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by Risto Tynni

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ORDOVICIAN HYSTRICHOSPHERES AND CHITINOZOANS IN LIMESTONE FROM THE BOTHNIAN SEA

BY

RISTO TYNNI

WITH 51 FIGURES AND TWO TABLES IN THE TEXT AND FOUR PLATES

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The investigation deals with microfossils in Ordovician limestone from the Bothnian Sea, mainly hystrichospheres and *Chitinozoa* forms. The material consists of Palaeozoic *in situ* samples from the Sylen Shoal and of Palaeozoic erratics found in the Quaternary deposits of the Bothnian Sea. There is a wealth of hystrichosphere species, totalling 22 morphographic genera, of which *Baltisphaeridium* is the richest in species. The microfossils are well preserved and the species can be determined with the aid of the abundant literature published for other parts of the Baltic area. The material also includes previously unpublished forms that are to be considered as new species.

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INTRODUCTION

The great abundance of microfossils in limestone samples from the Syles Shoal, Bothnian Sea, gave the impetus to the present study. The geology of the Sylen formation has been studied by Winterhalter (1963, 1967). The outcropping limestone was dated according to ostracodes and conodontes to the uppermost part of the Middle Ordovician. In the present study microfossils such as Hystrichosphaeres and Chitinozoa are used in an attempt to date samples of Paleozoic sedimentary rock from the Bothnian Sea.

Hystrichospheres are known from the Cambrian period onwards. In the Ordovician period they occur in an abundance of forms, and they are still common in the Quaternary period although differing in types. The hystrichospheres are predominantly marine plankton forms that occur in Palaeozoic limestone. The origin of the hystrichospheres has still not been solved, although the zysts of some recent dinoflagellates have been compared to fossil hystrichospheres (Erdtman 1954, Sarjeant 1969). The Palaeozoic hystrichospheres are of a completely different type, probably being algae of unknown, systematic status that grew as plankton (Eisenack 1969), They constitute a morphographic unit that is still frequently classified as acritarchic (see, Evitt 1963). The origin of the chitinozoas is obscure, although they are characteristic of the Ordovician and Devonian periods and often occur in association with hystrichopheres. Studies have been conducted on the hystrichospheres of the Baltic, notably by Eisenack.

Microfossil investigations on samples collected with a dredge from the bottom of the Bothnian Sea enable dates to be assigned to the limestones encountered and to interpret the occurrences of Palaeozoic sedimentary rocks, despite the fact that this work is hampered by the surficial Quarternary sediments. The Palaeozoic sedimentary rocks in the Bothnian Sea have been studied recently by Veltheim (1962) and Winterhalter (1972). According to Winterhalter, the Palaeozoic sediments are comparatively widely distributed in the Bothnian Sea (Fig. 1) and are of significant thickness.

Numerous hystrichosphere investigations have been conducted on the Palaeozoic strata in the Baltic area, e.g. by Eisenack (also on erratics and deposits in Germany) (1931, 1937, 1938, 1951, 1954, 1958, 1962, 1965, 1967, 1968, 1969), by Kjellström (1971) on drill cores from Ordovician strata in Gotland and by Timofeev (1959, 1966) and Andreeva (1966) in the USSR on the area of the Russian platform. The studies by

Timofeev (1963) include microfossils from the Lower Ordovician dictyonema schist in the Novgorod area. Hystrichospheres in glauconite sand have also been described from the USSR (Naumova 1950, Timofeev 1959, 1961).

The study by Górka (1969) on the micro-organisms in Polish Ordovician strata and erratics offers useful data for comparing the hystrichospheres found in them and in the nearby Baltic area in particular. Indeed some of the erratics in this part of Poland are from the Baltic area. The investigations in the Baltic area may fruitfully be compared with those by Deunff (1958, 1968), Henry (1969) and Le Corre and Deunff (1969) on Ordovician hystrichosphere forms in Brittany. Forms common to both areas are conspicuous. A close source of comparison with regard to time is the subject of the studies by Deflandre (1942, 1945) and Deflandre and Ters (1966). Other studies of hystrichospheres in Europe worthy of mention are those by Downie (1958), Lister, Burgess and Wadgen (1969), Lister, Cocks and Rushton (1969) and Lister and Holliday (1970) in England and by Martin (1965, 1968, 1969) in Belgium. Hystricospheres have been investigated in Czechoslovakia by Vavrdová (1965, 1966), in Bohemia by Konzalová-Mazanková (1969), in the German Democratic Republic by Burmann (1970) and in Spain by Cramer (1964).

Palaeozoic material transported by continental ice and *in situ* (Åland) is known in Southwest Finland and Åland Islands. It contains not only larger fossils but also the acritarch form *Leiophaera* sp. subsequently known as *Tasmanites* sp. described by Martinsson (1956 a, b). In 1958 Eisenack proposed the name *Tasmanites martinsson* for the sake of greater accuracy. In addition, Martinsson described the chitinozoans *Parachitina curvata* and *Conochitina* sp from the Ordovician material. Since then, Eisenack (1959, 1962, 1965) has reported an abundance of chitinozoans and hystrichospheres from the material collected by Martinsson. Eisenack dated this material to the time of deposition of »Baltic limestone». It is younger than the chasmops type of the Sylen Shoal, which has been dated to the upper part of the Middle Ordovician. The aim of the present study is to establish the age of the limestones in the Bothnian Sea with the aid of new material and a microfossil investigation. Microfossil investigations are nowdays considered a reliable means of dating, especially for those Palaeozoic sediments which have only few fossils, since on the whole, even they often exhibit a high microfossil content (Eisenack 1965).

MATERIAL AND INVESTIGATION METHODS

The in situ sample (1) from the Sylen Shoal (61°14′8″/18°27′4″) is greenish fine-grained limestone (chasmops). On the basis of fossil determinations by Bo Brännström, Winterhalter (1967) has dated it to the upper Middle Ordovician. This date has since been confirmed (Thorslund, lecture 1974). Sample 2 was collected with a dredge south of Kaskinen (62°35′0/19°56′0). Sample 3 (61°09′6″/19°36′0), which was also collected with a dredge, is limestone with grey, greenish and pink portions. Hystrichosphere forms were abundant in the grey and greenish limestone, and Chitinozoa forms in the greenish portion. The pink (*Orthoceras*) limestone did not contain any microfossils with the exception of some poorly-preserved remains of the *Tasmanites* species and a few annelides. It is a well-known fact that microfossils do not preserve well in reddish sedimentary rocks, which also explains their absence from the reddish Baltic limestone (*cf.* Eisenack 1965).

The greenish limestone occurring as erratics is similar to that of Sylen, but certain differences were observed in the fossil flora. The majority of the microfossils in the grey limestone differed from those in the greenish limestone erratics more than they did from the microfossils in the Sylen limestone. Relatively most abundant in the grey limestone were *Micrhystridium* forms. The site of sample 4 is off the coast near Pori. The material collected is composed of limestone with fragments of brachiopoda, either transported by continental ice or derived from local Palaeozoic remnants (Kukkonen 1969). No microfossils were found in the limestone near Pori.

It used to be presumed that the different hues of the rocks in the Bothnian Sea represented the different ages of the Ordovician limestones: grey-greenish-pink would correspond in the time scale to an order from youngest to oldest. The latest investigations have shown that the greenish limestone corresponds to the final stage of the Middle Ordovician. The grey limestone in the Bothnian Sea differs from the Ordovician so-called »Baltic limestone», which is usually a very light, yellowish-whitish grey and fine-grained rock. The greyish limestone of the Bothnian Sea is more distinctly grey in colour. Indications of the ages of these rocks are provided by the microfossils, to be discussed in a later chapter.

The samples were prepared by the HCl, HF, HNO_3 and heavy liquid method as described by Timofeev (1963), except that the heavy liquid employed was Bromoform solution, specific gravity 2,2 and not HgJ_2—KJ. The total weight of the samples was approximately 50 g. The preparations were examined and the microfossils photographed with a Leitz Wetzlar research microscope equipped with interference-contrast optics.

The preparations are of long-lasting type and are stored at the Geological Survey in Espoo.

MICROPHYTOPLANKTON

Systematics

In the presentation of the microfossils I have aimed at a short description, the stress being on the illustrations. I have only seldom made use of synonyms, and for these I refer to previous descriptions in the literature. The determinations are based on the descriptions available in Finland of microfossils that grew as plankton during the Ordovician period, the emphasis being on the hystrichospheres of Europe. An impottant source book was the »Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien, I Teil» edited by Eisenack (1973). The microfossils in the present study are also classified in alphabetical order in catalogue form. The systematics of the species is loosely restricted to algae forms; otherwise it is morphographic, although it is probable that the representatives of genera restricted in this way were closely related to each other under natural conditions as well.

In the description of genera and species the most important marks of indentification are presented on the basis of taxa descriptions (often abbreviated). Likewise the dimensions are first given on the basis of earlier descriptions. The size of the microfossils from the Bothnian Sea material can be seen from the scale accompanying the illustration. Otherwise they are indicated separately in brackets. The terminology employed in the hystrichosphere descriptions has been given earlier in works by Kjellström (1971) and Eisenack *et al.* (1973). The present description of species is usually so simplified that there is no need for a specific terminology
The sites where microfossils were found in the Bothnian Sea (1—4) are given first, abbreviation B, followed by observations made elsewhere in Europe, abbreviation E.

Group *ACRITARCHA* Evitt, 1963

Diagnosis (Downie, Evitt and Sarjeant 1963, p. 7): »Unicellular or apparently unicellular microfossils consisting of a test composed of organic substances and enclosing a central cavity. Shape of the test spherical, ellipsoidal, discoidal, elongate or polygonal; test surface smooth, granular, punctate or perforate. Spines or other processes, raised ridges (crests), flanges, wings or other outgrowths present or absent; where present, distributed regularly or irregularly. Inner capsule present or absent; where present, connected to the test by varied means or lacking such connection. Shell opens by rupture, splitting, or formation of a simple circular pylome. Rarely, a number of tests loosely associated in a chain».

Acanthodiacrodium Timofeev 1958, emend. Deflandre and Deflandre—Rigard 1962.
Type form: *A. dentiferun* Timofeev 1958

Vesicle round-ellipsoidal, equator smooth or wrinkled, poles similar to each other, bearing flanges, spines or funnel-shaped processes, transverse wrinkles present or absent, membrane single (?) (mince) or double. Species restricted to Middle and Upper Cambrian (Timofeev 1966) and Lower Ordovician (Górka 1969). The typical form is lacking in the Bothnian Sea material, but the rare form encountered in green limestone may be a transitional form referable to the *Acanthodiacrodium* genus.

A. bimorphispinae n. sp.
Pl. I: 1, Fig. 1.

Derivation of name: bimorphi, of two forms; spinae, spined.

Diagnosis (based on only one individual): slightly ellipsoidal, almost spherical vesicle, comparatively thick wall, numerous small spines on the surface (echinate) as well as some wider-set and longer non-furcate spines that are more abundant at the apical terminations. Transverse wrinkles and transverse smooth zone absent. Possibly a very small pylome at the meridian.

Dimensions: vesicle length c. 55 μ, length of longer spines c. 10 μ, of shorter spines c. 1—2 μ, breadth c. 1 μ.

B: green limestone, site 3, probably Middle Ordovician.

Percultisphaera Lister 1970

Vesicle hollow, subspherical to oval, moderately thin-walled. Ornamentation of two orders: a minor ornamentation comprising small (0.5—1 μ) close-set subconical to tubular elements, with distally expanded terminations (capitata). The larger elements are solid spines, irregularly spaced, simple or furcate. Excystment aperture apical or near-equatorial in position, and of subhexagonal outline. Confirmed occurrence (*P. stiphrospinata*) in Upper Silurian, Ludlow Series to Downtownian.

The Bothnian type differs in certain respects from the forementioned type genus, but it can be interpreted as a transitional form between *Acanthodiacrodium* and *Percultisphaera*.

Aremoricanium Deunff 1955.

Spherical or oval microfossils with both internal and external shell. Cylindrical or cylindrical-conical expansion on external shell, processes on external shell.

A. sp.
Plate I: 2.

Oval external shell diameter c. 44 μ, length c. 90 μ, numerous processes, length c. 10 μ, colour sepia, internal shell not visible.

B: green limestone, site 3, only one individual.

Baltisphaeridium Eisenack 1958, emend. Eisenack 1969

Spherical shells with »ungefeldert» surface structure, irregular number of hollow processes with closed terminations. Processes commonly non-furcate; only seldom are all processes furcate. Commonly separation of the interior of the processes from the vesicle cavity. Processes are evenly distributed even when few in number. Shell diameter is generally more than 30 μ (40—60 μ) and can be even 70 μ, overall dimension in excess of 300 μ. Pylomes (rare) are circular (normal pylomes).

B. brevifilicum Kjellström 1971
Plate I: 3

Vesicle diameter c. 77—86 μ, process length 8—10 μ, numerous processes.

B: green limestone, site 3.

E: Middle Ordovician (Viruan) Gotland (Kjellström 1971).

B. breivispinosum (Eisenack 1931) Eisenack 1958
Fig. 2 a, b

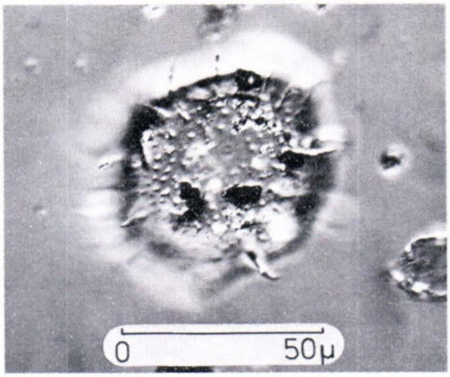
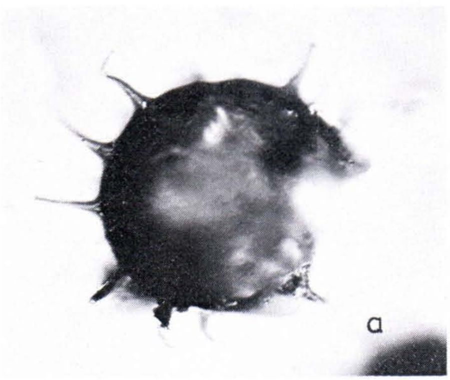
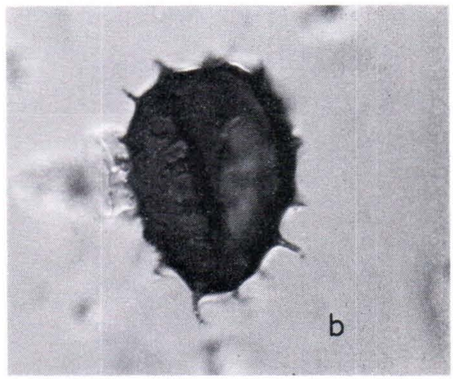


FIG. 1. *Acanthodiacrodium bimorphispinae* n. spec.





FIG, 2. a, b. *Baltisphaeridium brevispinosum*

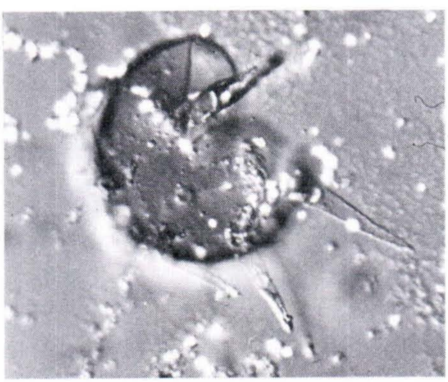


FIG. 3. *Baltisphaeridium calicispinae*

Vesicle shell rather thick, diameter 63—70 μ, process length c. 20—25 % of diameter, numerous processes with broad bases, rounded distal terminations, often slightly bulbous.

B: green limestone, site 3, fairly common.

E: Gotland Middle Ordovician (Viruan) (Kjellström 1971), Ordovician erratics (Eisenack 1931—69), Poland Lower Ordovician (Upper Arenigian) Górka 1969, Czechoslovakia Lower Ordovician (Arenigian) Vavrdová 1965, France (Veryhac'h) Ordovician (Deunff, Deunff et al. 1958—1969), (Henry 1969).

B. calicispinae Górka 1969
Fig. 3

Vesicle diameter 55—83 μ, process length 60—75 % of vesicle diameter, processes, about 11 in number, echinate. Separation of the interior of the process from the vesicle cavity.

B: grey limestone, site 3, rare.

E: Poland Upper Arenigian, Lower Caradocian (Górka 1969), Gotland Middle Ordovician (Viruan) Kjellström 1971.

B. cognitum (Timofeev 1959) Downie and Sarjeant 1964
Plate I: 4

Synonym: *Hystrichosphaeridium cognitum* Timofeev

Vesicle diameter 50—100 μ, (overall diameter 150—250 μ), processes 9—10 in number. (Timofeev p. 54, Pl. IV: 15). The Bothnian Sea material supplied only one specimen, some of whose processes were broken. Vesicle diameter c. 70 μ, surface covered with small warts, also visible in processes.

B: site 3, Ordovician erratics, rare.

E: Valdai Lower Ordovician (Timofeev 1959).

B. echinatum Kjellström 1971
Plate I: 5

Vesicle diameter 49—58 μ, surface with spines, processes, about 20 in number, length 29—32 μ.

B: green limestone, site 3, rare.

E: Gotland Middle Ordovician, subsurface material (Kjellström 1971).

B. filosum Kjellström 1971
Fig. 4

Vesicle diameter 61—73 μ, surface shagrinate, processes numerous, length 20 μ. Cf. *B. multipilosum* (Eisenack 1931)

B: green limestone, site 3.

E: Gotland Middle Ordovician (Kjellström 1971). The species was probably formerly referred to *B. multipilosum*.

B. globosum n. sp.
Pl. I: 6

Derivation of name: globosum, spherical, with reference to well-rounded vesicle.

Diagnosis: relatively thick-walled, psilate vesicle. Long median split for more than half of circumference, angular process junction (evidently can also be without split); processes, about 7 in number, curved and verrucate; process length equal to vesicle diameter. Separation of the interior of the process from the vesicle cavity, narrow separation. Colour dark brown, reddish. Dimensions: vesicle diameter 70 μ, process length c. 50—70 μ, width 4 μ.

Range: vesicle 60—70 μ, process length c. 50—70 μ, number 5—7.

Holotype — Gtl slide nr. 14 b, Pl. I:6.

B: Ordovician erratics, site 3.

B. hirsutoides (Eisenack 1931)
Plate I: 7

Vesicle diameter 59—68 μ, process length 20—25 μ, number about 20. According to Eisenack (1951), *B. hirsutoides* is a transitional form between *B. longispinosum* and *B. multipilosum.*

B: green limestone, Sylen, grey limestone site 3. Transitional forms to *B. longispinosum* common in limestone (Fig. 5 a, b.) Sylen and erratics (sites 2 and 3).

E: common species in Ordovician material. Gotland subsurface material. Middle Ordovician (Lower Viruan) Kjellström 1971.

B. lancettispinae Górka 1969
Plate I: 8

Vesicle diameter 50—100 μ (generally 50—60 μ), process length 80—110 % of vesicle diameter, average number 5—6. Cf. *B. latiradiatum* Eisenack 1959

B: green limestone, site 3, rare.

E: Poland Lower Caradocian subsurface material (Górka 1969).

B. latiradiatum (Eisenack 1959)
Plate I: 9

Vesicle diameter 60—87 μ, process length 68—90 μ, number about 7.

B: green limestone, site 3, fairly common.

E: Baltic erratics, Lower Ordovician (Eisenack 1959), Gotland Middle Ordovician (Viruan) Kjellström 1971.

B. longispinosum longispinosum (Eisenack 1959) Górka 1969
Synonym: *B. longispinosum* f. *filifera* Eisenack 1959
Plate I: 10

Vesicle diameter 50—70 μ, process length 70—92 μ, number c. 7—17 but can be as few as 3 (e.g. Bornholmer Stufe, according to Eisenack 1969).

B: green limestone, Sylen; site 3, comparatively common. Trispinal species in limestone at Bothnian Sea, site 2 (cf. *B. ternata*).

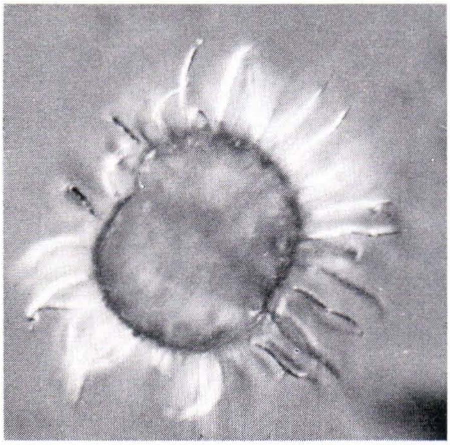


FIG. 4. *Baltisphaeridium filosum*

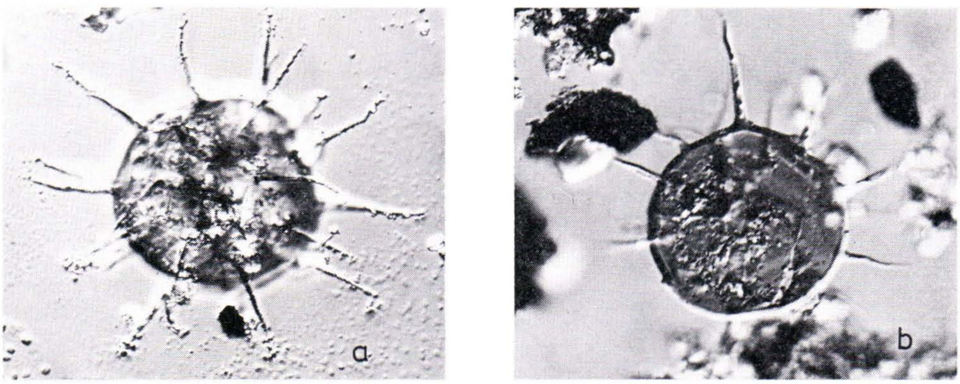


FIG. 5, a, b. *Baltisphaeridium hirsutoides — B. longispinosum*, transiotional forms.

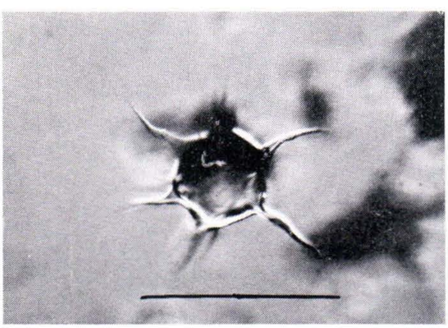


FIG. 6. *Baltisphaeridium longispinosum* var. *parvum*

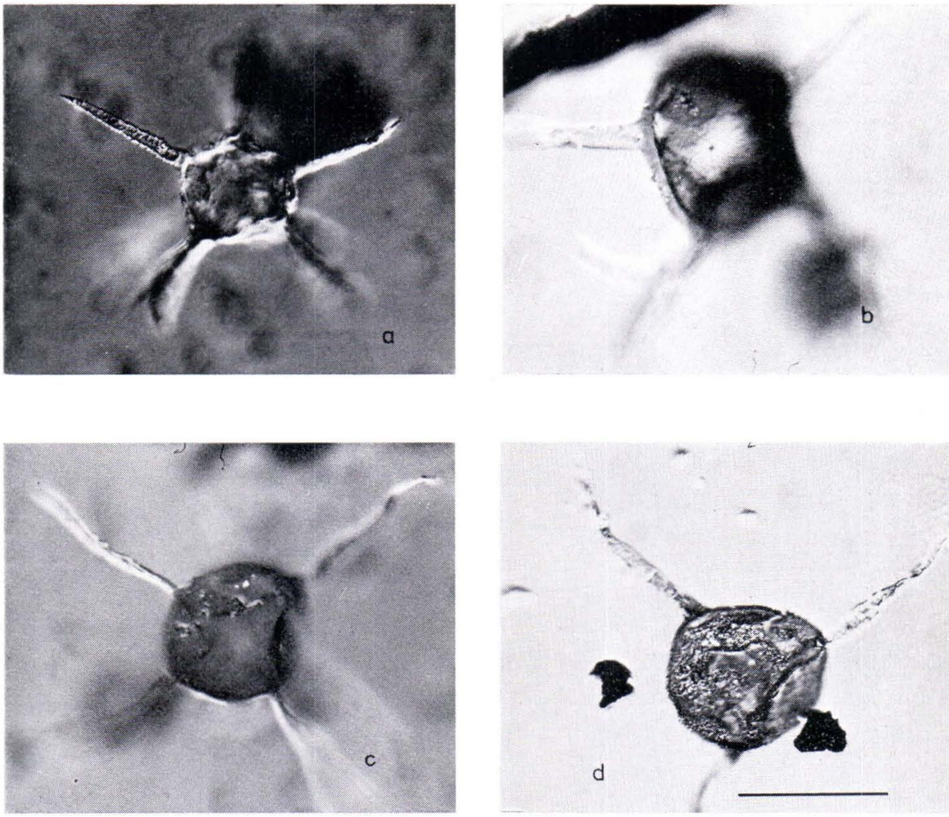


FIG. 7. *Baltisphearidium longispinosum*-types: a. *B. verrucatesspinosa*, b. *B. longispinosum*, thick single valled, c. *B. longispinosum*, four-radiate, d. *B. longispinosum*, tree-radiate.

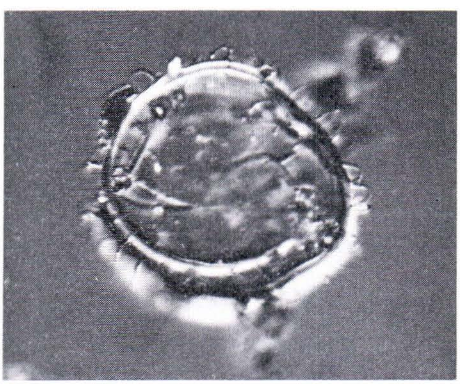


FIG. 8. *Baltisphaeridium microspinosum*

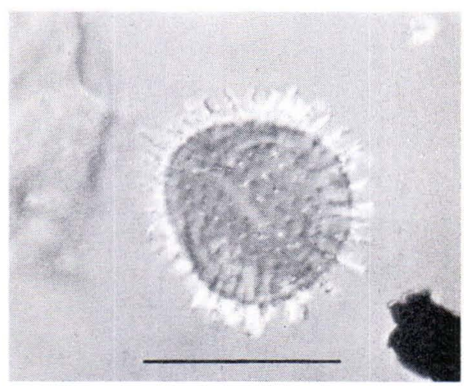


FIG. 9. *Baltisphaeridium multipilosum*

E: Baltic Middle Ordovician to Upper Llandoverian (Eisenack 1951, 1959, 1962), Gotland Middle Ordovician (Viruan) Kjellström 1971, also several Ordovician sites in Europe, e.g. Vologda (Timofeev 1959).

Var. *parvum* Downie 1963
Fig. 6

Synonym: *Micrhystridium stellatum* var. *inflatum* Downie 1959. It resembles *B. stimuliferum* (Deflandre) Serjeant 1960

B. longispinosum type, but considerably smaller.

Observed specimen: vesicle c. 23 μ, processes c. 100 % of vesicle diameter.

B: green limestone, site 3, comparatively rare.

E: England Silurian (Wenlock) Downie 1963.

B. longispinosum-types in Fig 7: a—d.

B. microspinosum (Eisenack 1954)
Fig. 8

Vesicle diameter 61—76 μ, (c. 45 μ according to Górka 1969), process length c. 6 μ (5—8), numerous.

B: green limestone, site 3.

E: Gotland Middle Ordovician (Viruan) Kjellström 1971, and Silurian (Upper Llandoverian Eisenack 1954, 1955, 1965, 1969), Estonia Silurian (Upper Ludlovian Eisenack 1954), England Silurian (Downie 1959, 1963, Lister 1970), Poland Ordovician (Górka 1969).

B. mochtiensis Górka 1969
Plate I: 11

Synonym: *Goniosphaeridium mochtiensis* (Górka) Kjellström 1971

Vesicle diameter 63—83 μ, process length 1/3—2/3 of vesicle diameter, number 15—30. Goniomic proximal process, bulbous distal process terminations, often curved.

B: green limestone, site 3, comparatively common.

E: Gotland Middle Ordovician (Lower Viruan) Kjellström 1971, Poland Middle Ordovician (Lower Caradocian), Ordovician floats (Górka 1969).

B. multipilosum Eisenack 1931)
Fig. 9

Vesicle diameter 70—86 μ, process length 7—8 μ, process breadth 1 μ, numerous. Cf. *B. trichophorum*.

B: chasmops limestone, Sylen; grey limestone, site 3.

E: Gotland Middle Ordovician (Viruan) Kjellström 1971, Bohemia Upper Ordovician (Ashgillian) (Konzalová—Mazancová 1969), Poland Upper Arenigian (Górka 1969), Brittany Ordovician (Deunff 1958, Henry 1969), Baltic erratics (Eisenack 1931, 1955, 1965).

B. nannium Eisenack 1965
Plate I: 12

Vesicle diameter 92—101 μ, close-set spines less than 1 μ.

B: green limestone, Sylen and site 3.

E: Gotland Silurian and Devonian (Eisenack 1965, 1968, 1969), Sweden, Dalarna Upper Llandoverian (Schultz 1967), Estonia Upper Llandoverian (Silurian) (Eisenack 1965).

B. pachycanthum (Eisenack 1963)
Plate II: 1

Synonym: *B. robustum* Eisenack 1963, *B. longispinosum* f. *robustum* Downie and Serjeant 1964.

Vesicle diameter 70—85 μ, process length 65—82 μ, number about 8, furcate processes not unusual. According to Eisenack (1965), *B. pachycanthum* and *B. brevispinosum* form a restricted series with transitional types.

B: green limestone, site 3.

E: Gotland Middle Ordovician (Viruan) subsurface material (Kjellström 1971), Baltic area Middle and Upper Ordovician (Eisenack 1959, 1963, Staplin, Jansonium and Pocock 1965), Sweden Dalarna Upper Llandoverian (Schultz 1967), Poland Upper Arenigian and Caradocian subsurface material (Górka 1969).

B. pauciverrucosum Kjellström 1971
Plate II: 2

Vesicle diameter 68—75 μ, thin-walled, process length 40—44 μ, number about 22, granulate.

B: green limestone, site 3, rare.

E: Gotland Middle Ordovician (Lower Viruan) (Kjellström 1971).

B. plicatispinae Górka 1969
Plate II: 3

Vesicle diameter 48—75 μ, process length 80—125 % of vesicle diameter, number 5—10.

B: green limestone, site 3, rare.

E: Poland Llandeilian and Upper Ashgillian subsurface material (Górka 1969), Gotland Middle Ordovician (Lower Viruan) (Kjellström 1971).

B. spinigerum Górka 1969
Plate II: 4

Vesicle diameter c. 60—82 μ, process length 25—67 μ, echinate, number 15—20.

B: green limestone, site 3, rare.

E: Poland Upper Arenigian, Ordovician erratics (Górka 1969).

B. ternata (Burmann) nov. comp.

Synonym: *Baltisphaera ternata* Burman 1970
Fig. 10

Vesicle subcircular, diameter 45—52 μ, three processes, length 142—225 μ, small spines on surface, reticulate vesicle surface. Separation of the interior of the process from the vesicle cavity. Junction tapering. Resembles the *B. longispinosum* trispinal species (*cf.* Eisenack 1969), except that the spines of the latter show no proximal tapering. Similar in structure are *Veryhachium macroceros* Deunff 1958 and *Hystrichosphaeridium quartiradiatum* Timofeev 1959, as are also some *Orthosphaeridium* speeies.

B: Ordovician erratics on the bottom of the Bothnian Sea, site 2.

E: German Democratic Republic Upper Llanvirnian (Burmann 1970).

B. trichophorum (Eisenack 1965) Kjellström 1971

Synonym: *B. multiplosum* f. *trichophora* Eisenack 1965
Fig. 11.

Vesicle diameter 48—58 μ, process length 7—8 μ, conical, curved, number about 35. Cf. *B. microspinosum*.

B: grey limestone, site 3, rare.

E: Gotland Lower Ordovician (Oelandian) (Kjellström 1971), erratics in Baltic area Lower Ordovician? (Eisenack 1965).

B. verrucatum Kjellström 1971
Plate II: 5

Vesicle diameter 70 μ, process length 68 μ, number about 16; verrucate vesicle and processes. Resembles *B. klabavensis* with the exception of the process junctions: *B. verrucatum* has angular proximal process junction, whereas *B. klabavensis* has tapered junction and shorter processes. Also similar to *B. spinigerum*, but differs in that the vesicle of the latter is reticulate and without conspicuous warts.

B: green limestone, site 3.

E: Gotland Middle Ordovician, subsurface material (Kjellström 1971).

B. sp. 1
Plate II: 6

Vesicle diameter c. 50 μ, process length 45 μ, number about 11, vesicle intensely granulate, processes smooth. Resembles *B. echinatum* Kjellström 1971, but processes of former are more widely spaced and relatively longer. The surface structure of the vesicle wall is more distinct than that of *B. longispinosum*.

B: green limestone, site 3.

Cymatiogalea Deunff (1961) 1964

Shell spherical or subspherical, diameter 20—50 μ; equipped with a large polar, circular or polygonal aperture of c. 15—30 μ. Surface texture provided by the processes and membranes that occur along the polygons on the shell surface (Deunff 1961). According to the emended diagnosis, the borders of the polygons consist of granulation, spines or membranes that are more or less developed. Height of ornaments along polygon borders 2—5 μ. Height of angular processes and membranes 7—15 μ.

C. aff. *polygonomorpha* Górka 1969
Fig. 12

Vesicle diameter 30—52.5 (40) μ, process length 5—7.5 μ, process branching not recorded.

B: greenish limestone, site 3, only one observation.

E: *C. polygonomorpha* Poland Upper Tremadocian (Górka 1967, 1969). Form resembles *Archaeohystrichosph. pentagonum* described by Timofeev (1959) from the USSR Lower Ordovician.

Cymatiosphaera O. Wetzel 1933, emend. Deflandre 1954

Shells spherical or ellipsoidal, external surface is divided into polygonal fields by perpendicular membranes; total absence of equatorial differentiations or processes; outer margin of membrane straight or slightly concave, unbroken, serrated or somewhat corroded. Test surface is smooth, punctate or granulate. The oldest known forms are from the Lower Ordovician, but the majority are younger than Ordovician. Some occurrences in the grey limestone of the Bothnian Sea.

C. aff. *areolata* (Deflandre 1941) Deflandre, G. 1954

Synonym: *Micrhystridium areolatum* Deflandre 1941.
Fig. 13

Vesicle diameter without ornamentation 20—21 μ, with ornamentation 24—26 μ. Ornaments: irregular polygons with small pillars at their corners.

B: greu limestone, site 3, rare.

E: *C. areolata*: Jurassic (Kimerize) France (Deflandre 1942).

Electoriskos Loeblich 1971

Vesicle subcircular; shell thin, less than 1 μ in thickness, surface rough, strongly granulate, rare specimens rugulate to pustules up to 1.3 μ across; the margin of the central body with large grana and pustules; numerous processes, about 1 μ in diameter, of nearly constant diameter throughout length, without communication with central body. Central body opens by splitting of the wall. (Description according to Loeblich 1971.)

E. aff. *pogonius* Loeblich
Plate II: 7

Very slender and thin-walled vesicle, diameter c. 45—30 μ. Processes threadlike with membranous proximal junction; in length almost equal to the vesicle diameter.

B: green limestone, Sylen and site 3.

E: resembles the form described by Kjellström (1971) from Gotland Middle Ordovician (Lower Viruan) and *Baltis phaeridium* cf. *ravum* Downie reported by Vavrdova (1965) from Klabava. *Archaeohystrichosphaeridium* cf. *lüberi* reported by Timofeev (1959) from a Cambrian stratum also resembles this form. Likewise, *Baltisphaeridium* sp. 2 described by Górka from an Ordovician erratic and *Archaeohystricho-*

FIG. 10. *Baltisphaeridium ternata* n. comp.

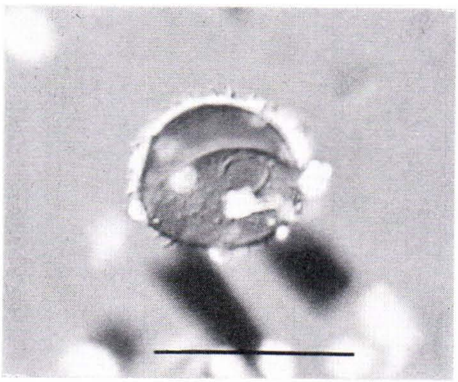


FIG. 11. *Baltisphaeridium trichophorum*

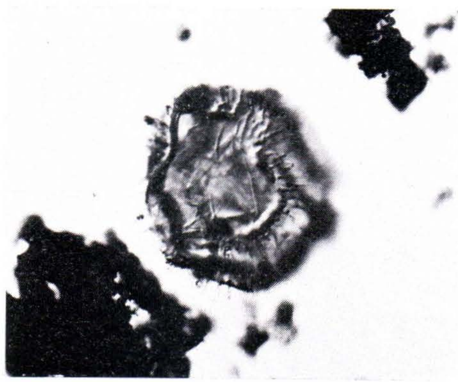


FIG. 12. *Cymatiogalea* aff. *polygonomorpha*

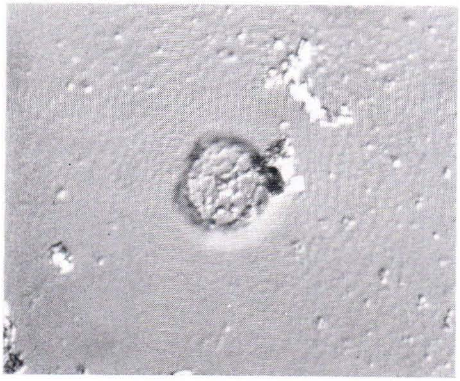


FIG. 13. *Cymatiosphaera* aff. *areolata*

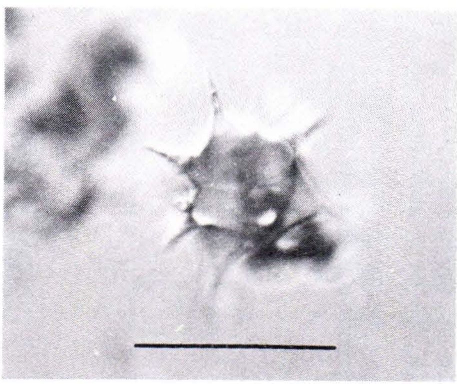


FIG. 14. *Goniosphaeridium connectum*

sphaeridium cf. *lüberi* Timofeev 1959 reported by Combaz 1967 from Algerian Tremadocian belong to this type form.

Goniosphaeridium Eisenack 1969

Emend. Kjellström 1971: Unicellular organic-walled microplankton with spherical to polygonal vesicle greater than 20 μ, not divided into fields or plates. Process interior communicates freely with vesicle cavity, the distal terminations of the processes always simple and closed. Walls psilate or shagrinate.

G. connectum Kjellström 1971
Fig. 14

Vesicle diameter 40—45 μ, process length 29—36 μ, number about 10. The species resembles *Hystrichosphaeridium inconspicuum* reported (Tb. IV: 13) by Timofeev (1959), but is smaller (*cf.* Fig 22).

B: green and grey limestone, site 3, relatively common.

E: Gotland Middle Ordovician, subsurface material (Kjellström 1971).

G. pellicidium (Timofeev 1959) n. comb.

Synonym: *Archaehystrichosphaeridium pellicidium* Timofeev 1959, *Goniosphaeridium conjunctum* Kjellström 1971
Fig. 15

The description by Timofeev is on p. 40 and the illustration III: 37. Evidently the same species as that later described in more detail by Kjellström: p. 43—44, despite some variations in dimensions. Kjellström has tentatively proposed *G. conjunctum* as a synonym for *Baltisphaeridium longispinosum* (Eisenack 1931) reported by Timofeev (1966, Pl. 33:6). However, the similarity is more striking between *G. conjunctum* and *Archaerohystrichosphaeridium pellicidium* and these may be considered as synonyms.

B: green and grey limestone, site 3, relatively common.

E: Vologda Lower Ordovician (Timofeev 1959), Gotland Middle Ordovician (Kjellström 1971).

G. polygonale (Eisenack 1931)
Plate II: 8

Vesicle diameter up to 350 μ, number of processes in optical section 6—12. Size of individuals in the Bothnian Sea material considerably under maximum. Forma *minor:* vesicle c. 60 μ, process length about 30 % of vesicle diameter, number about 18 on circumference. The Bothnian Sea material contains also forms with long processes f. *polyantha* Eisenack 1968 (Plate II: 9).

B: Bothnian Sea, Ordovician erratics, site 3.

E: Middle Ordovician Lower Silurian (Eisenack *et al.* 1973).

G. unciantum (Downie 1958) Kjellström 1971
Fig. 16

Vesicle diameter 51—65 μ, process length 23—25 μ, echinate.

B: green limestone, Sylen.

E: England Tremadocian (Downie 1958), Belgium Tremadocian-Llandvirnian (Martin 1965, 1968), Gotland Middle Ordovician (Kjellström 1971).

Granomarginata Naumova 1960

Spherical microfossils with relatively thick and delicate margin, surface verrucate. Type species: *G. prima*, Lower Cambrian. Similar form occurs in Bothnian Sea material but with a smoother surface and a pylome.

G. sp. 1
Plate II: 10, Fig. 18

Overall diameter c. 45 μ, margin breadth c. 3 μ. Thickness of the inner wall under the margin c. 1 μ, radial figuration at margin, surface rough, pylome diameter c. 6 μ.

B: grey limestone, site 3, rare.

Hystrichosphaeridium Deflandre 1937, restr. Eisenack 1958

The genus differs from *Baltisphaeridium* in having tubular distal processes (like *H. tubiferum* (Ehr. 1838) Deflandre 1937). Very rare genus in Bothnian Sea material, only one specimen, smaller in form and comparable to *H. anthophorum* reported by Cookson and Eisenack (1958) from Australia Upper Jurassic stratum, having been encountered in green limestone. The species also resembles the *Hystrichosphaeridium* form described by German (1974) in Table XI:5 from a glauconite deposit in the Vologda area and which is still referable to *H. dictyophorum* Cookson and Eisenack. The form also belongs to the Palaeozoic, even though the bulk of the species described are younger, mainly Mesozoic and Cainozoic as is revealed in the summary by Downie and Serjeant (1964). A known Ordovician form is *H. wimani* Eisenack 1968

Hystrichosphaeridium anthophorum Cookson and Eisenack 1958 *archaeoforme* nov. form.
Plate II: 11

Vesicle subangular with thin and slender shell, diameter c. 50 μ. Tubular, conically expanded processes, number about 10, length almost equal to diameter. Process suface is furrowed, but vesicle and processes evidently psilate. The form resembles *Peteinosphaeridium*. Especially the peteinos encasing the processes of some species are comparable to the conical processes of *Hystrichosphaeridium*.

B: green limestone, site 3.

Leiosphaeridia Eisenack 1958, emend. Downie and Serjeant 1963

Spherical thin-walled psilate or granulate microfossils without spines; no pores or canals. Shell with or without a pylome. *Leiosphaeridia* is a long-ranging type genus, which is known from the Precambrian to the Cretaceous at least. This genus constitutes a relatively small proportion of the Bothnian Sea material; most abundant in grey limestone.

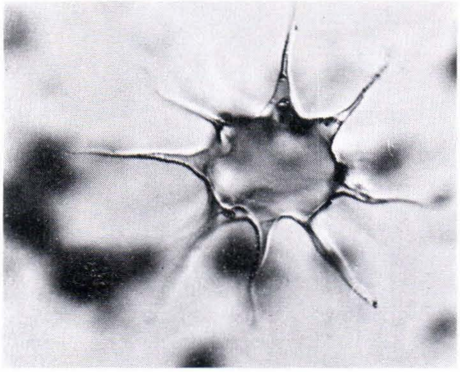


FIG. 15. *Goniosphaeridium pellicidium*

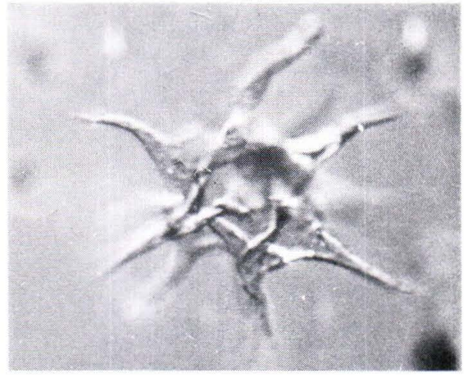


FIG. 16. *Goniosphaeridium uncinatum*

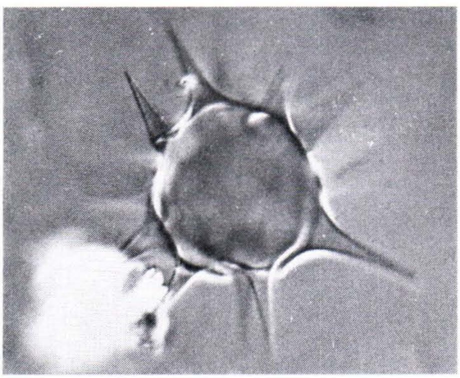


FIG. 17. *Goniosphaeridium* sp.

FIG. 18. *Granomarginata* sp. 1

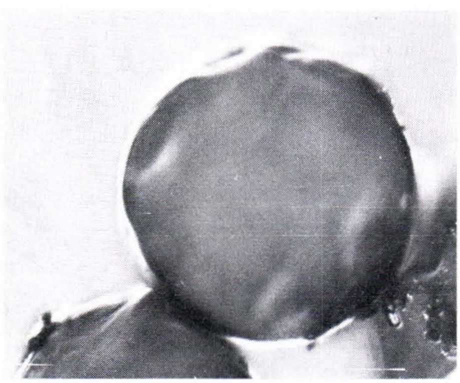


FIG. 19. *Leiosphaeridia baltica*

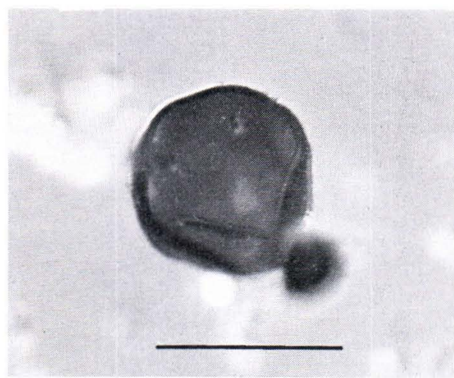


FIG. 20. *Leiosphaeridia* cf. *microcystis*

L. baltica Eisenack 1958
Fig. 19

Diameter c. 70—157 μ, thin- and smooth-walled. (Bothnian Sea form 70—90 μ, relatively thin and psilate).

B: grey limestone, site 3.

E: most common *Leiosphaeridia* species in Baltic limestone (Eisencak 1965).

L. laevigata Stockmans and Willière 1963
Plate II: 12

Vesicle spherical, psilate, transparent and often clearly wrinkled, diameter c. 70 μ. (Bothnian Sea form c. 65 μ).

B: green limestone, limestone till, site 3.

E: Belgium Silurian (Stockmans and Willière 1963).

The species bears a great resemblance to *L. baltica* Eisenack 1958, except that the latter is bigger.

L. cf. *microcystis* (Eisenack 1938)
Fig. 20

Diameter c. 65 μ (57—72), but with thicker wall than former species. (Diameter in Bothnian Sea material c. 60—70 μ. Colour yellowish or dark brown).

B: green and grey limestone, site 3.

E: *L. microcystis*: Baltic Ordovician and Silurian (Eisenack 1938, *cf.* Downie 1959).

L. sp.
Fig. 21

Diameter c. 25 μ; a clearly developed pore-shaped pylome, about 7 μ diameter. Wall relatively thick, psilate, yellowish.

Leiovalia Eisenack 1965

Oval psilate shells, organic matter, comparable to hystrichospheres. Type genus: *Leiovalia* (*Leiofusa*) *ovalis* (Eisenack 1938).

L. aff.*navicula* Eisenack 1951
Fig. 22

Spindle-shaped vesicle, cylindrical cavity, rounded terminations, length of type species 210 μ, breadth 50 μ.
Length in Bothnian Sea material 150 μ.

B: green limestone, site 3, rare.

E: *L. navicula*: Vaginaten limestone, Ordovician B_3 (Eisenack 1951).

L. similis Eisenack 1965
Plate III: 1

Oval shells, thin smooth wall and well-rounded terminations. Length 124 (149) μ, breadth 54 (78) μ. Additional distinctive features in Bothnian Sea material, or else a different but similar species: the oval shells show a triobal transverse zonality, the walls are thicker at the terminations, and one of the ends is more acuminate with a relatively large pylome or smaller ellipsoidal apertures, length 100—110 μ. Tentative name: *L. similis* fo. *triloba* n. fo.

B: grey limestone, site 3, several individuals.

E: *L. similis*: Baltic limestone (Eisenack 1965).

L. similis fo. *rugosa* n. fo.
Plate III: 2

Similar to previous species in outline and dimensions, but distinguishable as separate form by having a wrinkled surface, hence, genus definition should be broadened to include also wrinkled species.

B: grey limestone, site 3, only one individual.

Lophodiacrodium Timofeev 1958, Deflandre and Deflandre-Rigaud 1961

Granulate, subspherical, elongate microfossils that date largely from the Cambrian period (Timofeev 1966). The Bothnian Sea form differs somewhat from the type genus proper in that a constriction of the middle part of the body may be observed and the densely spaced, very small sized warts cover the entire body.

L. sp.
Fig. 23

Length c. 58 (70) μ, apical bulbous knobs breadth c. 38 (50) μ.

B: dredge sample till site 2, rare.

The form strongly reminiscent of *Diornatosphaera* Downie 1958 *tuber* reported by Deunff (1961) from the Sahara Tremadocian, tha latter, however, being a smaller species.

Lophosphaeridium Timofeev 1959, Downie 1963

Genus characterized by solid warts on the surface, which distinguishes it from the acuminate and short-spined *Leiosphaeridia* and *Baltisphaeridium* forms. Type species *L. rarum* Timofeev 1959.

L. cf. *citrinipeltatum* Cramer and Diez de Cramer 1972
Plate III: 3

Diameter 30—50 μ, wall 1 μ or less, sculpture elements 2 μ, of equal width at base and terminations. (In Bothnian Sea material diameter c. 50 μ, warts c. 1.5 μ, colour yellowish or brownish).

B: limestone material, site 2; green limestone, site 3.

E: *L. citripeltatum*: Alger Shale, Ohio (Cramer and Diez de Cramer 1972). The species shows typical peltate sculpture element and is a variant of the series that includes *L. citrinum* Downie 1973 (Cramer and Diez de Cramer 1972). *L. citrinum* is smaller (Fig. 24). It also resembles *L. pilosum* Downie 1963, diameter 35—40 μ. Certain similarities with the *Baltisphaeridium nannium*.

L. aff. *parveratum* Stockmans and Willière 1963
Plate III: 4

Diameter 20 μ, warts relatively widely spaced. The Bothnian Sea material shows a form with widely-spaced warts, diameter c. 18 μ, commonly ruptured.

B: grey limestone, site 3.

E: Belgium Silurian (Stockmans and Willière 1963).

L. sp
Fig. 25

Diameter c. 50—55 μ, walls relatively thick (1—2 μ) and covered with rounded warts. Colour yellowish or light brown.

B: grey limestone, site 3.

Micrhystridium (Deflandre 1973) Downie and Serjeant 1963

Hystrichospheres with spherical or oval shells not divided into fields or plates, bearing processes with closed tips, most often simple, rarely branching or ramifying, without distal connections of any kind. The processes are generally of one type only. Mean and modal diameter of shell less than 20 μ. The emendment by Lister (1970) does not essentially differ from the foregoing diagnosis. In definitions by Staplin (1961) and Eisenack (1969) the *Multiplicisphaeridium* genus is described without a lower size limit. Hence those forms that have branching processes do not belong to the *Micrhystridium* genus.

The *Micrhystridium* forms are comparatively sparse in the Ordovician material, being characteristic of younger strata. Certain *Micrhystridium* species from the Ordovician have been reported earlier. From the Upper Ordovician Deunff (1958) has described the forms *M* (?). *incertum*, *M. bacilliferum* and *M. nannacanthum*, Henry (1968) the forms *M* (?). *incertum*, *M. bacilliferum*, *M.* cf. *chinetonensis* and *M.* cf. *nannacanthum*. Vavrdová (1972) has reported *M. inspicuum* and *M. stellatum* from Klabava schist. Downie (1958) has described *M. robustum* and *M. shinetonensis* from England Upper Ordovician. Martin has described *M. campoae*, *M. comatum*, *M. fragile*, *M. imitatum*, *M. inconspicuum*, *M. nannacanthum*, *M. parinconspicuum*, *M. radians*, *M. robustum*, *M. shinetonensis*, *M. stellatum*. However, many hystrichosphere descriptions from Ordovician strata omit *Micrhystridium*. This type is fairly widespread in the Bothnian Sea material, but the objects are so small that their descriptions are not as comprehensive as for larger forms. In this work the intention is to present photographic material of the forms encountered in the Bothnian Sea and to compare them with forms described earlier. For the sake of caution the cf.-definition is employed for divergent types.

*M.*cf.*acum* Martin 1968
Plate III: 5

According to Martin, the vesicle is 10—13 μ, processes 4—7 μ. In the Bothnian Sea material the vesicle c. 9 μ, the processes c. 3 μ.

4 11553—75

B: grey limestone, site 3, rare.
E: *M. acum*: Belgium Silurian (Martin 1968).

M. cf. *campoae* Stockmans and Willière 1966
Plate III: 6

Spherical, diameter 13—23 μ, spines closely spaced, narrow and straight, length about $\frac{1}{4}$—$\frac{1}{3}$ of diameter (Martin). In the Bothnian Sea material diameter c. 12 μ, spines narrow and about $\frac{1}{3}$ of diameter.
B: grey limestone, site 3, rare.
E: Belgium Ordovician and Silurian (Martin 1968), Devonian (Stockmans and Willière 1966).

M. sp., cf. *nannacanthum* (?) Deflandre 1945
Fig. 26 a

Spherical, diameter 10—13 μ, spines closely spaced, length c. 1—2 μ (Martin). In the Bothnian Sea material diameter 7—10 μ, spines c. 1 μ.

B: grey limestone, site 3, rare.

E: *M. nannacanthum*: France (Finisterre and Brittany) Ordovician (Deunff 1951, 1959), (Henry 1969), Belgium Ordovician and Silurian (Martin 1968, Stockmans and Willière 1963).

M. cf. *parveroquesi* Stockmans and Willière 1963
Plate III: 7

Spherical, diameter 12.5—15 μ, processes short, finger-like, length 2.5—3 μ (Stockmans and Willière). In the Bothnian Sea material diameter c. 12 μ, processes c. 2.5 μ.

B: site 3, grey limestone.

E: *M. parveroquesi*: Belgium Lower Silurian (Stockmans and Willière 1963, Martin 1968), the Ardennes Lower Devonian (Bain and Doubinger 1965).

M. cf. *stellatum* (?) Deflandre 1942
Fig. 26 b

More or less polyhedral, diameter 9—20 μ, average 13 μ, processes angular, length 75—150 % vesicle diameter, number 8—18 (Martin). In the Bothnian Sea material diameter 14—20 μ, processes 8—10 μ.

B: grey limestone, site 3, relatively common.

E: Belgium numerous Ordovician strata and Silurian (Martin 1968), Lower Devonian (Stockmans and Willière 1960), also elsewhere in younger strata. Bohemia Ordovician (Vavrdová 1972), France Lower Ordovician (Paris 1971).

Multiplicisphaeridium Staplin 1961, restr. Staplin, Jansonius and Pocock 1965

Vesicle ellipsoidal, subspherical or spherical; processes separate, proximately slender, distally multifurcate, expanded, with closed terminations; processes on one vesicle all of one kind or variations one type, not differentiated into various kinds of

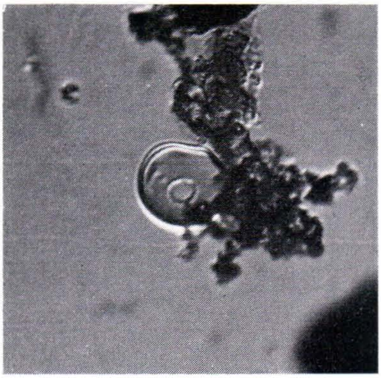


FIG. 21. *Leiosphaeridia* sp.

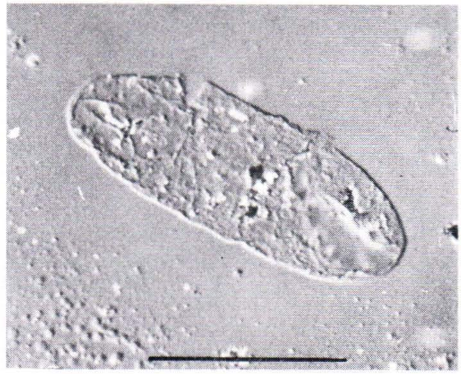


FIG. 22. *Leiovalia* aff. *navicula*

FIG. 23. *Lophodiacrodium* sp.

FIG. 24. *Lophosphaeridium* aff. *citrinium*, from Sylen

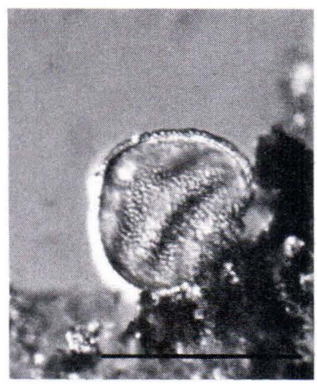


FIG. 25. *Lophosphaeridium* sp.

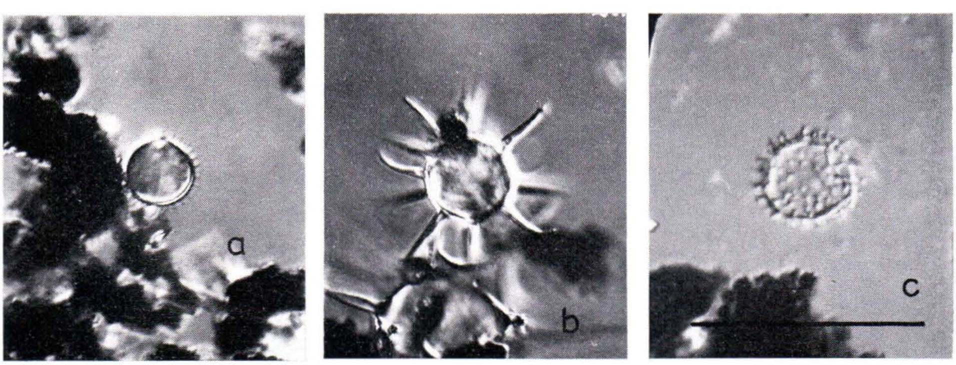


FIG. 26, a *Micrhystridium* cf. *nannacanthum*, b. *M.* cf. *stellatum*, c. *Multiplicisphaeridium alloiteaui* processes; wall smooth or with minor ornamentation; no differentiation between vesicle wall and processes; spine cavities in open connection with vesicle interior. According to the emended diagnosis by Eisenack (1969), one or more of the processes may also be non-furcate. Additional emendations: Eisenack *et al.* 1973.

M. alloteaui (Deunff 1955) Eisenack, Cramer, Rodriguez (1973)
Synonym: *Micrhystridium alloiteaui* Deunff
Fig. 26 c

Vesicle diameter 25—30 μ, process length 3—5 μ, breadth 2 μ, numerous. Process terminations bi- or trifurcate.

B: green limestone, Sylen; green and grey limestone, site 3.

E: Belgium Ordovician (Martin 1965, 1968), England Ordovician (Caradocian) (Lister, Cocks and Rushton 1969).

M. belmontiformis n. spec.
Plate III: 8, Fig. 27

Vesicle diameter c. 50 μ, process length 8—10 μ, numerous. Process terminations with palm-like branching, number of branches about 6 or more, length c. 4—5 μ. Processes resemble each other, angular junction with vesicle. Connection between process cavity and vesicle uncertain.

B: green limestone, Sylen, relatively common.

The species resembles *M. belmontis* (Cramer 1970) but is larger and with more regular process size. It also resembles *Peteinosphaeridium micranthum*, but the latter has shorter processes with wider-spaced branches.

M. bifurcatum Staplin, Jansonius and Pocock 1965
Plate III: 9

Vesicle diameter 25—35 μ, process length approximately the same as the vesicle diameter, number c. 13. Cf. *M. irregulare.*

B: grey limestone, site 3, comparatively common.

E: Gotland Middle Ordovician (Viruan) (Kjellström 1971), England Lower Ordovician (Arenigian-Llanvirnian) (Lister, Cocks and Rushton 1969).

M. cortracumense (Stockmans and Willière 1963) Eisenack 1973
Fig. 28

Vesicle diameter c. 17 μ, processes c. 4.5 μ. The majority of the processes are simple, but they may be subdivided. The vesicle in the Bothnian Sea material c. 15—21 μ.

B: grey limestone, site 3, rather common.

E: Belgium Silurian (Stockmans and Willière).

M. fissile (Stockmans and Willière 1963) Eisenack 1973
Fig. 29

Vesicle diameter 16—18 μ, process length almost equal to diameter, number about 15. Branching between lower and upper third of processes (Martin 1968). Vesicle diameter in the Bothnian Sea material 18—20 μ.

B: green limestone, Sylen; grey limestone, site 3, rare.

E: Belgium Silurian subsurface material (Stockmans and Willière) and Ordovician material (Martin 1968).

M. forquillum (Cramer and Diez 1972) Eisenack 1973
Fig. 30

Vesicle diameter 30—45 μ, process length 150—20 % of diameter, number 4.

B: green limestone, site 3, rare.

E: USA, Kentucky Estill Shale (Upper Llandoverian) (Cramer and Diez).

M. irregulare Staplin, Jansonius and Pocock 1965
Plate III: 10

Vesicle diameter 20—35 μ, process length somewhat less than diameter, number 15—25; the majority are furcate.

B: green and grey limestone, site 3.

E: eastern Canada Middle Ordovician (subsurface material) (Staplin, Jansonius and Pocock).

M. sylensis n. sp
Pl. III: 11

Derivation of name: Sylen shoal, sampling site.

Diagnosis (on basis of one individual): subspherical with relatively thick wall, hemisphere with c. 10 processes, the majority of which are furcate with gentle angles; some show secondary branching and some are non-branching. Processes proximally tapered, and about 50 % of the diameter in length. A rupture is visible in the section of the vesicle opposite the processes (possibly due to wear).

Dimensions: vesicle diameter c. 70 μ, spine length c. 35 μ.

Observations: Form resembles *M. ramusculosum oldhamensis*, but in common with other ramasculosum forms this one too has longer processes than *M. sylensis*. Also *M. fisherii* (Cramer 1968) can be likened to *M. ramusculosum oldhamensis*. The former differs however, in having processes that taper from the proximal to the distal end, or vice versa as in the species described.

B: the surficial portion of chasmops limestone in the Sylen shoal, Middle Ordovician.

M. sp. 1
Plate III: 12

Vesicle diameter c. 50 μ, process number c. 15, length 15—20 μ. Process terminations generally trifurcate, some of them with secondary branching. Vesicle in communication with process cavities. Colour sepia.

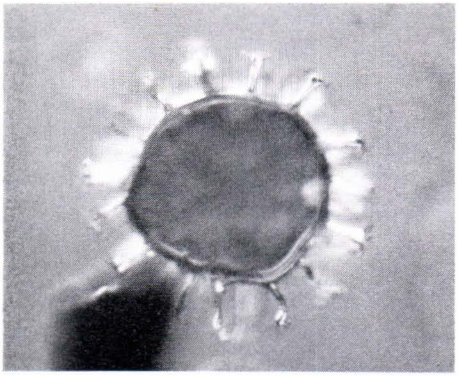


FIG. 27. *Multiplicisphaeridium belmontiformis* n. spec.

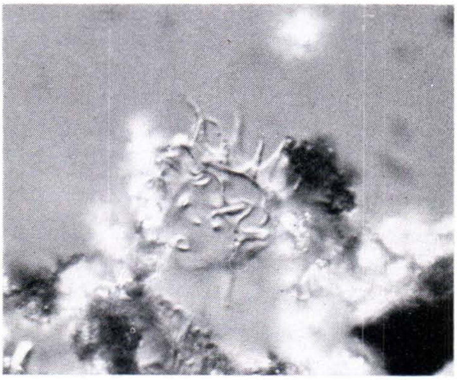


FIG. 28. *Multiplicisphaeridium cortracumense*

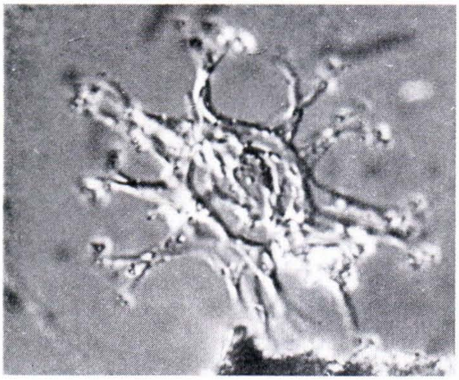


FIG. 29. *Multiplicisphaeridium fissile*

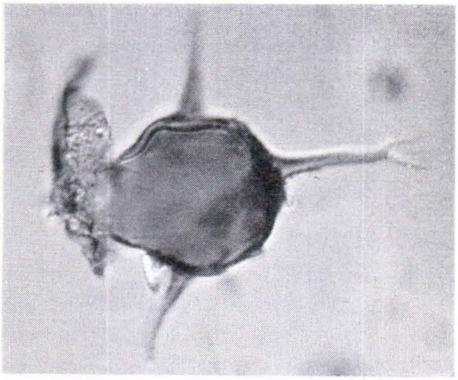


FIG. 30. *Multiplicisphaeridium forquillum*

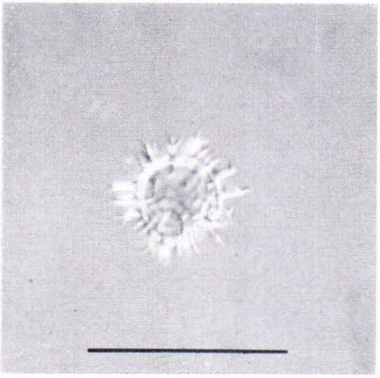


FIG. 31. *Multiplicisphaeridium* sp. 3

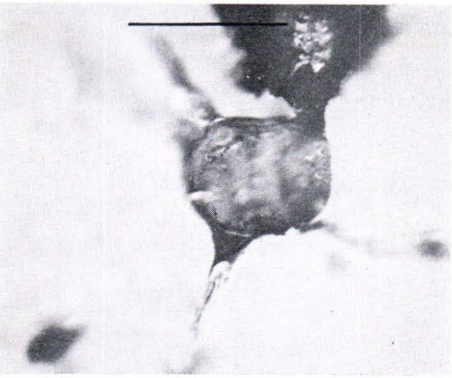


FIG. 32. *Orthosphaeridium densigranosum*

B: green limestone, site 3, rare.

Refers to *Peteinosphaeridium* species, but differs in that the termination branches are diagonal and not tangential to the vesicle.

M. sp. 2 (*M. angulatus*)
Plate IV: 1

Vesicle angular, tetrahedral to polygonal, diameter c. 15—20 μ, number of processes in optical section 4—8, shorter than diameter. Processes commonly bifurcate.

B: limestone material in site 2, grey limestone, site 3.

M. sp. 3
Fig. 31

Spherical, diameter c. 20 μ, process length 5—8 μ. Process terminations often trifurcate.

B: green limestone, Sylen.

Orthosphaeridium Eisenack 1968, emend. Kjellström 1971

Vesicle ± rectangular. Excystment structure always produced along a tranversal suture line, dividing the vesicle into two almost equal halves. Separation of processes from vesicle cavity. Processes simple or furcate. Type species *O. rectangulare* Eisenack (1963).

O. chondrododora Loeblich and Tappan 1971
Plate IV: 2

Cavity dimensions 67×78 μ, processes 4 in number, with length up to 116 μ (holotype). The species encountered in the Sylen limestone is about the same size.

B: green limestone, Sylen (only one observation).

E: Indiana Upper Ordovician (Loeblich and Tappan).

O. densigranosum Kjellström 1971
Fig. 32

Vesicle dimensions 38—44 μ × 33—39 μ (45×35 μ), processes 8 in number, with length almost equal to vesicle diameter, 4 processes on the same plane, vesicle surface verrucate.

B: green limestone, site 3, rare.

E: Grötlingbo, Gotland, Middle Ordovician (Lower Viruan) (Kjellström 1971).

O. rectangulare (Eisenack 1963)
Plate IV: 3

Vesicle dimensions: 40×49 μ (37×40), processes 4 in number, with length 84 μ (60 μ).

B: green limestone, site 3, rare.

E: Gotland, Middle Ordovician (Viruan) (Kjellström 1971), Upper Ordovician (Eisenack 1963).

Peteinosphaeridium Staplin, Jansonius and Pocock 1965, emend. Eisenack 1969

Vesicles relatively firm and spherical, with numerous similar and uniformly radial processes; solid or hollow. Their terminations are closed with two to three or more branches at wide angles or even tangential to each other. Some secondary furca may also be produced. The processes and furcates may be provided with longitudinal lists or fins (peteino). Either the suture or, as a result of intense development of the suture, the branching may be reduced. Pylomes are common. A widespread group in greenish limestone. This is particularly true of *P. nudum*, which is included in the Middle Ordovician forms.

P. breviradiatum Eisenack 1959, Kjellström 1971
Plate IV: 4

Characterized by numerous short (2—3 μ) branching processes (trifurcate); furca length about 3 μ. Vesicle diameter 40—44 μ. Close form: *P. nanofurcatum* Kjellström.

B: green limestone, site 3, rather rare.

E: Baltic area Ordovician erratics (Eisenack 1938, 1959, 1965, 1968, 1969). Poland Middle Ordovician material (Górka 1969), Gotland Middle Ordovician (Lower Viruan) (Kjellström 1971).

P. groetlingboensis Kjellström 1971
Fig. 33

Characterized by rather broad and closely spaced processes whose terminations divide into two branches in opposing directions and these again into two. Vesicle diameter 74 μ.

B: green limestone, site 3.

E: Gotland, Middle Ordovician (Viruan) Kjellström 1971.

P. cf. *heteromorphicum* Kjellström 1971
Plate IV: 5

About 25 processes, heteromorphic; process terminations either nonfurcate and bulbous or bifurcate with sharp tips. Vesicle diameter 74 μ (60 μ).

B: green limestone, Sylen.

E: Middle Ordovician, Gotland (Kjellström 1971).

P. majorfurcatum Kjellström 1971
Plate IV: 6

Resembles *P. nudum*, but with a thicker-walled vesicle, diameter 53 μ, and processes with larger bifurca.

B: green limestone, site 3, rare.

E: Gotland Middle Ordovician (Kjellström 1971).

P. micranthum Eisenack 1959
Fig. 34

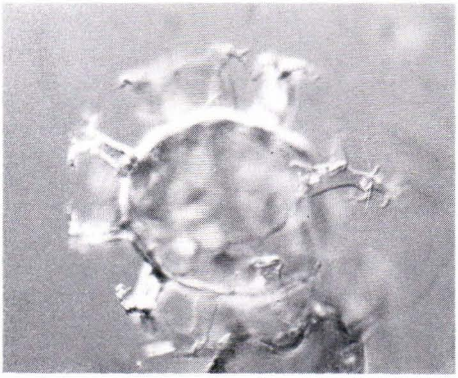


FIG. 33. *Peteinosphaeridium groetlingboensis*

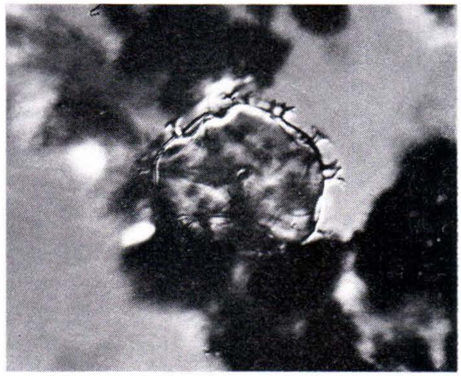


FIG. 34. *Peteinosphaeridium micracanthum*

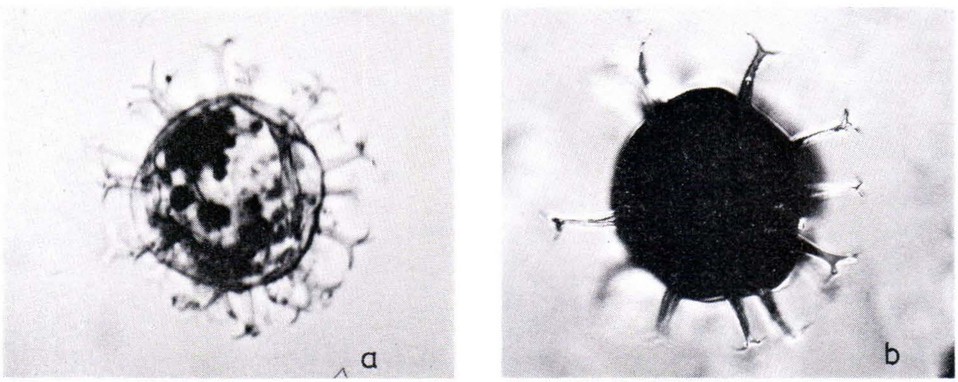


FIG. 35, a, b *Peteinosphaeridium nudum*

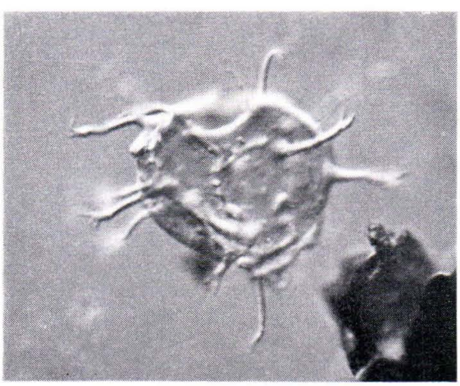


FIG. 36. *Peteinosphaeridium paucifurcatum*

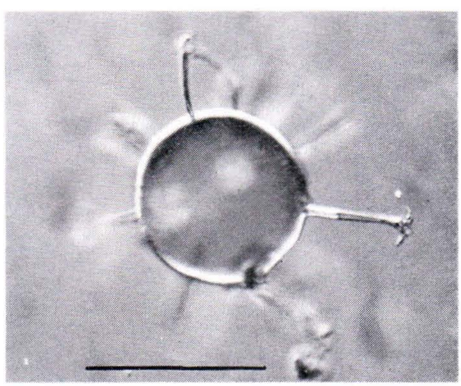


FIG. 37. *Peteinosphaeridium trifurcatum* var. *longiradiatum*

5 11453—75

Resembles *P. breiviradiatum*. The terminations of the short processes have 3 to 4 short furca and weakly developed peteinos. Vesicle diameter 68—88 μ, large pylome (40—50 % of vesicle diameter).

B: greenish limestone, site 3, rare.

E: Baltic area Lower Glauconite limestone, Megalaspis limestone (Lower Ordovician) Eisenack 1959.

P. nudum Eisenack 1959
Fig. 35 a, b

Processes c. 18 in number, about ⅓ of vesicle diameter (52 μ), no peteinos in association with processes (unlike *P. trifurcatum*).

B: greenish limestone, site 3, fairly common form.

E: Baltic area erratics and Estonia Middle Ordovician (Eisenack 1959, 1962, 1965, 1968), Poland Middle Ordovician (Górka 1969), Gotland Middle Ordovician (Kjellström 1971).

P. paucifurcatum Eisenack 1959
Fig. 36

Resembles former species; the processes are simple or with several short branches,: without peteinos. Vesicle diameter 37—52 μ.

B: green limestone, Sylen

E: Baltic Lower Ordovician (Eisenack 1959).

P. trifurcatum Eisenack 1931

Processes, about 10 in number, length about ⅓ of vesicle (60 μ), terminations with 2—4 branches, generally trifurcate. Processes covered by peteino.

B: grey limestone, site 3, rare.

E: Baltic area Ordovician erratics (Eisenack 1931—1969), Sweden Middle Ordovician (Staplin, Jansonius and Pocock 1965, Kjellström 1971), Poland Upper Arenigian and Ordovician floats (Górka 1969), Bohemia Upper Ashgillian (Konzalova-Mazancova 1969) and Arenigian (Vavrdová 1966), Gotland Middle Ordovician (Lower Viruan), Belgium Wenlockian (Martin 1968), Vologda area glauconite deposit (German 1974). According to Eisenack (1973), the species was at its peak from the Lower Ordovician period to the Revaler Stufe CI, that is, to the beginning of the Middle Ordovician period. Its rarity in the Bothnian Sea indicates a younger age for the sedimentation, contemporaneous with the upper Middle Ordovician. In Eisenack's opinion, *P. trifurcatum* was associated with *Baltisphaeridium longispinosum*, which also occurs in the Bothnian Sea.

Var. *longiradiatum* (Eisenack 1959).
Fig. 37

B: erratic site 3, rare.

E: Baltic area Upper Ordovician (Eisenack 1959, 1965).

P. sp
Fig. 38

Vesicle diameter c. 50 μ, process length 8—12 μ. Furca c. 7—8 μ, 2 to 3 per process.

B: green limestone, Sylen, several individuals.

Pterocystidiopsis Deflandre 1937

The original description was not available but on the basis of the description by Henry (1967) of *P. durande*, which belongs to the same type genus, the following occurrences from the Bothnian Sea are referred to the Deflandre genus. The Bothnian Sea microfossils are spherical and with a double membrane. The internal shell is smooth but the external one forms a folded veil, (*Plicasphaera*) that envelops the whole sphere and is connected to the surface of the internal sphere at the lower parts of the folds. The folds show a labyrinthal or serrated pattern, not polygonal as in the genus *Cymatiosphaera*, to which *Pterocystidiopsis* otherwise bears a great resemblance (cf. Henry 1967, Henry and Thadeu 1971). Cf. *Planiosphaeridium* Eisenack 1965.

P. elegans n. sp.
Plate IV: 7, Fig. 39 a

Internal shell relatively thick, outer shell folded comparatively far from the internal shell. Labyrinthine pattern on the folds. Internal shell diameter c. 12 μ, overall diameter c. 21 μ.

B: grey limestone, site 3, very rare, only 1 individual.

P.bottnica n. sp.
Plate IV: 8, Fig. 39 b

The external shell has labyrinthine and angular folds that extend almost to the internal shell. Internal shell diameter c. 18 μ, overall diameter c. 23 μ.

B: grey limestone, site 3, rare.

Symplassosphaeridium Timofeev 1959, p. 26

There is no genus description, but on the basis of pictures it can be recognized as a characteristic type in which at least the surface of the spherical body is composed of small tangential spheres. According to Timofeev (1966), it is in fact a Cambrian form although it has also been reported from a Lower Ordovician stratum.

S. aff. *incrustatum* Timofeev 1959
Plate IV: 9

Overall diameter c. 40—50 μ according to Timofeev, but c. 60 μ in the individual encountered.

B: Sylen, in situ, Middle Ordovician, only one observation.

E: *S. incrustratum*: USSR Lower Ordovician (Timofeev 1959).

Synsphaeridium Eisenack 1965

Hollow spheres with walls of organic matter; the spheres are connected with each other but do not form globular aggregates. Although the spheres often show flat

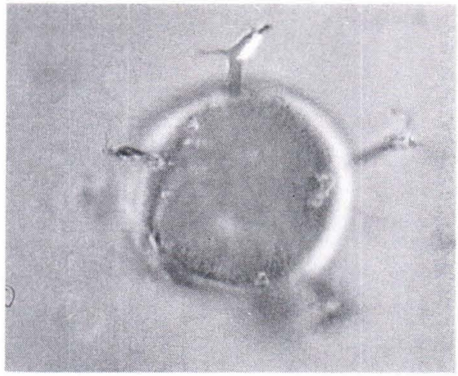


FIG. 38. *Peteinosphaeridium* sp.

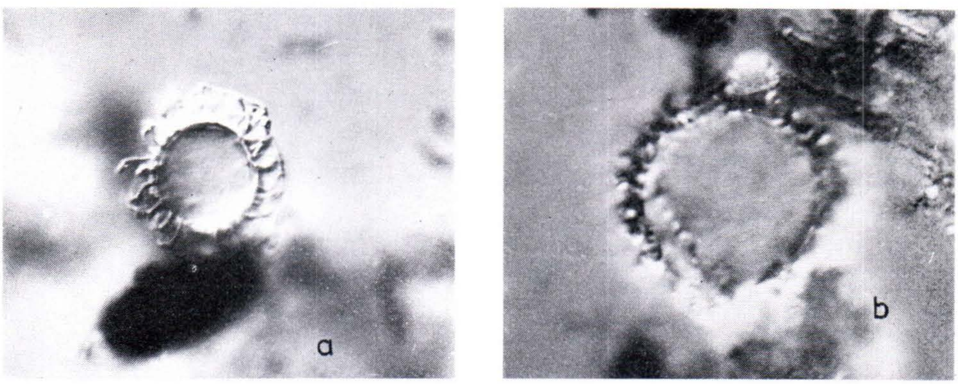


FIG. 39, a. *Pterocystidiopsis elegans* n. spec., b. *P. bottnica* n. spec.

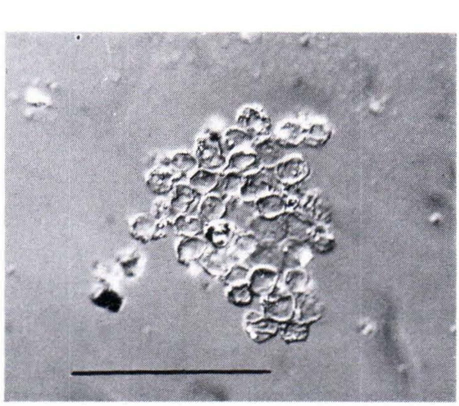


FIG. 40. *Synsphaeridium* aff. *tuberculatum*

clusters, they are seldom on the same plane and some spheres can be higher than the others. Type genus: *S. gothlandicum*.

S. aff. *tuberculatum* Eisenack 1965
Fig. 40

Sphere diameter c. 15 μ, small warts on the surface. Diameter of spheres in the Bothnian Sea material c. 8—17 μ. The warts can be distinguished on the biggest individuals. The aggregates of small spheres possibly represent early forms.

B: green limestone, site 3.

E: *S. tuberculatum*: Gotland Silurian (Eisenack 1965).

Tasmanites Newton 1875

Spherical, thick-walled and rather large microfossils, hollow at the centre. Walls penetrated by small pores; often with a conspicuously large rounded pylome provided with a cover. *Tasmanites* is known from the Palaeozoic in particular, but also from the Tertiary (Eisenack 1963). It is also referable to present-day green algae (Wall 1962). From Baltic limestone pebbles from South Finland Eisenack (1965) has reported large and well-preserved Tasmanite forms: *T. balticus* (mean diameter 368 μ) and *T. martinssoni* (see, Martinsson 1955, 1956). Although these large forms were absent in the Bothnian Sea material, the following small form was present.

T. minutus Eisenack 1965
Plate IV: 10

Vesicle diameter 50—70 μ, pylome cover opens inwards, diameter c. 28 μ. Surface smooth. Dimensions in the Bothnian Sea material: diameter c. 57 μ, pylome c. 20 μ.

B: Sylen, in situ, grey limestone, site 3.

E: Baltic Sea limestone and Jörden stage (Silurian) (Eisenack 1965).

Veryhachium Deunff 1955, emend. Downie and Serjeant 1963, Loeblich and Tappan 1969

Test habitus triangular or polygonal-subpolygonal with processes, 3 to 6 in number, at the corners. Processes pointed with closed terminations. According to Cramer (1970), *Micrhystridium* and *Veryhachium* are synonyms, *Veryhachium* being a variant with widely spaced processes. Vesicle diameter 10—40 μ, rarely smaller or greater.

V. europeum Stockmans and Willière 1960
Fig. 41 a

Processes, four in number, three of which form a triangle. The length of the processes is greater than 75 % of the length of an edge of the central body (Cramer 1970).

B: grey and green limestone, site 3, rare.

E: Belgium Upper Devonian (Stockmans and Willière 1960), Upper Caradocian very rare, Silurian common (Martin 1968), USSR Silurian (Piskun 1974, *cf.* German and Timofeev 1974).

V. lairdi (Deflandre 1935) Deunff 1959
Fig. 41 b

A rectangular form with 4 long processes. Vesicle 16—20 μ, spines 25—30 μ.

B: green limestone, site 3, rare.

E: Brittany Caradocian (Deunff 1959) and Llandvirnian (Henry 1969), Belgium Silurian (Stockmans and Willière 1963) and Ordovician (Martin 1968), northeastern Spain Silurian and Devonian (Cramer 1964), USSR Upper Ordovician (Piskun 1974).

V. oligospinosum Eisenack (1934) 1963
Synonym: *Goniosphaeridium oligospinosum* Eisenack *et al.* 1973
Fig. 41 c

A fairly large form with 4 (or 5 to 6) spines; tetrahedral habitus. According to Eisenack, the size can reach 300 μ. (About 90 μ in the Bothnian Sea material).

B: green limestone, site 3, only one individual.

E: Sweden Upper Visby Marl (Eisenack 1934), Ordovician erratics (Górka 1969), Vologda area Lower Ordovician (German 1974).

The form is not associated with the *Goniosphaeridium* genus, because it is more readily referable to the *Veryhachium lairdi* type.

V. trispinosum (Eisenack 1938)
Plate IV: 11

Forms with three processes, which are shorter than the diameter of the vesicle (*cf.* Henry 1969). Vesicle: 20—30 μ, spines: 15—20 μ.

B: common form in green limestone.

E: Baltic Lower Silurian (Eisenack 1938), Rhine Ordovician (Eisenack 1939), Belgium Devonian (Stockmans and Willière 1962), Arenigian-Llandvirnian, abundant (Martin 1968), Finisterre Lower Caradocian (Deunff 1959), England Lower Ordovician (Lister and Holliday 1970), Bohemia predominant in Upper Caradocian (Vavrdová 1965), USSR Upper Ordovician (Piskun 1974), France Lower Ordovician (Paris 1971).

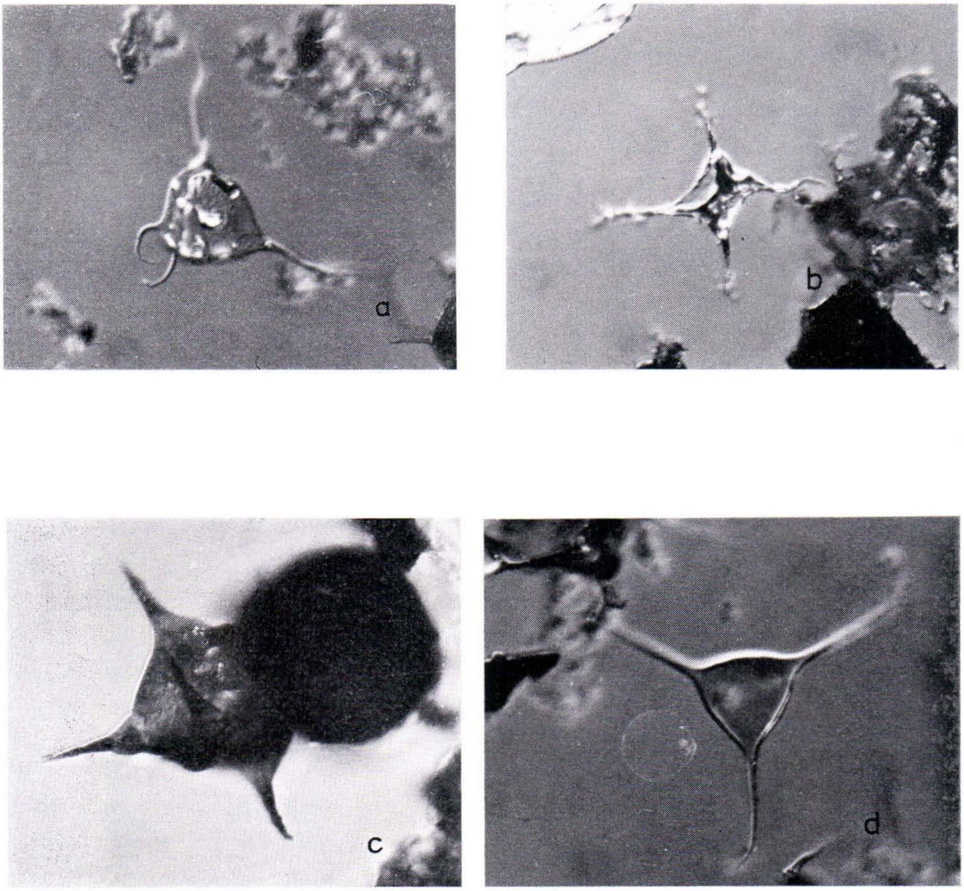
V. trisulcatum (Deunff 1958) Henry 1969
Fig. 41 d

Forms with three processes, which are longer than the diameter of the vesicle. Vesicle 20—30 μ, spines: 45—69 μ (Deunff 1963: 35—40, 75—100 μ).

B: green limestone, site 3, very common; Sylen, rare.

E: Veryhachium Middle Ordovician (Deunff 1958: large form), Crozon Upper Ordovician (Caradocian) (Henry 1969), Central Bohemia Ordovician (Arenigian) (Vavrdová 1965).

The form *V. triangulatum* (Konzalova), which is similar to *V. trispinosum*, also occurs in the Bothnian Sea material (Fig. 41 e). According to Piskun (1974), it dates to the end of the Ordovician period. It bears a great resemblance to the Baltic Ordovician form *V. balticum* Eisenack (1951) 1959.



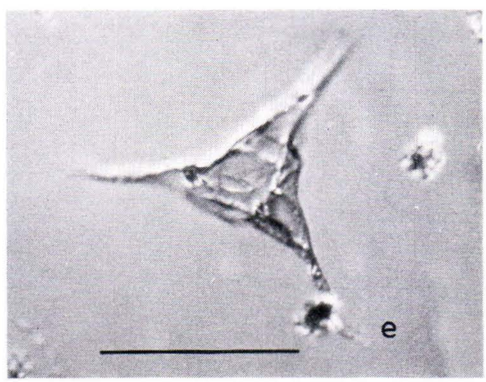


FIG. 41, a. *Veryhachium europeum*, b. *V. lairdi*, c. *V. oligospinosum*, d. *V. trisulcatum*, e. *V. triangulatum*.

Blue algae genus *Gloecapsomorpha* Zalessky (1916)

The microfossil type that received its name from the present-day blue algae genus *Gloecapsa* Kützing is known from the Precambrian, although it was especially common in the Ordovician Kuckersit-algae. Many Palaeozoic *Gloecapsomorpha* forms have been recognized, notably by Timofeev (1966). Particularly in the grey limestone, site 3, the Bothnian Sea material shows well-preserved *Gloecapsomorpha* species.

G. sp.

Plate IV: 12

Thin-walled, small-celled spherical or irregular complexes. Diameter of one eight-cell complex c. 10 μ, that is, smaller than *G. prisca* and *G. macrocysta* Eisenack 1960.

B: grey limestone, site 3.

The abundances and the comparative dating of the hystrichosphere species in the limestone of the Sylen Shoal and in limestone erratics on the bottom of the Bothnian Sea

Owing to its scarcity the material investigated cannot be dated in detail on the basis of hystrichosphere flora. The most fruitful sources of comparison for the occurrences established are the data of Kjellström (1971 a and b) from Middle Ordovician material and of Eisenack (1965) from microfossil investigations in Baltic limestone. The *Baltisphaeridium* genus plays a key role in these studies and the bulk of the species are the same as those in the Bothnian Sea material (Table 1). Despite the scarcity of the material from the Bothnian Sea, separate investigations have been conducted on the species from the Sylen Shoal (Middle Ordovician in the light of conodont studies),

TABLE 1

The abundance of the most common *Acritarcha* genera in the material from the Bothnian Sea.

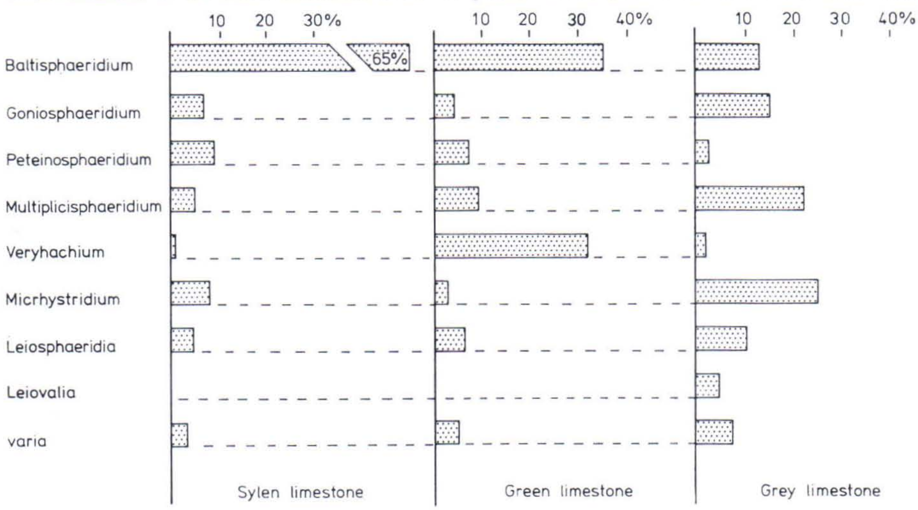


TABLE 2

The stratigraphic division of the Ordovician

Baltic	Estonia*	Estonia**	Central Europe
Harjuan (Upper Ordovician)	Porkuni (F_{II})	Borkholmer Stufe (F_2)	Ashgillian
	Pirgu (F_{Ic})		
	Vormsi (F_{Ia})	Lyckholmer Stufe (F_1)	
	Nabala (F_{Ia})		
	Rakvere (E)	Wesenberger Stufe (E) »Baltic limestone»	
Viruan (Middle Ordovician)	Oandu (D_{III})	Wasalemmsche Stufe (D_3)	Caradocian
	Keila (D_{II})	Kagel'sche Stufe (D_2) »Sylen limestone»	
	Johvi (D_I)	Jewe'sche Stufe (D_1)	
	Idavere (C_{III})	Itfer'sche Stufe (C_3)	
	Kukruse (C_{II})	Kuckersche Stufe (C_2)	
	Uhaku (C_{Ic})	Revaler Stufe (C_1)	
	Lasnamägi ($_{Ib}$)		Llandeilian
	Aseri (C_{Ia})		
			Llanvirnian
Oelandian (Lower Ordovician)	Kunda (B_{III})		Arenigian
	Volkhov (B_{II})	Glaukonitkalk (B $_2$)	
	Leetse (B[)		
	Pakerort (A_{2-3})		
			Tremadocian

*) Röömusoks, 1960

**) Eisenack's division

from the green limestones in erratics and from grey limestones. The stratigraphic table (Table 2) illustrates the division of the Ordovician period in the Baltic and Central European areas, from which comparative observations of the occurrences of the species are reported in the section on systematics.

The green limestone of the Sylen Shoal

Baltisphaeridium hirsutoides — longispinosum, *B. nannium*, *B. latiradiata*, *Goniosphaeridium uncinatum*, *G. polygonale*, *Multiplicisphaeridium allotei*, *Electoriscos* aff. *pagonius*, *Peteinosphaeridium heteromorphicum*, *P. paucifurcatum*, *P.* sp., *Tasmanite minutum* are the main species, *B. hirsutoides-longispinosum* being the most common. This composition of species is suggestive of a deposition during the Middle Ordovician period (see, Kjellström 1971, p. 61—63).

Material from green limestone erratics

The genus with the most abundant forms is *Baltisphaeridium*. It includes the majority of the species described without any one species being conspicuously dominant. However, *B. longispinosum-hirsutoides* and *B. multipilosum* are the most common of these species, *Peteinosphaeridium nudum* is the dominant representative of its genus and *G. pellicicidium* (*G. conjunctum*) of the *Goniosphaeridium* genus. These occurrences refer convincingly to the Upper and Middle stages of the Middle Ordovician period (see. Kjellström 1971). The bulk of the microfossil material is composed of *Veryhachium trispinosum* found in the green limestone. The *Veryhacium* species are known particularly from the latter half of the Ordovician period, but *V. trisulcatum* from as early as the Arenigian stage (see, Vavrdova 1965). On the basis of these species it is not possible within the scope of this study to determine the dates more accurately. The hystrichosphere flora seem to indicate that the deposits represented by the green erratics were formed during the Middle Ordovician, contemporaneously with the Sylen surface stratum. However, they may possibly be younger than the latter, owing to the absence or marked scarcity of *Veryhachium* in the Sylen samples.

Grey limestone erratic material

This material shows the most heterogeneous groups of species. Except for the relative paucity of large *Baltisphaeridium* species, many of the species studied are the same as those in the green limestone: *B. hirsutoides*, *B. multipilosum*, *B. globosum*. *P. nudum* is the most common of the *Peteinosphaeridium* genus, and *bifurcatum* and *alloteaui* of the *Multiplicisphaeridium* genus. Other species found in both sets of material are *Goniosphaeridium pellicidium* and *Tasmanites minutum*. In addition, some *Micrhystridium* species occur in abundance, *M.* cf. *bacilliferum* and *stellatum* being the most common. They have been encountered in Ordovician strata, although also in some younger strata. The *Leiosphaeridia* genus is represented by the *baltica* species, which, according to Eisenack, is typical of Baltic limestone. Relatively many of the species reported from Baltic limestone (Eisenack 1965) also occur in the grey limestone of the Bothnian Sea: *Baltisphaeridium hirsutoides*, *B. multipilosum*, *Peteinosphaeridium trifurcatum* ssp. *longiradiata*, *Leiosphaeridia baltica*, *Leiovalia similis*, *Tasmanites minutum*. Species that at present cannot be compared with those of the strata dated to the Ordovician period in adjacent areas include representatives of the *Granomarginata*, *Lophosphaeridium*, and *Pterocystidiopsis* genera. In short, it is not possible on the basis of the species to date the samples with such accuracy as it was with the two former examples; even so the species suggest the Ordovician period, and possibly a stage younger still than that indicated by the species in the greenish limestone.

ZOO MICROFOSSILS

Order *Chitinozoa* Eisenack 1931

Chitinous remains of an animal group (possibly a protozoan group or Hydrozoa), whose systematic position is still uncertain; the remains show axial symmetry, and are rod-, club-, flask- or pot-like in shape. They are generally less than 0.4 mm in length, maximum 1 mm, and black in colour. The *Chitinozoa* occurrences are restricted to the period from the beginning of the Ordovician to the Devonian (Jansonius 1967, Combaz 1972). The main sources of comparison in the Bothnian Sea investigations are Eisenack's species determinations, the bulk of which are based on investigations of Ordovician and Silurian material in the Baltic. Of the numerous *Chitinozoa* studies conducted elsewhere in Europe, mention should be made of those by Taugourdeau (1966), Laufeld (1967), Cramer (1964), Doubinger (1963) and German (1974).

In the present description of *Chitinozoa* the stress is on the illustrations. The most important dimensions of each species are also given, first for material from earlier investigations, followed in brackets by those for the Bothnian Sea material (if given). The dimensions can be seen roughly on the scale. Whenever more explicit dimensions are given, the practice of Eisenack (1955) is followed: length/greatest breadth/aperture diameter (the aperture is downwards in the illustrations)/ smallest breadth.

Eisenack (1959, 1962, 1965) has earlier reported *Chitinozoa* occurrences in Baltic limestone from the Hanko—Tammisaari area in South Finland investigated by Martinsson (1956). The following species were deseribed: *Ancyrochitina ancyrea*, *A. capillata*, reported as early as 1962 (Eisenack), *A. multiradiata*, *Conochitina elegans*, *C. micracantha* and divers forms, *C. minnesotensis*, *C. tuberculata*, *Cyathochitina calix*, *C. campanulaeformis*, *C. kuckersina* f. *brevis*, *Desmochitina lecaniella*, *D. minor* f. *typica*, f. *amphorea*, *Lagenochitina baltica*, *L. prussica*, *Parachitina curvata*, *Rhabdochitina magna*.

Chitinozoa are common in Sylen limestone and farther north in the limestone erratics on the bottom of the Bothnian Sea. The following forms are encountered most frequently.

Ancyrochitina Eisenack 1955

Subcylindrical lower part ($1/2$—$2/3$ of length) and an overturned conical, seldom spherical upper part. Polar plane $\pm$ smooth, the edges provided with long processes from 4 to 10 in number (average 6 to 8). The terminations of the processes show anchor-or antler-like or very irregular branching. The walls are without spines.

A. ancyrea (Eisenack 1931) Eisenack 1955

Type size 138/68/21/32. The type proper has well-developed anchorlike processes. Eisenack (1965) has described this form from South Finland, but also a form whose processes are not markedly furcate (A. sp. Table 10:11—12). The latter is probably a primitive form; it occurs also at Sylen in the Bothnian Sea (Fig. 42 a, b). *A. ancyrea* is mainly a Silurian (Gothlandian) form, *despite* the fact that occurrences are known from Ordovician erratics in Finland (Bothnian Sea limestone, Eisenack 1965).

Conochitina Eisenack 1931

Type species: *C. claviformis*. Distinctive marks: length 0.26 mm, length/breadth = 4:1. A cone-, rod-shaped form; the lower part, however, is more cylindrical and rewidens somewhat at the aperture. The cone base opposite the aperture is generally flat, but sometimes it is indented, and a few individuals have a copula.

C. cactacea Eisenack 1937
Fig. 43 a

The species is characterized by spinules along the conical surface.

B: green limestone, site 3.

E: in erratics of Baltic limestone (Eisenack 1965).

C. cervicornis Eisenack 1931
Fig. 43 b

Characteristic and rather large spines at the edge of the conical expansion, non-furcate, length 16—20 μ. Overall length (240 μ), length: breadth=2.5:1. Cf. *C. taugourdeaui*.

B: Sylen erratics sample, Middle Ordovician.

E: Samland coastal erratics (Eisenack 1931).

C. conulus Eisenack 1955
Fig. 44 a

Dimensions: 113/67/29/37 μ (Eisenack, Typus)

B: limestone, Sylen in situ.

E: Ordovician erratics (Eisenack 1955).

C. micracantha Eisenack 1931, subsp. *micracantha* Eisenack 1959
Fig. 44 b

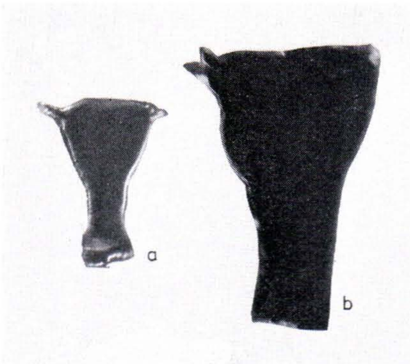


FIG. 42, a, b. *Ancyrochitina* sp.

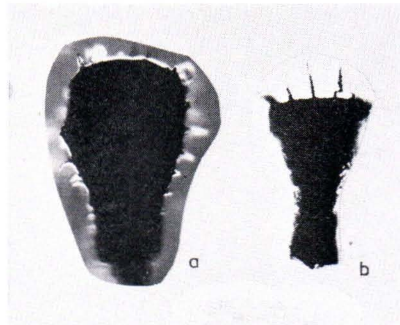


FIG. 43, a. *Conochitina cactacae*, b. *C. cervicornis*

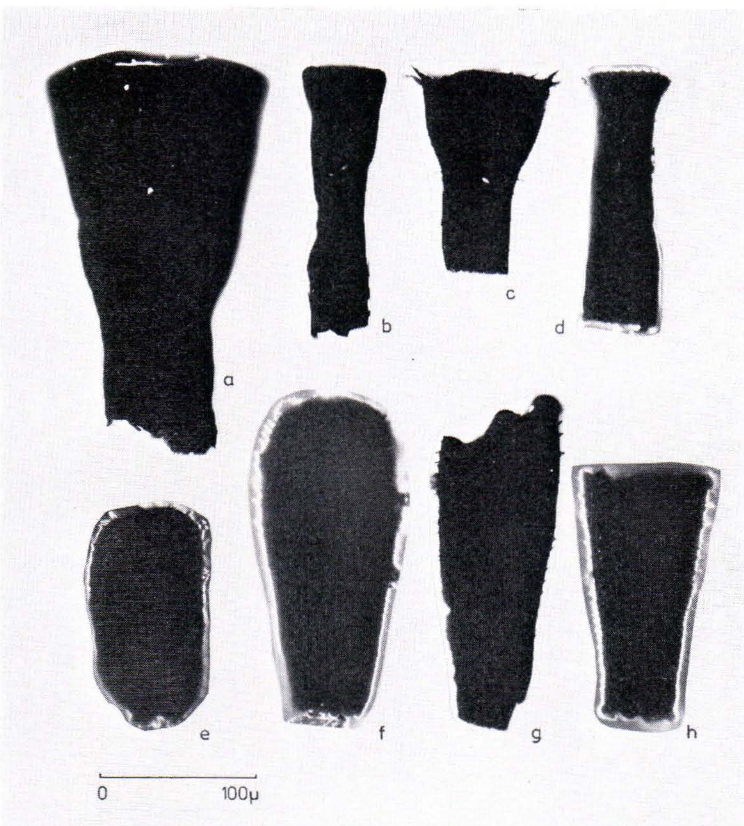


FIG. 44, a. *Conochitina conulus*, b. *C. micracantha*, c. *C. micracantha* f. *barbata*, d. *C. micracantha* subsp. *comma*, e. *C. micracantha* subsp. *sylensis*, f. *C. micracantha* subsp. *synclinalis*, g, h. *C. micracantha* subsp. *wesenbergensis*

Resembles type species of genus, length 0.23—0.38 mm, length: breadth = 4—5:1.

B: Erratics, site 2, grey limestone, site 3.

E: common form in Lower Silurian boulders = Ordovician (Eisenack 1931), *Diplograptus gracilis*- limestone (Eisenack 1959), Baltic Ordovician (Eisenack 1962), most common form in Baltic limestone (Eisenack 1965, p. 123).

C. micracantha f. *barbata* Eisenack 1965
Fig. 44 c

The species is characterized by spinules groups along the basal margin.

B: Sylen sample, Middle Ordovician.

E: in erratics of Baltic limestone (Eisenack 1965).

C. micracantha subsp. *comma* Eisenack 1959
Fig. 44 d

A sparsely-spined form; spines either at pole or totally absent.

B: green limestone, Sylen

E: Baltic limestone Wesenberger Stufe (Eisenack), also in South Finland.

C. micracanta subsp. *sylensis* n. subspec.
Fig. 44 e

A cylindrical conical form characterized by tapering at the aperture and the absence of a neck. Hence it is relatively short. There are small spines on the base and cylinder walls. Dimensions: length c. 150—240 μ, greatest breadth 80—100 μ, aperture diameter 30—60 μ.

B: green limestone, Sylen.

It resembles *C. tuba* in dimensions but differs in that it is provided with spines.

C. micracantha subsp. *synclinalis* Eisenack 1965
Fig. 44 f

Length 200—340 μ, breadth 105 μ, the broadest part is $\frac{1}{4}$ of pole.

B: Sylen; Bothnian Sea dredge sample, site 2.

E: Baltic limestone form (Eisenack 1965).

C. micracantha sub. sp. *wesenbergensis* (Eisenack 1959)
Fig. 44 g, h

Eisenack 1965, Table 9, Fig. 10—17, Table 10, Fig. 3.

B: Erratics, site 2, grey limestone, site 3, relatively common.

E: Baltic limestone (Eisenack 1965), Baltic Ordovician, Wesenberger Stufe (Eisenack 1959, 1962).

C. taugourdeaui Eisenack 1968
Fig. 45 a—c

Relatively sharply conical with ± straight edges, or slender and cupular, in which case it resembles *C. calix*. The polar edge has large simple or bifurcate spines project-

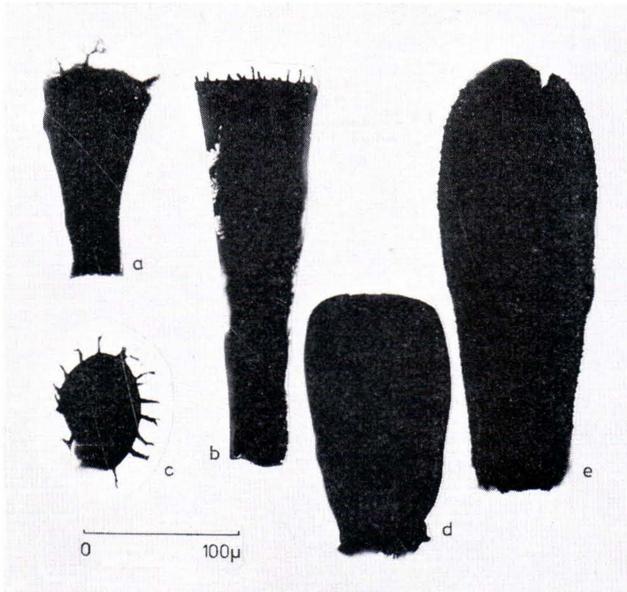


FIG. 45, a—c. *Conochitina taugourdeaui*, d. *C. tuba*, e. *Conochitina/Angochitina*, transitional form.

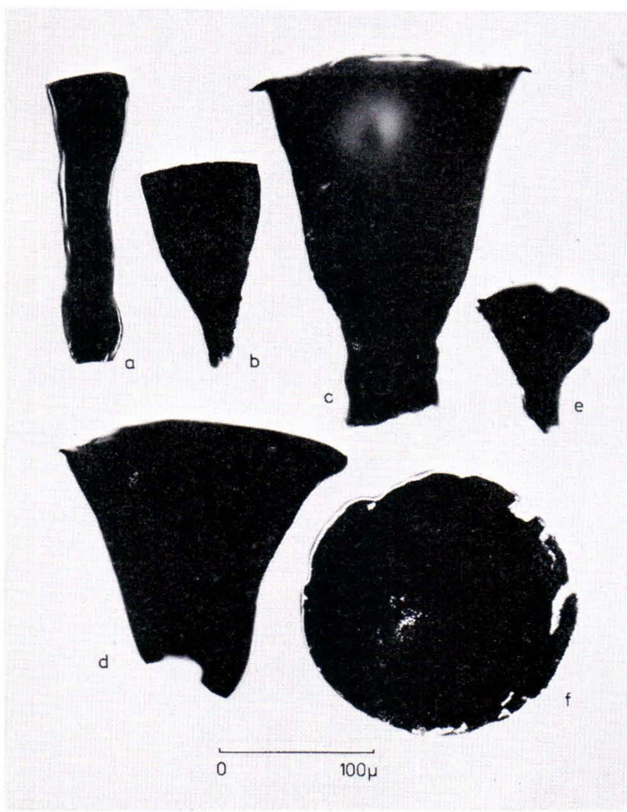


FIG. 46, a. *Cyathoctina calix*, b, c. *C. campanulaeformis*, d. *C. kuckersiana*, e. *C. kuckersiana* f. *brevis*, f. *C. campanulaeformis*, basal view.

ing diagonally sidewards. Small spines also commonly on the sides. Type: 266/86/68/50.

B: green limestone, Sylen.

E: found in the Berlin area in transported material that probably belongs to the Borkholm stage (Eisenack 1968). The species is very reminiscent of *C. cervicornis*. The age of the Sylen stratum indicates that the form lived as early as the end of the Middle Ordovician.

C. tuba Eisenack 1932
Fig. 45 d

A form resembling *C. micracantha wesenbergensis* and *C.m. synclinalis* (length 143—284 μ, length: breadth = 1.9—3.6:1), membrane psilate.

B: green limestone, Sylen.

E: Slite marl, Wenlock (Silurian) Gotland (Eisenack 1962).

Conochitina/Angochitina in Fig. 45 e from site 2.

Cyathochitina Eisenack 1955

Chitinozoans with $\pm$ cylindrical lower part, conical or bell-shaped upper part and a sharp-edged pole, which may also form a narrow transparent edge. Wall psilate or at the most fine grained and verrucate. Type species: *C. campanulaeformis*.

C. calix Eisenack (1931) 1955
Fig. 46 a

Length 190—450 μ, length: breadth 1.9—4.1:1

B: Erratics, site 2

E: Baltic Ordovician, stages B_1—B_3 (Estonian glauconite limestone) (Eisenack 1962), South Finland Baltic limestone erratics (Eisenack 1965).

According to Eisenack (1962), *C. calix*, *C. campanulaeformis* and *C. kuckersiana* constitute an important stratigraphic Ordovician series that no longer occurs in the Silurian. The species are similar to each other and display gradational forms. These forms include a significant portion of the chitinozoans in the Bothnian Sea material.

C. campanulaeformis Eisenack (1931)
Fig. 46 b, c

Length 250—300 μ, length: breadth = 1.3—1.6:1.

B: green limestone, Sylen relatively common, erratics, site 2.

E: Baltic Silurian (Ordovician) erratics off the coast at Samland (Eisenack 1931), Estonia Ordovician (Eisenack 1962), Echinosphaerid limestone (C_1)- Lyckholmer Stufe (F_1) (Eisenack 1962 c), South Finland Baltic limestone (Eisenack 1965), Central Sweden Ordovician (Caradocian) (Laufeld 1967).

C. kuckersiana Eisenack (1924) 1955
Fig. 46 d

Resemblance to former species, length 147—360 μ, length: breadth = 1.3—1.95:1.

B: green limestone, Sylen.

E: Baltic Ordovician, Kuckers' stage (CII)- Jewe'-stage (DI), Central Sweden Ordovician (Caradocian) (Laufeld 1967).

C. kuckersiana f. *brevis* Eisenack 1962
Fig. 46 e

Shorter than the main species and relatively wider bowled.

B: Bothnian Sea limestone erratics, site 2.

E: Baltic Ordovician, Jewe to Wasalemm stages (Eisenack 1962 c), South Finland Baltic limestone (Eisenack 1965).

Desmochitina Eisenack 1931

Type genus: *D. nodosa*

Spherical short-necked species, aggregated in colonies. Maximum length of colony 0.3 mm, individual bubble 77—90 μ, length: breadth = c. 1:1. Most often as single forms in Bothnian Sea material.

D. lecaniella Eisenack 1965
Fig. 47 a

Longitudinal axis shorter than latitudinal axis, rounded base. Diameter c. 64 μ, aperture 36 μ.

B: Bothnian Sea dredge sample, site 2, rare.

E: Baltic limestone erratics, also South Finland (Eisenack 1965).

D. minor Eisenack 1931 f. *typica* Eisenack 1958
Fig. 47 b, c

Elliptical or ovoidal with a pronounced neck. Surface psilate or granulate. Length/greatest breadth/aperture/narrowest point between neck and ellipse in Fig. 47 b is 110/90/50/40.

B: greenish limestone, site 3.

E: glauconite limestone and younger Ordovician strata, generally common (Eisenack 1958), reported also from South Finland (Eisenack 1965).

D. sp. cf. f. *amphorea* Eisenack (1931) 1962
Fig. 47 d

B: green limestone, site 3, a form represented by only one individual.

E: Ordovician stages C_1, D_1, D_3 (Eisenack 1962), South Finland Baltic limestone (Eisenack 1965).

D. minor f. *ovulum* Eisenack 1962. Fig. 47 e, green limestone in site 3.

Lagenochitina Eisenack 1931

Test without spines, type species: *L. baltica.*

L. aff. *sphaerocephala* Eisenack 1932
Fig. 48 a

The cylindrical part comprising c. $^3/_4$ of the overall length widens at the top to a sphere, whose distal pole seldom shows a planar area. Without spines, aperture often distended. Length 200 μ, length: breadth = 2.7—2.8:1. The Bothnian Sea material exhibits smaller forms: 70/140 μ.

B: green and grey limestone, site 3, rare.

E: *L. sphaerocephala*$_1$ Beyrichian limestone, common (Eisenack 1931).

L. sp., Fig. 48 b
Rhabdochitina Eisenack 1931

Type species: *R. magna*

A large form, length 0.5—c. 1 mm, breadth 80—100 μ, cylindrical. I have not observed this large form in the Bothnian Sea material, although Eisenack (1965) has reported it from several Baltic limestone erratics in South Finland. On the other hand, small individuals with similar shape occur in the Bothnian Sea material at site 2. They are *R. gracilis* f. *minor* n. fo. and are also smaller then *R. gracilis*, length c. 330, breadth 25 μ. (Fig. 49 a).

Rhabdochitina? taenia Eisenack 1932
Fig. 49 b, c

Cylindrical test, long and narrow in outline, but with a conical or spherical swelling at the base. Length 200—300 μ, Bothnian Sea material 190—230 μ.

B: green limestone, Sylen.

E: Baltic Silurian (Ordovician) (Eisenack).

R. sp., Fig. 49 d, grey limestone in site 3.
Sphaerochitina Eisenack 1955

Chitinozoa with almost cylindrical »lower part». The »upper part» shows a conical, spherical or wide mushroom-like expansion. Wall psilate or with small warts or very closely-spaced small spines.

S. pistilliformis (Eisenack 1931) Eisenack 1955 b. Table 1, Fig. 7—8.
Fig. 49 e

B: greenish limestone, site 3, rare.

E: pink *Beyrichia* limestone, Silurian material probably transported from Sweden to the Königsberg (Kaliningrad) region on the coast of Samland.

The dating of the material on the basis of a comparative study of chitinozoans

Although the chitinizoans do not display such an abundance of forms as the hystrichospheres, some of them at least play a significant role in stratigraphic dating, e.g. the group *Cyathochitina calix — campanulaeformis — kuckersiana — kuckersiana* f.

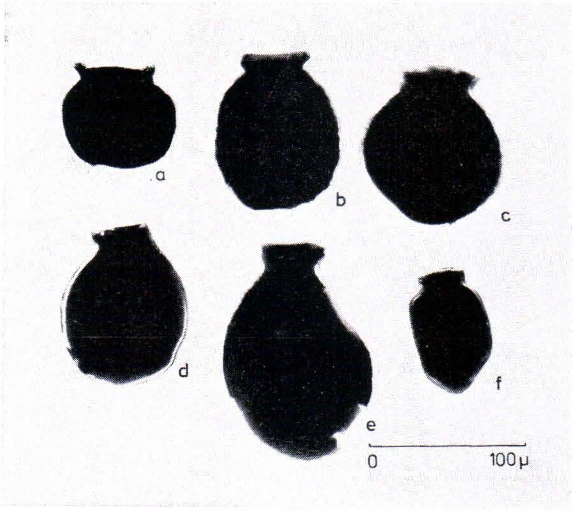


FIG. 47, a. *Desmochitina lecaniella*, b, c. *D. minor* f. typica, d. *D. minor* f. *amphorea*, e. *D. minor* f. *ovulum*, f. *D.* sp.

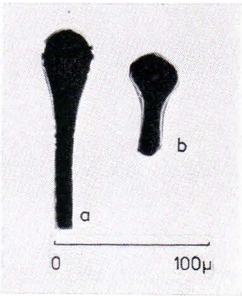


FIG. 48, a. *Lagenochitina* aff. *sphaerocephala*, b. *L.* sp.

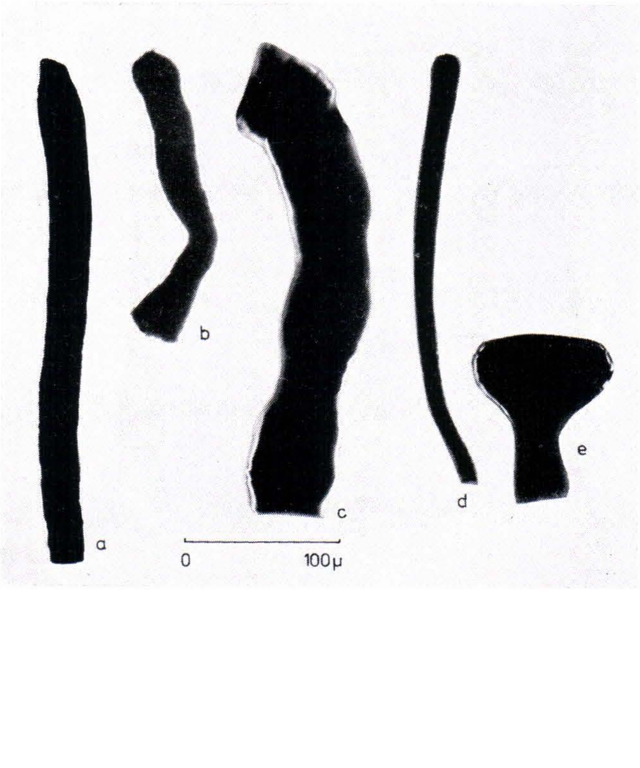


FIG. 49, a. *Rhabdochitina gracilis* f. *minor* n. f., b, c. *R. taenia*, d. *R.* sp., e. *Sphaerochitina pistilliformis* *brevis*, which, according to Eisenack 1962, correspond to stages B_1—B_3 of the Ordovician period (*calix*); C_1—F_1 (*campanulaeformis*); C_2 (*kuckersiana*); D_1—D_3 (*kuckersiana* f. *brevis*). These species also occur in the Bothnian Sea material. There have been earlier reports from South Finland of *C. kuckersiana* f. *brevis* from three Trätjeland Baltic limestone samples and of *C. campanulaeformis* from one sample (Eisenack 1965). This indicates that the Bothnian Sea erratics under discussion can be dated to the Jewe'—Wasalemm'-stage. Since the same type also occurs in the dredge sample from site 2 in the Bothnian Sea, it is conceivable that some of the material at this site is of the same age (hystrichospheres are sparse at site 2; the predominant type is *Baltisphaeridium hirsutoides—longispinosum*, which is characteristic of the middle stage of the Ordovician period.

The Sylen Shoal green limestone

A large portion of the forms encountered were broken or unfamiliar types that could not be determined, e.g. long *Conochitina* forms (Fig. 50 a) with spines at their base. Two of the types identified were *C. taugourdeaui* and *C. cervicornis*. *Ancyrochitina* sp., the same form as that described by Eisenack (1965) from Baltic limestone, was found in the material. Rare *Cyothochitina* species were *campanulaeformis* and *kuckersiana*. It is also possible that the genus *Eremochitina* was present, although the species have not been well defined either. (*cf.* Fig. 50 c—e). All in all, the forms seem to indicate Ordovician sedimentation, but do not allow more precise dating.

Green limestone erratics

The species differed considerably from those or the green limestone, but owing to the relatively small number of samples a comparison is not of much significance. The population consists of *Desmochitina minor*, *Sphaerochitina pistilliformis*, *Conochitina* and *Sphaerochitina* species; these are Ordovician forms, although some of them also occur in Silurian strata.

Grey limestone erratics

The species typical of the material is *Conochitina micracantha* and especially subspecies *wesenbergensis*. According to Kraft (1926) and Eisenack (1965), subspecies *micracantha* is characteristic of *Diplograptus* (*Orthograptus*) *gracilis* Baltic limestone. In the present study some specimens of what has been assumed to be *Orthograptus gracilis* (Syn. *Diplograptus gracilis*) were found in the green limestone from the site 3 (Fig. 51). According to Kraft, *Diplograptus gracilis* is represented in the Baltian echinospherehorizon, (C) but it has also been observed even in the Jewé stage. Glimberg (1961) has recorded *Orthograptus gracilis* from Upper Ordovician strate of Scania, southern Sweden.

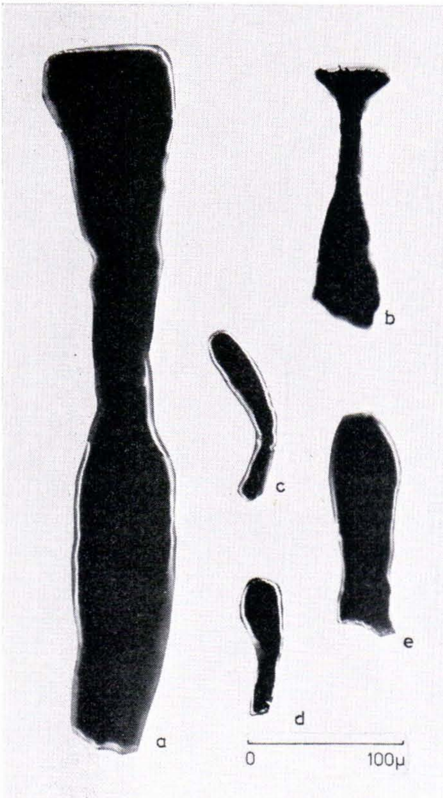


FIG. 50, a. *Conochitina* sp. 1, b. C. sp. 2, c, d. *Eremochitina* sp, e. *Eremochitina* sp.

FIG. 51. *Orthograptus (Diplograptus) gracilis*, sicula

Conochitina micracantha sub. sp. *wesenbergensis* is characteristic of Wesenberg stage Baltic limestone. If the hystrichosphere species are also taken into account, it is evident that the grey limestone erratics from the Bothnian Sea, here denoted as Baltic limestone, are younger than the greenish limestones and were probably formed during the early stages of the Upper Ordovician (Wesenberger Stufe, Table I, Thorslund 1960).

As pointed out by Eisenack, there is considerable disagreement about the use of the term Baltic limestone since in the literature this term has been applied to limestones both older older and younger than the Wesenberger stage. The further use of microfossils in the subdivision of the microfossil-poor Middle Ordovician Baltic Limestone will probably shed new light on this question.

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Plate I

1. *Acanthodiacrodium bimorphispinae* n. spec.
2. *Aremoricanium* sp.
3. *Baltisphaeridium brevifilicum*
4. *B. cognitum*
5. *B. echinatum*
6. *B. globosum* n. spec.
7. *B. hirsutoides*
8. *B. lancettispinae*
9. *B. latiradiatum*
10. *B. longispinosum longispinosum*
11. *B. mochtiensis*
12. *B. nannium*

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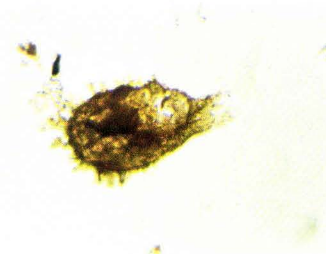
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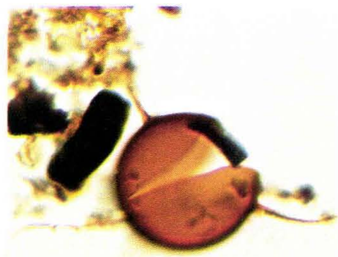
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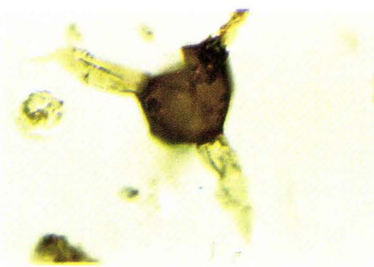
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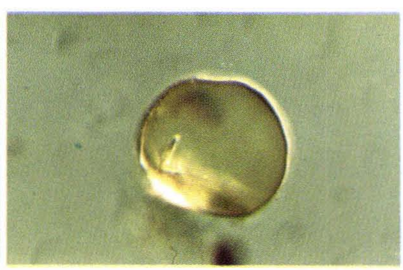
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Plate II

1. *Baltisphaeridium pachycanthum*
2. *B. pauciverrucosum*
3. *B. plicatispinae*
4. *B. spinigerum*
5. *B. verrucatum*
6. *B.* sp. 1
7. *Electoriskos* aff. *pagonius*
8. *Goniosphaeridium polugonale*
9. *G. polygonale* f. *polyantha*
10. *Granomarginata* sp. 1
11. *Hystrichosphaeridium anthophorum archaeforme*
12. *Leiosphaeridia laevigata*

Bar equals 20 μ


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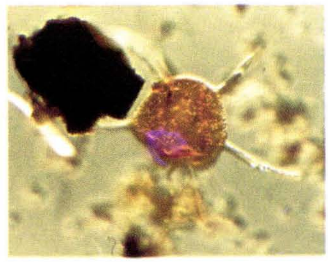
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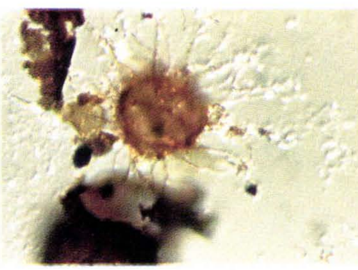
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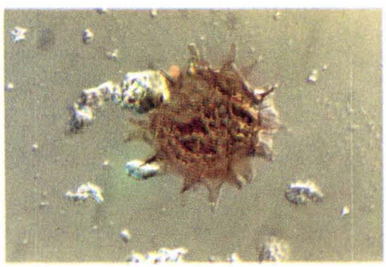
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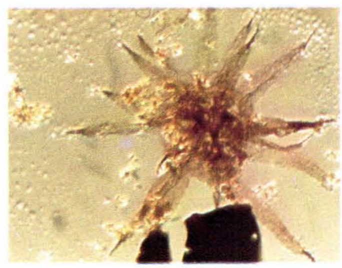
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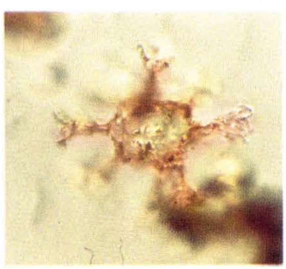
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Plate III

1. *Leiovalia similis*
2. *L. similis* f. *rugosa* n. fo.
3. *Lophosphaeridium* cf. *citripeltatum*
4. *L.* aff. *parveratum*
5. *Micrhystridium* cf. *acum*
6. *M.* cf. *campoae*
7. *M.* cf. *perveroquesi*
8. *Multiplicisphaeridium belmontiforme* n. spec.
9. *M. bifurcatum*
10. *M. irregulare*
11. *M. sylense*
12. *M.* sp. 1

Bar equals 20 μ
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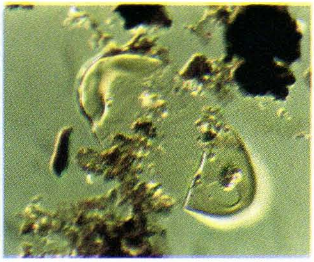
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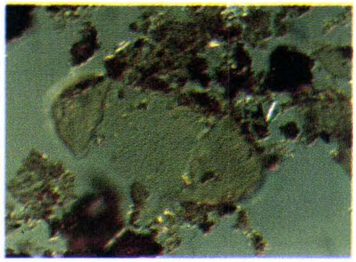
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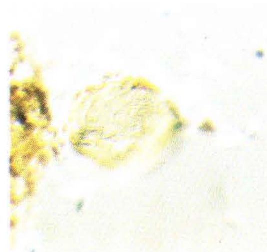
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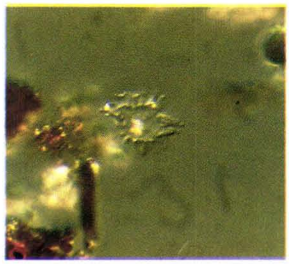
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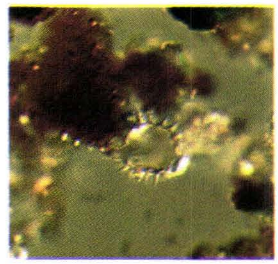
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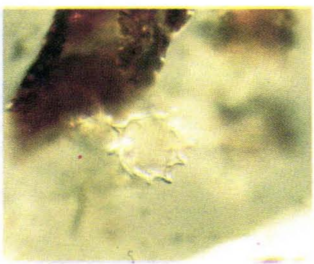
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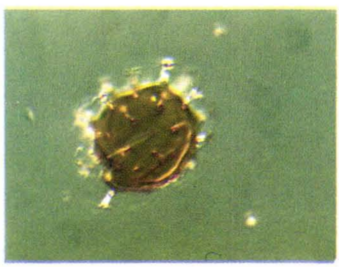
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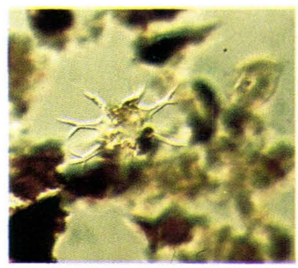
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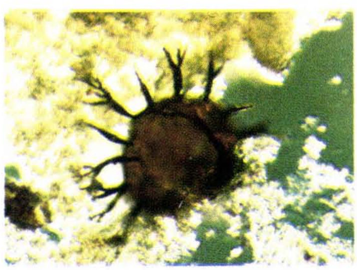
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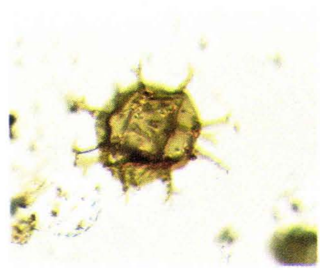
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Plate IV

1. *Multiplicisphaeridium* sp. 2
2. *Orthosphaeridium chondrododora*
3. *O. rectangulare*
4. *Peteinosphaeridium breviradiatum*
5. *P.* cf. *heteromorpicum*
6. *P. majorfurcatum*
7. *Pterocystidiopsis elegans* n. spec.
8. *P. bottnica* n. spec.
9. *Symplassosphaeridium* aff. *incrustatum*
10. *Tasmanites minutus*
11. *Veryhachium trispinosum*
12. *Gloecapsomorpha* sp.

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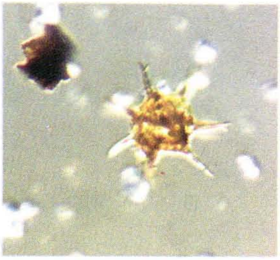

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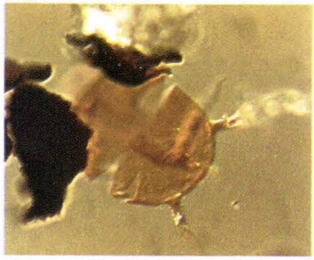

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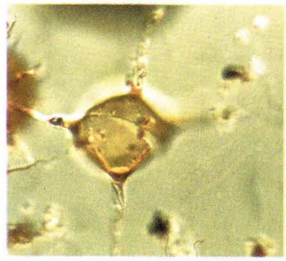

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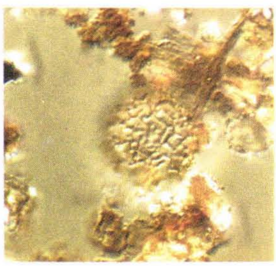

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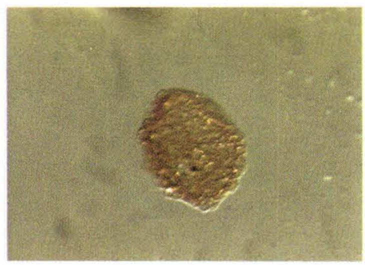

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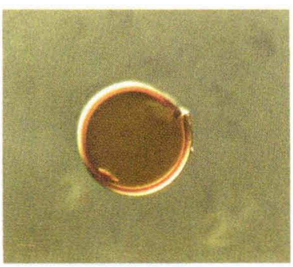

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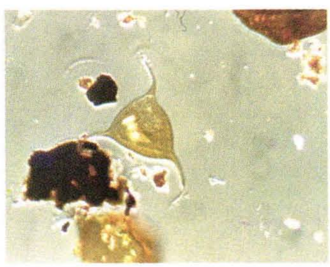

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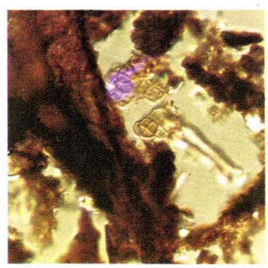

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ERRATA

p. 8, line 34, p. 10, fig. 1 and plate I: 1 : *A. bimorphispinae* n. sp., shall be *A. heterospinosum* n. sp.

p. 16, line 38, p. 19, fig. 10: *B. ternata* nov. comp., shall be *B. ternatum* nov. comb.

p. 28, line 13, p. 30, fig. 27: *M. belmontiformis* n. spec., shall be *M. belmontiforme* n. spec.

p. 29, line 19: *M. sylensis* n. sp., shall be *M. sylense* n. sp.

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