ORDOVICIAN CHITINOZOA FROM SHROPSHIRE

by W. A. M. JENKINS

ABSTRACT. Chitinozoan assemblages from the Llanvirnian, Llandeilian, and Caradocian sediments of the Shelve and Caradoc districts of Shropshire have been examined. Thirty-one species belonging to twelve genera are recorded and described; of these, nineteen species and one genus (*Siphonochitina*) are new. The genera *Acanthochitina* and *Hercochitina* are emended. The locations and lithologies of the samples are briefly described and the techniques used in preparing the chitinozoans for microscopic examination are outlined; it has been determined from an examination of material in thin section that these techniques do not appreciably affect the chitinozoans. The character of the chitinozoan fauna in Shropshire is traced from the base of the Llanvirnian to the top of the Caradocian, and the Ordovician faunas of Shropshire, the Baltic, and North Africa are compared. It is concluded that the British fauna, whilst having a distinct character of its own, compares fairly closely with that of the Baltic, but only remotely with that of North Africa. Other acid-resistant microfossils accompanying the chitinozoans are described briefly.

THE Chitinozoa are an extinct group of microscopic marine organisms having hollow organic-walled tests, which are radially symmetrical about a central longitudinal axis and closed at one end. They vary greatly in shape and the test wall may be smooth or furnished with various types of processes. Little is known about the detailed structure of the test, but its original chemical composition, though not certainly known, was probably pseudochitinous (Collinson and Schwalb 1955). Chitinozoan tests may occur singly or they may be joined together in various ways to form chains; rarely, tests are found loosely attached in an organic cocoon (Kozłowski 1963). Single tests are thought to result from the dissociation of members of a chain or the break up of a cocoon. The systematic position of the Chitinozoa is not known, yet they are occasionally referred to the Protozoa. They have certain characteristics in common with the flagellates and others in common with the rhizopods, but they do not fit perfectly into either class of protozoans (Eisenack 1931, 1932; Collinson and Schwalb 1955). Kozłowski (1963) maintains that the Chitinozoa are not protozoans but are remotely analogous with the eggs and egg capsules of existing metazoans. The present consensus of opinion appears to be that these organisms were benthonic; it is my own belief that for part of their lives some forms (e.g. *Cyathochitina kuckersiana* (Eisenack 1934), *Lagenochitina baltica* Eisenack 1931 and *L. shelvensis* sp. nov.) were benthonic and attached to the substrate, and later became free living. The group was already well-established in Arenig times, and flourished during the Ordovician and Silurian; it survived into the late Devonian and is of wide geographical distribution.

Several palaeontologists (Lange 1952, Collinson and Schwalb 1955, Collinson and Scott 1958, Taugourdeau and Jekhowsky 1960, Jodry and Campau 1961) have expressed the belief that this little-known group of microfossils promises to be of considerable value in the correlation of Palaeozoic rocks. Among their reasons for this belief they state that: (1) Chitinozoans have a wide geographical distribution; Taugourdeau and Jekhowsky (1960) claim that in the Sahara, zones based upon chitinozoans persist for over a thousand kilometres. (2) Many species have short vertical ranges. (3) They are virtually indestructible, so they are preserved in great numbers and they can be processed easily, being recoverable from strong acid residues. (4) It has been established

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that chitinozoan species in the Devonian of North America have considerable lateral distribution independent of facies changes (Collinson and Scott 1958, p. 5).

Previous work on chitinozoans from Britain is limited to two short publications: Lewis (1940) recorded two species in thin sections of the Upper Caradocian Phosphate Deposits of Montgomeryshire, and Rhodes (1961) described an assemblage from the Nod Glas Formation of Merioneth. The aims of the present paper are to describe assemblages of British Ordovician chitinozoans, to compare them with Ordovician assemblages from the Baltic and North Africa, and to discuss the stratigraphical distribution of forms encountered in the Llanvirnian and Llandeilian sediments of the Shelve area and in the Caradocian sediments of the Caradoc area. Arenig and Caradocian chitinozoans from the Shelve area will be described in a subsequent publication. It is hoped that this work will form the basis for further research on British chitinozoans, particularly within the Welsh Borderland.

To assess the stratigraphical value of these microfossils requires a systematic study of their vertical distribution within a reasonably restricted area, preferably where the age of the rock is known from other fossil evidence. The successions in the Shelve Inlier and the Caradoc area appear to be most suitable for such a study because they are considered to be fairly complete, are exposed within a small area, and have experienced relatively little metamorphism; the geology of both areas has received much attention from palaeontologists and stratigraphers and is sufficiently well understood and documented to provide fairly precisely dated rock samples.

Location of samples. In the Shelve area, samples were collected from exposures described and dated by Whittard (1955); recently, in correspondence, Professor Whittard has been able to precisely date many of them. Samples from the Caradoc area were collected from exposures described and dated by Bancroft (1949), Whittard (Geol. Ass. Guide No. 27), and Dean (1958). Owing to the absence of continuous exposures through most formations, samples were not collected at regular stratigraphical intervals and there is uncertainty, particularly in the Shelve succession, about the precise stratigraphical positions of some samples. However, there is no doubt about the relative positions of the samples, and the correct chronological order of the chitinozoan assemblages obtained from them is known.

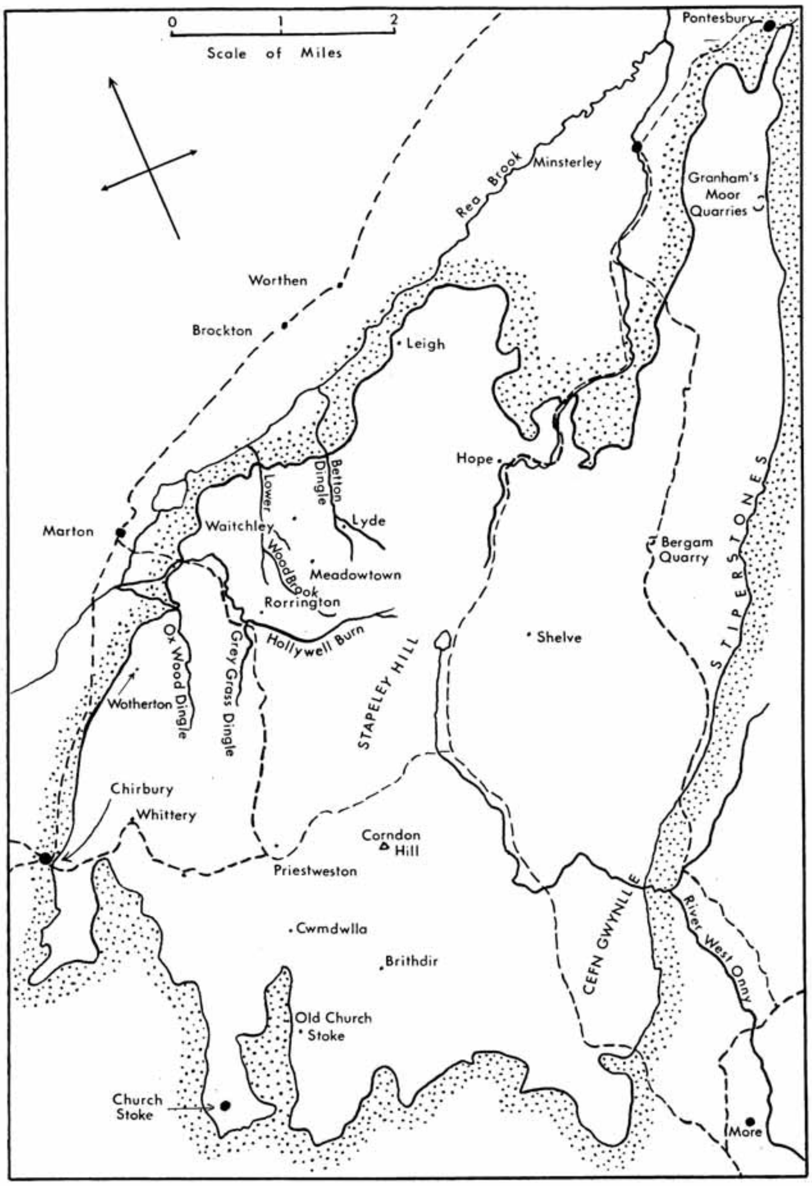
Shelve area. Hope Shales. S25 Massive rusty-weathering black shale from base of Hope Shales, Hope Dingle, behind Hope Cottage and 23 ft. upstream from stone and brick outhouse behind cottage; G.R. 33/345014. S24 As for S25, but stratigraphically higher and 12 ft. further upstream. S21 As for S25, but stratigraphically above S24 and 25 ft. upstream from S25. S22 'Chinastone Ash', half-inch stratigraphically above S21. S23 Olive-green soft shale, half-inch band in 'Chinastone Ash', 6 in. stratigraphically above S21. S26 'Chinastone Ash', 33 ft. upstream from S25 and stratigraphically above S23. S27 'Chinastone Ash', about 40 yd. along road to Lord's Stone from main road through Hope village, in north-east bank of road, 28 in. stratigraphically above lowest horizon in small anticline; G.R. 33/342015. S28 Black shale, 8 in. stratigraphically above S27. S29 Greenish-black shale, near top of Hope Shales, from roadside excavation in Lordstone Lane (Leigh), 230 yd. south-east of Blue Barn; G.R. 33/335025. S36 Blue-black rusty-weathering fissile shale, about 500 ft. stratigraphically below summit of Hope Shales, behind Brithdir Farm, 1 mile east-north-east of Old Church Stoke; G.R. 32/301953.

Stapeley Shales. S37 Yellow-brown crumbly gritty rock from Passage Beds between Stapeley Shales and Weston Beds, collected about 210 yd. south-south-east of Cwmdwla Farm; on lithological grounds Whittard is inclined to include these beds in the Stapeley Shales; G.R. 32/291962.

Weston Beds. S1 Brown weathered micaceous shale, about 200 ft. stratigraphically below top of Weston Beds, in angle between the two streams east of Lyde; G.R. 33/318015.

Betton Beds. S2 Black flags, 200 ft. stratigraphically above base of Betton Beds, in Betton Dingle, about 10 yd. downstream from road, Lyde; G.R. 33/316017.

Meadowtown Beds. S7 Black micaceous hard shale, 12 ft. stratigraphically below S8. S8 Black



TEXT-FIG. 1. Map of the Shelve area showing the Ordovician outcrop (enclosed by stippling) and some of the places referred to in the descriptions of the sample localities.

micaceous hard shale, about 130 ft. stratigraphically above base of Meadowtown Beds, high horizon in Meadowtown Quarry; G.R. 33/311011. S3 Massive blue-grey limestone, Middle Meadowtown Beds, in lane from Meadowtown to Waitchley, about 140 yd. due north of chapel; G.R. 33/311014. S4 Massive highly calcareous blue-grey rock, Middle Meadowtown Beds, located 22 yd. north of and stratigraphically above S3. S5 Highly calcareous black and brown thinly laminated flagstone, 2 ft. stratigraphically above S4. S6 Decalcified rusty-weathering flagstone, 520 ft. stratigraphically below top of Meadowtown Beds, in small excavation in corner of field, alongside cart-track from Meadowtown to Waitchley; G.R. 33/311015. S11 Dark olive shale, 290 ft. stratigraphically below top of Meadowtown Beds, 12 yd. east of where Rorrington–Meadowtown road crosses Lower Wood Brook, 6 ft. above road in south bank, in small excavation; G.R. 33/307009.

Caradoc area. Coston Beds. C16 Shelly sandy limestone, from lenticular shell-bed containing abundant *Harknessella*, exposed in quarry in New Plantation on north-west side of Lodge Hill, Ruckley; G.R. 32/516994. The Costonian limestones of the north containing *Harknessella* are considered by Dean (1958, p. 200) to be equivalent in age to the *Harknessella* Beds and *Costonia ultima* Beds of the south, the strata containing *Harknessella* being diachronic; the sample is probably Middle or Upper Costonian in age.

Smeathen Wood Beds. C13 Greenish-grey sandy mudstone, 10–25 ft. stratigraphically above base of Harnagian, in old cart track, 60 yd. north of extreme south-east corner of Smeathen Wood, Horderley; G.R. 32/406855.

Glenburrell Beds. C11 Olive-green shaley mudstone with concretions, basal mudstones of Glenburrell Beds, exposed by north side of cartway, north-west of Glenburrell and about 75 ft. north-east of stackyard gate; G.R. 32/412862.

Upper Horderley Sandstone. C10/c Olive-green to yellow-brown, purple-spotted sandstone, 10 ft. stratigraphically below C10/b. C10/a As C10/c, but 6 ft. stratigraphically below C10/b. C10/b Decalcified green shelly sandstone, top Horderley Sandstone, a few feet below Alternata Limestone phase, from highest horizon in quarry by side of New House, Horderley; G.R. 32/417859.

Alternata Limestone. C9 Greenish shelly sandstone, in side of old railway cutting, a few yards south-east of foot bridge over river, south of New House, Horderley; G.R. 32/418857.

Lower Cheney Longville Flags. C8/b Partly decalcified, highly fossiliferous shelly green sandstone, 14 ft. stratigraphically below C8/a. C8/c Laminated green flaggy sandstone, 6 ft. stratigraphically below C8/a. C8/a Slightly calcareous fine green sandstone, from succession of thin-bedded flags, sandy shales, and greenish sandstone; 5 ft. stratigraphically below highest horizon exposed above small pool at north-east corner of Burrell's Coppice, due north of Cheney Longville; G.R. 32/421855.

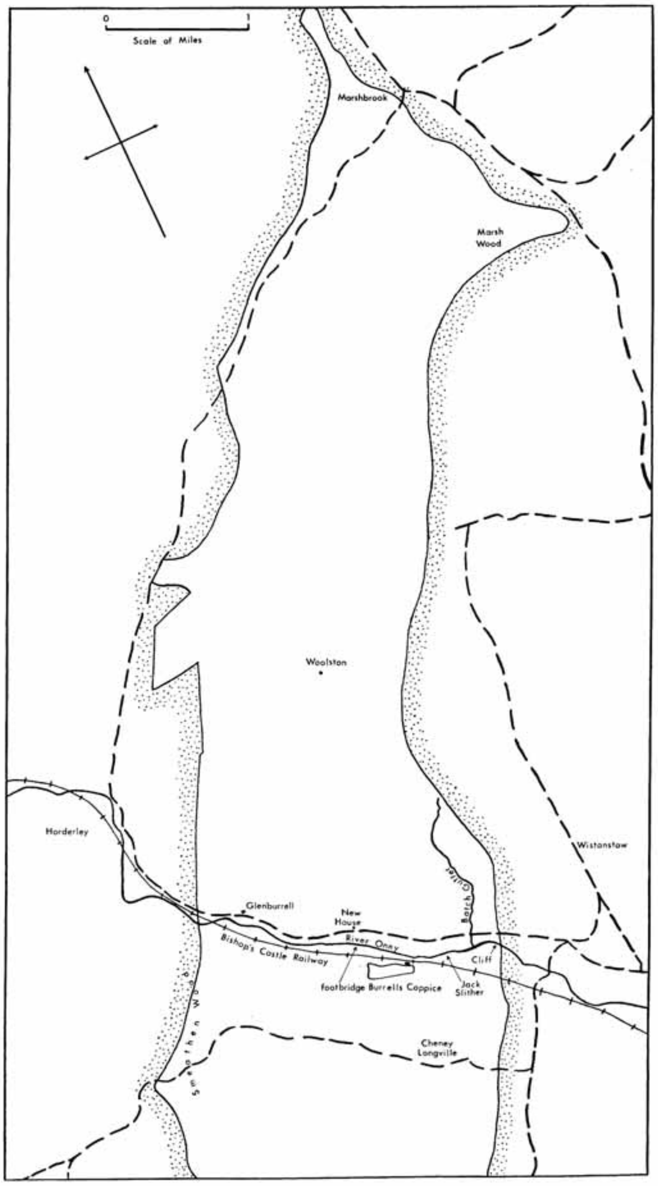
Upper Cheney Longville Flags. C14/b Brownish flaggy siltstone, 18 in. below C14/a. C14/a Highly fossiliferous band within massive olive-green siltstone, Middle Marshbrookian, 7–8 ft. above lowest horizon exposed in Marsh Wood Quarry, about half a mile south of Marshbrook railway station; G.R. 32/443891.

Acton Scott Beds. C6 Olive-green sandy mudstone, basal Actonian, from below tree above Jack Slither, Onny River, Horderley; locality P7, Bancroft 1949; G.R. 32/422854. C4 Highly calcareous grey rubbly micaceous mudstone, containing numerous trilobites, topmost Actonian, from low down in north bank of River Onny, about 85 ft. east of Batch Gutter; locality Py3, Bancroft 1949; G.R. 32/424854.

Onnia Beds. Samples C2/a–d are calcareous blue-grey sandy mudstones. C2/a From low ledge of calcareous mudstone in Onny River about 120 ft. west of 'Cliff Section', Horderley, about 100 ft. stratigraphically above C4; locality Pc, Bancroft 1949; G.R. 32/424854. C2/b 45 ft. downstream from C2/a and stratigraphically 15 ft. higher. C2/c 66 ft. downstream from C2/a and stratigraphically 22 ft. higher. C2/d 110 ft. downstream from C2/a, stratigraphically 38 ft. above C2/a and 15 ft. below C1/a. Samples C1/a–h are orange- to buff-weathering shaley mudstones at top of *Onnia* Beds; they lie 3 ft. (C1/a), 5 ft. (C1/d), 6 ft. (C1/b), 9 ft. (C1/c), 15 ft. (C1/e), 20 ft. (C1/f), 25 ft. (C1/g), and 30 ft. (C1/h) stratigraphically above the lowest horizon exposed in 'Cliff Section', Horderley; G.R. 32/425854.

TECHNIQUES OF PREPARATION AND STUDY

About 250 gm. of sediment were fragmented to about 1 cm. particle size. This size was judged to be the best compromise, smaller fragments yielding more broken chitinozoans, larger ones taking too



TEXT-FIG. 2. Map of part of the Caradoc area showing the Ordovician outcrop (enclosed by stippling) and some of the places referred to in the descriptions of the sample localities.

long to break down in the acid treatment. The fine powder resulting from the fragmentation was discarded since any chitinozoans in it would likely be broken. Dilute hydrochloric acid was used to dissolve the calcareous minerals, 40 per cent. hot (70° C) hydrofluoric acid to disaggregate and remove the clay minerals and quartz; the former was used only if the rock was calcareous. After acid treatment the residue consists mainly of very small particles and the relatively large chitinozoans can be further concentrated by sieving. The sieve (aperture 53 μ) containing the residue was immersed in water to within $\frac{1}{4}$ in. of its top. By gently moving the sieve up and down in the water, keeping the mesh below the water-surface and the top of the sieve above it, the coarser material (including the chitinozoans) was retained while the finer material passed through the mesh into the water beyond. This operation was most successful when a small quantity of the residue was sieved at a time. Several changes of clean water were used, the procedure being continued until no more material passed through the sieve.

Bleaching. During initial experiments to find the most satisfactory method of bleaching chitinozoans, several bleaching agents were used (Schulze's solution, fuming nitric acid, concentrated nitric acid, sodium hypochlorite, and hydrogen peroxide). The experiments indicated that successful bleaching depended not so much on the reagent used but on the state of preservation of the chitinozoans. If the latter were strongly carbonized, as was commonly the case, none of the reagents would bleach them and prolonged treatment served only to break them up; if they were relatively uncarbonized any of the reagents would bleach them. However, sodium hypochlorite is much easier to control than acid reagents, since it can be used under the microscope; its action can be observed and stopped immediately the specimens attain the desired clarity. The most satisfactory method of bleaching the chitinozoans was as follows. A fraction of the residue (roughly a fifth) was transferred in water to a white-bottomed Petri-dish (3·5 in. in diameter, 0·5 in. in depth). When the residue had settled on the floor of the dish the water-level was adjusted to a depth of $\frac{1}{8}$ in. A few drops of sodium hypochlorite solution were then mixed thoroughly into the water and the dish was placed under the microscope. The progress of the reaction was closely observed, and when the chitinozoans were sufficiently translucent the bleaching was stopped by adding an excess of sodium sulphite solution; use of a reducing agent in this manner enables the bleaching process to be precisely controlled even in concentrated solutions of sodium hypochlorite. The residue was then washed by decantation with distilled water until a drop of liquid, taken from the dish after the residue had settled, left no trace of a precipitate when evaporated on a glass slide.

Mounting. The residue, now consisting of chitinozoans, other organic remains, and some insoluble mineral material, was spread thinly over the bottom of a white-bottomed Petri-dish in about $\frac{1}{8}$ in. depth of water and searched systematically under a binocular microscope. Each specimen required for mounting was transferred in a pipette to a second white-bottomed Petri-dish containing distilled water; here, individuals belonging to the same, or apparently similar, species were grouped together and then, in turn, each group was transferred to a watch-glass containing a 2 per cent. aqueous solution of cellosize; only one group occupied this vessel at a time. From here, each specimen was taken up in cellosize solution into a pipette and deposited in a small drop of the solution on a glass coverslip ($2 \times \frac{7}{8}$ in.). Up to thirty such drops, each containing a single specimen, were arranged in rows on each coverslip, which was then placed on a hot-plate (55° C.) for one hour. When dry, each drop of cellosize solution left a thin, tough, colourless transparent film (refractive index 1·50–1·51) adhering to the coverslip; this film holds the specimen against the coverslip and so facilitates its detailed examination at high magnification. The coverslip was then inverted and carefully lowered on to a layer of liquid pre-cooked Canada balsam on a glass slide, which rested on a hot-plate at 120° C.; the balsam had been cooked at this temperature for one to two minutes until it would immediately harden when cooled. These two-layer permanent mounts were immediately ready for filing or use. Ideally, they contained undamaged chitinozoans lying in a single focal plane and quite free of other residual material.

Slide collection. When mounted, each chitinozoan was ringed and given a reference number (e.g. C14/61/1/G) comprising the appropriate sample number (C14), two numbers indicating a particular type of chitinozoan (61/1), and a letter indicating a particular specimen (G). Mounted specimens were examined under a compound microscope in transmitted and oblique reflected light. All the preparations will be housed in the Micropalaeontology Laboratory, Department of Geology, University of Sheffield.

The relative abundance of each species or form was roughly assessed while the microfossils were being picked from the residue. No attempt was made to count the actual numbers of each species or form since generally much of the chitinozoan material consisted of broken, often unidentifiable, fragments. However, it was possible to approximately determine the absolute concentration of chitinozoans and some associated microfossils in two samples (C1/a and S36) where they were exceptionally well-preserved. For both samples, three completely disaggregated residues were prepared by separately digesting three clean fragments (each of known dry-weight) in hydrofluoric acid. The chitinozoans and larger types of associated microfossils in each residue were counted. In C1/a the concentrations were, chitinozoans 156–175 per gm., scolecodonts 5–9 per gm., graptolite siculae 24–39 per gm.; in S36, chitinozoans 32–47 per gm., graptolite siculae 0–2 per gm. Both samples are considered to contain an abundance of chitinozoans and, of all samples examined, C1/a is believed to be among the richest in chitinozoans and graptolite siculae.

Appearance of samples in thin section. Two samples known to contain abundant chitinozoans and other microfossils were examined in thin section; samples C11 and C1/a were chosen for sectioning because of their pale colour, against which the dark chitinozoans stood out clearly. No microfossil material was recognized in sections cut normal to the bedding. In sections cut parallel with the bedding, chitinozoans were seen to lie with their longer axes always in the plane of the section; they and the scolecodonts and graptolite siculae were clearly distinguishable against the pale green, orange, and brownish mineral material. It has been determined from the examination of the specimens in thin section that the techniques used in preparing the microfossils do not (except for bleaching) appreciably alter the chitinozoans.

SYSTEMATIC DESCRIPTIONS

Classification. The straightforward morphological system of classification established by Eisenack is adopted here in preference to the system proposed by Jansonius (1964), which I find difficult to apply to the British material. In the older system chitinozoans are grouped according to their more obvious morphological features, while in the newer system they are, to a considerable extent, grouped into families and genera according to the number of layers in the test wall and the structure of the prosome. In the present material it has generally proved impossible to determine the structure of the test wall, and frequently the prosome is not even discernible. Jansonius's system of classification does not appear to be an improvement on the older system and is considerably less easy to apply. Some of Jansonius's statements, particularly those concerning the structure of the test wall, are not supported by satisfactory explanations or by photographs bearing out his interpretations. Furthermore, it should be noted that the structure of the test wall and the prosome has been interpreted and satisfactorily demonstrated in only a few species.

Terminology. The descriptive terminology proposed by Combaz and Poumot (1962), and by the sub-committee for chitinozoans of the International Committee of the Microflora of the Palaeozoic is adopted in this paper. Until 1955 the terms 'distal' and 'proximal' were applied to the closed and open ends of the test, respectively. Then Collinson and Schwalb (1955) abandoned them, claiming they had been applied in a sense contrary to general usage, and in place of them proposed 'aboral' and 'oral', respectively. The latter terms are used here as proposed by Collinson and Schwalb, while 'distal' and 'proximal' are reintroduced for the restricted purpose of facilitating the description of ornamental and structural processes; these are considered to join the test proximally and to terminate distally. When the neck and siphon are cylindrical their diameters are each expressed in a single measurement. When they are flaring, their diameters are each expressed by two values, the first (left of the arrow) indicating the diameter closest to the chamber, the second indicating the terminal diameter of the part concerned. In assemblages from Shropshire the relative abundance of a species is expressed in one of the following terms: rare (less than one example per 1,000 chitinozoans), uncommon (1–10 per 1,000), common (10–50 per 1,000), very common (50–100 per 1,000) and abundant (more than 100 per 1,000).

Order CHITINOZOA Eisenack 1931
Genus ACANTHOCHITINA Eisenack 1931 emend.

Type species. A. barbata Eisenack 1931, Ordovician, Baltic.

Emended diagnosis. Variable flask-shaped chitinozoans with ornament of uniformly distributed processes standing normal to test wall. At a uniform distance from the test wall each process divides into a number of arms which lie roughly parallel to the test wall. Arms of adjacent processes may unite to form a more or less complete, raised reticulum. Basal margin may bear more strongly developed processes which can be simple or branching. A membrane may unite marginal processes.

Remarks. This genus, based on one individual and a fragment, was erected by Eisenack in 1931. It was not recorded again until Schallreuter (1963) found a single specimen, which he named *A. secunda*, in Middle Ordovician drift material from the island of Hiddensee. Jansonius (1964) reported 'specimens very close to the type species' from the Middle Ordovician of Anticosti Island, Quebec. The genus is abundant in the upper Caradocian of Shropshire. In all known specimens the maximum diameter lies about half-way along the chamber; the base is commonly flat, occasionally slightly concave or slightly convex.

Acanthochitina barbata Eisenack 1931 emend.

Plate 68, figs. 1–9; text-fig. 3

1931 *Acanthochitina barbata* Eisenack, p. 82, pl. 1, figs. 10 (holotype), 11.

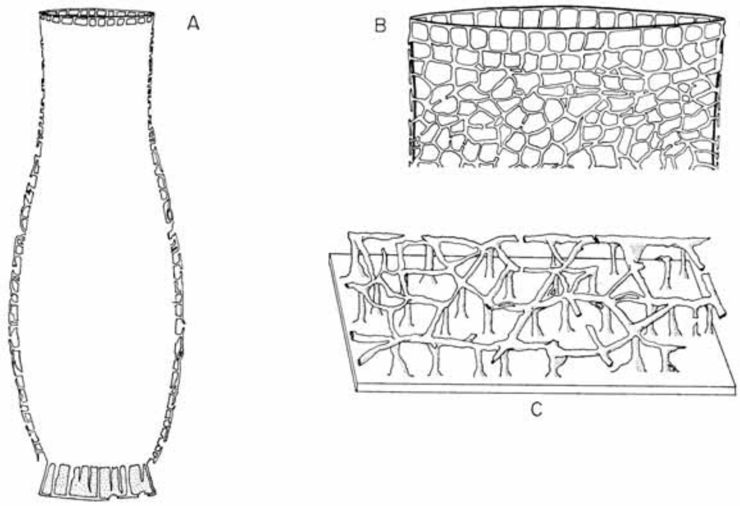
Emended diagnosis. Elongate, swollen cylindrical chamber, generally greater than two-thirds total length; maximum diameter midway along chamber, 35–60 per cent. chamber length; base flat or almost so. Neck cylindrical, about two-thirds maximum diameter in width. Ornament of many closely spaced short processes; arms usually united, forming a fairly complete raised reticulum close to the test wall. Processes on basal margin relatively large, connected by a very thin translucent membrane.

Dimensions in microns. (25 specimens measured.)

	Total length	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*
Range:	300–485	125–150	75–96	77–107
Mean:	408	134	89	94

Since the chamber and neck often merge gradually, their lengths cannot always be measured precisely

Description. The base appears to be smooth, but in lateral view is usually obscured by the ornament of the basal margin. The collarette is more translucent than the neck and is occasionally slightly flaring. The aperture is straight, but only rarely preserved intact. Processes on the chamber, except those on the basal margin, are very uniform in size (text-fig. 3 A, C) and stand up to 12 μ in height (about 20 μ in the holotype). Processes on the oral tube become steadily smaller orally, and, near the aperture, the arms of the



TEXT-FIG. 3. *Acanthochitina barbata* Eisenack 1931 emend. A, Diagrammatic lateral view of test showing ornament only in profile; the membrane connecting the processes on the basal margin is stippled, $\times$190. B, Detail of oral tube immediately below aperture showing the openings of the reticulum arranged in transverse rows, $\times$550. C, Reconstruction of the ornament on the chamber wall in full relief, $\times$1,200.

processes appear contiguous with the test wall. The reticulum is often seen clearly near the aperture (text-fig. 3B), where the test wall is most translucent; immediately below the aperture, the openings of the reticulum are roughly arranged in rows parallel with the transverse axis of the test. Processes on the basal margin are stouter than those

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EXPLANATION OF PLATE 68

Figs. 1–9. *Acanthochitina barbata* Eisenack emend. 1, C1/51/2/Z, short example with strongly developed ornament and scarcely distinguishable neck, $\times$190. 2, C1/51/2/A, typical example, $\times$190. 3, C1/51/2/F, aboral polar view of isolated base showing strongly developed processes on basal margin, $\times$400. 4, C1/51/2/B, $\times$190. 5, C1/51/2/D, $\times$190. 6, C1/51/2/L, ornamental elements, $\times$625. 7, C1/51/2/V, ornamental elements, $\times$280. 8, C1/51/2/J, oral end of oral tube, illustrating the reticulum and the arrangement of the openings roughly into rows parallel with the transverse axis of the test, $\times$370. 9, C1/51/2/U, aboral end of a specimen having particularly strongly developed ornamental elements, $\times$275.

Figs. 10–11. *Ancyrochitina onniensis* sp. nov. 10, C1/53/1/C, $\times$400. 11, C1/53/1/A, holotype, $\times$400.

elsewhere, and up to 30 μ in height. The membrane connecting them is always thin, and generally damaged or missing. It may be compared, at least superficially, with the carinae of other forms.

Remarks. Jansonius (1964) reports finding specimens of *Acanthochitina* 'very close to the type species' in Middle Ordovician strata of Anticosti Island. He states that their 'ornaments consist of a mat of intertwined and intergrown spines forming a rough cocoon around the vesicle which constitutes the outer layer of the cuticle'. However, I have been unable to distinguish two wall layers in British specimens of *A. barbata* Eisenack, and am not convinced that the ornament in this species constitutes a distinct structural layer; furthermore, I believe that the term 'cocoon' should be reserved for the sac-like structures described by Kozłowski (1963).

Comparison. Only two species of *Acanthochitina* have been described, *A. barbata* and *A. secunda* Schallreuter 1963. The former was based on a broken specimen and a fragment, the latter on one specimen. I consider that the British specimens belong to *A. barbata* and that the holotype of this species (Eisenack 1931, pl. 1, fig. 10) has lost its oral tube. The only certain difference between the holotype and the British specimens lies in the height of the processes, and this alone is not sufficient, at present, to justify the erection of a new species for the British forms. It is possible that the few very short elevations (1 to 2 μ high) on the test of *A. secunda* are the remains of an ornament which has been largely lost; many British specimens, having lost much or all of their ornament, closely resemble *A. secunda*. Moreover, it is not uncommon in British examples of *A. barbata* for the processes on the basal margin to be unbranched as they are in *A. secunda* and for the membrane they support to have been lost. Further, if one accepts that the holotype of *A. barbata* has lost its oral tube, then the position of the maximum diameter in *A. barbata* and *A. secunda* is roughly the same and cannot be used to distinguish the two species.

The ornament of *Stephanochitina africana* Grignani and Mantovani 1964 resembles that of *Acanthochitina barbata* in so far as the processes are distributed uniformly, and adjacent processes, discrete for most of their lengths, are joined at their distal ends to form a raised reticulum ('treillis' of Grignani and Mantovani); in other respects the two species are distinct.

Material. Three thousand to four thousand single tests.

Occurrence. Onnia Beds: C2/d (very common), C1/a–h (abundant). The type material is from the Lyckholm Beds, F_1, of the Baltic.

Genus ANCYROCHITINA Eisenack 1955*a*

Type species. A. ancyrea (Eisenack 1931), Silurian, Baltic.

Ancyrochitina onniensis sp. nov.

Plate 68, figs. 10–11; Plate 69, figs. 1–2; text-fig. 4

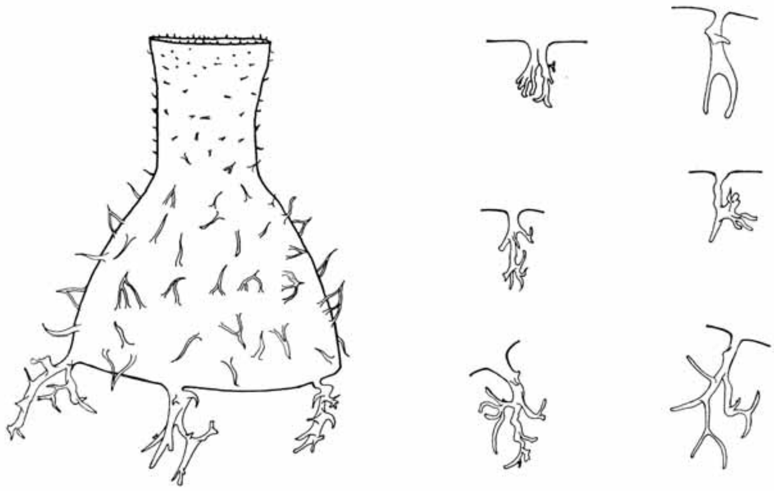
Holotype. Plate 68, fig. 11. Specimen C1/53/1/A; *Onnia* Beds, sample C1/a.

Diagnosis. Small cylindroconical test. Chamber half to two-thirds total length; maximum diameter considerably greater than chamber length; base flat or slightly convex.

Commonly three to six stout branching appendices, about half maximum diameter in length; one to three (rarely four) orders of branching into two to five generally unequal limbs. Neck diameter about half maximum diameter; collarette flaring, with fringe of fine terminal hairs. Small simple spines and wishbone spines thinly distributed over test, absent on base and basal margin.

Dimensions in microns. (25 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Appendix length*
Holotype:	108	58	64	50	27 → 38	up to 30
Range:	77–115	46–62	62–75	31–50	24–33 → 38–45	up to 35
Mean:	92	54	68	38	29 → 32	—



TEXT-FIG. 4. *Ancyrochitina onniensis* sp. nov. Lateral view of test (left) and six drawings illustrating variation in the shape and branching pattern of the appendices, ×620.

Description. The flanks of the short broad chamber either taper uniformly or are somewhat swollen and associated with a more or less pronounced shoulder. The maximum diameter is 110–160 per cent. of the chamber length. The appendices appear to be hollow or filled with a granular substance and, where they branch, their courses often alter sharply. Complete appendices are generally 20–30 μ in length. The neck and chamber are distinct and the apical angle is at least 60°. Generally the neck is cylindrical, occasionally flaring, but never tapering. The proportion of simple to wishbone spines is variable but in most specimens the majority are simple. Their distribution on the neck is slightly less dense than on the chamber. Both types of spine measure up to 11 μ in length. Spines which have a single proximal base and multiple distal extremities are unknown in *A. onniensis* sp. nov.

Comparison. Several similar species from the Siluro-Devonian of North Africa differ from *A. onniensis* as follows. *A. tomentosa* Taugourdeau and Jekhowsky 1960 lacks wishbone spines, the ornament being of strong flexible spines, sometimes with multiple distal extremities. In *A. pilosa* Taugourdeau and Jekhowsky 1960 the appendices are simple, or forked only near their distal ends, and the upper part of the neck is strongly ornamented. *A. tumida* Taugourdeau and Jekhowsky 1960 has a very short neck, and *A. multiramosa* Taugourdeau and Jekhowsky 1960 and *A. saharica* Taugourdeau 1962 have between twelve and twenty appendices.

Material. Approximately six hundred single tests.

Occurrence. *Onnia* Beds: C2/b (common), C2/c (abundant), C2/d (very common), and C1/a–h (abundant).

Ancyrochitina alaticornis sp. nov.

Plate 69, figs. 3–13; text-fig. 5

Holotype. Plate 69, fig. 3. Specimen C9/61/1/A; Alternata Limestone, sample C9.

Diagnosis. Elongate bell-shaped chamber, slightly more than half total length; maximum diameter at base, about two-thirds chamber length; base flat, margin sharply rounded. Three to eight curved wing- or blade-like appendices (flattened vertically), up to 60 per cent. maximum diameter in length; aboral edge of appendix thick, entire; oral edge attenuated, irregular in outline, differentiated into secondary processes of variable shape, size, and disposition. Neck cylindrical or slightly flaring, about half maximum diameter in width. Collarette short, strongly flaring, with fringe of fine terminal hairs. Wall generally smooth; rarely with minute processes on neck.

Dimensions in microns. (35 specimens measured.)

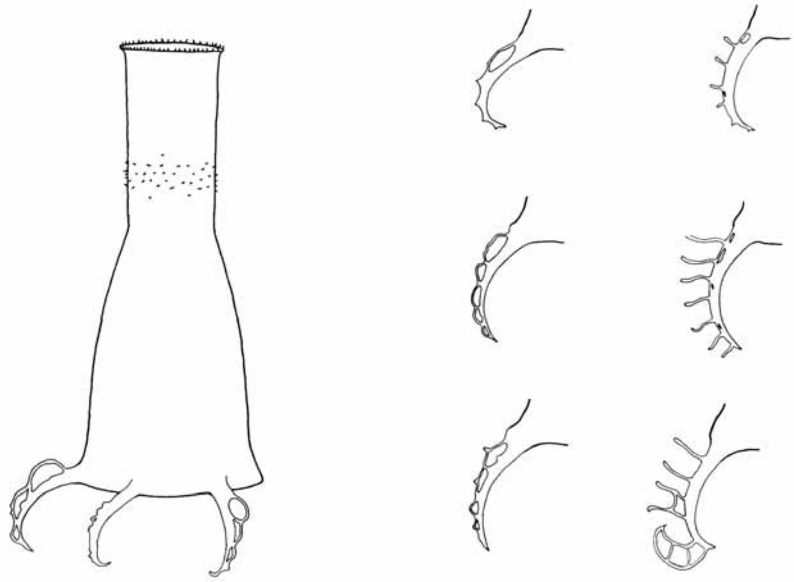
	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Neck diameter*	*Apertural diameter*	*Appendix length*
Holotype:	171	90	67	81	35	44	up to 34
Range:	123–267	85–165	55–104	—	31–55 → 35–55	40–58	up to 53
Mean:	192	113	80	84	38 → 41	46	—

Description. The roughly conical chamber often narrows rather more rapidly near the base than elsewhere; a swelling is superimposed on the flanks and a slight but distinct shoulder may be developed. The maximum diameter is 60–80 per cent. of the chamber length. Proximally, the appendices are directed laterally outward from the basal margin; distally, owing to their curvature, they come to lie roughly parallel with the longitudinal axis of the text. The thick edge is invariably directed aborally; from it the appendix becomes thinner towards the oral edge. Large and small openings, elongate along the length of the appendix, often perforate the appendices. Occasionally an appendix divides in a transverse plane, joining the basal margin at two or more points (Pl. 69, fig. 7); appendices do not divide to form multiple distal extremities. Generally the test wall is smooth, but in each of four populations from fairly wide stratigraphical intervals (samples C9, C8/b–c, C6) the necks of a few tests bear cones or spines, up to 1·5 μ in length.

Remarks. The style of the appendices and the shape of the test make *A. alaticornis* sp. nov. quite distinct.

Material. Between four hundred and five hundred single tests.

Occurrence. Alternata Limestone: C9 (abundant). Cheney Longville Flags: C8/b–c (abundant), C14/b (abundant). Acton Scott Beds: C6 (abundant).



TEXT-FIG. 5. *Ancyrochitina alaticornis* sp. nov. Lateral view of test (left) and six drawings illustrating the variation shown by the appendices, ×375.

Ancyrochitina bulmani (Jansonius 1964) comb. nov.

Text-fig. 6

1964 *Conochitina bulmani* Jansonius, p. 907, pl. 1, figs. 3, 4 (holotype).

EXPLANATION OF PLATE 69

Figs. 1–2. *Ancyrochitina onniensis* sp. nov. 1, C1/53/1/R, ×400. 2, C1/53/1/B, ×400.

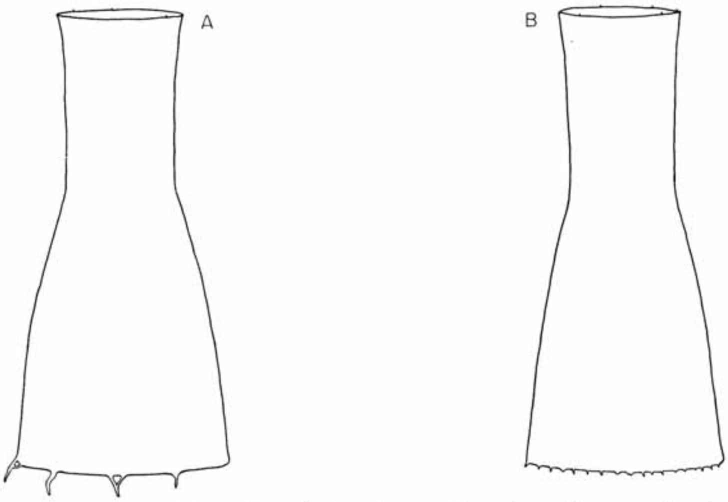
Figs. 3–13. *Ancyrochitina alaticornis* sp. nov. 3, C9/61/1/A, holotype, ×300. 4, C9/61/1/B, ×300. 5, C6/61/1/K, oblique lateral view of aboral end of test showing arrangement of appendices, ×300. 6, C6/61/1/X, oblique aboral polar view of isolated base showing arrangement of appendices, ×415. 7, C6/61/1/Z, polar view of isolated base showing three appendices each joining the basal margin at two points, ×275. 8–13, isolated appendices; showing some of the morphological variation assumed by the appendices. 8, C6/61/1/D, ×830. 9, C6/61/1/H, ×625. 10, C6/61/1/I, ×625. 11, C6/61/1/J, ×625. 12–13, C6/61/1/D, ×830.

Figs. 14–17. *Angochitina communis* sp. nov. 14, C1/54/1/A, holotype, ×360. 15, C1/54/1/C, ×360. 16, C1/54/1/B, ×360. 17, C1/54/1/D, ×360.

Dimensions in microns. (18 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Appendix length*
Range:	154–180	95–131	69–88	43–80	35–46 → 44–48	up to 11
Mean:	166	101	79	66	41 → 45	—

Remarks. In Shropshire, several specimens identical with that figured by Jansonius (1964, pl. 1, fig. 3) were found in association with otherwise similar forms having smaller and more numerous processes restricted to the narrow, sharply rounded basal margin. These forms, which are similar in age to the Scottish type material, conform closely with Jansonius's description (p. 907) of *Conochitina bulmani*. However, I do not follow



TEXT-FIG. 6. *Ancyrochitina bulmani* (Jansonius) comb. nov. Two extreme forms: A, characterized by a small number of relatively well-developed appendices, and B, characterized by more numerous, but smaller appendices, ×450.

Jansonius's emendation of *Conochitina*, and, by virtue of its well-developed and distinct neck and because the processes are restricted to the basal margin and not merely 'particularly well developed aborally' (Eisenack 1955*b*), this species is unquestionably closer to *Ancyrochitina* than *Conochitina* emend. Eisenack 1955.

Comparison. Sphaerochitina collinsoni Dunn 1959 (Devonian of Iowa) is distinguished from *Ancyrochitina bulmani* by its fungiform test and much longer neck. The processes of *Sphaerochitina nodulosa* Collinson and Scott 1958 (Devonian of Illinois), although somewhat similar to those of *A. bulmani* and confined to the aboral end of the test, are not restricted to the basal margin.

Material. One hundred and thirty single tests.

Occurrence. Glenburrell Beds: C11 (abundant).

Genus ANGOCHITINA Eisenack 1931

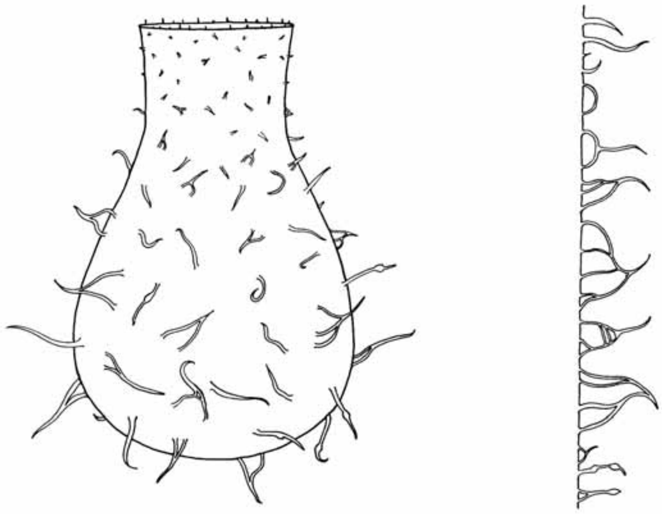
Type species. *A. echinata* Eisenack 1931, Silurian, Baltic.

Angochitina communis sp. nov.

Plate 69, figs. 14–17; text-fig. 7

Holotype. Plate 69, fig. 14. Specimen C1/54/1/A; *Onnia* Beds, sample C1/a.

Diagnosis. Test small. Chamber ovoid, about four-fifths total length; maximum diameter in lower half of chamber, about four-fifths chamber length; base slightly to strongly convex. Neck distinct, short, cylindrical, or slightly flaring, about half maximum diameter in width. Collarette with fringe of short hairs. Slender simple and wishbone spines with pointed tips, up to 35 per cent. maximum diameter in length, evenly distributed over whole test.



TEXT-FIG. 7. *Angochitina communis* sp. nov. Lateral view of test (left) and diagram illustrating the range of variation in shape and complexity of the spines, ×575.

Dimensions in microns. (25 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Process length*
Holotype:	130	92	80	38	39 → 46	up to 25
Range:	100–145	75–110	70–85	22–40	35–42 → 39–46	up to 25
Mean:	122	90	77	32	38 → 42	—

Description. A dark lenticular shape running transversely across the test is often seen near the base; it appears to be a fold in the test wall; no opisthosome has been recognized. The terminal hairs around the aperture are simple and up to 2 μ in length.

Generally the test bears both wishbone and simple spines, the latter usually predominating. Both types of spine are similar in length, thickness, and texture; they stand normal to the test wall, which they meet abruptly. They are most strongly developed aborally, shortest on the neck. Small node-like thickenings sometimes occur on them and, occasionally, small cross-bars join two limbs of a wishbone spine. The internal surface of the oral tube often bears short simple spines with sharp tips.

Comparison. Several species, including *A. globosa* Collinson and Scott 1958 and *A. milanensis* Collinson and Scott 1958, are similar in shape to *A. communis* but have very different ornamentation.

Material. Six thousand to seven thousand single tests.

Occurrence. Onnia Beds: C1/a–h (abundant).

Angochitina dicranum sp. nov.

Plate 70, fig. 1; text-fig. 8

Holotype. Plate 70, fig. 1. Specimen C2/c/54/3/A; *Onnia* Beds, sample C2/c.

Diagnosis. Test small. Chamber ovoid, about two-thirds total length; maximum diameter one-third to half-way up chamber, about three-quarters chamber length; base convex. Neck distinct, slender, cylindrical, about half maximum diameter in width; collarette flaring, with fringe of short terminal hairs. Ornament of sharply pointed, simple, and pitchfork-shaped spines up to half maximum diameter in length, distributed over whole test.

Dimensions in microns. (12 specimens measured.)

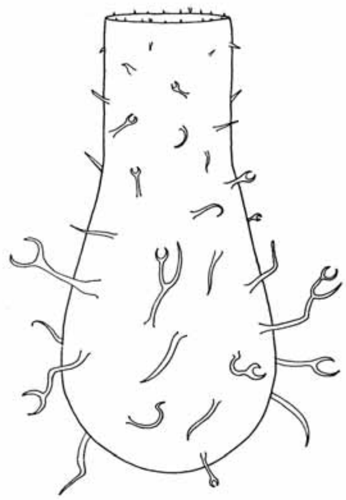
	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Holotype:	147	89	62	58	27	35	up to 23
Range:	101–158	60–120	55–82	33–55	25–38	30–38	up to 30
Mean:	130	86	60	45	32	35	—

Description. The ornament consists of relatively few spines (10–35 per test), all having pointed tips and standing normal to the test wall, which they meet abruptly. Forked spines have very wide angled bifurcations and are shaped like pitchforks; initially the limbs of each fork diverge rapidly, distally they run parallel with each other but rarely converge. Commonly, forked spines have only first order branching; second order branching is rare. The proportion of simple to forked spines is variable and either may predominate. Both types are roughly the same in length, becoming shorter orally, and are distributed fairly uniformly over the whole test. Near the aperture the inner surface of the oral tube often bears short simple spines with pointed tips. Rarely, the terminal fringe of hairs on the collarette includes small pitchfork-shaped spines.

Comparison. A. dicranum sp. nov. and *A. communis* sp. nov. are distinguished mainly by their different ornaments. They are closely similar in size and shape, but the oral tube of *A. dicranum* is slightly longer and thinner than that of *A. communis.* No specimen of *Angochitina* bearing both wishbone spines and pitchfork-shaped spines was found in Shropshire. In *A. bifurcata* Collinson and Schwalb 1955 all the spines fork, but none is shaped like a pitchfork. *A. capillata* Eisenack 1937 has numerous simple, very short spines.

Material. One hundred and fifty single tests.

Occurrence. Onnia Beds: C2/c (very common), C2/d (abundant).



TEXT-FIG. 8. *Angochitina dicranum* sp. nov. Lateral view of test, ×565.

Genus CONOCHITINA Eisenack 1931 emend. 1955*b*

Type species. C. claviformis Eisenack 1931, Baltic drift.

Original diagnosis (Eisenack 1931, p. 83). 'Chitinozoa with generally conical tests, the maximum diameter lying near the base.'

Upon the establishment of the genera *Sphaerochitina* Eisenack 1955*a*, *Ancyrochitina* Eisenack 1955*a*, and *Cyathochitina* Eisenack 1955*b*, to which were transferred several species from *Conochitina*, Eisenack (1955*b*) gave the following emended diagnosis for *Conochitina*: 'Chitinozoa with conical tests and rounded basal margins. Wall smooth or bearing numerous more or less short spines, which in general are particularly well developed aborally.'

Conochitina lepida sp. nov.

Plate 70, figs. 2–3

Holotype. Plate 70, fig. 2. Specimen C1/52/1/A; *Onnia* Beds, sample C1/a.

Diagnosis. Wide conical chamber with swollen flanks, about three-quarters total length; maximum diameter at base, approximately equal to chamber length; base almost flat, margin sharply rounded. Neck distinct, cylindrical, half to two-thirds maximum diameter in width. Aperture straight. Wall smooth.

EXPLANATION OF PLATE 70

Fig. 1. *Angochitina dicranum* sp. nov., C2/c/54/3/A, holotype, ×415.

Figs. 2–3. *Conochitina lepida* sp. nov. 2, C1/52/1/A, holotype, ×230. 3, C1/52/1/B, ×230.

Figs. 4–8. *Conochitina chydaea* sp. nov. 4, S21/35/3/A, holotype, ×230. 5, S21/35/8/var. A/2, test not differentiated into chamber and neck, ×230. 6, S21/33/1/C, example with hemispherical base, ×230. 7, S21/35/5/A, ×230. 8, S21/35/9/B, ×230.

Figs. 9–14. *Conochitina parviventer* sp. nov. 9, S36/3/1/J, small example, ×230. 10, S36/3/1/C, ×230. 11, S36/3/1/B, ×230. 12, S36/3/1/H, ×230. 13, S36/3/1/A, holotype, ×230. 14, S36/3/1/E, ×230. The dark transverse bands in the upper parts of some tests (figs. 10 and 12) are discussed briefly in the text.

Dimensions in microns.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Neck diameter*
Holotype:	167	123	108	44	55
Specimen C1/52/1/B:	159	120	102	39	55
Specimen C11/52/1/A:	142+	96	112	46+	69

Description. In the lower half of the chamber the flanks are roughly parallel. They meet the base abruptly, but the basal margin is clearly rounded and there is no evidence of an incipient carina. The base is slightly concave near the margin, becoming slightly convex towards the centre; originally, however, it may have been flat.

Comparison. The swollen flanks and the sharply rounded basal margin distinguish this species from *Conochitina lagenomorpha* Eisenack 1931, *C. filifera* Eisenack 1931, *C. conulus* Eisenack 1955*b*, and *C. communis* Taugourdeau 1961.

Material. Twelve single tests, the majority of which are damaged.

Occurrence. Glenburrell Beds: C11 (rare). *Onnia* Beds: C2/d and C1/a–c (rare).

Conochitina chydaea sp. nov.

Plate 70, figs. 4–8

Holotype. Plate 70, fig. 4. Specimen S21/35/3/A; lower Hope Shales, sample S21.

Diagnosis. Test conical or cylindroconical with flat or slightly convex base and rounded basal margin. Maximum diameter at base, 30–40 per cent. total length. Neck cylindrical or slightly flaring, shorter than chamber, about two-thirds maximum diameter in width, not always developed. Aperture straight. Wall smooth or bearing small cones.

Dimensions in microns. (45 specimens measured.)

	Total length	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*
Holotype:	204	75	52	54
Range:	123–323	57–96	41–71	31–78
Mean:	199	76	55	52

Description. The tests vary considerably in shape. The chamber may be slender or stout, and the neck absent or up to nearly half the total length. Most populations consist of smooth and ornamented individuals, the latter generally forming one-tenth to one-fifth of the population. In the lower and upper Hope Shales the populations consist entirely of smooth specimens, while in a sample from the upper Llandeilian (S11) more than three-quarters of the population are ornamented with small cones up to 1·5 μ in length. However, it has not been established that there was a trend towards ornamentation. The cones are largest and most densely concentrated at the basal margin; orally they always become smaller and scarcer, and only rarely do they occur on the neck.

Comparison. Several species closely resemble *C. chydaea*; they are *Conochitina simplex* Eisenack 1931, *C. primitiva* Eisenack 1939, *C. intermedia* Eisenack 1955*a*, and *C. edjelensis* Taugourdeau 1963. They differ from *C. chydaea* as follows. Populations of *C. simplex* contain a few individuals whose bases extend aborally in inverted cones. In *C. primitiva* the flanks taper more rapidly near the base than elsewhere. *C. intermedia* has a simple conical test (no neck) and a larger apical angle. *C. edjelensis* shows similar variation in form to the new species but has a concave base.

Material. Several thousand single tests.

Occurrence. Hope Shales: S25 (abundant), S21 (abundant), S36 (abundant). Stapeley Shales: S37 (abundant). Weston Beds: S1 (abundant). Betton Beds: S2 (abundant). Meadowtown Beds: S8 (abundant), S3 (abundant), S4 (abundant), S5 (abundant), S11 (abundant). Coston Beds: C16 (uncommon). Glenburrell Beds: C11 (uncommon). *Onnia* Beds: C1/a–h (uncommon).

Conochitina parviventer sp. nov.

Plate 70, figs. 9–14

Holotype. Plate 70, fig. 13. Specimen S36/3/1/A; upper Hope Shales, sample S36.

Diagnosis. Small uniformly tapering conical chamber, 20–30 per cent. total length; maximum diameter at base, 15–20 per cent. total length; base flat or slightly convex, basal margin sharply rounded. Oral tube long, cylindrical, about two-thirds maximum diameter in width; aperture straight. Wall smooth.

Dimensions in microns. (26 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Holotype:	498	125	85	375	58
Range:	215–498	69–150	58–90	142–375	42–65
Mean:	390	106	74	284	51

Description. *C. parviventer* sp. nov. shows very little morphological variation. The chamber and neck are characteristically distinct, yet their junction is rarely very abrupt. The wall of the oral tube is translucent for most of its length, particularly so near the aperture, becoming progressively more opaque towards the chamber. A collarette cannot be distinguished. Narrow, dark transverse striations frequently cross the oral tube; it has not been determined whether these are elements of an extended prosome or structures within the test wall.

Comparison. The separation of its test into a chamber and oral tube distinguishes *C. parviventer* sp. nov. from *C. elegans* Eisenack 1931. Many examples of both these species have been found in the Welsh Borderland but transitional forms are unknown and the two species were not found together; their known stratigraphical ranges do not overlap.

Material. Seventy-five single tests.

Occurrence. Hope Shales: S21 (rare), S36 (abundant). Meadowtown Beds: S3 (rare).

Conochitina elegans Eisenack 1931

Plate 71, figs. 1–4

1931 *Conochitina elegans* Eisenack, p. 87, pl. 2, fig. 4 (holotype).
1934 *Rhabdochitina conocephala* Eisenack, p. 61, pl. 4, figs. 10–12; text-fig. 32.
1959*a* *Conochitina elegans* Eisenack; Eisenack, p. 3, pl. 2, figs. 4 (neotype), 5; text-fig. 1.
1960 *Rhabdochitina conocephala* Eisenack; Taugourdeau and Jekhowsky, p. 1230, pl. 9, fig. 131.
non 1962 *Conochitina elegans* Eisenack; Beju and Danet, p. 531, pl. 1, figs. 31, 32.
non 1964 *Rhabdochitina conocephala* Eisenack; Cramer, p. 351, pl. 22, fig. 14; pl. 23, figs. 7, 11, 12.

Dimensions in microns. (30 specimens measured.)

		Total length	*Maximum diameter*
	Range:	200–616	58–92
	Mean:	388	73
26 specimens from Estonia (Eisenack 1959*a*)	Range:	288–667	
	Mean:	467	
	Neotype:	482	76

Remarks. A study of much material led Eisenack (1959*a*) to unite *Conochitina elegans* Eisenack 1931 and *Rhabdochitina conocephala* Eisenack 1934 as one species. The British material leads me also to conclude that the two are the same. Eisenack (1959*a*, p. 4) remarked that *Rhabdochitina pistillifrons* Eisenack 1939 was possibly an extreme form of *C. elegans*, but he was not able to determine the nature of their relationship owing to the lack of enough specimens. The morphological variation shown by the very numerous British specimens of *C. elegans*, however, does not suggest that *R. pistillifrons* and *C. elegans* are one species.

Except for slight differences in size the British and Estonian examples of *C. elegans* are indistinguishable. The specimens figured by Cramer (1964, pl. 22, fig. 14; pl. 23, figs. 7, 11, 12), and incorrectly identified as *Rhabdochitina conocephala* Eisenack 1934, bear little resemblance to *Conochitina elegans*. Also, I am inclined not to include in this species the two specimens figured by Beju and Danet (1962, pl. 1, figs. 31, 32); they differ from Baltic and British specimens in having sharp basal margins and poorly developed aboral swellings.

Material. Between two thousand and three thousand single tests.

Occurrence. Coston Beds: C16 (uncommon). Glenburrell Beds: C11 (uncommon). Alternata Limestone: C9 (very common). Upper Cheney Longville Flags: C14/b (very common). Acton Scott Beds: C6 (common), C4 (common). *Onnia* Beds: C2/a (very common), C2/b (common), C2/d (common), C1/a–h (common). In Estonia the species occurs in the Kuckers Beds, C_2, the Jewe Beds, D_1, and the Kegel Beds, D_2 (Eisenack 1959*a*, 1962*b*). It has been found in many samples of Ostseekalk drift, the type specimens coming from such material from the Hangö–Ekenäs region of South Finland (Eisenack 1959*a*). Taugourdeau and Jekhowsky (1960) record the species (as *Rhabdochitina conocephala*) in the lower Silurian of the Sahara.

Genus CYATHOCHITINA Eisenack 1955*b*

Type species. C. campanulaeformis (Eisenack 1931), Ordovician, Baltic.

Cyathochitina calix (Eisenack 1931)

Plate 71, figs. 5–7

1931 *Conochitina calix* Eisenack, p. 87, pl. 2, fig. 3 (holotype); pl. 4, fig. 14; text-fig. 1.
1939 *Conochitina calix* Eisenack; Eisenack, p. 137, pl. B, figs. 4, 5.
1958*b* *Cyathochitina calix* (Eisenack); Eisenack, p. 397, pl. 2, figs. 26, 27.
1962*a* *Cyathochitina calix* (Eisenack); Eisenack, p. 296, pl. 14, figs. 3, 4 (neotype).

Dimensions in microns. (6 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Range:	255–308	145–174	80–95	96–140	50–69
Mean:	283	159	90	124	58

The average total length of 57 Baltic specimens (Eisenack 1962*a*) is 299 μ (min. 190 μ, max. 450 μ).

Remarks. At the base of the Hope Shales, *C. calix* and *C. campanulaeformis* (Eisenack 1931) were found together. While most specimens could be allocated with certainty to one or the other of these species, a few were transitional. Most British examples of *C. calix* are somewhat stouter (total length : maximum diameter = 1·5–2·1 : 1) than the Baltic specimens (total length : maximum diameter = 1·9–4·1 : 1) described by Eisenack (1962*a*).

Material. About twenty-five single tests.

Occurrence. Hope Shales: S25 (abundant). The species has been found (Eisenack 1962*a*) in the Glaukonitkalk of Estonia and in the *expansus*-Kalk of Dalarna and Öland, Sweden.

Cyathochitina campanulaeformis (Eisenack 1931)

Plate 71, figs. 8–11

1931 *Conochitina campanulaeformis* Eisenack, p. 86, pl. 2, figs. 1, 2 (holotype); pl. 4, figs. 1, 11–13 (non 14).
1939 *Conochitina campanulaeformis* Eisenack; Eisenack, p. 137, pl. B, figs. 1–3.
1948 *Conochitina campanulaeformis* Eisenack; Eisenack, p. 112, text-figs. 1, 7–9.
1955*b* *Cyathochitina campanulaeformis* (Eisenack); Eisenack, p. 313.

EXPLANATION OF PLATE 71

Figs. 1–4. *Conochitina elegans* Eisenack. 1, C9/17/2/C, short cylindrical example, ×190. 2, C9/17/2/A, slightly tapering conical example, ×190. 3, C9/17/2/B, ×190. 4, C14/17/2/A, ×190.

Figs. 5–7. *Cyathochitina calix* (Eisenack). 5, S25/10/4/A, ×190. 6, S25/10/4/B, ×190. 7, S25/10/4/C, ×190.

Figs. 8–11. *Cyathochitina campanulaeformis* (Eisenack). 8, S21/10/1/2, ×190. 9, S21/10/1/44, ×190. 10, S21/10/2/A, atypical example with short wide chamber, ×190. 11, S21/10/1/45, ×190.

Figs. 12–13. *Desmochitina minor* Eisenack f. *cocca* Eisenack. 12, C11/45/1/F, ×230. 13, C11/45/1/G, ×230.

Figs. 14–15, 18. *Desmochitina minor* f. *typica* Eisenack. 14, C16/45/1/A, ×230. 15, C9/45/1/B, ×230. 18, C1/45/1/D, ×230.

Figs. 16–17. *Desmochitina minor*, typical Llandeilian examples having wide chambers and wide apertures. 16, S11/45/1/B, ×230. 17, S11/45/1/A, ×230.

1962*a* *Cyathochitina campanulaeformis* (Eisenack); Eisenack, p. 297, pl. 14, figs. 5 (neotype), 6, 7; text-fig. 3 (neotype).
non 1964 *Cyathochitina campanulaeformis* (Eisenack); Cramer, p. 344, pl. 24, figs. 6–8, 12–15; (figs. 7, 8, 14 = *Cyathochitina kuckersiana* Eisenack).

Diagnosis. Eisenack (1962*a*, p. 297) gives the following shortened diagnosis. 'Oral tube cylindrical, chamber bell- or funnel-shaped with relatively sharp basal margin, which not uncommonly is drawn out into a narrow knife-edge rim. Aperture straight. Wall slightly rough, very finely granular, or with extremely fine grooves, like bark.'

Dimensions in microns. (45 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Range:	170–285	100–202	108–183	40–108	49–70
Mean:	225	160	140	70	60

Eisenack's (1948) Bohemian specimens measure 190–266 μ in length, his (1962*a*) Baltic specimens 200–428 (mean 306) μ in length.

Remarks. In shape, the British specimens are similar to the stockier of Eisenack's (1962*a*) Baltic specimens; in the former the total length : maximum diameter = 1·18–1·82 : 1 (mean 1·58 : 1); in the latter the ratio is 1·28–2·46 : 1 (mean 1·9 : 1). In size, the British specimens are comparable with the Bohemian specimens (Eisenack 1948) and the smaller of the Baltic specimens. Some individuals from Shropshire are considerably shorter than the shortest Baltic specimens.

In British specimens the base appears to have been a fairly rigid structure. In reflected light it is often seen to have preserved its original circular outline and to have rotated during compression so that it now lies close to, or parallel with, the plane occupied by the remainder of the test. Aboral pores could not be discerned in the isolated bases of several specimens mounted in polar view.

There is little doubt that some of the figured specimens identified by Cramer (1964, pl. 24, figs. 7, 8, 14) as *C. campanulaeformis* are, in fact, examples of *Cyathochitina kuckersiana* (Eisenack 1934); two of these (figs. 7, 14) are fairly close in appearance to *C. kuckersiana* forma *brevis* Eisenack 1962*a*. The two species may be distinguished readily on the basis of their carinae. The carina of *C. campanulaeformis* is a fairly narrow, sharp rim, whilst that of *C. kuckersiana* is a wide, membranous, skirt-like lateral extension of the basal margin. This distinction (Eisenack, *personal communication*) gives some pure populations of *C. campanulaeformis* and equally pure populations of *C. kuckersiana*; however, since both species show very considerable morphological variation, it also gives populations in which the two species grade into each other.

Material. Several hundred single tests.

Occurrence. Hope Shales: S25 (uncommon), S21 (very common). Weston Beds: S1 (abundant). Betton Beds: S2 (uncommon). Meadowtown Beds: S3 (uncommon), S4 (very common), S5 (very common). In Estonia *C. campanulaeformis* ranges from the Vaginatenkalk, B_3, to the Lyckholm Beds, F_1 (Eisenack 1962*a*, 1962*b*); from the Echinosphaeritenkalk, C_1, to the Lyckholm Beds it is occasionally very common, while in the Vaginatenkalk it occurs sporadically. It is also known from the *schroeteri*-Kalk of Öland, Sweden (Eisenack 1962*a*); some chert nodules from the Rhenish Schiefergebirge

(Eisenack 1939); and the Middle Ordovician, d_1–d_2, of Bohemia (Eisenack 1948). Taugourdeau (1961) records rare specimens of rather variable shape from the Ordovician or Silurian of Aquitaine and (1962) rare atypical examples from the Middle and Upper Llandoverian of the Sahara. Benoit and Taugourdeau (1961) list the species in the chitinozoan fauna from the Upper Shale-Grit Formation (Arenigian) of North Africa.

Cyathochitina kuckersiana (Eisenack 1934)

Plate 72, figs. 3–9; Plate 73, fig. 1

1934 *Conochitina kuckersiana* Eisenack, p. 62, pl. 4, fig. 14 (holotype); text-figs. 30 (holotype), 31.

1962*a* *Cyathochitina kuckersiana* (Eisenack); Eisenack, p. 298, pl. 14, figs. 8 (neotype), 9; text-figs. 4 (neotype), 5.

1964 *Cyathochitina campanulaeformis* (Eisenack); Cramer (pars), pl. 24, figs. 7, 8, 14.

Dimensions in microns. (35 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Carina width*
Range:	146–300	92–202	112–180	50–130	45–60	6–30
Mean:	193	129	143	87	52	20

In size, the British specimens are similar to the smaller of the specimens from the Baltic Kuckers Beds, C_2, where the total length of 25 specimens ranges from 147 to 360 (mean 253) μ (Eisenack 1962*a*).

Remarks. In the twenty British populations of this species which have been examined, *C. kuckersiana* (Eisenack 1934) is represented by a large majority of forms closer to

EXPLANATION OF PLATE 72

Fig. 1. *Desmochitina minor* f. *cocca* Eisenack, C11/45/1/A, ×230.

Fig. 2. *Desmochitina minor*, C11/45/4/D, agglomeration of approximately eighty tests, ×90.

Figs. 3–9. *Cyathochitina kuckersiana* (Eisenack). 3, C1/10/14/A, ×230. 4, C1/10/14/B, the translucent membranous carina is of about average width for British examples, ×230. 5, C1/10/14/X, ×230. 6–7, C1/10/14/Zi and C1/10/14/Zii respectively, two aboral polar views of isolated bases showing the wide translucent carinae, ×230; faint concentric striations in the carinae may be distinguished, but the darker radial and oblique radial lines result from folding of this membrane. 8, C1/10/14/U, specimen perforated by circular holes, possibly the result of fungal attack, ×570. 9, C1/10/14/V, three holes immediately above basal margin (the base and carina are missing), ×540. These perforations are described and briefly discussed in the description of this species and in the section devoted to the associated microfossils.

EXPLANATION OF PLATE 73

Fig. 1. *Cyathochitina kuckersiana* (Eisenack), C1/10/14/W, aboral polar view of isolated base perforated by numerous circular holes, ×415.

Figs. 2–3. *Lagenochitina capax* sp. nov. 2, C11/12/5/B, ×230. 3, C11/12/5/A, holotype, ×230.

Figs. 4–5. *Hoegisphaera complanata* (Eisenack). 4, C6/65/1/D, oral polar view, ×230. 5, C6/65/1/G, oral polar view clearly showing the aperture, ×230; this specimen was purposely crushed between slide and coverslip in very viscous Canada balsam.

Figs. 6–7. *Lagenochitina baltica* Eisenack. 6, C11/12/3/A, example with slender neck, ×230. 7, C1/12/3/A, example of less common form having wide neck, ×230.

Figs. 8–12. *Hercochitina downiei* sp. nov. 8, C2/b/70/4/C, ornamental elements arranged in rows which show up against translucent oral portion of test wall, ×230. 9, C2/b/70/2/C, holotype, ×230. 10, C2/b/70/4/B, ×230. 11–12, C2/b/70/4/T, ×230; fig. 12 is a phase contrast photograph taken (with the assistance of Dr. L. R. Wilson, Research Professor of Geology, University of Oklahoma) to show somewhat more clearly the nature of the ornamentation.

C. kuckersiana forma *brevis* Eisenack 1962*a* than to the holotype and neotype. However, separation of typical *C. kuckersiana* from *C. kuckersiana* forma *brevis* on the basis of the British material would be quite artificial, since they are linked, in each population, by a continuous series of intermediate forms.

The wide, membranous, skirt-like carina is translucent and deep amber in colour, contrasting sharply with the opaque black chamber; in bleached specimens the carina is orange to pale yellow. Faint striations, concentric with the basal margin, have been observed in the carinae of several specimens from Shropshire, but radial strengthenings (reported in some Baltic specimens, Eisenack 1934) are apparently absent. In all samples but one, the width of the carina ranges between 15 and 30 μ (10–20 per cent. maximum diameter); in well-preserved specimens from sample C8/b the carina width does not exceed 12 μ (7·5 per cent. maximum diameter), yet in all other respects these specimens are indistinguishable from those found elsewhere in Shropshire.

As in *C. campanulaeformis* (Eisenack 1931), the base appears to have been fairly rigid. Its original circular outline is often preserved and, during compression, it may have rotated so that it now lies in a plane close to, or parallel with, the longitudinal axis. The bases of twelve specimens were dissected away from the remainder of the tests and mounted for examination in polar view (Pl. 72, figs. 6–7); one of these bases was perforated by a pore situated centrally within the base and measuring about 1 μ in diameter.

The wall is generally smooth, but a more or less pronounced longitudinal ribbing is occasionally developed on the shoulder, the upper flanks, and the lower part of the neck.

The existence of unidentified boring organisms (? fungi) is suggested by the occurrence of holes in the tests of some chitinozoans. In most British populations of *C. kuckersiana*, several specimens are perforated by a number of small circular holes, apparently similar to those in *C. campanulaeformis* from the Baltic (Eisenack 1931, pl. 4, figs. 11, 13) and *C. kuckersiana* forma *brevis* (Eisenack 1962*a*, pl. 14, fig. 9; holes not mentioned in text). These holes are remarkably uniform in size (4–8 μ in diameter) and distributed irregularly over the test. That they occur selectively in certain species and do not penetrate both sides of the test in completely flattened specimens suggests that the organisms responsible for them were active before fossilization took place. Eisenack (1931) suggested that the holes in *C. campanulaeformis* might be due to microscopic fungi.

Material. Approximately eight thousand single tests.

Occurrence. Coston Beds: C16 (common). Glenburrell Beds: C11 (abundant). Alternata Limestone: C9 (uncommon). Cheney Longville Flags: C8/b–c (abundant), C14/b (very common). Acton Scott Beds: C6 (common), C4 (abundant). *Onnia* Beds: C2/a–d and C1/a–h (abundant). In the Baltic (Eisenack 1962*a*), *C. kuckersiana* ranges from the Kuckers Beds, C_2, to the Lyckholm Beds, F_1; forma *brevis* is common from the Jewe Beds, D_1, to the Wasalemm Beds, D_3.

Genus DESMOCHITINA Eisenack 1931 emend. 1962*a*

Type species. *D. nodosa* Eisenack 1931, Ordovician, Baltic.

Desmochitina minor Eisenack 1931

Plate 71, figs. 12–18; Plate 72, figs. 1–2

1931 *Desmochitina*? *minor* Eisenack, p. 93, pl. 3, figs. 9 (holotype), 10, 11.

1931 *Desmochitina*? *erinacea* Eisenack, p. 93, pl. 3, fig. 13.
1931 *Desmochitina*? *cocca* Eisenack, p. 94, pl. 3, figs. 14, 15.
1931 *Desmochitina amphorea* Eisenack, p. 93, pl. 3, figs. 5, 12.
1932 *Desmochitina amphorea* Eisenack; Eisenack, p. 267, pl. 12, fig. 6.
1939 *Desmochitina minor* Eisenack; Eisenack, p. 142, pl. A, figs. 2–5; text-figs. 1–7.
1948 *Desmochitina minor* Eisenack; Eisenack, p. 115, text-figs. 14, 15.
1958*b* *Desmochitina minor* Eisenack; Eisenack, p. 397, pl. 2, figs. 29 (neotype), 30–32.
1962*a* *Desmochitina minor* Eisenack; Eisenack, p. 303, pl. 16, figs. 1, 2, 3 (neotype), 4–10 13–20; pl. 17, figs. 1–9.

Dimensions in microns. (6 Llanvirnian and 40 Caradocian specimens measured.)

		Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Apertural diameter*
Llanvirnian specimens	Range:	77–106	67–92	78–93	7–14	47–58	53–63
	Mean:	88	77	82	10	50	56
Caradocian specimens	Range:	65–120	55–112	50–115	5–15	26–45	32–53
	Mean:	95	80	75	10	36	45

Remarks. Eisenack (1958*b* and 1962*a*) united the four previously named species, *D. minor* Eisenack 1931, *D. erinacea* Eisenack 1931, *D. cocca* Eisenack 1931, and *D. amphorea* Eisenack 1931, regarding them as different forms of a single species, and distinguished the new forms *D. minor* forma *grandicolla* Eisenack 1958*b*, *D. minor* forma *elongata* Eisenack 1958*b*, *D. minor* forma *rugosa* Eisenack 1962*a*, *D. minor* forma *ovulum* Eisenack 1962*a*, and *D. minor* forma *typica* Eisenack 1958*b*. Two of Eisenack's forms, *D. minor* f. *typica* and *D. minor* f. *cocca*, have been recognized in Caradocian assemblages from Shropshire. Most specimens allocated to f. *typica* are indistinguishable from some of the examples of *D. minor* from Bohemia (Eisenack 1948, text-figs. 14, 15) and the Ordovician Rhenish Schiefergebirge (Eisenack 1939, text-figs. 1–3, 6), but have smaller, less strongly flaring oral tubes than the specimens of f. *typica* figured by Eisenack (1962*a*) from the Baltic. However, Eisenack states (1962*a*, p. 305) that the oral tubes in f. *typica* may be reduced. Baltic and British examples of f. *cocca* are closely similar.

All the examples of *D. minor* from the Llandeilian of Shropshire have relatively wide tests (Pl. 71, figs. 16–17) and closely resemble *D. minor* f. *typica*? (Eisenack 1962*a*, pl. 16, fig. 10); however, none compares closely with *Desmochitina* sp. (Eisenack 1962*a*, pl. 16, figs. 11, 12) or *D. lata* Schallreuter 1963.

Material. Several thousand single tests, and chains of up to ten individuals. Agglomerations of up to four hundred loosely attached tests (Pl. 72, fig. 2), superficially similar to those described by Kozłowski (1963), were occasionally found in samples from the basal Caradocian. No evidence was found of an organic-walled envelope around these agglomerations.

Occurrence. (*a*) *D. minor* f. *typica*: Coston Beds: C16 (common). Glenburrell Beds: C11 (very common). Alternata Limestone: C9 (abundant). Upper Cheney Longville Flags: C14/b (rare). Acton Scott Beds: C6 (common). *Onnia* Beds: C2/b–d and C1/a–h (abundant).

(*b*) *D. minor* f. *cocca*: Glenburrell Beds: C11 (common).

(*c*) Llandeilian specimens of *D. minor*: Meadowtown Beds: S8 (rare), S5 and S11 (uncommon).

In the Ordovician of Estonia (Eisenack 1962*a*) f. *typica* ranges from the Glaukonitkalk, B_2, to the Kuckers Beds, C_2, and also occurs in the Kegel Beds, D_2, the Wesenberg Beds, E, and the Lyckholm Beds, F_1; f. *cocca* occurs in the Reval Beds, C_1, and the Kuckers Beds.

Genus HERCOCHITINA Jansonius 1964 emend.

Type species. H. crickmayi Jansonius 1964, Upper Ordovician, Quebec.

Emended diagnosis. Variable conical or cylindroconical tests with ornament of narrow ridges, or spines of uniform length, standing normal to test wall and arranged in longitudinal rows. Spines in each row connected at their tips by a more or less continuous bar running roughly parallel with test wall.

Hercochitina downiei sp. nov.

Plate 73, figs. 8–12

Holotype. Plate 73, fig. 9. Specimen C2/b/70/2/C; *Onnia* Beds, sample C2/b.

Diagnosis. Cylindroconical test. Chamber about two-thirds total length; maximum diameter at base, approximately three-quarters chamber length; base flat or slightly convex, basal margin sharply rounded. Oral tube cylindrical, aperture bearing fringe of fine spines (up to 1·5 μ in length). Ornament of slender simple and wishbone spines, up to two-thirds maximum diameter in length, arranged in 12–16 longitudinal rows, which extend from basal margin to aperture. Bars connecting spine tips continuous, extending whole length of test.

Dimensions in microns. (21 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Holotype:	152	114	87	38	64	64	up to 54
Range:	135–188	89–119	69–98	35–69	40–62	42–53	up to 59
Mean:	153	101	80	50	50	46	—

Description. Variation in this species is apparently limited to small changes in the size and shape of the test. All spines situated on the chamber are of approximately equal length, whilst those on the oral tube become progressively shorter towards the aperture. Occasionally, two spines in adjacent rows are connected at their tips by an oblique or transverse bar. Generally, however, there is no connexion between spine rows. Spines and the bars connecting them are identical in thickness and texture. Spines on the base are relatively short, up to 6 μ in length, their tips not connected by bars.

Comparison. H. downiei sp. nov. is smaller and has a more strongly developed ornament than *H. crickmayi* Jansonius 1964, but it lacks the longitudinal ridges which characterize the type species.

Material. Between four hundred and five hundred single tests.

Occurrence. Onnia Beds: C2/a (abundant) and C2/b (abundant).

Genus HOEGISPHAERA Staplin 1961

Type species. H. glabra Staplin 1961, Upper Devonian, Alberta.

Hoegisphaera complanata (Eisenack) Jansonius 1964

Plate 73, figs. 4–5

1932 *Desmochitina? complanata* Eisenack, p. 272, pl. 12, figs. 24 (holotype), 25.
1959*a* *Desmochitina? complanata* Eisenack; Eisenack, p. 16, pl. 3, fig. 13 (neotype).
1962 *Desmochitina complanata* Eisenack; Combaz and Poumot, pl. 4, figs. 62, 65.

Dimensions in microns. The following measurements are of ten specimens mounted in polar view. In distorted specimens a maximum and a minimum value were obtained for each measurement; the average of these two values was considered the true value.

	Maximum diameter	*Diameter of aperture*
Range:	97–127	38–46
Mean:	112	41

Remarks. In polar view, the British examples appear identical to those from the Baltic (Eisenack 1932, 1959*a*) and North Africa (Combaz and Poumot 1962). Attempts to mount specimens in lateral view proved unsuccessful but, after examining about twenty unmounted specimens in a Petri-dish and rotating them into lateral view, I estimate the chamber length to be about one-third of the maximum diameter (situated centrally) and the collarette length to be only a few microns; it is not known whether the short length of these specimens is wholly original or due partly to compression. The collarette could not be distinguished on specimens examined in polar view and its existence became evident only when the unmounted test was rotated into lateral view.

Material. Approximately one hundred single tests.

Occurrence. Acton Scott Beds: C6 (abundant).

Genus LAGENOCHITINA Eisenack 1931

Type species. L. baltica Eisenack 1931, Baltic drift.

Lagenochitina baltica Eisenack 1931

Plate 73, figs. 6–7

1931 *Lagenochitina baltica* Eisenack, p. 80, pl. 1, figs. 1 (holotype), 2, 3.
1959*a* *Lagenochitina baltica* Eisenack; Eisenack, p. 2, pl. 3, figs. 6 (neotype), 7.

Dimensions in microns. (18 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Range:	196–295	130–215	100–152	54–97	40–69
Mean:	248	170	118	65	58

Remarks. Except for some slight discrepancy in size, the British specimens are virtually identical to those from the Baltic. The Silurian specimens from Rumania figured by Beju and Danet (1962, pl. 2, figs. 9, 10), differ in shape subtly, but perhaps critically, from the holotype and neotype.

Material. Forty-five single tests.

Occurrence. Coston Beds: C16 (rare). Glenburrell Beds: C11 (rare). Alternata Limestone: C9 (rare). *Onnia* Beds: C2/a (common), C1/a–d, f–h (rare). The species has been found in Ostseekalk erratics, in the *Diplograptus*-Kalk and in limestones of the Lyckholm Beds, F_1. In Estonia it is known only from the Lyckholm Beds (Eisenack 1962*b*).

Lagenochitina cylindrica Eisenack 1931

Plate 74, figs. 1–3

1931 *Lagenochitina cylindrica* Eisenack, p. 81, pl. 2, figs. 18, 19 (holotype).

Dimensions in microns. (10 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Range:	207–331	123–246	108–126	61–143	60–76
Mean:	268	170	113	88	67

Remarks. The chamber forms 53–75 per cent. of the total length, the maximum diameter is 40–55 per cent. of the chamber length (32–38 per cent. total length) and the neck width is half to two-thirds of the maximum diameter. Some British specimens are very similar in size and shape (total length : maximum diameter = 3 : 1) to the Baltic specimens figured by Eisenack (1931, pl 2, figs. 18, 19); others are shorter and relatively stout (total length : maximum diameter as low as 2·1 : 1). In one British specimen (as in the specimen illustrated in Eisenack 1931, pl. 2, fig. 18) a distinct waist is developed about one-third of the way up the chamber. Three other British specimens have very weakly developed waists located in this same position, whilst in the remaining six specimens no waist can be distinguished and the flanks are quite cylindrical or slightly swollen. A waist appears to be characteristic of this species but it is not developed in all individuals.

Material. Ten single tests.

Occurrence. Hope Shales: S21 (uncommon).

Lagenochitina esthonica Eisenack 1955*b*

Plate 74, figs. 4–5

1955*b* *Lagenochitina esthonica* Eisenack, p. 311, pl. 1, figs. 8 (holotype), 9.
1958*b* *Lagenochitina esthonica* Eisenack; Eisenack, p. 395.

Dimensions in microns.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Apertural diameter*
Specimen S21/2/1/A (fig. 4):	987	605	203	382	143	188
Specimen S21/2/1/B (fig. 5):	802	495	180	307	108	150
Holotype (Eisenack 1955*b* pl. 1, fig. 8):	530	—	194	—	—	—

Remarks. The British specimens of *L. esthonica* Eisenack are larger but more slender than those found by Eisenack (1955*b*, 1958*b*) in Estonia. They are similar in length but considerably thinner than the Swedish examples (Eisenack 1955*b*) from the *expansus*-Kalk. In both British specimens the base is hemispherical, the chamber forms 61 per cent. of the total length and the maximum diameter, lying midway along the chamber, is one-third of the chamber length; the chamber is not slightly conical as in the two specimens figured by Eisenack (1955*b*). The oral tube is cylindrical and, except for the flaring oral end, 60–70 per cent. of the maximum diameter in width; it is considerably narrower than this in the Estonian and Swedish examples.

Material. Two single tests.

Occurrence. Hope Shales: S21 (rare). Eisenack records the species in the Glaukonitsand, B_1, and the Glaukonitkalk, B_{2a}, of Estonia, and in the *expansus*-Kalk, B_{3a}, of Fjäka, Dalarna, Sweden.

Lagenochitina shelvensis sp. nov.

Plate 74, figs. 7–8

Holotype. Plate 74, fig. 7. Specimen C11/59/1/A (upper test); basal Glenburrell Beds, sample C11.

Diagnosis. Large test. Chamber ovoid to conical, about two-thirds total length; maximum diameter in lower half or middle of chamber, about two-thirds chamber length; base flat to slightly convex, basal margin rounded. Oral tube tapering, cylindrical, or slightly flaring for most of its length; sharply flaring below aperture.

Dimensions in microns. (3 tests measured.)

		Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Apertural diameter*
Specimen C11/59/1/A (fig. 7)	upper test (holotype):	585	365	246	220	146→157	177
	lower test:	562	370	238	192	146→157	176
Specimen C11/59/2/A: (fig. 8)		702	432	308	270	193→165	195

EXPLANATION OF PLATE 74

Figs. 1–3. *Lagenochitina cylindrica* Eisenack. 1, S21/12/1/A, ×150. 2, S21/11/1/A, ×150. 3, S21/11/1/B, ×150.

Figs. 4–5. *Lagenochitina esthonica* Eisenack. 4, S21/2/1/A, ×80. 5, S21/2/1/B, ×80.

Figs. 7–8. *Lagenochitina shelvensis* sp. nov. 7, C11/59/1/A, a chain of two tests, ×80; the upper test is the holotype. 8, C11/59/2/A, ×80. Specimen broken in two during mounting; the two parts have been photographed separately.

Figs. 6, 9–10, 12. *Rhabdochitina magna* Eisenack. 6, S8/16/1/C, ×80. 9, S8/16/1/A, ×80. 10, S8/16/1/B, ×80. 12, S21/17/1/A, ×80. The specimens illustrated in figs. 6, 9, and 10 are traversed by parallel splits, which are thought to result from cleavage of the rock, the splits reflecting the orientation of the cleavage plane relative to the original orientation of the specimen in the sediment.

Fig. 11. *Pterochitina sp*., S37/62/1/A, polar view, ×230.

Figs. 13–15, 20. *Rhabdochitina usitata* sp. nov. 13, S21/16/5/A, ×150. 14, S21/16/2/B, ×150. 15, S21/15/5/A, showing stump of basal process, ×230. 20, S21/16/3/B, ×150.

Figs. 16–19. *Rhabdochitina turgida* sp. nov. 16, S21/23/1/B, ×150. 17, S21/16/4/A, ×150. 18, S21/16/4/B, ×150. 19, S21/23/1/A, holotype, ×150.

Comparison. In size and general shape *L. shelvensis*, sp. nov. compares closely with *L. bohemica* Eisenack 1948, but lacks the pronounced apertural thickening of typical members of that species. Eisenack (*personal communication*) states that he would not include these specimens in *L. bohemica* and that they appear to be a new species, perhaps related to *L. bohemica*. It will not be possible to precisely define and distinguish *L. bohemica* Eisenack and *L. shelvensis* sp. nov. until numerically larger populations of both species have been found.

Material. One single test, one chain of two tests, and several fragments.

Occurrence. Glenburrell Beds: C11 (rare).

Lagenochitina capax sp. nov.

Plate 73, figs. 2–3

Holotype. Plate 73, fig. 3. Specimen C11/12/5/A; basal Glenburrell Beds, sample C11.

Diagnosis. Swollen cylindrical chamber, slightly wider than long, about two-thirds total length; shoulder pronounced; maximum diameter midway along chamber; base flat or almost so, basal margin rounded. Neck distinct, wider than long, cylindrical, half to two-thirds maximum diameter in width. Aperture straight.

Dimensions in microns.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Neck diameter*	*Apertural diameter*
Holotype:	209	140	150	69	100	104
Specimen C11/12/5/B:	122	88	95	34	46	50

Remarks. The outer surface of the test wall is rough but lacks processes; this texture may not be original. *L. capax* sp. nov. is quite distinct.

Material. Two single tests.

Occurrence. Glenburrell Beds: C11 (rare).

Genus PTEROCHITINA Eisenack 1955*a*

Type species. *P. perivelata* (Eisenack 1937), Silurian, Baltic.

Diagnosis. 'Chitinozoa in which the chamber width equals or exceeds the test length, and bearing a circular wing-like membrane' (Eisenack 1955*a*, p. 177).

Pterochitina sp.

Plate 74, fig. 11

Dimensions. Owing to slight distortion of the test, a minimum and maximum value were obtained for each dimension.

	Over-all diameter (including membrane)	*Diameter of chamber*
Specimen S37/62/1/A:	136×165	73×85

Remarks. The test consists of a dark opaque chamber lying centrally within a translucent, apparently thin-walled membrane. In polar view, the chamber and membrane are almost circular in outline (slightly distorted during fossilization) and the diameter of the chamber is about half that of the over-all diameter. Since the test is poorly preserved and has been examined only in polar view, the relationship of the chamber to the membrane has not been determined; in particular, it is not known how, and where, the two are attached. The aperture was not discernible owing to the opaque nature of the chamber wall; this is also the case in some examples of *P. perivelata* (Eisenack 1955*a*).

Comparison. The British specimens are smaller than *P. makroptera* Eisenack 1959*a* (p. 17; over-all diameter of twelve specimens: min. 180, max. 347) and lack concentric striations on the outer membrane. They are similar in size to *P. retracta* Eisenack 1955*b* and *P. perivelata*, but apparently lack the umbrella-like outer membrane of the former species and have relatively smaller chambers than the latter. For the present, the British form is designated *Pterochitina sp.*

Material. One complete specimen and several fragments.

Occurrence. Stapeley Shales: S37 (rare).

Genus RHABDOCHITINA Eisenack 1931

Type species. R. magna Eisenack 1931, Baltic drift.

Rhabdochitina magna Eisenack 1931

Plate 74, figs. 6, 9–10, 12

1931 *Rhabdochitina magna* Eisenack, p. 90, pl. 3, figs. 16, 17, 18 (holotype); text-figs. 3–5.
1939 *Rhabdochitina magna* Eisenack; Eisenack, p. 145, pl. B, fig. 9.
1960 *Rhabdochitina magna* Eisenack; Taugourdeau and Jekhowsky, p. 1230, pl. 9, fig. 132 (*non* pl. 10, fig. 133).
1961 *Rhabdochitina magna* Eisenack; Benoit and Taugourdeau, p. 1411, pl. 5, fig. 54 (*non* pl. 5, fig. 53).
1962*a* *Rhabdochitina magna* Eisenack; Eisenack, p. 292, pl. 14, fig. 1; pl. 15, fig. 5; text-fig. 1.

Dimensions in microns. (1 Llanvirnian and 15 Llandeilian specimens measured.)

		Total length	*Maximum diameter*	*Apertural diameter*
Llanvirnian specimen (S21/17/1/A):		562	77	39
Llandeilian specimens	Range:	750–909	110–142	90–139
	Mean:	823	131	115

The original dimensions given for the species (Eisenack 1931) were: total length 500–1,000 μ, width 80–100 μ. The mean total length and mean width of eight complete Baltic specimens (Eisenack 1962*a*) are 1,100 μ (max. 1,350, min. 874) and 93 μ (max. 113, min. 80), respectively.

Remarks. Typical examples of *R. magna* were found in only two samples. Those from the lower Meadowtown Beds (S8) are wider than the Baltic examples and generally somewhat shorter, while the sole example from the Hope Shales (S21) is relatively small. The base shows the same variety of shape as it does in the Baltic examples (Eisenack

1962*a*). The specimens from sample S8 (Pl. 74, figs. 6, 9–10) are traversed by parallel splits, which are thought to result from cleavage of the rock, the splits reflecting the orientation of the cleavage plane relative to the original orientation of the specimen in the sediment.

Material. Several hundred single tests.

Occurrence. Hope Shales: S21 (rare). Meadowtown Beds: S8 (abundant). Short wide atypical forms of *R. magna* were found in the Hope Shales (S21, S36) and the Meadowtown Beds (S8, S3). Typical examples of *R. magna* are occasionally very common (Eisenack 1962*a*) in the Ostseekalk and also occur (Eisenack 1962*b*) in B_3 and C_1 of Estonia. Atypical forms occur in the Vaginatenkalk of Reval, $B_{3\gamma}$, and the Echinosphaeritenkalk of Reval, C_1, the *Chasmops*-Kalk (Caradocian) of Böda, Öland, the Ordovician Rhenish Schiefergebirge, and the Middle Ordovician, D_γ, of Bohemia. In Estonia, a whole range of forms can only be described as *R.* cf. *magna* (Eisenack 1962*a*). Taugourdeau and Jekhowsky (1960) give the stratigraphical range of the species in the Sahara as Ordovician (zone 2) to Silurian (zone 3), and Benoit and Taugourdeau (1961) record it at nine horizons in the Arenigian of North Africa. It is evident from the specimens identified as *R. magna* and figured by Taugourdeau and Jekhowsky (1960), and Benoit and Taugourdeau (1961) that these authors interpret *R. magna* more widely than does Eisenack.

Rhabdochitina turgida sp. nov.

Plate 74, figs. 16–19

Holotype. Plate 74, fig. 19. Specimen S21/23/1/A; basal Hope Shales, sample S21.

Diagnosis. Stout, slightly swollen cylindrical test; maximum diameter central, one-third to half total length. Base wide, concave or flat; basal margin rounded. Wall smooth.

Dimensions in microns. (10 specimens measured.)

	Total length	*Maximum diameter*	*Apertural diameter*
Holotype:	231	87	46
Range:	146–362	69–131	38–81
Mean:	252	95	55

Description. From its widest part, the test narrows slightly towards the base and towards the straight aperture, both of which are between half and three-quarters of the maximum diameter in width.

Comparison. This species differs from short, wide examples of *R. striata* Eisenack (1958*b*, pl. 2, fig. 25) only in its lack of longitudinal striations. Typical examples of *R. gallica* Taugourdeau 1961 are widest aborally, although two of Taugourdeau's figured specimens (1961, pls. 4 and 5, figs. 72, 74) appear to be quite cylindrical.

Material. Twenty-five single tests.

Occurrence. Hope Shales: S21 (uncommon), S36 (rare). Weston Beds: S1 (rare). Meadowtown Beds: S3 (rare).

Rhabdochitina usitata sp. nov.

Plate 74, figs. 13–15, 20; Plate 75, fig. 1

Holotype. Plate 75, fig. 1. Specimen S21/16/2/A; basal Hope Shales, sample S21.

Diagnosis. Stout, cylindrical or weakly conical test; maximum diameter one-fifth to one-third total length. Base hemispherical. Aperture straight, 60–80 per cent. maximum diameter in width. Wall smooth.

Dimensions in microns. (35 specimens measured.)

	Total length	*Maximum diameter*	*Apertural diameter*	*Basal process diameter*
Holotype:	418	108	70	—
Range:	262–578	85–130	42–93	30–43 (4 specimens measured)
Mean:	414	112	75	36 (4 specimens measured)

Description. The base is invariably hemispherical, and approximately one specimen in five appears to have borne a stout process attached to the centre of the base (fig. 15); at its origin, this process is 26–37 per cent. of the maximum diameter in width. Generally only the scar of its attachment remains, and it has not been found complete.

Comparison. In general shape *R. usitata* sp. nov. is similar to *R. gallica* Taugourdeau 1961, but the latter has no basal process and its base may be flat. *R. turgida* sp. nov. is readily distinguished from *R. usitata* sp. nov. by its swollen cylindrical test and its flat or concave base; these two species sometimes occur together but no intermediate forms have been found. *R. usitata* sp. nov. is distinguished from *R. magna* Eisenack 1931 by its shorter, sometimes weakly conical test, and by its invariably hemispherical base.

Material. Several hundred single tests.

Occurrence. Hope Shales: S25 (rare), S21 (abundant), S36 (uncommon). Weston Beds: S1 (uncommon). Betton Beds: S2 (uncommon). Meadowtown Beds: S8 (uncommon), S3 (common), S11 (rare). Glenburrell Beds: C11 (rare). Acton Scott Beds: C4 (uncommon). *Onnia* Beds: C2/a (uncommon), C2/b–c (rare).

Genus SIPHONOCHITINA gen. nov.

Type species. *S. formosa* sp. nov., Hope Shales, Llanvirnian, Shropshire.

Diagnosis. Chitinozoa with variably shaped, generally slender tests. The test wall consists of two layers which separate at or near the basal margin, the inner layer forming the convex or hemispherical base, the outer layer extending aborally beyond the base as a hollow, cylindrical or flaring, open-ended tube, the siphon.

Remarks. The diagnostic feature of *Siphonochitina* gen. nov. is the separation of the inner and outer wall layers to form, respectively, the base and the siphon. This characteristic appears to be common to a group of otherwise similar species; it is recognizable even in distorted material, and generic separation based upon it should prove reasonably objective. A chamber and a neck are usually distinguishable, but only occasionally is their junction sharply defined, e.g. *Siphonochitina pellucida* (Benoit and Taugourdeau) comb. nov. Because of the frequent difficulty in recognizing the junction of the neck and the chamber, the maximum diameter is sometimes more reliably expressed, in diagnoses, as a percentage of the total length (excluding siphon) than as a percentage of the chamber length. The test wall is smooth. The two wall layers adhere closely, and are usually distinguishable only aborally, where they separate. The outer layer forming the siphon is commonly translucent, relatively thin, and often folded or damaged. The inner layer, especially aborally, is more opaque and apparently thicker than the outer layer. In some species (*S. formosa* sp. nov., *S. robusta* sp. nov.) a short process is attached to the centre of the base; it lies within the siphon and is directed aborally. The aperture is straight. The structure at the aboral end of the test in *Desmochitina* may prove to be quite different to that in *Siphonochitina*.

The following species are assigned to *Siphonochitina*: *S. formosa* sp. nov., *S. tenuicollis* sp. nov., *S. clavata* sp. nov., *S. robusta* sp. nov., and, with reservations, *S. pellucida* (Benoit and Taugourdeau 1961) comb. nov. *Desmochitina*? *gigantea* Eisenack 1948 possibly belongs here but the description and illustrations of this species do not indicate the existence of two wall layers. Also, certain forms presently assigned to *Eremochitina* Benoit and Taugourdeau 1961 may prove to belong in *Siphonochitina*.

Siphonochitina formosa sp. nov.

Plate 75, figs. 2–5; text-fig. 9

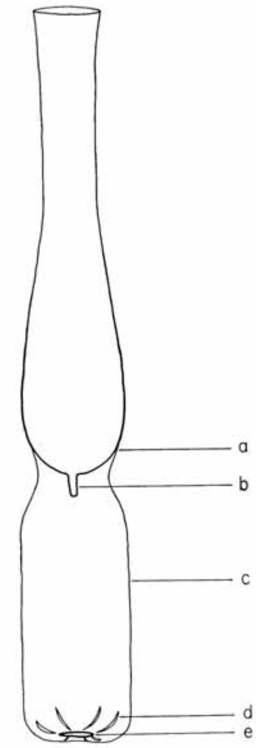
Holotype. Plate 75, fig. 2. Specimen S36/1/8/A; upper Hope Shales, sample S36.

Diagnosis. Gently tapering, slender conical chamber, 50–60 per cent. total length (excluding siphon); maximum diameter (of chamber) in lower part of chamber, 15–35 per cent. total length (excluding siphon). Oral tube cylindrical or slightly flaring, half to two-thirds maximum diameter (of chamber) in width. Siphon cylindrical, similar to chamber in length and width; sharply constricted at its distal end to a circular opening surrounded by a dark opaque ring, 15–20 μ in diameter; wall of siphon apparently thin. A small opaque cylindrical or conical process, about 10 μ in length, firmly attached to centre of base.

Dimensions in microns. (23 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter (of chamber)*	*Oral tube length*	*Oral tube diameter*	*Siphon length*	*Siphon diameter*
Holotype:	380	142	54	88	30	150	55
Range:	250–452	90–182	48–54	60–134	23–30→30–40	90–190	46–62
Mean:	373	140	51	96	27→34	137	55

Description. While a large majority of specimens have conical chambers, a few have swollen cylindrical chambers in which the maximum diameter lies centrally; transitional forms link these with the holotype. The base, clearly visible through the siphon wall, is strongly or slightly convex. Commonly, the neck and chamber merge gradually, but sometimes their junction is abrupt (Pl. 75, fig. 5). The prosome is generally present and clearly visible, often lying at the base of the neck as a short, opaque, cylindrical plug. Occasionally, up to twenty faint, narrow transverse striations occur fairly evenly distributed along the length of the neck; structurally it is not known whether these striations lie



TEXT-FIG. 9. *Siphonochitina formosa* gen. et sp. nov. Diagrammatic lateral view of test, ×320. *a*, point of separation of the inner and outer wall layers. *b*, basal process. *c*, siphon. *d*, folds disposed radially about the distal opening of the siphon. *e*, dark ring around the distal opening of the siphon.

within the test wall or are part of the prosome. The collarette is often paler, and sometimes more strongly flaring than the neck; the aperture is straight. The siphon is remarkably large, commonly as long as the chamber and generally slightly wider than the maximum diameter of the chamber. The dark ring around the distal opening is considerably narrower than the oral aperture, suggesting that individuals in chains were not connected aperture-to-base. The siphon is pale yellow-brown and translucent, and folds, radially disposed about the distal opening, are common. The small process on the base shows clearly through the wall of the siphon. It is remarkably constant in size, invariably opaque, and is directed aborally along the longitudinal axis of the test.

Comparison. The size of the siphon and the presence of a small basal process distinguish *S. formosa* sp. nov.

Material. Five hundred to six hundred single tests.

Occurrence. Hope Shales: S36 (abundant).

Siphonochitina tenuicollis sp. nov.

Plate 75, figs. 6–7

Holotype. Plate 75, fig. 7. Specimen S21/1/5/A; basal Hope Shales, sample S21.

Diagnosis. Slender, swollen cylindrical or conical chamber, about half total length (excluding siphon); maximum diameter midway along chamber or near base, 20–25 per cent. total length (excluding siphon). Slender, cylindrical, or slightly tapering neck, 40–55 per cent. maximum diameter in width. Siphon about one-fifth to one-third chamber length, cylindrical or flaring, half to four-fifths chamber diameter in width.

Dimensions in microns. (15 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Siphon length*	*Siphon diameter*
Holotype:	322	150	54	120	25 → 20	52	24 → 47
Range:	223–337	90–157	50–60	80–181	23–33 → 19–33	31–73	24–44 → 28–52
Mean:	291	127	53	110	26 → 26	50	32 → 40

Description. The chamber and neck may merge or, less commonly, they may meet abruptly. The neck is generally cylindrical, sometimes slightly tapering. The base is convex and there is apparently no basal process. The siphon may be cylindrical or flaring, or a composite of both, and is always considerably wider than the neck. Owing to poor preservation the siphon is generally distorted or torn, and I was unable to determine whether the distal opening of the siphon is constricted and enclosed by an opaque ring, as it is in *S. formosa* sp. nov.

Comparison. S. tenuicollis sp. nov. has a much shorter siphon and a somewhat narrower neck than *S. formosa* sp. nov., and apparently lacks a basal process; however, the two species are probably closely related.

Material. Twenty-five single tests.

Occurrence. Hope Shales: S25 (uncommon), S21 (common).

Siphonochitina cf. *pellucida* (Benoit and Taugourdeau) comb. nov.

Plate 75, figs. 9–11

Dimensions in microns. (4 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Siphon length*	*Siphon diameter*
Range:	167–224	83–116	65–73	50	50	20–58	38–58
Mean:	184	101	70	50	50	35	45

Remarks. The British specimens compare closely with those described by Benoit and Taugourdeau (1961, p. 1408, pl. 3, figs. 31–36; pl. 4, fig. 37) from the Lower Ordovician of the Sahara, but they have slightly less swollen chambers than the latter. The siphon may be a cylindrical tube about half as long as the body chamber and considerably narrower than the neck (fig. 10), as in the Saharan specimens, or it may be strongly flaring, only about one-fifth as long as the chamber and slightly wider than the neck (fig. 11). I suspect that the 'tunique semblant envelopper tout le Chitinozoaire, et plus ou moins separée de la copula' (Benoit and Taugourdeau 1961, p. 1408, pl. 3, figs. 31, 32) represents the outer layer of a two-layered test wall, and also forms the siphon. Too few specimens were found to decide whether, on the basis of their wide flaring siphons, some of the British specimens should be assigned to a new species. For the present, all are referred to *S.* cf. *pellucida* Benoit and Taugourdeau 1961.

Comparison. This form is readily distinguished from species of *Desmochitina* by its more elongate test and its well-developed cylindrical neck. The short swollen chamber and its abrupt junction with the neck distinguish *S. pellucida* from other species of *Siphonochitina*.

Material. Seven single tests.

Occurrence. Glenburrell Beds: C11 (uncommon). Typical *S. pellucida* is very common in the Hamra Quartzites and the Lower Shale-Grit Complex of the Sahara, in samples dated by graptolites as Lower Arenig.

Siphonochitina clavata sp. nov.

Plate 75, figs. 8, 12–13

Holotype. Plate 75, fig. 8. Specimen C11/1/6/A; basal Glenburrell Beds, sample C11.

Diagnosis. Gently tapering, elongate conical chamber, about two-thirds total length; maximum diameter close to base, 20–30 per cent. total length. Oral tube cylindrical

EXPLANATION OF PLATE 75

Fig. 1. *Rhabdochitina usitata* sp. nov., S21/16/2/A, holotype, ×150.

Figs. 2–5. *Siphonochitina formosa* gen. et sp. nov. 2, S36/1/8/A, holotype, ×150. 3, S36/1/9/A, ×150. 4, S36/1/8/B, ×150. 5, S36/1/8/C, example with considerably longer siphon than chamber, ×150.

Figs. 6–7. *Siphonochitina tenuicollis* gen. et sp. nov. 6, S21/1/3/A, ×150. 7, S21/1/5/A, holotype, ×150.

Figs. 9–11. *Siphonochitina* cf. *pellucida* (Benoit and Taugourdeau) comb. nov. 9, C11/1/7/C, ×230. 10, C11/1/7/A, example with cylindrical siphon, ×230. 11, C11/1/7/D, ×230.

Figs. 8, 12–13. *Siphonochitina clavata* gen. et sp. nov. 8, C11/1/6/A, holotype, ×230. 12, S2/1/10/A, ×230. 13, C11/1/6/D, ×230.

Figs. 14–18. *Siphonochitina robusta* gen. et sp. nov. 14, S21/29/5/B, ×150. 15, S21/29/5/C, ×150. 16, S21/29/5/A, ×150. 17, S21/29/4/A, holotype, ×150. 18, S36/29/6/I, ×230; the siphon has been dissected away to show the base and the basal process.

Figs. 19, 21–22. *Sphaerochitina vulgaris* sp. nov. 19, S21/5/1/H, holotype, ×230. 21, S21/5/1/C, ×230. 22, S21/5/1/D, ×230; this example bears small spines and cones at the aboral end of the chamber.

Figs. 20, 23–24. *Sphaerochitina actonica* sp. nov. 20, C6/54/3/C, holotype, ×230. 23, C6/54/3/A, ×230. 24, C6/54/3/F, ×230; a single photograph; the upper part of the oral tube has broken away from the remainder of the test.

for most of its length, slightly flaring orally, about two-thirds maximum diameter in width. Siphon short, about one-tenth total length, sharply flaring.

Dimensions in microns. (3 Llandeilian and 4 Caradocian specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Siphon length*	*Siphon diameter*
Holotype:	228	131	65	77	42	20	45 → 55
Llandeilian specimens Range:	248+–381	123–200	82–90	95+–154	—	27+–46	65 → 77 (one specimen)
Caradocian specimens Range:	228–278	131–181	58–77	77–78	38–54	20–26	35–50 → 45–72

Description. The base is slightly convex and a basal process is lacking. The chamber merges with the neck, the collarette is flaring, and the aperture is straight. Proximally, the siphon is about as wide as the cylindrical portion of the oral tube; it flares sharply throughout its length, and at its distal end it may be almost as wide as the widest part of the chamber. Little is known of the variation shown by this species since only seven specimens have been found.

Comparison. Some specimens of *Desmochitina*? *gigantea* Eisenack (1948, pl. 1, figs. 1–4) are similar in shape to *S. clavata* sp. nov. but are much larger and may have a prominent ledge (Halskrause) developed on the shoulder.

Material. Seven single tests.

Occurrence. Betton Beds: S2 (rare). Glenburrell Beds: C11 (rare).

Siphonochitina robusta sp. nov.

Plate 75, figs. 14–18, text-fig. 10

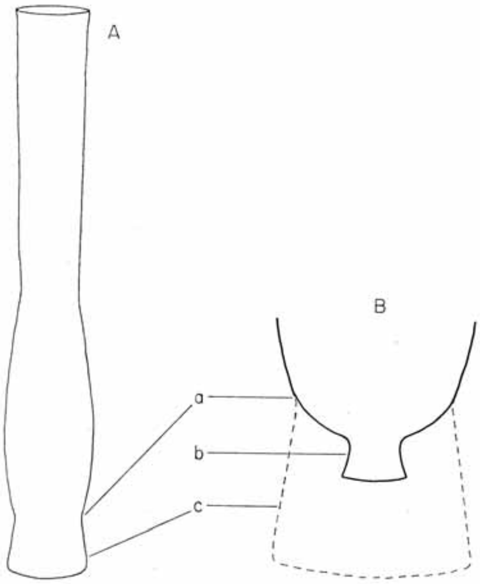
Holotype. Plate 75, fig. 17. Specimen S21/29/4/A; basal Hope Shales, sample S21.

Diagnosis. Large slender test. Chamber elongate, conical or swollen cylindrical, about half total length (excluding siphon); maximum diameter midway along chamber or close to base, 15–22 per cent. total length (excluding siphon). Oral tube cylindrical or flaring. Siphon short, wide, cylindrical or sharply flaring. Stout process attached to centre of base.

Dimensions in microns. (45 specimens measured.)

	Total length (excluding siphon)	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*	*Siphon length*	*Siphon diameter*
Holotype:	531	223	96	308	69 → 85	65	77
Range:	362–616	150–308	77–98	208–385	58–69 → 58–85	20–65	40–85
Mean:	489	229	88	297	62 → 66	40	64

Description. The chamber and neck sometimes merge so gradually that their lengths cannot be measured precisely. Where their junction is more abrupt the maximum diameter is seen to be 25–40 per cent. of the chamber length. The base is convex or hemispherical, but in complete specimens it is hidden by the siphon, which in the present material is always opaque. When cylindrical, the oral tube is about three-quarters of the maximum diameter in width; when flaring, it is about three-quarters of the maximum



TEXT-FIG. 10. *Siphonochitina robusta* gen. et sp. nov. A, Lateral view of intact test, ×190. B, Diagram to illustrate the structure at the aboral end of the test, ×450. *a*, point of separation of the inner and outer wall layers. *b*, basal process. *c*, siphon.

diameter in width near the chamber, and nearly as wide as the maximum diameter at its oral end. In general, the collarette is slightly translucent and contrasts with the opaque neck; the aperture is straight. The structure at the aboral end of the test (text-fig. 10) has been interpreted with some difficulty, owing to the opaque nature of the test wall. The siphon rises from the basal margin and extends aborally as a short, wide, cylindrical or flaring tube with a straight, smooth termination. The close and persistent similarity between the terminal diameter of the siphon and the diameter of the aperture suggests that these, at one time, may have been the points of contact between individuals in chains. When the siphon has not been preserved intact, or when it is removed (Pl. 75, fig. 18), a stout process can be seen attached to the centre of the base. This process is directed aborally and its distal end is often broken. Populations of *S. robusta* sp. nov. from samples S21 and S36 show the same morphological variation.

Material. Approximately eight hundred single tests.

Occurrence. Hope Shales: S21 (abundant), S36 (abundant). Glenburrell Beds: C11 (rare).

Genus SPHAEROCHITINA Eisenack 1955*a*

Type species. S. sphaerocephala (Eisenack 1932), Silurian drift, Baltic.

Diagnosis. 'Chitinozoa with roughly cylindrical neck and conical, spherical or broad fungiform chamber. Wall smooth, bearing minute tubercles, or covered with closely spaced, tiny spines; large processes absent' (Eisenack 1955*a*, p. 162).

Remarks. Part of the original diagnosis, 'dicht stehenden', has been translated into English by Collinson and Scott (1958) and Dunn (1959) as 'thick, erect', and into French by Taugourdeau and Magloire (1963 MS.) as 'très près les unes des autres'. The correct English translation would appear to be 'closely spaced'.

Sphaerochitina vulgaris sp. nov.

Plate 75, figs. 19, 21, 22; text-fig. 11

Holotype. Plate 75, fig. 19. Specimen S21/5/1/H; basal Hope Shales, sample S21.

Diagnosis. Small cylindroconical test. Chamber about half total length; maximum diameter at base, half to two-thirds total length; basal margin sharp, base flat or slightly convex. Neck cylindrical, half to two-thirds maximum diameter in width. Collarette translucent, occasionally flaring. Wall smooth or bearing small cones and, rarely, a few short simple spines.

Dimensions in microns. (12 specimens measured.)

	Total length	*Maximum diameter*	*Neck diameter*	*Apertural diameter*
Holotype:	111	71	44	50
Range:	108–135	68–87	41–50	41–48
Mean:	119	78	44	44

Description. The chamber and neck may meet abruptly and be sharply distinct, or they may merge so that their junction cannot be precisely located and reliable measurements of their lengths cannot be taken. The aperture is usually straight but occasionally it bears a fringe of small cones; it is half to two-thirds of the maximum diameter in width. In a small majority of specimens, the test walls are ornamented with few or many small cones (up to 1 μ in length) and, uncommonly, very small spines (up to 2·5 μ in length). These processes are most strongly developed and occur most frequently near the basal margin; orally they become progressively smaller and less common.

Comparison. S. fungiformis (Eisenack 1931) differs from *S. vulgaris* sp. nov. in having a fungiform test, a proportionately longer neck and a rounded basal margin; in *S. nodulosa* Collinson and Scott 1958 the ornament consists of thorn-like spines, which sometimes occur on the neck, or rounded nodes. In *S. collinsoni* Dunn 1959 the chamber is more depressed than in the new species, the neck is relatively longer and narrower, and the processes are larger.

Material. Fifty-five single tests.

Occurrence. Hope Shales: S21 (common).

Sphaerochitina actonica sp. nov.

Plate 75, figs. 20, 23, 24; text-fig. 12

Holotype. Plate 75, fig. 20. Specimen C6/54/3/C; basal Acton Scott Beds, sample C6.

Diagnosis. Small fungiform test. Chamber wide, about 60 per cent. total length; maximum diameter at base, 120–140 per cent. chamber length; basal margin bluntly rounded;

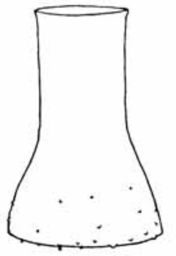


Fig. 11

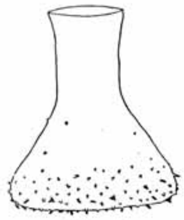


Fig. 12

TEXT-FIG. 11. *Sphaerochitina vulgaris* sp. nov. Lateral view of an ornamented test illustrating the nature, size, and distribution of the processes, ×325.

TEXT-FIG. 12. *Sphaerochitina actonica* sp. nov. Lateral view of an ornamented test illustrating the nature, size, and distribution of the processes, ×310.

base flat or convex. Neck cylindrical or slightly flaring, one-third to half maximum diameter in width; collarette often strongly flaring. Wall smooth or bearing numerous small simple and wishbone spines, restricted to the chamber and concentrated around the basal margin.

Dimensions in microns. (6 specimens measured.)

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube length*	*Oral tube diameter*
Holotype:	110	62	85	48	29 → 35
Range:	95–118	56–67	75–90	41–49	29–35 → 35–44
Mean:	104	62	85	44	32 → 38

Description. In general the chamber and neck are distinct, and their lengths can be measured precisely. The nature of the aperture is not known with certainty, since only specimens with damaged collarettes have been found; in two slightly damaged specimens, however, the aperture appears to be straight. The spines have sharp or blunt tips and are up to 4 μ in length. They are largest and most closely spaced near the basal margin, whilst on the upper flanks they are minute and very scarce; the neck is quite smooth.

Comparison. *S. pistilliformis* (Eisenack 1931) and *S. fungiformis* (Eisenack 1931) lack wishbone spines and have proportionately longer necks (two-thirds of the total length) than *S. actonica* sp. nov. *S. schwalbi* Collinson and Scott 1958 has a slightly shorter neck than *S. actonica* sp. nov. and a dense ornament of very short, simple spines covering the whole test.

Material. Several hundred single tests.

Occurrence. Acton Scott Beds: C6 (abundant).

ASSOCIATED MICROFOSSILS

Several other kinds of acid-resistant microfossils, including graptolite siculae, scolecodonts, acritarchs, and the organic linings of foraminifera, were found in association with the chitinozoans. These associated microfossils have not been studied systematically but are described briefly below. Their state of preservation is often excellent.

Graptolite siculae. Siculae and other graptolite fragments occur in various sediments throughout the Ordovician successions of the Shelve and Caradoc districts. Surprisingly, very large numbers were found in several samples from horizons in the Caradoc succession where graptolites in the form of macrofossils are exceedingly rare or have not been recorded; in the Shelve area siculae were not found in the Weston Beds. In some of the more well-preserved material, the prosicula, metasicula, and virgella are clearly distinguishable.

Scolecodonts. Scolecodonts, the jaws of polychaete worms, occur throughout the two Ordovician successions in virtually all types of sediment, except volcanic ash. A considerable variety of jaws was found but no attempt has been made to identify them. Scolecodonts are relatively resistant to oxidation. In weathered samples they are preserved noticeably better than the other groups of organic-walled microfossils (including the Chitinozoa), and they are the least readily bleached in several oxidizing agents, including Schultze's solution, concentrated nitric acid, fuming nitric acid, and sodium hypochlorite.

Acritarchs. Acritarchs have been found at more than twenty horizons between the base of the Llanvirnian and the top of the Caradocian. In some cases their preservation is excellent (samples C14/b and C1/a–h) but, since they are readily destroyed by carbonization and oxidation, they are not found in cleaved or greatly weathered sediments. Those acritarchs which have been examined and identified were retained on the 300-mesh sieve and represent only the larger size-fractions of much larger acritarch assemblages. They belong to five genera:

1. *Baltisphaeridium* Eisenack 1958*a* emend. Downie and Sarjeant 1963.

Three species of *Baltisphaeridium* were recorded. *B. longispinosum* (Eisenack 1931) is the commonest, ranging from the base of the Hope Shales to the top of the Caradocian and frequently occurring in large numbers (samples S21, C14/b). Populations of *B. longispinosum* show great morphological variation and consist of the forms *latiradiata* Eisenack 1959*b* and *filifera* Eisenack 1959*b*, and specimens transitional to *B. robustum*

(Sannemann 1955) and to *B. hirsuitoides* (Eisenack 1939 emend. Eisenack 1951). Typical *B. robustum* and *B. hirsuitoides* were not found. Rarely, however, forms attributable to *B. hirsuitoides* but transitional to *B. longispinosum* were found in upper Caradocian sediments. Specimens attributable to *B. polygonale* (Eisenack 1931) were found in the lower Llanvirnian and upper Caradocian. In contrast with the Baltic specimens (Eisenack 1959*b*) the spine tips appear to contain no dark material.

2. *Veryhachium* Deunff (1954) 1958 emend. Downie and Sarjeant 1963.

Two species of *Veryhachium* have been found. *V. lairdi* (Deflandre 1946) Deunff 1954 from the Hope Shales was represented by specimens up to 150 μ in diameter (body diameter + process length). The largest specimens from Veryhac'h (Deunff 1958) are 100 μ in diameter, whilst those from the Upper Llandoverian of Belgium (Stockmans and Willière 1963) are considerably smaller. *Veryhachium sp.* ranges from the base of the Hope Shales to the top of the Caradocian. The body is rounded triangular in outline and, from its apices, three long blade-like processes extend radially. Variation is apparently limited to the shape of the processes, which may be short and wide or long and thin. This species differs from *V.*? *macroceras* Deunff 1958 in always having three processes, each weakly constricted where it meets the central body.

3. *Leiofusa* Eisenack 1938.

Three species of Leiofusa were found. Numerous specimens closely resembling *Leiofusa tumida* Downie 1959 were found in the upper Caradocian. They are much larger (total length = 200–350 μ) than typical examples of *L. tumida* from the Wenlockian, and the spherical to subspherical central body makes up only one-fifth of the total length; to some extent, however, the difference in size between the Wenlockian and Caradocian specimens may be a reflection of the different techniques used in their preparation. All the Caradocian specimens are closely similar in shape and have a clear hyaline test wall texture. They may belong to a new species, but until whole populations can be examined they are designated *L.* cf. *tumida* Downie.

Many specimens resembling *Leiofusa filifera* Downie 1959 were found in the Hope Shales. They are larger (total length = 300–650 μ) than Wenlockian examples of *L. filifera* (total length = 30–350 μ), and have proportionately smaller and less sharply defined central bodies. These specimens possibly belong to a new species also, but whole populations have not been examined; for the present they are designated *L.* cf. *filifera* Downie. Transitional forms linking *L.* cf. *tumida* and *L.* cf. *filifera* were not encountered.

A single specimen of *Leiofusa navicula* Eisenack 1951, twice the size of the holotype (total length = 420 μ, diameter = 100 μ), was found in the upper Caradocian (sample C14/b). The type material is from the Vaginatenkalk of Estonia.

4. *Bacisphaeridium* Eisenack 1962*b*.

About thirty specimens belonging to a single species of *Bacisphaeridium* were found in sample C14/b (middle Marshbrookian, Caradocian). They are closely similar in shape, and vary only slightly in size. The body is circular in outline and 105–172 μ in diameter, the process is uniformly wide and 230–284 μ in length. A single specimen found in sample C6 (basal Actonian, Caradocian) is considerably smaller than any of the Marshbrookian examples (body diameter = 70 μ, process length = 225 μ). No examples were found having two or more processes. The British species has a much longer process

(60–75 per cent. total length) than *B. bacifer* (Eisenack 1934) from the Wesenberg Beds of Estonia. *Deunffia monacantha* (Deunff 1958) Downie 1960 has an oval-shaped body and a tapering process, and is one-third to half as large as the British specimens.

5. *Leiosphaeridia* Eisenack 1958*a* emend. Downie and Sarjeant 1963.

Leiospheres of various sizes were encountered, frequently in abundance, throughout the Ordovician successions of the Shelve and Caradoc districts, but no attempt has been made to classify them. Some specimens compare closely with *Leiosphaeridia voigti* Eisenack 1958 in the size and the thickness of their test walls. A number of tests folded into a fusiform shape like *Leiosphaeridia* cf. *baltica* Eisenack 1958*a* (pl. 2, fig. 12), but much larger, were found in a few Llandeilian and Caradocian assemblages. These are attributed to *Leiosphaeridia* for the present, but their frequent occurrence in clusters, each specimen apparently folded in exactly the same manner, makes the propriety of this identification doubtful.

In order to ascertain the prospects for future research on the Ordovician acritarchs of Shropshire, the fine-fractions of several residues (i.e. the portions of the residues passing the 300-mesh sieve) were mounted for examination under the microscope. In the Shelve samples the preservation of acritarchs is generally poor. The fine-fractions of the residues from samples S21 (basal Hope Shales), S1 (Weston Beds), S11 (Meadowtown Beds) contained a variety of forms including species of *Baltisphaeridium*, *Micrhystridium* Deflandre 1937 emend. Downie and Sarjeant 1963, *Veryhachium*, and *Leiofusa*. The actual numbers of specimens, however, were generally small, and only a small proportion of them were identifiable. The large numbers of fragmentary specimens in the Shelve assemblages suggests that quantitative studies will not generally be possible.

Well-preserved acritarchs are common in samples from the Caradoc area. The fine-fractions of the residues from samples C11 (lower Caradocian), C9 (middle Caradocian), C14/b, and C1/a (upper Caradocian) contained a variety of forms belonging to *Baltisphaeridium*, *Micrhystridium*, *Veryhachium*, *Leiosphaeridia*, and *Leiofusa*. Large numbers of well-preserved, identifiable specimens were found, and it appears that quantitative studies will generally be possible.

It is noteworthy that representatives of *Tasmanites* Newton 1875 (Chlorophyceae) were not found during the present study.

? Fungi. The existence of unidentified boring organisms (? fungi) is suggested by the occurrence of holes in the tests of some chitinozoans (Pl. 72, figs. 8–9). These hypothetical organisms appear to have been active before fossilization took place and to have affected only certain species, in particular *Cyathochitina kuckersiana* (q.v., p. 459). Evidence for their existence, in Britain, has been found only in sediments from the Caradoc area, while no actual remains of the organisms themselves have been seen.

Foraminifera. In carefully prepared residues, the organic linings of Foraminifera may be found more or less complete. They break up readily and the organic residues of some samples contain large quantities of fragmented linings.

STRATIGRAPHICAL DISTRIBUTION OF CHITINOZOANS IN SHROPSHIRE

The average stratigraphical interval between samples is about 170 ft. At several localities, however, a number of samples were collected at intervals of a few feet in order to determine the extent to which the character of the chitinozoan fauna was varying within short vertical intervals. After examining several sets of these adjacent samples it appears that within short sequences of either mixed or uniform lithology, the concentration of chitinozoans in the sediment may vary greatly and capriciously, but the relative abundance of each species (i.e. number of examples per thousand chitinozoans) remains much the same, and the same species are present.

A very common and perhaps universal character of chitinozoan assemblages is the relatively small number of species they contain. The average number of species in each of thirty-one assemblages from Shropshire is seven, the least varied assemblages consisting of only two species, the most varied consisting of twelve to fourteen species and up to nine other forms. The chitinozoans from the Shropshire assemblages belong to thirteen genera, one of them new, and have been allocated to thirty-two species, nineteen of which are new. A considerable number of forms occurring in these assemblages have not been described in this paper; in general they are neither referable to previously named species, nor are they adequate bases for the establishment of new species.

The previously named species found in Shropshire appear to be characteristic Ordovician forms. None of them has been recorded in the Devonian of the New World, North Africa, or Europe, nor in the Silurian of the Baltic. The few reported from the Silurian of the Sahara require special mention. *Lagenochitina cylindrica* Eisenack (undescribed and unillustrated by Taugourdeau and Jekhowsky (1960)) was recorded in a single Middle Silurian sample where it was very rare; *Conochitina elegans* (recorded as *Rhabdochitina conocephala* by Taugourdeau and Jekhowsky (1960)) was found in a single Lower Silurian sample; and rare specimens of *Cyathochitina campanulaeformis* (unillustrated and described as being somewhat different from typical forms by Taugourdeau (1962)) occurred in one or more Llandoverian samples. *Rhabdochitina magna* has been recorded in two Lower Silurian samples by Taugourdeau and Jekhowsky (1960) who, I believe, interpret this species more widely than would be justifiable on the basis of the Baltic and British material. Cramer's (1964) reports of *Conochitina elegans* (designated *Rhabdochitina conocephala*) and *Cyathochitina campanulaeformis* from the Silurian of Spain are probably based upon misidentified material; the specimens Cramer figures as examples of these two species clearly do not support his identifications.

Distribution in the Llanvirnian. Except for some examples of *Sphaerochitina vulgaris* bearing very small spines and cones, chitinozoans from the Llanvirnian of Shropshire have perfectly smooth test walls. Several species, including *Conochitina chydaea*, *Cyathochitina campanulaeformis*, *Rhabdochitina usitata*, *R. turgida*, and *Siphonochitina robusta* range through the whole of the Llanvirnian but are not restricted to it, whilst others have more limited ranges and may prove useful in subdividing the series. Assemblages from the lower Llanvirnian (Hope Shales) are strikingly characterized by species of *Siphonochitina* having slender tests and large siphons (*S. formosa* and *S. tenuicollis*); nothing comparable with them has been found elsewhere and they may prove to be useful stratigraphical markers, at least locally. With them, and sometimes in large numbers, occur *Siphonochitina robusta* and *Conochitina parviventer*, but the latter do occur elsewhere, though infrequently and only in reduced numbers. *Cyathochitina calix*, *Lagenochitina cylindrica*, and *L. esthonica* have been found only in the basal Hope Shales.

Only two new forms (*Pterochitina sp.* and *Siphonochitina clavata*) appeared in the middle and upper Llanvirnian (Stapeley Shales, Weston Beds, Betton Beds) to take the place of the missing lower Llanvirnian forms. *Pterochitina sp.* was found at the top of the Stapeley Shales whilst *S. clavata* was first recorded in the Betton Beds and extends into the lower Caradocian. It is remarkable that *Desmochitina minor* was not found in British Llanvirnian sediments, since it occurs in considerable numbers at this time in the Baltic.

Distribution in the Llandeilian. Llandeilian assemblages differ from those of the Llanvirnian in that species of *Siphonochitina* are absent and *Desmochitina minor* is present. There are otherwise no marked differences between upper Llanvirnian and Llandeilian assemblages, the latter being comprised almost entirely of forms continuing from the Llanvirnian. With the exception of some examples of *Conochitina chydaea* which bear an ornament of small cones, Llandeilian chitinozoans, like those of the Llanvirnian, have smooth test walls. *Desmochitina minor* was found throughout the series, where its shape is quite distinct and somewhat different from that of *D. minor* forma *typica* and forma *cocca* of the Caradocian. Llandeilian chitinozoans from Shropshire are morphologically simple, lacking elaborate ornamental and structural elements; and numerically large assemblages contain very few species. These do not appear capable of supporting any subdivision of the series.

Distribution in the Caradocian. The chitinozoan assemblages of the Llandeilian and Caradocian are quite distinct and separated by an abrupt faunal change. Caradocian assemblages are characterized by forms with wide skirt-like carinae, appendices of various types and, in the upper part, several distinct styles of ornamentation; in addition, fifteen species and five genera appear for the first time in this series.

Conochitina elegans, *Cyathochitina kuckersiana*, *Desmochitina minor* forma *typica*, and *Lagenochitina baltica* first appear at the base of the Caradocian and persist throughout the series. Whilst they play no part in subdividing the series these forms readily distinguish Caradocian from earlier assemblages. In Britain, it is not known whether these four forms continue above the Caradocian, but in the Baltic, where younger sediments have been studied, *C. elegans* has been found only in the lower part of the Caradocian (C_2–D_2), *L. baltica* only in the Ashgillian (F_1), and *C. kuckersiana* and *D. minor* f. *typica* in both the Caradocian and Ashgillian (C_2–F_1). None of these four forms has been recorded from the Baltic Silurian.

The lowest Caradocian strata are distinctive because *Ancyrochitina* is absent. It first appears at the base of the Glenburrell Beds but with the main generic character, the appendices, weakly developed (*A. bulmani*). Typical forms of *Ancyrochitina* first occur about half-way through the Caradocian (*A. alaticornis*), at roughly the same time as the earliest Baltic record (*A. multiradiata* in D_1, Eisenack 1959*a*). *A. alaticornis* ranges from the Alternata Limestone through the Cheney Longville Flags and into the basal Acton Scott Beds, where it is accompanied, in abundance, by *Hoegisphaera complanata* and *Sphaerochitina actonica*, neither of which has been found elsewhere in Britain.

Near the top of the Caradocian, a pronounced and fairly abrupt change takes place in the chitinozoan fauna. Earlier assemblages, consisting very largely of forms with smooth test walls, give way to assemblages containing forms with strongly developed

LLANVIRNIAN						LLANDEILIAN					CARADOCIAN															
S25	S21	S36	S37	S1	S2	S8	S3	S4	S5	S11	C16	C11	C9	C8/b–c	C14/b	C6	C4	C2/a	C2/b	C2/c	C2/d	C1/a–c	C1/d	C1/e	C1/f–h	*Sample* / *Species*
																+										*Sphaerochitina actonica*
	+																									*S. vulgaris*
	+	+										+														*Siphonochitina robusta*
					+							+														*S. clavata*
												+														*S.* cf. *pellucida*
+	+																									*S. tenuicollis*
		+																								*S. formosa*
+	+	+		+	+	+	+			+		+					+	+	+	+						*Rhabdochitina usitata*
	+	+		+			+																			*R. turgida*
	+					+																				*R. magna*
			+																							*Pterochitina sp.*
												+														*Lagenochitina capax*
												+														*L. shelvensis*
	+																									*L. esthonica*
	+																									*L. cylindrica*
											+	+	+					+				+	+		+	*L. baltica*
																+										*Hoegisphaera complanata*
																		+	+							*Hercochitina downiei*
												+														*D. minor* f. *cocca*
											+	+	+		+	+			+	+	+	+	+	+	+	*D. minor* f. *typica*
						+			+	+	+	+	+		+	+			+	+	+	+	+	+	+	*Desmochitina minor* s.l.
											+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	*Cyathochitina kuckersiana*
+	+			+	+		+	+	+																	*C. campanulaeformis*
+																										*C. calix*
											+	+	+		+	+	+	+	+		+	+	+	+	+	*Conochitina elegans*
	+	+					+																			*C. parviventer*
+	+	+	+	+	+	+	+	+	+	+	+	+										+	+	+	+	*C. chydaea*
												+									+	+				*C. lepida*
																				+	+					*Angochitina dicranum*
																						+	+	+	+	*A. communis*
												+														*Ancyrochitina bulmani*
													+	+	+	+										*A. alaticornis*
																			+	+	+	+	+	+	+	*A. onniensis*
																					+	+	+	+	+	*Acanthochitina barbata*

Table I. Vertical distribution of some species of chitinozoans in the Ordovician of Shropshire and very varied ornamental processes. Within a stratigraphical interval of 50 ft., five strongly ornamented species (*Acanthochitina barbata*, *Ancyrochitina onniensis*, *Angochitina communis*, *A. dicranum*, and *Hercochitina downiei*), and three genera (*Acanthochitina*, *Angochitina*, and *Hercochitina*) whose chief diagnostic features are their ornamentation, appear for the first time in Britain. Whilst *Angochitina dicranum* and *Hercochitina downiei* appear to be very short lived and may prove useful in local correlation, *Acanthochitina barbata*, *Ancyrochitina onniensis*, and *Angochitina communis* continue to the top of the succession.

Four types of chitinozoan assemblage have been distinguished in the Caradocian of Shropshire.

Assemblage type 1. The oldest Caradocian assemblages are characterized by the four typical Caradocian forms (*Conochitina elegans*, *Cyathochitina kuckersiana*, *Desmochitina minor* forma *typica*, and *Lagenochitina baltica*) and the absence of species of *Ancyrochitina*. This type of assemblage occurs at the base of the Caradocian, extending into the Harnagian but no higher than the base of the Glenburrell Beds.

Assemblage type 2. The stratigraphical range of this type of assemblage is known only approximately, extending certainly from the middle Harnagian and possibly from the lower Harnagian to a level somewhere below the Alternata Limestone. Chitinozoans characteristic of this type of assemblage are *Ancyrochitina bulmani*, which has remarkably small and sometimes numerous appendices, and *Desmochitina minor* forma *cocca*.

Assemblage type 3. The most important feature of this type of assemblage is the presence of *Ancyrochitina alaticornis*, readily distinguished by its spectacular wing-like appendices, which commonly bear secondary processes on the thinner edge. The vertical range of this type of assemblage embraces the Alternata Limestone, the Cheney Longville Flags, and the basal Acton Scott Beds; it possibly includes older strata but it does not reach the top of the Acton Scott Beds. *Hoegisphaera complanata* and *Sphaerochitina actonica* are abundant in the basal Acton Scott Beds and may prove useful in dividing this assemblage type further.

Assemblage types 3 and 4 are separated by about 250 ft. of beds in which neither *Ancyrochitina alaticornis* nor the diagnostic chitinozoans of assemblage type 4 have been found.

Assemblage type 4. This type of assemblage is distinctive because of the variety and abundance of forms with ornamental processes. It is strikingly different from the assemblages found at lower horizons, in which forms with smooth test walls predominate. Characteristic species are *Acanthochitina barbata*, which is furnished with uniformly distributed short pillars supporting a raised reticulum, and *Ancyrochitina onniensis* and *Angochitina communis*, both of which bear simple and wishbone spines. Assemblages of this type occur only in the top 70–80 ft. of the series (upper *Onnia* Beds). Two distinctive species with known vertical ranges of about 15 ft. characterize the earliest assemblages of this type. They are *Angochitina dicranum*, which has pitchfork-shaped spines, and *Hercochitina downiei*, the spines of which are arranged in longitudinal rows and connected at their tips by longitudinal bars running parallel with the test wall.

COMPARISON WITH ORDOVICIAN FAUNAS FROM THE BALTIC AND NORTH AFRICA

In many respects the chitinozoan faunas of the Baltic and British Ordovician are closely comparable. Communication between them appears to have been generally fairly free and apparently at its maximum during the Caradocian. Eleven species found in Shropshire (*Acanthochitina barbata*, *Conochitina elegans*, *Cyathochitina calix*, *C. campanulaeformis*, *C. kuckersiana*, *Desmochitina minor*, *Hoegisphaera complanata*, *Lagenochitina baltica*, *L. cylindrica*, *L. esthonica*, and *Rhabdochitina magna*) have been described by Eisenack from the Baltic, where they appear to be characteristic Ordovician forms.

In Llanvirnian times, communication between the Baltic and British faunas appears to have been less free than it was during the remainder of the Ordovician. The most striking differences between the two faunas at this time are, firstly, the abundance and variety of *Siphonochitina* in Britain and its apparent absence in the Baltic, and secondly, the absence of *Desmochitina* in British assemblages; this distribution suggests that some factor, perhaps an ecological difference, was hindering the spread of certain forms between the two regions. However, in spite of this hypothetical factor five of fourteen British Llanvirnian species (*Cyathochitina calix*, *C. campanulaeformis*, *Lagenochitina cylindrica*, *L. esthonica*, and *Rhabdochitina magna*) occurred in the Baltic, all but *L. cylindrica* (horizon unspecified) during some part of the Llanvirnian.

It appears that the generic differences between the two North European Llanvirnian faunas did not persist into the Llandeilian. In both regions at this time, species of *Siphonochitina* were apparently absent and *Desmochitina* was represented by *D. minor*. However, the conservative morphology of *D. minor* throughout the British Llandeilian contrasts with the variety it assumes in the Baltic. Three of seven British Llandeilian species (*Cyathochitina campanulaeformis*, *Desmochitina minor*, and *Rhabdochitina magna*) have also been found in the Baltic at this time. These facts suggest that communication between the two faunas in Llandeilian times was, to some extent, more free than in the Llanvirnian.

The Caradocian faunas of Shropshire and the Baltic correspond closely. In both regions *Cyathochitina kuckersiana* and *Desmochitina minor* f. *typica* occur throughout the series, and typical examples of *Ancyrochitina* first appear at approximately the same stratigraphical level. *Conochitina elegans*, which has been found throughout the series in Britain, ranges through at least the lower half of the Baltic Caradocian (C_2–D_2). A variety of cylindroconical forms having simple, generally short, spines occurs in the majority of British Caradocian assemblages. These forms are not described in this paper but they possibly represent *Conochitina micracantha* Eisenack 1931 of the Baltic; further work is necessary to determine which, if any, of Eisenack's several forms of this species are represented in Britain.

Besides these similarities, however, there are several striking differences between the two Caradocian faunas. In Britain, *Cyathochitina campanulaeformis* is last found in the Llandeilian, whilst in the Baltic it continues through the Caradocian and into the Ashgillian. *Lagenochitina baltica* is characteristic of assemblages from the base and summit of the British Caradocian, but in the Baltic it occurs in the *Diplograptus*-Kalk, and in the Lyckholm Beds which are considered to be Ashgillian. The difference between the two faunas is emphasized by the lack of variety and scarcity of *Ancyrochitina* in the Baltic, and by the absence of *Parachitina* and *Conochitina minnesotensis* Stauffer 1933 in Shropshire. The appearance of *Acanthochitina barbata* and the genus *Angochitina* at the top of the British Caradocian slightly anticipates their appearance in the Lyckholm Beds of the Baltic, suggesting that the dispersal of chitinozoans was sometimes fairly slow, or that the *Onnia* Beds are only slightly older than the Lyckholm Beds.

Eisenack (1962*a*) outlined the stratigraphical occurrence, in the Baltic, of three apparently closely related species of *Cyathochitina* (*C. calix*, *C. campanulaeformis*, *C. kuckersiana*). *C. calix* ranges from B_2 (Arenig) to C_1 (upper Llanvirnian–Llandeilian) and is then replaced by *C. campanulaeformis*. *C. kuckersiana* develops from *C. campanulaeformis* in the lowest Caradocian, C_2, and both species continue through the Caradocian into the Ashgillian, F_1. These three species also occur in Shropshire. However, *C. calix* has been found only at the base of the Llanvirnian, where it is accompanied by typical examples of *C. campanulaeformis* and a few forms transitional between the two species. *C. campanulaeformis* ranges from the base of the Llanvirnian into the Llandeilian but was not found in the Caradocian. As in the Baltic, *C. kuckersiana* first appears at the base of the Caradocian and continues to the top of the series, but the species is generally represented by forms closer to forma *brevis* than to typical *C. kuckersiana*; in the Baltic, f. *brevis* is found from D_1 to D_3 (middle Caradocian). Since these three species are so similar their identification is possibly somewhat subjective. However, I have attempted to distinguish them in precisely the same manner as their author (Eisenack), and have discussed with him, in correspondence, the differences between *C. campanulaeformis* and *C. kuckersiana*.

The Ordovician chitinozoan faunas described by Taugourdeau and Jekhowsky (1960), and Benoit and Taugourdeau (1961) from North Africa compare only remotely with the British fauna and include only two of the species (*Rhabdochitina magna* and *Siphonochitina pellucida*) recognized in Shropshire. It should be noted, however, that three species known from the Ordovician of Britain and the Baltic (*Cyathochitina campanulaeformis*, *Lagenochitina baltica*, *L. cylindrica*) have been included in a chart (Benoit and Taugourdeau 1961) showing the ranges of some North African Ordovician chitinozoans, but that none of them has been described or figured. The fact that *Clathrochitina* is represented in several North African Ordovician assemblages but has not been found in Shropshire emphasizes the differences between the two faunas. On the other hand, however, it is remarkable that chitinozoans belonging to the genus *Siphonochitina* occur in Ordovician assemblages from North Africa (Benoit and Taugourdeau 1961, Combaz and Poumot 1962) and Britain, but are unknown in the Baltic.

From the information presently available, it appears that communication between the Ordovician faunas of Shropshire and the Baltic was fairly free, especially in Caradocian times, whilst communication between the North European and North African faunas was considerably more limited.

Chitinozoan assemblages have also been found in the Ordovician Rhenish Schiefergebirge (Eisenack 1939), the Llanvirnian–Llandeilian of Bohemia (Eisenack 1948), the Middle Ordovician Tulip Creek Formation of Oklahoma (Wilson and Dolly 1964), the Upper Ordovician Sylvan Shale Formation of Oklahoma (Wilson 1958) and the Caradocian Nod Glas Formation of Merioneth (Rhodes 1961). These assemblages are Ordovician in character but too little is known about them to allow adequate comparison with the chitinozoan faunas from the Baltic, Shropshire, and North Africa.

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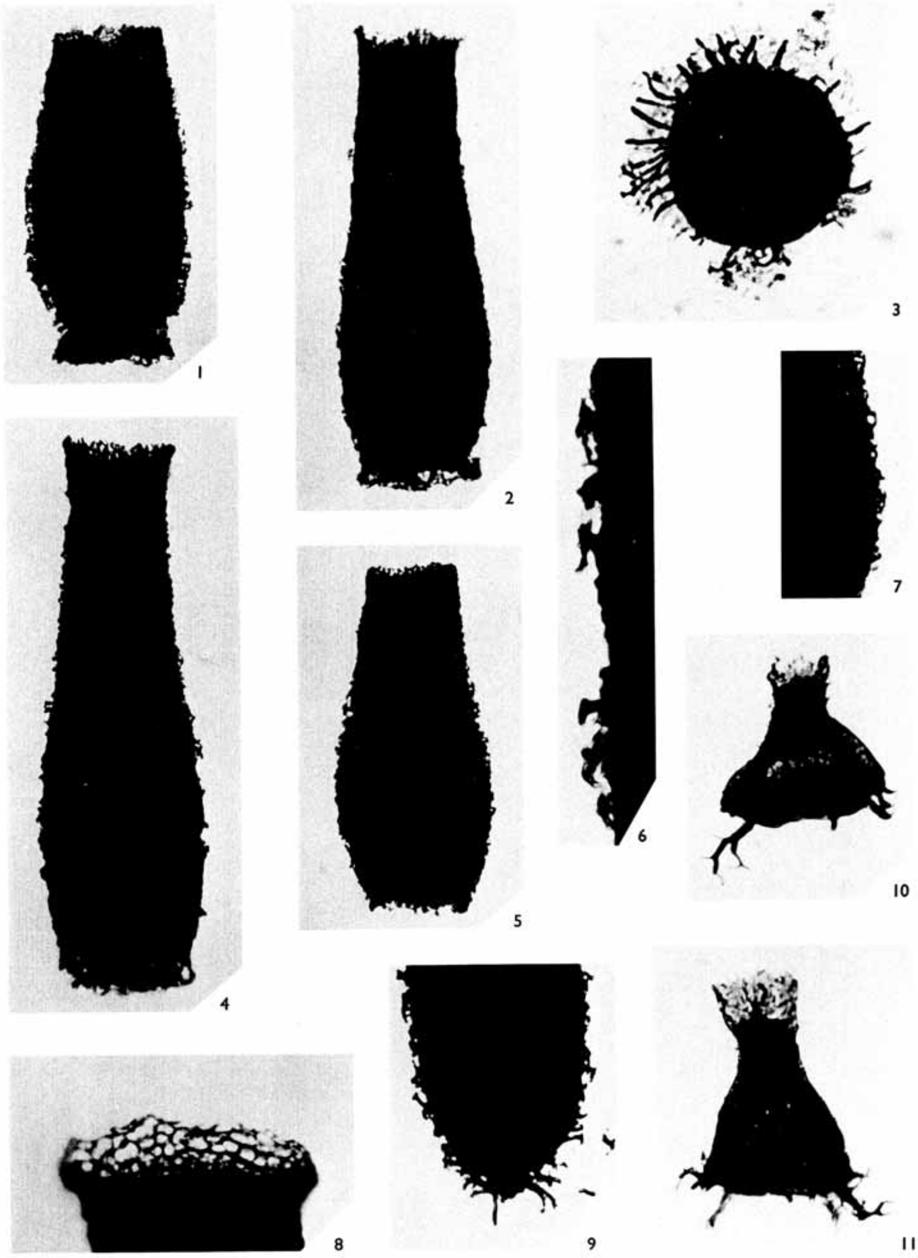

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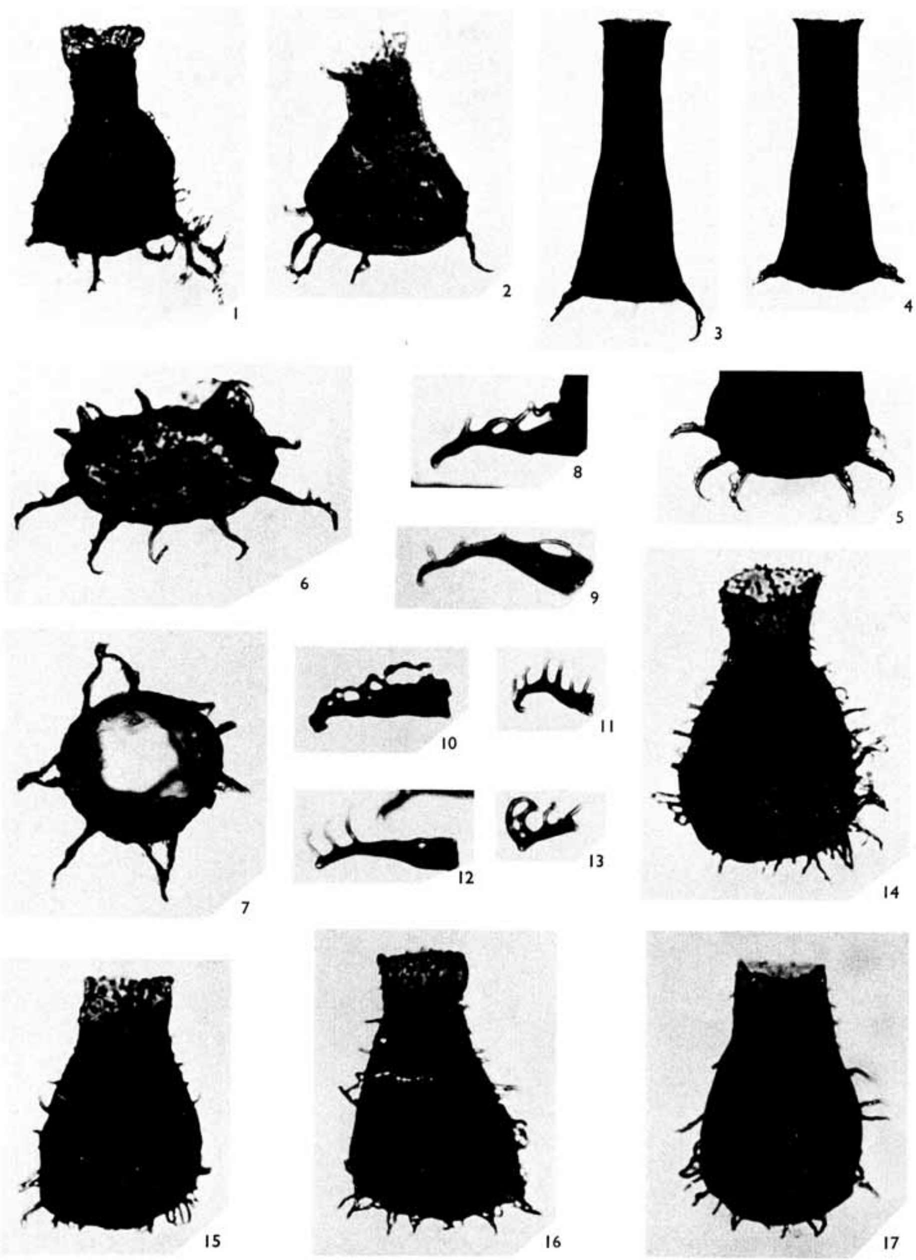

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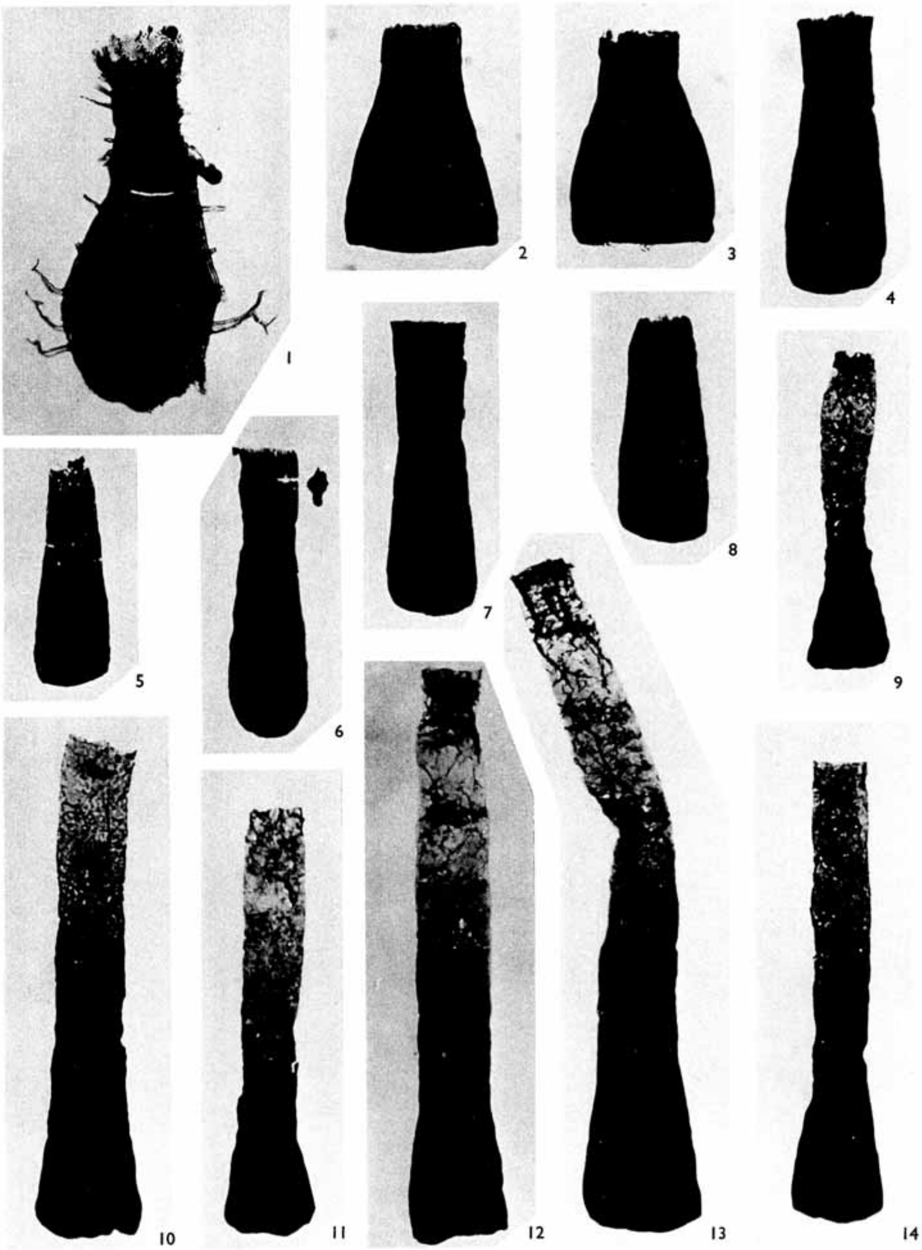

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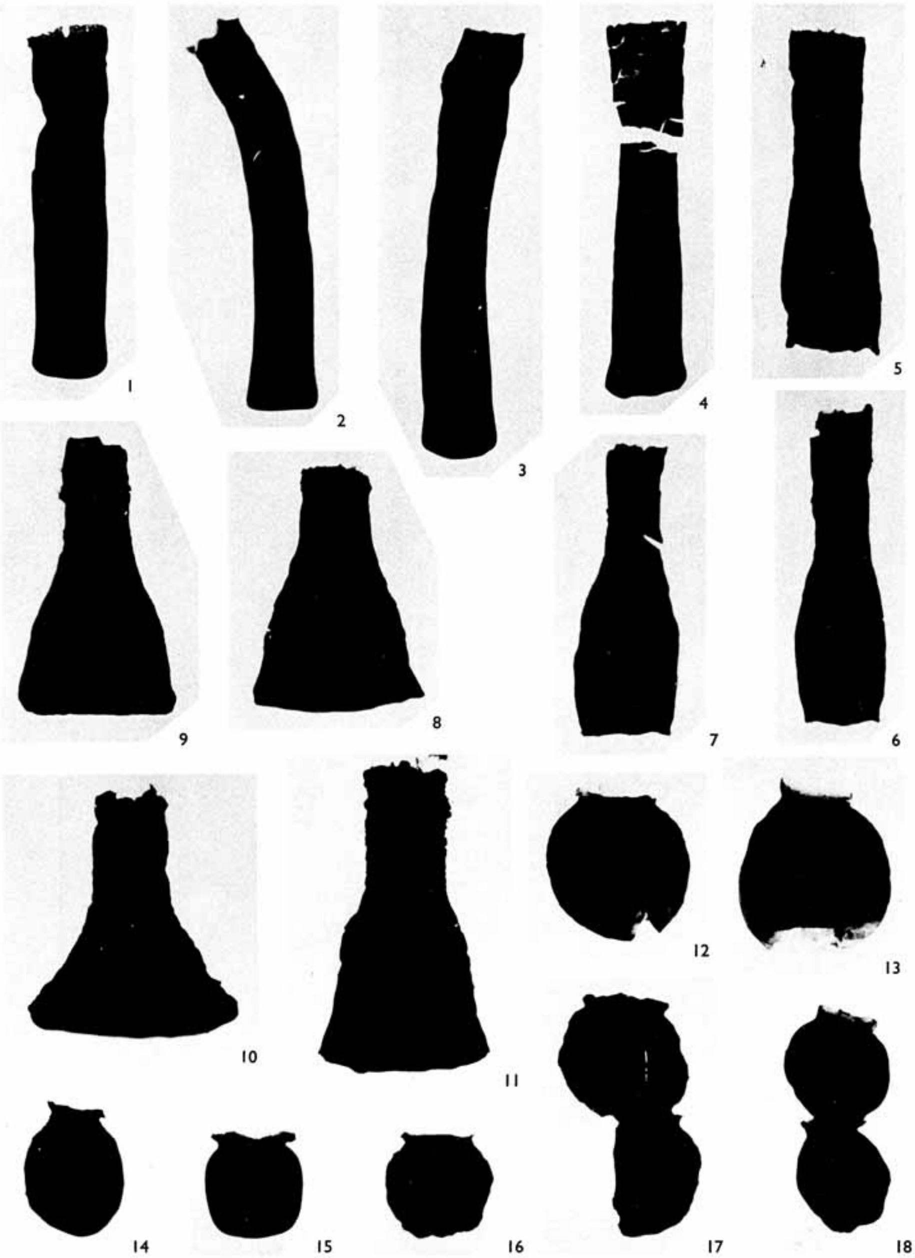

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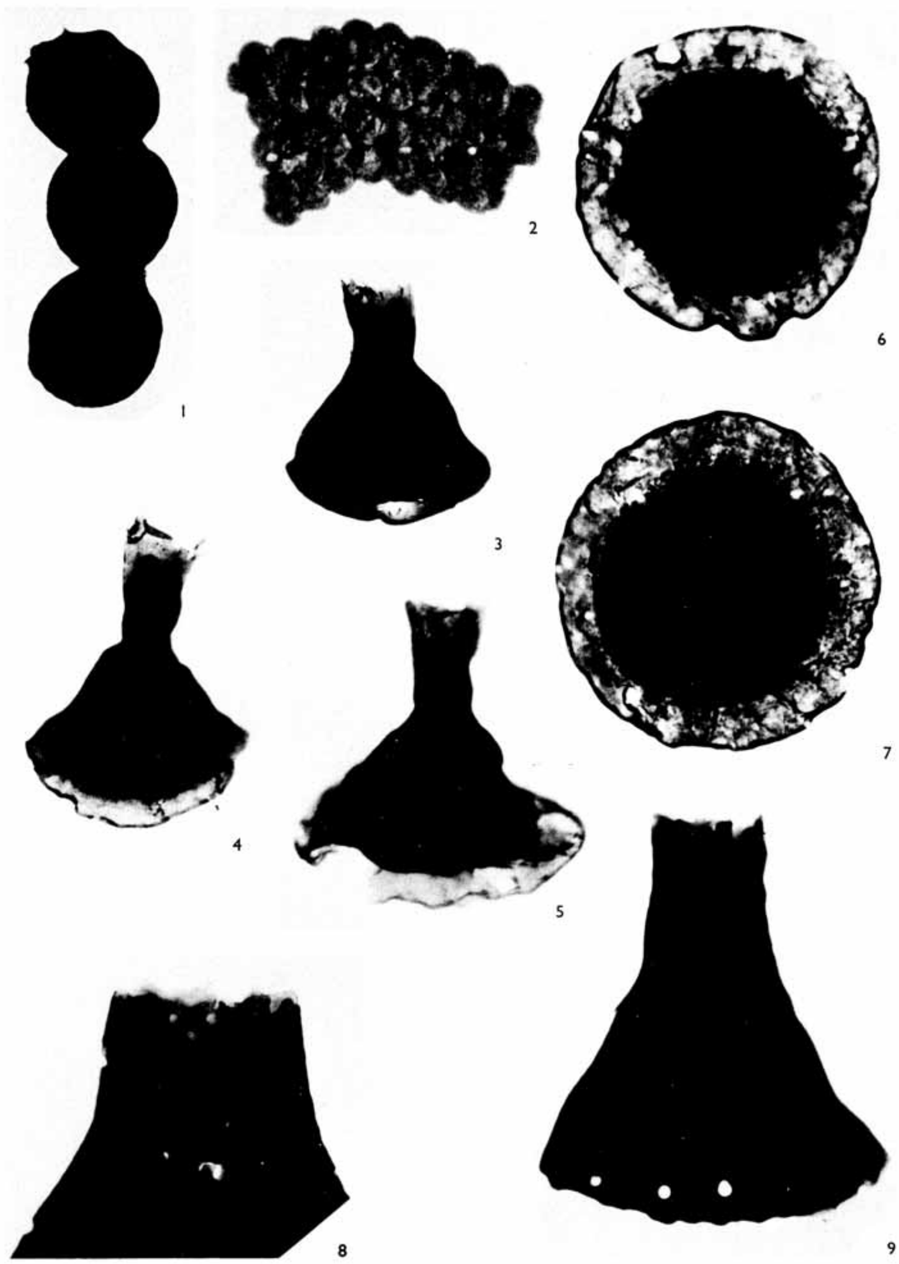

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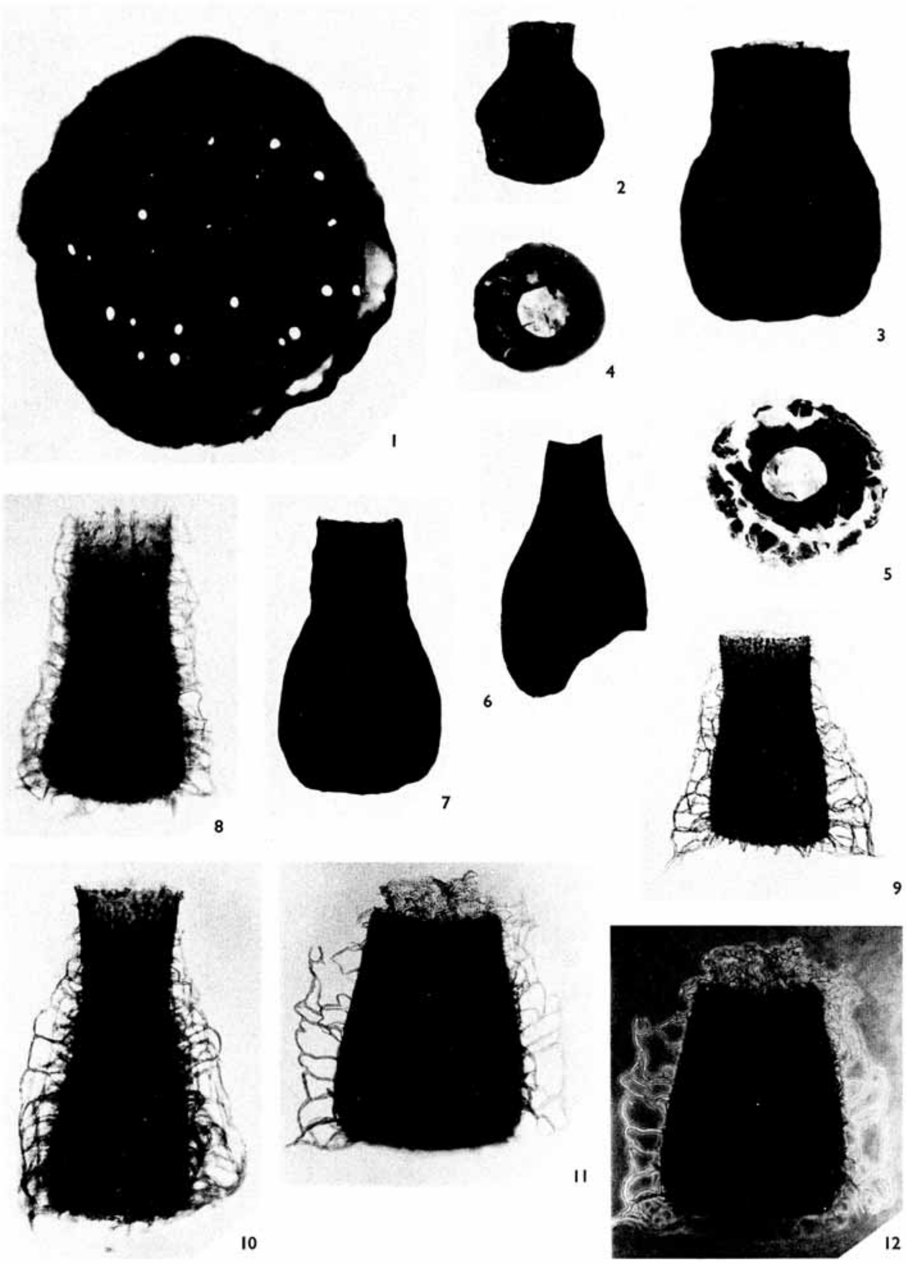

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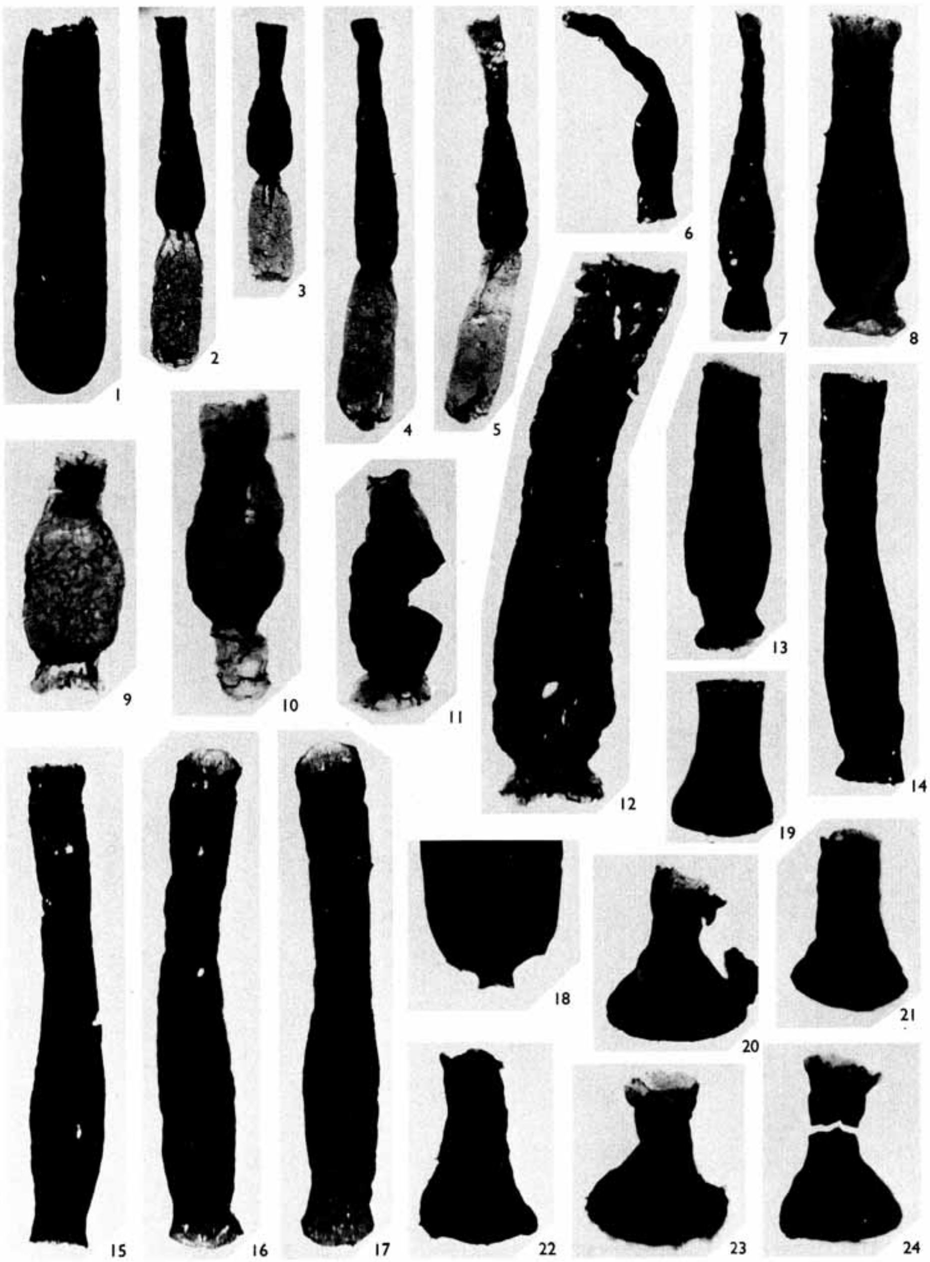

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