only six or seven spines, length greater than the radius, bases expanded. This form is transitional to *V. ? irregulare* f. *subhexaedron* Jekhowsky, differing by its greater spine length and additional spine.

Genus VERYHACHIUM Deunff

Veryhachium ? irregulare Jekhowsky 1961

Plate 113, figs. 6–8; text-fig. 1*g–n*

Remarks. The British Permian hystrichospheres belonging to this species agree closely with those described by Jekhowsky. The spines are equally variable in size and may be less than 1 μ in length, but rarely exceed the test radius. One new forma must be distinguished to cover the range of variation shown.

Forma 1 (Pl. 113, fig. 8; text-figs. 1*g*, *h*). Test subglobular, subpolygonal possessing five or six extremely short and conical spines (1 to 3 μ). This forma includes individuals equivalent to f. *irregulare* and f. *subhexaedron* but with shorter spines.

Veryhachium rhomboidium Downie 1959

Remarks. Many forms resembling the Silurian type material (Downie 1959) occur in the British Permian, but minor differences are recognizable. The Permian forms range from 14 to 25 μ in size (test only) and the spines vary from below 50 per cent. to a 100 per cent. of the maximum test dimensions in length and from four to nine in number. Several morphotypes are described to illustrate the variation encountered.

Forma 1 (Pl. 113, fig. 9; text-fig. 1*a*). Test sides straight or weakly convex, spine length less than half the test dimension, bases more or less narrow (1 to 2 μ). *V. minor* Staplin may be identical with this morphotype.

Forma 2 (Pl. 113, figs. 10, 11; text-figs. 1*b*, c). Test more or less straight-sided, spine bases distinctly enlarged, about 50 per cent. of the test measurements in length. This form is transitional to *V. minutum* Downie but differs from it in that the spine bases are separated from one another.

Forma 3 (Pl. 113, fig. 12; Pl. 114, fig. 1; text-fig. 1*d*). Test elongate, sides more or less straight, spine length 75 to 100 per cent. of the maximum test dimension; spines slender, flexuous.

Forma 4 (Pl. 114, figs. 2, 3; text-fig. 1*e*). Test rhomboidal with typical spine arrangement, but possessing additional irregularly inserted spines;. spines seven to nine in number.

Forma *rhomboidium*. The typical Silurian form does not occur in the Permian. Forma 3 closely resembles it but has more slender, flexuous spines.

Veryhachium cf. *lairdi* (Defl.) Deunff

Text-fig. 1*f*

Description. Test subquadrate, sides more or less straight, bearing four short spines with slightly enlarged bases at each corner; spine length approximately one-third of the test size. Size 17 μ (test only).

Remarks. This morphotype differs from *V. lairdi* (Defl.) Deunff 1954 by possessing restricted spine bases and from *V. minor* Staplin by only having four spines.

Veryhachium europaeum Stockmans and Willière 1960

Remarks. A large number of small hystrichospheres with four equal spines occur in the British Permian, although the spine length never exceeds the test size as in the typical material described by Stockmans and Willière 1960 from the Devonian of Belgium. The British specimens are referred to this species however and a number of morphotypes have been selected.

Forma 1 (Pl. 114, figs. 4, 5; text-fig. 1*o*). Test tetrahedral, spine length between one-third to a half of the test dimension, spine bases restricted.

Forma 2 (Pl. 114, fig. 6; text-fig. 1*p*). Test tetrahedral, spine length above 50 per cent., but not exceeding 100 per cent. of the test size, bases relatively narrow.

Forma *wenlockianum*. The forms described as *Veryhachium tetraëdron* var. *wenlockia* Downie 1959 from the Silurian of Britain are allocated to *V. europaeum* since the species *V. tetraëdron* is invalid. The type and description are those given by Downie 1959 (p. 62). This forma differs from the holotype of *V. europaeum* by its distinct and restricted spine bases and from the British Permian forms by its greater spine length (up to approximately five times greater than the test dimensions).

EXPLANATION OF PLATE 114

All figures $\times$1,000.

Figs. 1–3. *Veryhachium rhomboidium* Downie. 1, Forma 3. 2, 3, Forma 4. All from sample B.

Figs. 4–6. *V. europaeum* Stock. and Will. 4, 5, Forma 1. 6, Forma 2. All from sample A.

Figs. 7–11 *V. formosum* Stock. and Will. 7, 8, Forma 1. 9–11, Forma 2. All from sample B.

Fig. 12. *Veryhachium sp.* showing the presence of a small spine near the centre of the test. Sample A.

Comparisons. The species is here restricted to forms whose tests have more or less straight sides. Inflated, subglobular forms are referred to *V. ? irregulare* f. *subtetraedron* Jekhowsky.

Veryhachium formosum Stockmans and Willière 1960

Remarks. Forms allocated to this species from the British Permian differ from the holotype from the Devonian of Belgium in their shorter spine length and from *V. ? riburgense* f. *regulare* Brosius and Bitterli by their less inflated tests. They possess from five to rarely nine appendages but always maintain a triangular outline.

Forma 1 (Pl. 114, figs. 7, 8; text-fig. 1*q*). Test more or less tetrahedral, with four apical spines and one additional spine on one face. Spine length from 50 to 100 per cent. of the test size, spine bases relatively narrow. Test *c.* 15 to 20 μ.

Forma 2 (Pl. 114, figs. 9–11; text-fig. 1*r*). Test more or less tetrahedral, with four apical spines and two to four supplementary processes ornamenting the faces. Spine length less than the test size. Spine bases may be expanded. Test *c.* 15 μ.

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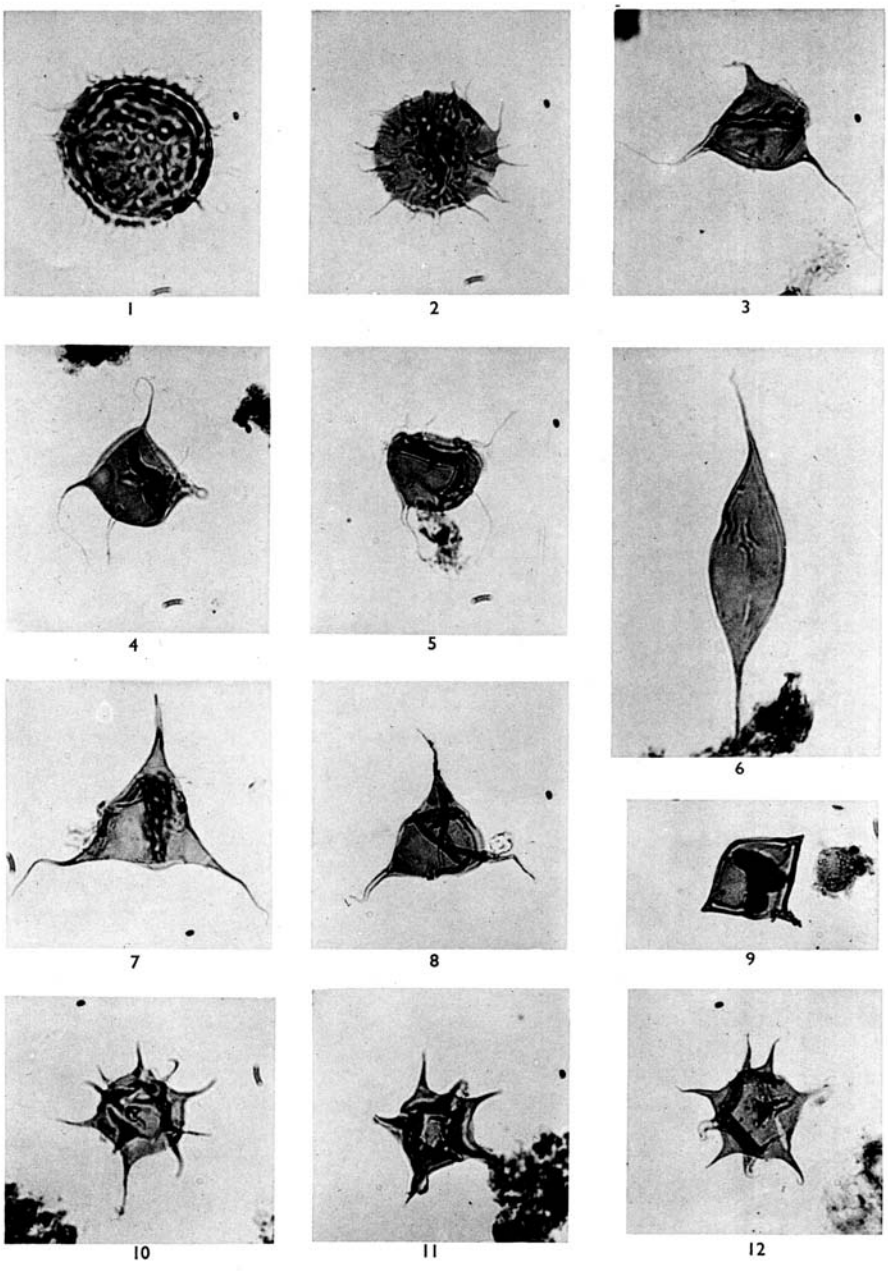
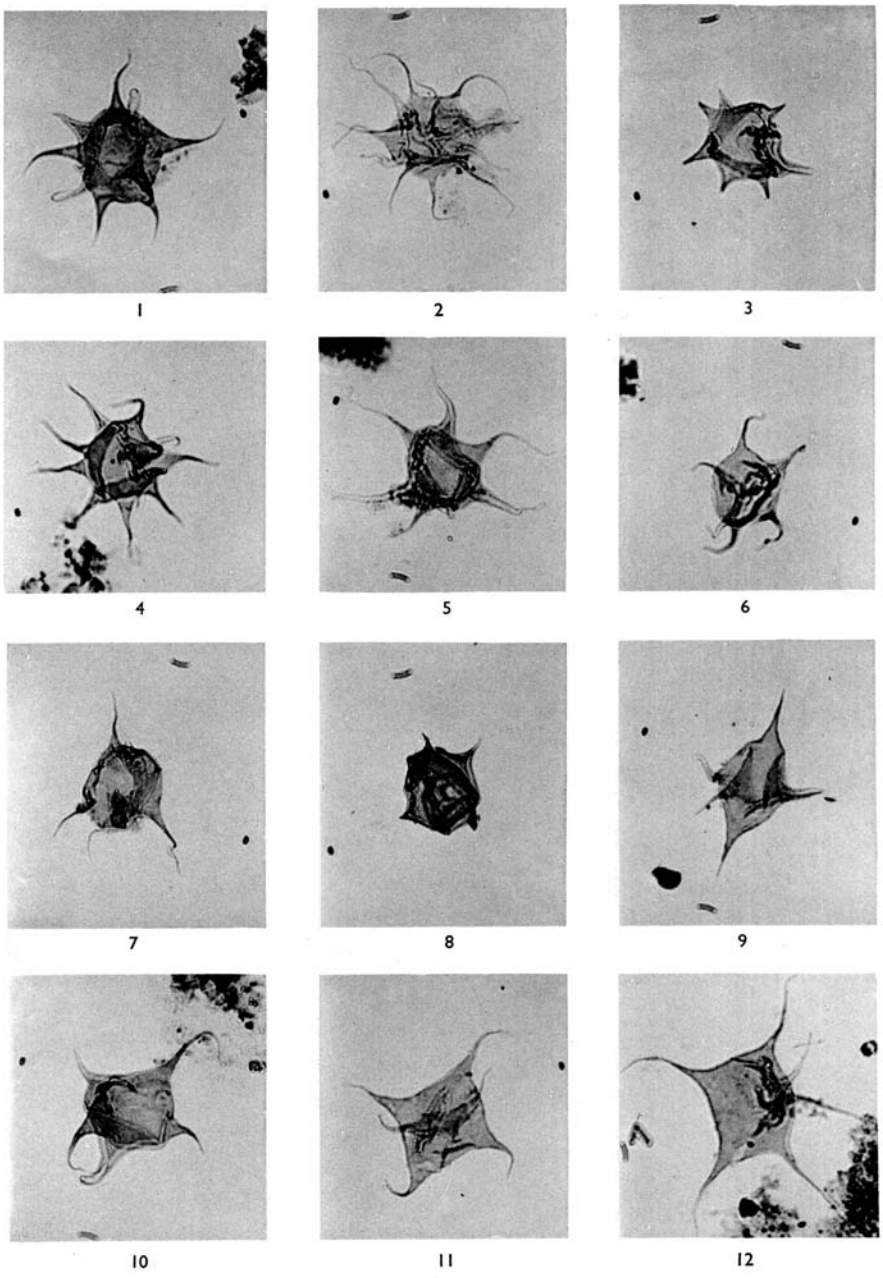


WALL and DOWNIE, Permian hystrichospheres



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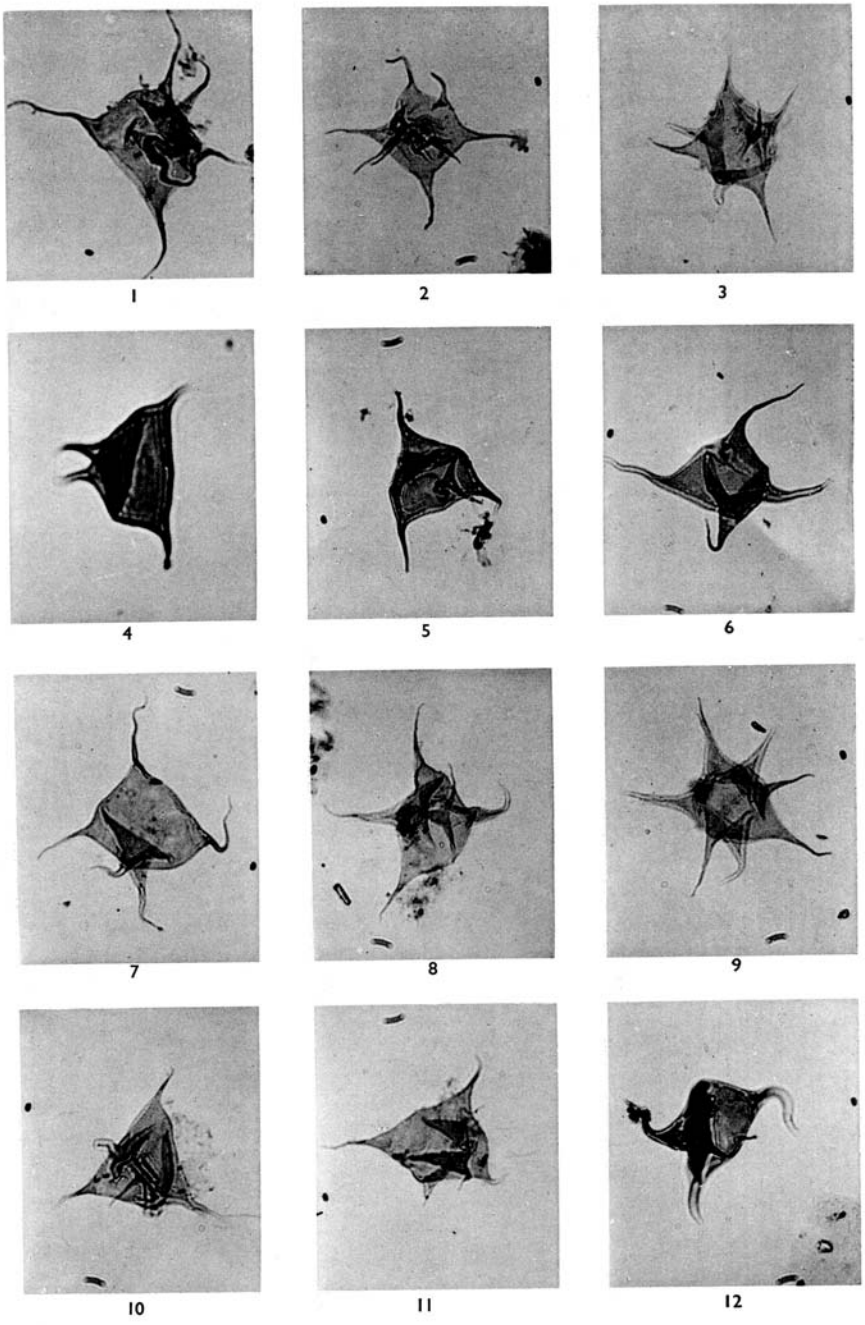

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