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W. A. M. JENKINS

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With 9 plates

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CONTENTS

ABSTRACT. Chitinozoa referable to ten genera, and twenty species of which six are new, occur abundantly throughout the Viola–Fernvale limestone sequence in the Arbuckle Mountains of southern Oklahoma. The chitinozoan fauna is strikingly similar to Upper Ordovician faunas of Europe and comprises two elements. A cosmopolitan element consists of species known also from the Caradoc–Ashgill, C_2–F_2, of Estonia, Sweden, and Britain and from the Ostseekalk of north Germany, Gotland, and south Finland. A smaller and apparently provincial element consists of species known only from North America, several of which are characterized by a general style of ornamentation that is typical of North American forms and peculiar to the Upper Ordovician. The fauna is described systematically, and a provisional zonation of the Viola–Fernvale sequence is proposed.

The general continuity of the faunal succession indicates that deposition was virtually continuous throughout most of the Viola–Fernvale sequence; this view is strongly supported for the lower half of the sequence by the continuity of the evolutionary series *Conochitina robusta–Hercochitina crickmayi* f. *spinetum–H. crickmayi* f. *normalis*. An abrupt faunal break occurs, however, near the top of the Viola Limestone. Although the magnitude of the depositional hiatus which it represents is difficult to deduce, the break in the faunal succession is quite spectacular. This provides a palaeontological basis for concluding that a significant hiatus exists here and indicates that the uppermost Viola–Fernvale strata are substantially younger than the beds immediately below. The break does not coincide with the change from Viola to Fernvale lithology but lies within the Viola Limestone. No faunal or stratigraphical evidence for a break in deposition has been detected at the base of the Fernvale Limestone.

This study demonstrates that many chitinozoan species have a very wide geographical distribution in the Upper Ordovician and that a large proportion of Upper Ordovician species are shared between North America and northern Europe. Most important perhaps, it indicates that correlation between the two continents is clearly feasible on the basis of these microfossils.

INTRODUCTION

CHITINOZOA are organic-walled microfossils of established value in the correlation of Lower Palaeozoic and Devonian sediments. In this paper they are applied for the first time to the North American Lower Palaeozoic succession in an effort to establish an Upper Ordovician chitinozoan reference section, and to demonstrate that chitinozoans provide an additional basis for correlations between North America and northern Europe. An incidental objective of the present study was to determine if the Viola and Fernvale Limestones in the Arbuckle Mountains of southern Oklahoma are separated by a major stratigraphical break.

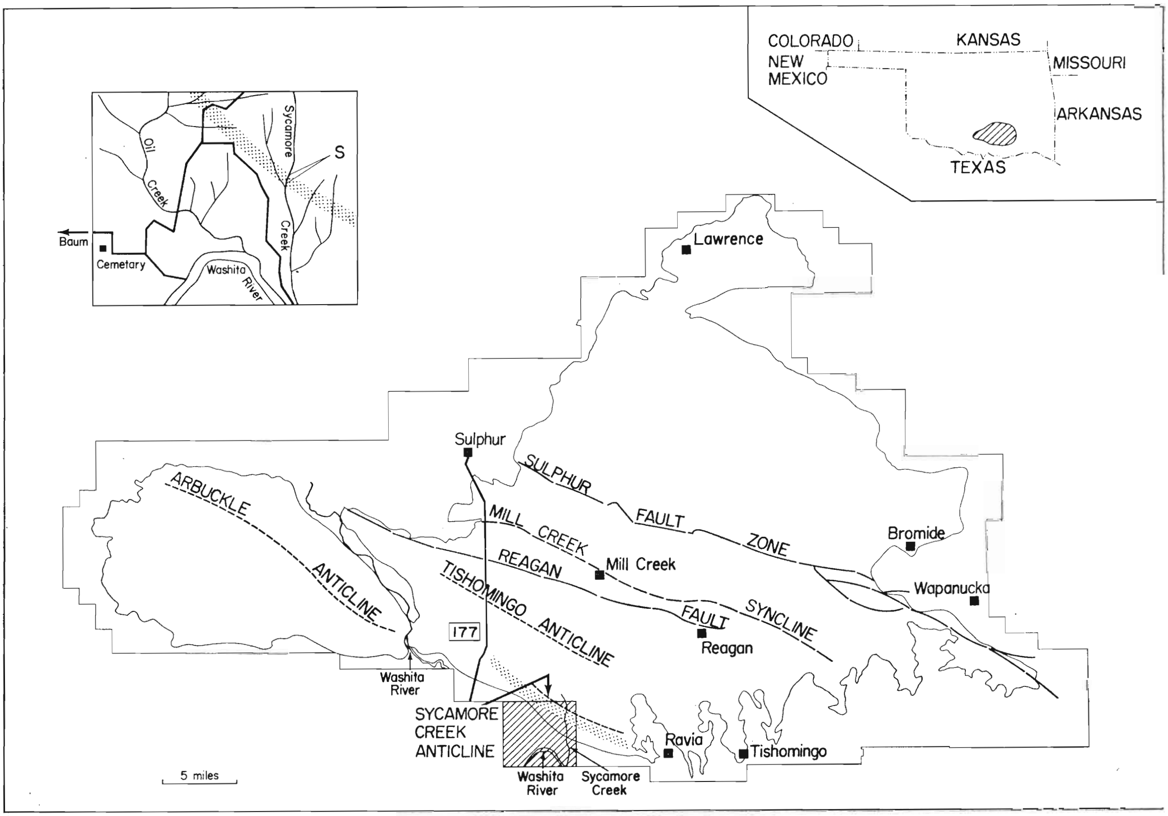
The Viola and Fernvale formations make up a distinct lithostratigraphical limestone unit within the upper part of the Ordovician sequence exposed in the Arbuckle Mountains. The unit was chosen for this study primarily because an initial examination of samples from several North American Upper Ordovician formations showed it to contain numerous, well-preserved chitinozoans at practically all stratigraphical levels. Several additional factors also favoured its selection as a standard for stratigraphical reference. In particular, it is a well-defined, readily recognizable stratigraphical unit, bounded above and below by regional unconformities. The unit is completely exposed in the Arbuckle Mountains, for which reason the samples were collected there, and has been widely recognized in the subsurface of south-central and south-western Oklahoma.

The Viola–Fernvale unit is particularly well exposed and little disturbed by faulting in a narrow strip of country 14 miles long, running west-north-west from Ravia to the Washita River along the steeply dipping southern flank of the Sycamore Creek Anticline (text-fig. 1). Chitinozoans from this outcrop form the basis of this study.

The Fernvale Limestone of southern Oklahoma is so termed on the basis of an extremely tenuous correlation with the Fernvale Limestone of Tennessee. In this paper the term 'Fernvale' is used only with reluctance and because no more satisfactory name for the rocks in question is available. A comprehensive lithostratigraphical and biostratigraphical study of the Viola–Fernvale unit by Drs. L. P. Alberstadt and G. C. Glaser is expected to be published shortly by the Oklahoma Geological Survey. In it, Dr. Alberstadt has kindly informed me, the authors propose new names for the unit, and refer to the entire Viola–Fernvale sequence as the Viola Formation, which they divide into four members. The uppermost member corresponds exactly to the Fernvale Limestone of the present study, and the three lower members correspond to the Viola Limestone as used here. The unpublished dissertations of Alberstadt (1967) and Glaser (1965), presented to the University of Oklahoma, have been consulted.

PREVIOUS RESEARCH ON CHITINOZOANS FROM THE VIOLA AND FERNVALE LIMESTONES AND THEIR CORRELATIVES

North American chitinozoans were recorded for the first time by Stauffer (1933), who described one species, *Rhabdochitina? minnesotensis*, from the Decorah Formation of Minnesota. This formation has been correlated with part of the lower Viola Limestone of Oklahoma by Twenhofel *et al.* (1954) but is considered somewhat older than the Viola by Templeton and Willman (1963, figs. 27, 29*b*).



TEXT-FIG. 1. Chart showing the outcrop (outlined) and structural features of the pre-Pennsylvanian rocks in the Arbuckle Mountains. The upper left inset map (represented by the shaded rectangle in the chart) shows the outcrop (stippled) of the Viola and Fernvale Limestones exposed in the Sycamore Creek Anticline, and the road from Baum (on U.S. Highway 177) to the section (S) which provided the rock samples for this study. Compiled from Ham, W. E. 1955, *Geology of the Arbuckle Mountain Region.* Guide Book III; Ham, W. E. *et al.* 1954, *Geologic Map and Sections of the Arbuckle Mountains, Oklahoma.* Guide Book III. Both published by the Oklahoma Geological Survey.

Cooper (1942) referred briefly to chitinozoans in the Palaeozoic of the Mississippi Valley, and Whittington (1955), in the course of his graptolite studies in the Viola Limestone of Oklahoma, encountered 'elongate sacs' which he photographed in infra-red light and referred to *Rhabdochitina* cf. *R. minnesotensis*. Recently, Taugourdeau (1965) has recorded chitinozoans in one sample of Viola Limestone from the Criner Hills of Oklahoma, and Miller (1966) has accompanied a discussion of chitinozoan processing techniques with photographs of *Conochitina robusta* Eisenack 1959 (Miller, op. cit., pl. 3, figs. 4*a*, *b*), *C. minnesotensis* (Stauffer 1933) (op. cit., pl. 4, figs. 2*a*, *b*) and *Cyathochitina kuckersiana* (Eisenack 1934) (op. cit., pl. 1, figs. 1, 4–5) from the Viola Limestone of Oklahoma.

Echols and Levin (1966) have recognized chitinozoans in the Plattin, Decorah and Kimmswick Formations in Missouri, which have been correlated with part of the Viola Limestone by Twenhofel *et al.* (1954). These formations, however, may include considerably older strata than the Viola Limestone (Templeton and Willman 1963, fig. 27).

GENERAL GEOLOGY OF THE VIOLA–FERNVALE UNIT IN THE ARBUCKLE MOUNTAINS

Lithology and thickness of the Viola Limestone. The lower part of the Viola Limestone cropping out in the south-western Arbuckle Mountains consists of greyish to dark brown, hard siliceous calcite mudstones in beds ranging from a few inches to 1 or 2 ft. in thickness and having flat bedding planes. The beds of siliceous limestone frequently alternate with thin beds (an inch or so thick) of unsilicified calcite mudstone with a shaly structure, but which, according to Ham (personal communication, 1966), contain no clay minerals. Chert is often abundant. These beds contain abundant graptolites at some horizons and cryptolithid trilobites. In the north-eastern Arbuckle Mountains the lower part of the formation is made up of thinly bedded to massive, non-siliceous, grey calcite mudstones, and light grey to brown calcarenites containing very little chert. Sandstone partings a few inches thick, thin sandy limestones, thin limestones with a shaly structure, and thin siliceous limestones occur interbedded within the calcite mudstones and calcarenites. Bedding planes are flat or slightly wavy. Graptolites are numerous at certain horizons and cryptolithid trilobites are present.

The upper part of the Viola Limestone throughout the Arbuckle Mountains consists of thinly bedded to massive, light grey to brown, non-siliceous, calcarenitic calcite mudstones containing variable, and sometimes abundant, quantities of nodular chert. Thin, irregularly bedded limestones with some shaly structure occur locally, and dolomitic beds up to 3 in. thick occur infrequently throughout the sequence. The upper part of the Viola Limestone is characterized by wavy to very irregular bedding planes and contains a fauna of crinoids, cryptolithid trilobites, and brachiopods.

The Viola sediments of the south-western Arbuckle Mountains were laid down in the rapidly subsiding basin of the Arbuckle Geosyncline, whereas those to the north and east of a line now followed approximately by the Reagan Fault (text-fig. 1) were deposited on a slowly subsiding geosynclinal shelf. This led to the accumulation of less sediment in the north-east than in the south-west and explains the general thinning of the formation toward the north-east. The average thickness of the lower Viola Limestone south-west of the Reagan Fault is about 200 ft., with a maximum thickness of nearly 350 ft. in the extreme south-west. To the north and east this lower division thins to about 50 ft. The upper Viola Limestone in the south-west averages between 400 and 450 ft. in thickness, reaching a maximum thickness of about 480 ft., but thins to an average of 250–300 ft. in the north and east.

Lithology and thickness of the Fernvale Limestone. The Fernvale Limestone is a medium- to coarse-grained, fossiliferous calcarenite containing very little fine-grained material, no siliceous limestone and no chert. The fresh rock varies from light, sometimes pinkish, grey to dark grey or buff and is massively bedded with indistinct, flat or slightly wavy bedding planes. Characteristically, it weathers into dull grey slabs which give it a less massive appearance. The rock, which is locally highly fossiliferous, contains brachiopods, which may be silicified, trilobites, and abundant crinoidal detritus. The formation attains its maximum thickness of about 100 ft. in the Mill Creek Syncline between Mill Creek and Reagan and in the Sulphur Fault Zone near Wapanucka. It becomes progressively thinner toward the south-west, where its average thickness is between 30 and 40 ft. in the Tishomingo Anticline and about 20 ft. in the Arbuckle and Sycamore Creek Anticlines. In the north-eastern outcrops between Bromide and Lawrence the formation is generally between 55 and 85 ft. thick with an average thickness of about 70 ft.

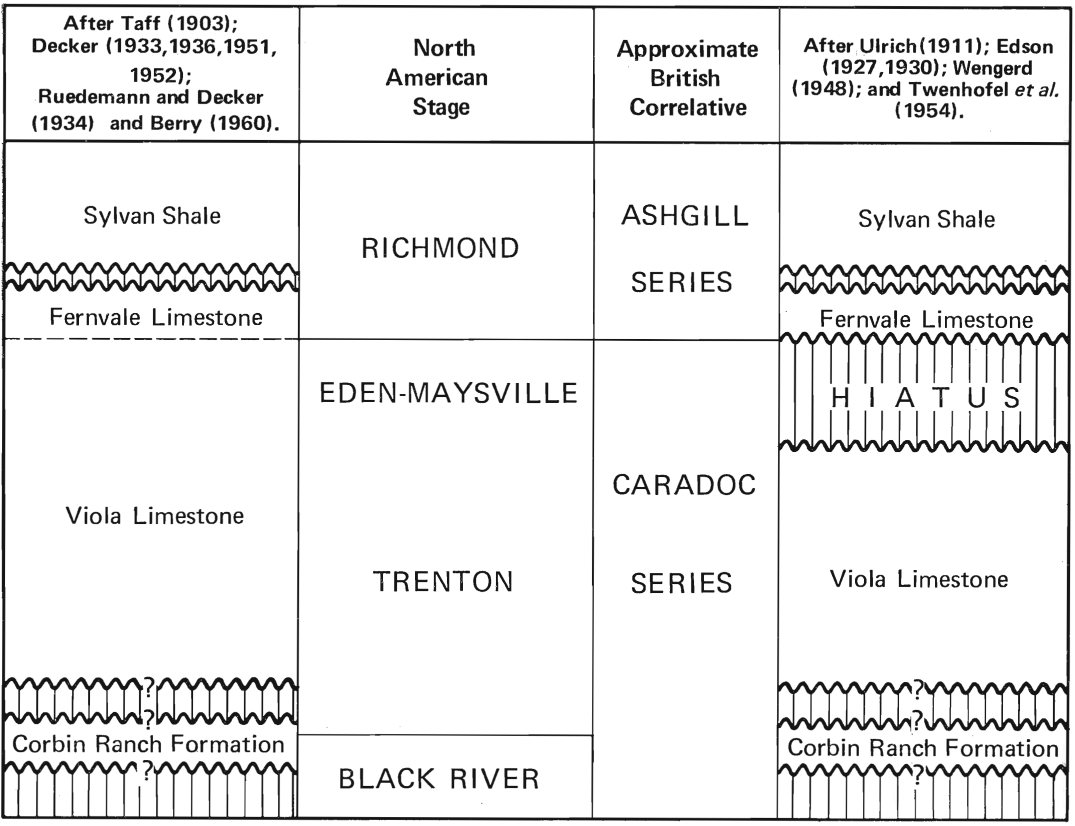
The direction in which the Fernvale Limestone thickens is essentially opposite to that in which the Viola Limestone thickens but, to my knowledge, no satisfactory explanation for this reversal in the direction of thickening has been published. The increase in thickness of the Fernvale Limestone toward the north-east is possibly an original feature of the formation, and may result from differing rates of sedimentation within the area. On the other hand, the Fernvale Limestone once may have been fairly uniform in thickness, but during the pre-Sylvan erosion cycle it may have been more deeply eroded in the south-west than in the north-east.

Stratigraphical relations. The Viola–Fernvale unit is separated by regional unconformities from the underlying Corbin Ranch Formation (Harris 1957, p. 100; Schramm 1964, p. 1187; Ham and Wilson 1967, pp. 347–9, fig. 12) and the overlying Sylvan Shale (Edson 1930; Ham and Wilson 1967, pp. 350–2, fig. 12). Its fauna differs strikingly from the faunas which precede and follow it (Decker 1933, p. 1405; Amsden 1957; Harris 1957, pp. 100–1, 103).

The sharp contact of the Viola Limestone with the Corbin Ranch Formation is exposed in the bed of Sycamore Creek, about 2 ft. stratigraphically above a prominent ledge of massive, light grey, lithographic limestone in the Corbin Ranch Formation; map reference NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 3 S., R. 4 E., Johnston County, Oklahoma (text-fig. 1). Although the dips of the two formations do not differ appreciably at this exposure, the basal beds of the Viola Limestone clearly were laid down on an eroded and weathered surface of the already indurated Corbin Ranch Formation. The beds which comprise the Corbin Ranch Formation are correlated by Loeblich (1942, p. 417), Decker (1951, p. 914, table 1; 1952, pp. 100, 134–9, table 5) and Harris (1957, pp. 101–3, figs. 1 and 19) with the Trenton Stage, which is typically developed in northern New York and approximately correlative with the middle Caradoc Series of Britain. The same beds are correlated by Twenhofel *et al.* (1954) with the slightly older Black River Stage, which is typically developed in northern New York also, and approximately correlative with the British lower Caradoc.

The sharp contact of the Fernvale Limestone and the Sylvan Shale also is exposed in Sycamore Creek, about 1000 ft. downstream from the Corbin Ranch–Viola contact. The dips of the two formations appear to be the same, but close examination reveals that the top of the Fernvale Limestone is an erosion surface that had been extensively weathered before the shale was laid down. The Sylvan Shale is a very young Ordovician deposit correlated (Decker 1935; Twenhofel *et al.* 1954) with the Richmond Stage, which is typically developed in the upper valley of the Ohio River and approximately correlative with the Ashgill Series of Britain.

Age and correlation of the Viola and Fernvale Limestones. The Viola–Fernvale unit is here considered late Ordovician in age, following the twofold division of the Ordovician System advocated by Lapworth (1879*a*, p. 15; 1880, table x, pp. 16–22, 27, 192) and revived by Whittington and Williams (1964), in which the base of the widely distributed and readily recognized *Nemagraptus gracilis* Zone (or its correlatives) is taken as the lower limit of the Upper Ordovician. The zone has been recognized in south-eastern Australia (Berry 1960*a*, p. 42; Skevington 1963, p. 304), Argentina (Harrington and Leanza 1957, p. 1938), western Texas (Berry 1960*a*, p. 43; 1960*b*, p. 105), eastern North America (Twenhofel *et al.* 1954, p. 261), northern Yukon (Jackson and Lenz 1962, pp. 35, 40), the British Isles (Elles 1925; Dean 1958, p. 227; 1960, p. 75), Scania (Jaanusson and Strachan 1954; Skevington 1963, p. 302), the Taimyr region in the Arctic of the U.S.S.R. (Sokolov *et al.* 1960), and eastern China (Hsü 1934). It is associated with a major Palaeozoic transgression, and its base conveniently separates remarkably provincial, older Ordovician faunas (graptolitic as well as shelly) from faunas of very wide geographical distribution in the younger part of the system. Numerous different definitions



TEXT-FIG. 2. Two interpretations of the stratigraphical relationship between the Viola and Fernvale Limestones in the Arbuckle Mountains of southern Oklahoma, and their correlation with the standard successions of North America and Britain.

of the terms Lower, Middle, and Upper Ordovician occur throughout the literature, and it is frequently difficult to ascertain what part of the system these terms denote. Within North America, the term Upper Ordovician is understood (Kay 1960, p. 28) to invariably include the Eden, Maysville, and Richmond Stages (qq.v. below), and the Trenton Stage in varying degrees (q.v. above); the Black River Stage (q.v. above) is generally considered Middle Ordovician. As defined in the present paper, however, the Upper Ordovician includes the basal beds of the North American Black River Stage and their correlatives (Twenhofel *et al.* 1954; Berry 1960*a*, *b*; Kay 1960, p. 30) at the base of the Caradoc Series in Britain.

The literature reveals no general agreement on the relationship between the Viola and Fernvale Limestones (text-fig. 2). The Viola, as defined by Decker and Merritt (1931), most frequently is correlated with the Trenton Stage or with the Trenton and upper Black River Stages, which are approximately correlative with the British lower and middle Caradoc; and the Fernvale Limestone generally is correlated with part of the Richmond Stage, which is typically developed in the upper Ohio River valley and approximately correlative with the British Ashgill. The view has been widely held that the Eden and Maysville Stages, which are also typically developed in the upper valley of the Ohio River and approximately correlative with the British upper Caradoc, are absent or only poorly represented in the Arbuckle Mountains, and that a major hiatus exists there below the Fernvale Limestone (Ulrich 1911, p. 308, pl. 27; Ulrich *in* Baker and Bowman 1917, pp. 89–92 and Berry 1960*a*, p. 30; Ulrich 1927, p. 29; Edson 1927, p. 970 and fig. 1; Edson 1930; Wengerd 1948, pp. 2189–91, 2247, 2250; Twenhofel *et al.* 1954; Templeton and Willman 1963, p. 192). This interpretation of the relationship between the two formations, however, conflicts with the views of Taff (1903, pp. 3–4), Dake (1921, pl. 2), Decker (1933, pp. 1410, 1415, 1417, 1433–4; 1936, p. 308; 1951, table I; 1952, p. 137, table 5) and Ruedemann and Decker (1934, p. 326), who believed the formations to be a continuous deposit. They observed that the Viola–Fernvale contact seemed gradational and that several species of graptolites and a trilobite range from the Viola Limestone into the Fernvale Limestone. In particular, they correlated the upper part of the Viola Limestone containing *Climacograptus lorrainensis* with the New York Lorraine Group, which is considered to be Eden–Maysville (upper Caradoc) in age by Ruedemann (1925) and Twenhofel *et al.* (1954).

The correlations proposed by Twenhofel *et al.* (1954) and Berry (1960*a*, pp. 31, 38; table 2) illustrate the basic differences of opinion that have existed on the relationship between the Fernvale and Viola Limestones in the Arbuckle Mountains and on the correlation of the two formations. Twenhofel *et al.* correlated the Viola Limestone with the uppermost Black River and Trenton Stages and the middle Caradoc of Britain, and correlated the Fernvale Limestone with the lowermost part of the Richmond Stage and the lowermost Ashgill of Britain. The Eden and Maysville Stages (correlated with the British upper Caradoc) were marked on their correlation chart as an hiatus.

Berry's (1960*a*) correlation, based on graptolites, is fundamentally different. It approximately equated the lower part of the Viola Limestone with the Trenton Stage and the middle Caradoc of Britain, and correlated the middle and upper parts of the Viola Limestone with the Eden and Maysville Stages and the upper Caradoc (graptolite zones of *Dicranograptus clingani* and *Pleurograptus linearis*) of Britain. The Fernvale Limestone was correlated with the lower part of the Richmond Stage and the lower

Ashgill of Britain (approximately the graptolite zone of *Dicellograptus complanatus*). Berry's correlation, unlike that of Twenhofel *et al.* (1954), does not provide for the existence of a major hiatus between the Viola and Fernvale Limestones.

In the field, the relationship between the Viola and Fernvale Limestones appears to be essentially one of conformity, and direct physical evidence for the existence of a break between the two formations is not apparent. The contact is seemingly gradational and, in places, upper Viola and Fernvale lithologies alternate at or about the contact. The only abrupt lithological change at this stratigraphical level is the sudden disappearance, at certain localities, of the abundant chert which is present in the upper part of the Viola Limestone but which is characteristically lacking in the Fernvale Limestone.

It has not yet been adequately demonstrated that in the Arbuckle Mountains the Eden and Maysville Stages are represented by a major hiatus below the Fernvale Limestone, nor, on the other hand, has it yet been convincingly shown that the Viola–Fernvale unit represents more or less continuous deposition during Trenton, Eden, Maysville, and Richmond time. The present study indicates the existence, within an otherwise virtually continuous depositional sequence, of a significant hiatus near the top of the Viola–Fernvale unit and suggests that the uppermost Viola–Fernvale strata are substantially younger than the beds immediately below. The evidence for the existence of this hiatus is discussed subsequently.

Detailed accounts of the lithology, fauna, stratigraphy, and correlation of these formations are given by Amsden (1957), Decker (1933, 1936), Ruedemann and Decker (1934), Templeton and Willman (1963), Wengerd (1948) and Whittington (1954, 1955).

Collection and preparation of material. Samples were collected at stratigraphical intervals of 20 ft. throughout the Viola–Fernvale limestone succession exposed in the bed and banks of Sycamore Creek, map reference NW¼ SE¼ sec. 27, T. 3 S., R. 4 E., Johnston County, Oklahoma (text-fig. 1), commencing one foot below the Fernvale–Sylvan Shale erosion contact and continuing to the base of the Viola Limestone. The Fernvale–Sylvan contact serves as a reference datum, and samples are numbered according to their original stratigraphical positions (measured in feet) below it. Thus, sample Sc581, for example, represents a horizon 581 ft. below the contact, the prefix 'Sc' indicating that the sample is from Sycamore Creek. At the outcrop the precise points from which samples have been taken, and their stratigraphical positions (in feet) below the Fernvale–Sylvan Shale contact, were marked with red paint.

The collection of a complete sequence of samples at regular and reliably measured stratigraphical intervals was greatly simplified at Sycamore Creek by the steep inclination of the strata, complete exposure of the Viola–Fernvale sequence, and the virtual absence of faulting. The Viola–Fernvale unit was measured with considerable care by Mr. J. A. Turnbull and myself, and found to be 654 ft. thick. This figure differs somewhat from Decker's (1933, p. 1423) figure of 686 ft., but corresponds exactly to that of Glaser and Alberstadt (Glaser 1965, p 188, unpublished dissertation, University of Oklahoma). The samples are described in the appendix.

The chitinozoans were prepared for microscopical examination in the manner outlined by Jenkins (1967, pp. 439–41). When mounted, each specimen was ringed and given a reference number (e.g. Sc621/102/1/A) comprising the appropriate sample number (Sc621), two numbers (102/1) indicating a particular type of chitinozoan (in this case *Sphaerochitina compactilis*), and a letter (A) indicating a particular specimen. The type material, all figured specimens, and portions of each rock sample, are housed in the Micropalaeontology Laboratory, Department of Geology, The University, Sheffield, England.

SYSTEMATIC PALAEONTOLOGY

Descriptive terms applied to the Chitinozoa are far from standardized, particularly in English language publications. In order to avoid possible confusion a few terms used in this paper are defined below. In general the terminology proposed by Combaz and Poumot (1962) and Combaz *et al.* (1967) has been followed. 'Oral' and 'aboral' are used as proposed by Collinson and Schwalb (1955), 'proximal' and 'distal' as employed by Jenkins (1967, p. 442). The term '*appendix*' (plural '*appendices*') is used to denote a variety of strongly developed, discrete processes suspended from the basal margin and not considered as ornamentation; it is used in no other sense. A λ-spine (wishbone spine) has a single distal limb which divides into two or more proximal limbs rising from the surface of the test wall. A π-spine consists of two or more upright proximal elements connected at their tips by a continuous longitudinal bar. Individual π-spines often appear to be the remnants of a once more complete ornament, although in some cases they are possibly complete processes in themselves. In the evolutionary series *Conochitina robusta–Hercochitina crickmayi*, λ-spines gave rise, phylogenetically, to π-spines.

Order CHITINOZOA Eisenack 1931
Genus ANCYROCHITINA Eisenack 1955*a*

Type species. Conochitina ancyrea Eisenack 1931 (by original designation), Silurian, Baltic.

Ancyrochitina corniculans sp. nov.

Plate 1, figs. 1–6; text-fig. 3

Holotype. Plate 1, figs. 1*a*, *b*. Specimen Sc61/1/1/C; Viola Limestone, 61 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. Small cylindroconical test. Chamber length equal to or slightly greater than oral tube length; maximum diameter approximately equal to chamber length; base flat or slightly convex, margin bluntly rounded. Generally four to six simple or dichotomously branching appendices with pointed or bluntly rounded tips, up to one-third of the maximum diameter in length; rarely more than one order of branching. Oral tube cylindrical or slightly flaring for most of its length, about half maximum diameter

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EXPLANATION OF PLATE 1

Figs. 1–6. *Ancyrochitina corniculans* sp. nov. 1, Sc61/1/1/C, holotype; 1*a*, ×250; 1*b*, π-spine, ×1000. 2, Sc61/1/1/F, bearing simple appendices, ×250. 3, Sc61/1/1/E, appendix (detached) with bifurcate tip, ×250. 4, Sc61/1/1/L, appendices with furcate tips, ×250. 5, Sc61/1/1/D, ×250. 6, Sc61/1/1/M, bearing simple appendices, ×250.

Figs. 7–13. *Angochitina capillata* Eisenack 1937. 7, Sc161/100/1/A, ×250. 8, Sc161/100/1/E, ×250. 9, Sc161/100/1/C, ×250. 10, Sc161/100/1/B, showing ornament through translucent upper part of test, ×250. 11, Sc321/100/1/D, ×250. 12, Sc601/100/1/C, with spherical chamber, ×250. 13, Sc321/100/1/A, showing ornament through translucent chamber wall; 13*a*, ×250; 13b, ×1000.

Figs. 14–16, 22. *Conochitina wesenbergensis* Eisenack 1959. 14, Sc441/56/3/E, with conical chamber, ×250. 15, Sc441/56/3/G, ×250. 16, Sc441/56/3/K, with conical chamber, ×250. 22, Sc621/56/3/D, with swollen cylindrical chamber, ×250.

Figs. 17–21. *Conochitina micracantha* Eisenack 1931. 17, Sc281/2/1/A, ×160. 18, Sc281/2/1/H, ×160. 19, Sc281/2/1/J, ×160. 20, Sc201/2/1/E, aboral polar view of isolated base, ×250; 20*a*, focusing on ornament; 20*b*, focusing on the thin-walled, translucent central zone. 21, Sc201/2/1/F, oblique aboral polar view of isolated base, ×250; 21*a*, focusing on the thin-walled, translucent central zone; 21*b*, focusing on ornament.

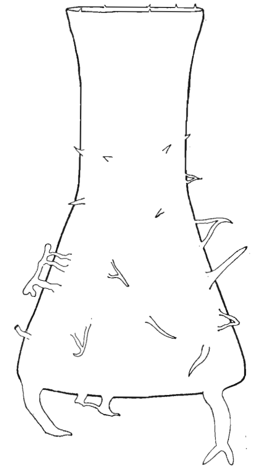
in width (more strongly flaring near aperture). Aperture up to two-thirds maximum diameter in width, bearing few short (*c.* 1 μ in length) spines or cones. Ornament of simple spines, λ-spines and, infrequently, π-spines distributed thinly over test, absent on base and basal margin.

Dimensions (*in microns*). 25 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Appendix length*
Holotype:	120	70	72	36	< 20
Range:	100–53	56–91	59–90	22–45 → 38–51	< 23
Mean:	127	69	74	35 → 45	—

Description. The chamber tapers fairly uniformly and it is generally possible to locate precisely its junction with the neck. The ornament consists of thinly distributed, straight or curving, simple spines or λ-spines, up to 20 μ in length (25% maximum diameter). Infrequently, several proximal elements standing normal to the test wall are aligned, as in some species of *Hercochitina* (Jansonius 1964), roughly parallel with the longitudinal axis of the test and connected at their tips by a longitudinal bar (π-spines). Spines on the oral tube become smaller and scarcer toward the aperture.

Comparison. Several similar species of *Ancyrochitina* differ from *A. corniculans* as follows. *A. multiramosa* Taugourdeau and Jekhowsky 1960 and *A. saharica* Taugourdeau 1962 have between twelve and twenty appendices. In *A. onniensis* Jenkins 1967 the appendices branch in a more complex manner (up to four orders of branching into two to five generally unequal limbs) and are larger (up to 35 μ and over half the maximum diameter in length); the ornamental processes are shorter and π-spines are absent. *A. tumida* Taugourdeau and Jekhowsky 1960 has a very short neck. *A. spinosa* (Eisenack 1932) bears antler-shaped appendices and ornamental processes, and lacks λ-spines. *A. tomentosa* Taugourdeau and Jekhowsky 1960 also lacks λ-spines and its ornament sometimes includes strongly developed processes with multiple distal extremities. *A. pilosa* Taugourdeau and Jekhowsky 1960 bears processes up to 35 μ in length on the upper part of its oral tube. The poorly preserved Ordovician material from Iowa and Oklahoma, referred to *Ancyrochitina ancyrea* (Eisenack 1931) by Taugourdeau (1965), resembles *A. corniculans* and may be conspecific with it. Unfortunately, however, it cannot be determined from the text or the illustrations whether Taugourdeau's specimens are smooth or ornamented.



TEXT-FIG. 3. *Ancyrochitina corniculans* sp. nov. Lateral view of test showing the appendices and the ornament of π-spines, λ-spines, and simple spines, ×400.

Material. Approximately fifty single tests, most of which are broken; only occasionally were the appendices and spines preserved intact.

Occurrence. Sc61, ?Sc41, Scl.

Genus ANGOCHITINA Eisenack 1931

Type species. Angochitina echinata Eisenack 1931 (by original designation), Silurian, Baltic.

Angochitina capillata Eisenack 1937

Plate 1, figs. 7–13

1937 *Angochitina capillata* Eisenack, p. 225, pl. 15, figs. 12, 13 (holotype).
1961 Unnamed chitinozoan Jodry and Campau, pl. 3, fig. 10.
1962*a* *Angochitina capillata* Eisenack; Eisenack, p. 300, pl. 15, figs. 9 (neotype), 10.
1962*b* *Angochitina capillata* Eisenack; Eisenack, p. 357.
1965 *Angochitina capillata* Eisenack; Eisenack, p. 122, pl. 11, fig. 3.

Dimensions (*in microns*). 36 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Range:	115–66	77–102	61–89	33–89	41–8	< 6
Mean:	135	90	73	40	45	—
Neotype (Eisenack 1962*a*):	172	—	84	—	—	—

Remarks. The chamber may be spherical, ellipsoidal, or conical, and generally makes up about two-thirds of the total length. It often merges with the oral tube, which is half as wide as the chamber, cylindrical or slightly flaring, and sometimes sharply flaring at the aperture. The latter may be straight, serrate, or furnished with short, thin spines with blunt or swollen tips. The test is thickly covered with short bristles (1–2 μ in length) and/or short simple spines with pointed tips (up to 6 μ in length). These processes are distributed uniformly on the chamber and the oral tube but sometimes are lacking near the aperture.

Material. Several thousand single tests.

Occurrence. Sc621–Sc321, Sc281–Sc161, ?Sc141, ?Sc121, Sc81. Corroded specimens, lacking ornament but otherwise referable to *A. capillata*, occur in Sc141 and Sc121.

Jodry and Campau (1961, pl. 3, fig. 10) figure a specimen probably referable to *A. capillata* from the Upper Ordovician Red River Group of the North American Williston Basin; Jodry (personal communication, January 1967) considers the specimen to be 'probably Black River–Trenton . . . possibly lowest Cincinnatian'. The species occurs in the Lyckholm Beds, F_1, of Estonia (Eisenack 1962*b*, 1965) and sporadically in the Ostseekalk of north Germany, Gotland, and south Finland (Eisenack 1962*a*, 1965).

Genus CONOCHITINA Eisenack 1931 restr. 1955*b*

Type species. Conochitina claviformis Eisenack 1931 (by original designation), Baltic drift.

Conochitina micracantha Eisenack 1931

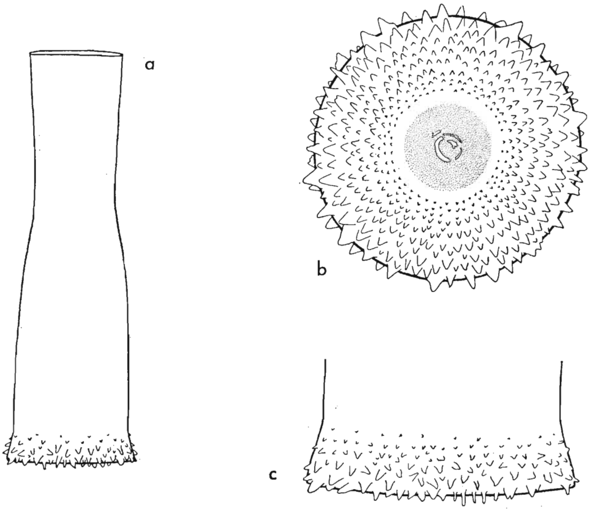
Plate 1, figs. 17–21; text-fig. 4

1931 *Conochitina micracantha* Eisenack (*pars*), p. 84, pl. 1, fig. 19 (holotype).
1959 *Conochitina micracantha* ssp. *micracantha* Eisenack, p. 7, pl. 1, fig. 5 (neotype); pl. 3, fig. 12.
1962*b* *Conochitina micracantha* ssp. *micracantha* Eisenack; Eisenack, p. 357.
1965 *Conochitina micracantha* ssp. *micracantha* Eisenack; Eisenack, p. 123, pl. 9, figs. 4–9.

Dimensions (*in microns*). 35 specimens measured.

	Total length	*Maximum diameter*	*Minimum neck diameter*	*Apertural diameter*
Range:	178–357	61–90	40–58	40–72
Mean:	252	78	50	56
Neotype (Eisenack 1959):	260	81	49	52

The mean total length of fifty specimens recovered from Ostseekalk erratics found near Berlin is 228 μ, maximum 347 μ, minimum 126 μ (Eisenack 1959, p. 7).



TEXT-FIG. 4. *Conochitina micracantha* Eisenack 1931. *a*, Lateral view, ×230. *b*, Aboral polar view showing size and distribution of ornamental processes on the base and basal margin, ×450. *c*, Lateral view showing size and distribution of ornamental processes on the lower flanks and basal margin, ×450.

Description. In size and shape the specimens from the Viola Limestone closely resemble those from the Ostseekalk which Eisenack (1965) assigned to *Conochitina micracantha micracantha*. They differ from the Ostseekalk specimens, however, in having very little or no ornament on the flanks and neck. The test is slender, cylindroconical or campanulate, and bears an ornament of cones and tapering spines with rounded or pointed tips, up to 5 μ in length. The processes are concentrated about the basal margin and only rarely extend beyond the lower flanks. The basal margin and the test wall immediately adjacent to it may bear several hundred processes, but in lateral view only 25 to 40 of these project beyond the silhouette of the test. The centre of the base is seen, in polar view, to be encircled by a paler, relatively thin-walled zone, 23–8 μ in diameter (Pl. 1, figs. 20–1; text-fig. 4*b*) which may have been open at some stage in the species' life history and perhaps provided for communication between the interiors of adjacent tests in chains.

This species differs little in size and shape from one horizon to another. Morphological variation is always slight but may include a few tests entirely devoid of ornamentation. In the two youngest populations (Sc101, Sc81), however, tests without ornament predominate; they are distinguished from smooth examples of *Conochitina comma* Eisenack 1959 by their campanulate or cylindroconical tests.

Remarks. Three subspecies designated by Eisenack, *Conochitina micracantha micracantha, C. micracantha wesenbergensis*, and *C. micracantha robusta*, are considered here to merit recognition as separate species. Each occurs over a wide area and, while some intermediate forms may be known, they are generally quite distinct. Recognition of these forms at specific level will, in addition, avoid some of the unwieldy nomenclature (e.g. *Conochitina micracantha wesenbergensis* forma *elongata*) developing within the numerous infraspecific taxa of *Conochitina micracantha* (*sensu* Eisenack). Future studies may show that other subspecies of *C. micracantha* (*sensu* Eisenack) are appropriately considered as separate species.

Material. Several thousand single tests.

Occurrence. Sc281–Sc81. In the Baltic (Eisenack 1959, 1965) this species ranges from the Revaler Beds, C_1, to the Jewe Beds, D_1, and from the Wesenberg Beds, E, to the Lyckholm Beds, F_1; it is generally the most abundant chitinozoan in the Ostseekalk, and is particularly abundant in the Diplograptus-Kalk.

Conochitina wesenbergensis Eisenack 1959

Plate 1, figs. 14–16, 22; Plate 2, figs. 1–4

1931 *Conochitina micracantha* Eisenack (*pars*), p. 84, pl. 2, figs. 21, 22.
1959 *Conochitina micracantha* ssp. *wesenbergense* Eisenack; Eisenack, p. 10, pl. 1, fig. 11 (holotype); pl. 3, fig. 8.
1962*b* *Conochitina micracantha* ssp. *wesenbergensis* Eisenack; Eisenack, p. 357, pl. 44, fig. 13.
1965 *Conochitina micracantha* ssp. *wesenbergensis* Eisenack; Eisenack, p. 123, pl. 9, figs. 10–17; pl. 10, fig. 3.

Dimensions (*in microns*). 40 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Range:	105–201	64–179	56–102	35–56	41–59	< 15
Mean:	159	113	77	44	49	—
Holotype (Eisenack 1959):	218	—	76	38	44	—

Remarks. In the Viola Limestone, this species varies considerably in the shape of its test and the development of its ornamentation. The test is most commonly conical and furnished with small cones or simple spines up to 5 μ in length. Variants with swollen cylindrical chambers are present in most populations, and bear tapering spines, up to 15 μ in length, which meet the test wall abruptly. The aperture may be straight, finely serrate, or furnished with cones and short spines.

Material. Several thousand single tests.

Occurrence. Sc653·8–Sc381. The species is present in the Ostseekalk of north Germany, Gotland, and south Finland (Eisenack 1965) and occurs in the Wesenberg and Lyckholm Beds, E–F_1, of Estonia (Eisenack 1962*b*). Its chief occurrence is in the Wesenberg Beds (op. cit., p. 124).

Conochitina seriespinosa sp. nov.

Plate 2, figs. 5–14; text-fig. 5

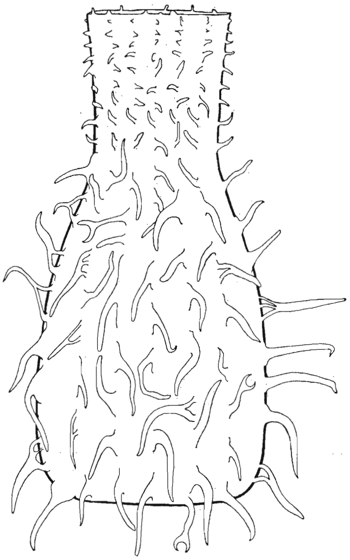
Holotype. Plate 2, fig. 5. Specimen Sc161/56/3/R; Viola Limestone, 161 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. Conical to cylindrical chamber with swollen flanks, about two-thirds total length; base flat, margin rounded. Ornament of slender, simple spines and rare, distally bifurcate, pitchfork-shaped spines with pointed tips; spine bases commonly expanded in a plane parallel with the longitudinal axis of the test. Spines, up to one quarter (rarely one-third) maximum diameter in length, distributed thinly in ten to sixteen longitudinal rows extending from base to aperture.

Dimensions (*in microns*). 50 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Holotype:	170	115	74	37	44	< 16
Range:	127–204	89–133	61–90	33–52	40–55	< 28
Mean:	163	112	75	41	47	—

Description. The maximum diameter lies at the base or midway along the chamber and is one-third to half the total length. The oral tube flares slightly, the minimum diameter is half to two-thirds the maximum diameter, and the aperture bears small spines or cones (up to 2 μ in length). The ornament consists largely of simple, tapering, straight or curving spines with pointed tips. Characteristically, the proximal end of each spine widens rapidly toward its junction with the test wall, in a plane parallel with the test's longitudinal axis (Pl. 2, fig. 14; text-fig. 5), so that in lateral view the base of the spine appears to merge with the test wall, but in polar view it appears to meet the test wall abruptly. Sometimes openings occur in the expanded spine bases forming, in effect, λ-spines with two or three discrete bases; occasionally a spine divides once into two equal distal limbs (Pl. 2, fig. 13*b*). On the chamber, spines attain a length of up to 28 μ and are arranged in ten to sixteen longitudinal rows of eight to eleven spines each; often these spines are arranged in transverse, as well as longitudinal rows. The longitudinal rows continue from the chamber onto the oral tube, where the spines become progressively smaller (to a few microns in length) and more closely spaced toward the aperture, and are frequently arranged in up to ten transverse rows. It is generally necessary to bleach examples of this species before the orderly arrangement of their spines becomes obvious.



TEXT-FIG. 5. *Conochitina seriespinosa* sp. nov. Lateral view illustrating the character and distribution of the ornamental processes, ×400.

Comparison. The longitudinally expanded spine bases and the arrangement of its spines into longitudinal rows distinguish this species. It resembles species of *Hercochitina* in that its spines stand in longitudinal rows, but the spine tips are not connected by longitudinal bars, and continuous longitudinal ridges are not developed.

Material. Approximately 1500 single tests.

Occurrence. Sc161–Sc121, Sc81.

Conochitina hirsuta Laufeld 1967

Plate 3, figs. 1–2, 6–7

1967 *Conochitina hirsuta* Laufeld, p. 304, fig. 12.
1967 *Angochitina communis* Jenkins, p. 450, pl. 69, figs. 14–17; text-fig. 7.

Dimensions (*in microns*). 12 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Spine length*
Range:	107–40	77–93	63–84	36–54	< 21
Mean:	122	88	73	47	—
Holotype (Laufeld 1967):	135	—	—	—	—

Remarks. The ornament consists largely of λ-spines with two to eight proximal limbs, and relatively few simple spines, distributed evenly over the test. It compares more closely with the ornament of the Swedish type material (Laufeld 1967, p. 305) than with that of the British examples described by Jenkins (1967, pp. 450–1). In the latter, simple spines usually predominate over λ-spines which have only two or three (occasionally five) proximal limbs. The spines, which are not aligned in rows, distinguish this species from *Hercochitina turnbulli* sp. nov. The aperture generally bears short terminal spines (Pl. 3, fig. 2). The younger Viola populations (Sc181, Sc161, Sc121, Sc101, Sc81) contain variants thickly covered with short spines (up to 6 μ in length); they also include specimens which are transitional to *Hercochitina turnbulli* sp. nov. and which may correspond to those Swedish specimens referred to *Conochitina hirsuta* by Laufeld (1967, p. 305), in which the bases of spines on the chamber are aligned in longitudinal rows.

A case could be made for assigning this species to *Angochitina*, where it was placed by Jenkins (1967). For the present Laufeld's (1967) precedent is followed and the species referred to *Conochitina*.

EXPLANATION OF PLATE 2

Figs. 1–4. *Conochitina wesenbergensis* Eisenack 1959. 1, Sc621/56/3/L, with conical chamber, ×250. 2, Sc621/56/3/K, with conical chamber, ×250. 3, Sc641/56/3/D, with cylindrical chamber, ×250. 4, Sc461/56/3/A, with swollen cylindrical chamber, ×250.

Figs. 5–14. *Conochitina seriespinosa* sp. nov. 5, Sc161/56/3/R, holotype, ×250. 6, Sc161/56/3/K, ×250. 7, Sc81/56/3/D, showing transverse rows of processes on the oral tube, ×250. 8, Sc121/56/3/A, showing stumps of processes on oral tube arranged in longitudinal rows, ×250. 9, Sc161/56/3/H, ×250. 10–12, Sc161/56/3/L, N, and M, respectively, broken specimens showing ornament through translucent test wall, all ×250. 13, Sc161/56/3/S; 13*a*, ×250; 13*b*, detail of base in lateral view, showing a simple spine and a distally bifurcate pitchfork-shaped spine, × 400. 14, Sc161/56/3/T, showing ornament through translucent chamber wall, and longitudinally expanded bases of spines on upper part of oral tube, × 400.

Material. Several thousand single tests.

Occurrence. Sc501–Sc481, Sc241–Sc221, Sc181–Sc161, Sc121–Sc81. The species occurs in the upper Dalby Formation (Caradoc) of Dalarna, Sweden (Laufeld 1967), and the upper Caradocian Onnia Beds of Shropshire, England (Jenkins 1967).

Conochitina robusta Eisenack 1959

Plate 3, figs. 3–5, 10; text-figs. 6, 10

1959 *Conochitina micracantha* ssp. *robusta* Eisenack, p. 9, pl. 1, fig. 6; pl. 3, figs. 4 (holotype), 5.
1962*b* *Conochitina micracantha* ssp. *robusta* Eisenack; Eisenack, p. 357.
1964 *Belonechitina robusta* (Eisenack); Jansonius, p. 906, pl. 2, figs. 24, 25.
1965 *Conochitina micracantha* ssp. *robusta* Eisenack; Eisenack, p. 123.
1967 *Conochitina robusta* Eisenack; Laufeld, p. 307, fig. 14.

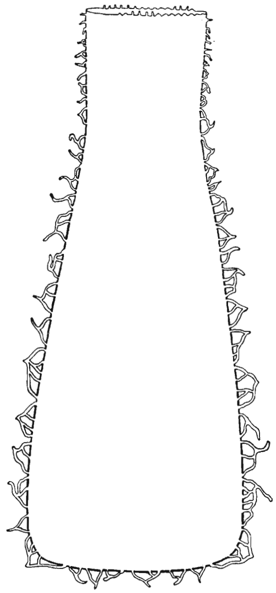
Dimensions (*in microns*). 50 specimens measured.

	Total length	*Maximum diameter*	*Minimum diameter (at base of neck)*	*Apertural diameter*
Range:	204–438	81–160	63–102	58–104
Mean:	312	122	82	87
Holotype (Eisenack 1959):	249	100	65	68

The mean total length of forty-one examples from the Baltic (Eisenack 1959) is 293 μ (maximum 423μ, minimum 204μ). Laufeld's Swedish examples are 218–442 μ in length, 71–100 μ in width and have an apertural diameter of 45–74 μ.

Remarks. The Viola material compares very closely with that from Estonia (Eisenack 1959) and Dalarna, Sweden (Laufeld 1967). The aperture may be straight (as in the Estonian specimens and some Swedish specimens), fimbriate (as in some Swedish specimens), serrate, or a combination of these three (text-fig. 6). A few specimens in each population bear a short cylindrical or distally tapering rod-like basal process ('copula', Eisenack 1959; 'mucro', Laufeld 1967), 12–20 μ in width where it meets the base, 6–10 μ in width at its distal end, and up to 12 μ in length (Pl. 3, fig. 3).

The ornament consists almost exclusively of λ-spines up to 12 μ in length, each with two to five (occasionally eight) discrete bases and a single, distal tip. Short simple spines (up to 3 μ in length) may occur near the aperture. The proximal limbs of each λ-spine lie in approximately the same longitudinal plane, and thus form a short longitudinal row of 'spine legs'; in this respect *Conochitina robusta* is comparable with some species of *Hercochitina* (Jansonius 1964). Spines become shorter orally.


TEXT-FIG. 6. *Conochitina robusta* Eisenack 1959. Lateral profile, ×230.

Although many tests have clearly suffered differential erosion of their ornamental processes, the latter show no consistent pattern of asymmetrical distribution, and it is felt that the 'common asymmetrical distribution of ornaments' referred to by Jansonius (1964, plate explanations, pl. 2, fig. 24) is not an original feature. For the present, I share Laufeld's opinion (1967, pp. 307–8) that this form merits recognition as a separate species, and that it belongs in *Conochitina* Eisenack 1931 restr. 1955*b*.

Material. Several thousand single tests.

Occurrence. Sc621–Sc521. In the Ordovician of Estonia (Eisenack 1959, 1965) the species ranges from the Wasalemm Beds, D_3, to the Lyckholm Beds, F_1; it is especially common in the Wasalemm Beds and the Wesenberg Beds, E, and occurs sporadically in the Jewe Beds, D_1. In 1962 (1962*b*, Table I) Eisenack indicated that the occurrence of this species in the D_1 beds was questionable; and in 1965 (p. 123) stated that its main distribution was in the Wesenberg Beds. It ranges from the Dalby Formation to the Slandrom Formation in Dalarna, Sweden, and occurs sporadically in the Ostseekalk of north Germany, Gotland, and south Finland (Eisenack 1965). Jansonius (1964) records this form, designated *Belonechitina robusta*, in the Caradoc of south Scotland.

Conochitina tribulosa sp. nov.

Plate 3, figs. 8–9

Holotype. Plate 3, figs. 9*a*, *b*. Specimen Sc281/101/1/A; Viola Limestone, 281 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. Cylindroconical to campanulate test bearing short thornlike spines (up to 4 μ in length) with wide bases, concave sides, and pointed tips, densely and uniformly distributed over whole test.

Dimensions (*in microns*). 6 typical specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Holotype:	155	115	73	36	51	—
Range:	150–76	110–53	66–78	36–48	45–53	< 4
Mean:	164	131	72	43	48	—

EXPLANATION OF PLATE 3

Figs. 1–2, 6–7. *Conochitina hirsuta* Laufeld 1967. 1, Sc221/100/1/A; 1*a*, ×400; 1*b–e*, λ-spines, ×1000. 2, Sc221/100/1/B, aperture bearing short terminal spines, ×400. 6, Sc81/54/1/A, showing λ-spines and terminal spines on aperture, ×400. 7, Sc501/54/1/B, with swollen cylindrical chamber, ×400.

Figs. 3–5, 10. *Conochitina robusta* Eisenack 1959. 3, Sc521/56/2/B, with basal process, ×100. 4, Sc601/56/2/E; 4*a*, detail of ornament, ×250; 4*b*, ×100. 5, Sc601/56/2/F; 5*a*, detail of ornament, ×250; 5*b*, ×100. 10, Sc601/56/2/D, ×100.

Figs. 8–9. *Conochitina tribulosa* sp. nov. 8, Sc281/101/1/F; 8*a*, ×250; 8*b*, thornlike spines, ×1000. 9, Sc281/101/1/A, holotype; 9*a*, ×250; 9*b*, thornlike spines, ×1000.

Figs. 11–22. *Conochitina minnesotensis* (Stauffer 1933), showing variation in shape of base and basal process, all ×100. 11, Sc161/103/1/G. 12, Sc161/103/1/D. 13, Sc241/103/1/H. 14, Sc121/103/1/B. 15, Sc161/103/1/E. 16, Sc161/103/1/H. 17, Sc121/103/1/A. 18, Sc161/103/1/A. 19, Sc161/103/1/C. 20, Sc141/103/1/A. 21, Sc61/103/1/D. 22, Sc161/103/1/J, specimen perforated by circular holes, possibly the result of fungal attack; 22*a*, focusing on holes; 22*b*, focusing on outline of base and basal process.

Description. The chamber makes up approximately two-thirds of the total length; the maximum diameter lies at the base and is one-third to half the total length. The base is flat, the basal margin bluntly rounded. The oral tube is cylindrical or slightly flaring, half to two-thirds maximum diameter in width; the aperture is straight or finely serrate.

Comparison. Typical examples of *Conochitina tribulosa* sp. nov. and *Angochitina capillata* Eisenack 1937 are distinct, but in Sc281 and Sc261 transitional forms, intermediate in test shape and in the character and density of the ornamental processes, link the two species. *Conochitina cactacea* Eisenack 1937 is shorter (total length 100–33 μ, mean 116 μ; Eisenack 1959) and has longer spines (occasionally with multiple bases) than the new species.

Material. Thirty-five single tests.

Occurrence. Sc281–Sc241. Populations of *Angochitina capillata* in samples Sc281 to Sc161 include forms transitional to *Conochitina tribulosa*.

Conochitina minnesotensis (Stauffer 1933)

Plate 3, figs. 11–22; Plate 4, figs. 1–5; Plate 5, figs. 1–5, 15

1933 *Rhabdochitina? minnesotensis* Stauffer, p. 1209, pl. 60, fig. 39 (holotype).
1939 *Rhabdochitina? minnesotensis* Stauffer; Eisenack, p. 146, pl. B, fig. 13.
1955 *Rhabdochitina? minnesotensis* Stauffer; Collinson and Schwalb, p. 30, fig. 10 (holotype, reillustrated from Stauffer).
1955 *Rhabdochitina?* cf. *R. minnesotensis* Stauffer; Whittington, p. 850, pl. 83, figs. 3, 6.
1962*b* *Conochitina minnesotensis* (Stauffer); Eisenack, p. 353, 357, text-fig. 1–6.
1965 *Conochitina minnesotensis* (Stauffer); Eisenack, p. 126, pl. 10, figs. 7, 8.
1967 *Conochitina minnesotensis* (Stauffer); Laufeld, p. 306, fig. 13.

Dimensions (*in microns*). 30 specimens measured.

	Total length	*Maximum diameter*	*Minimum (neck) diameter*	*Apertural diameter*
Range:	750–1560	120–85	85–122	104–35
Mean:	1038	161	106	123

Specimens up to 2000 μ in length are recorded in the Baltic region by Eisenack (1965), and examples up to 1500 μ in length and 120 μ in diameter occur in the Caradoc of Dalarna, Sweden (Laufeld 1967). This is the largest named species in both the Baltic and North America.

Remarks. In the Viola–Fernvale sequence, this species varies in shape so that it does not satisfactorily fit into any one of the currently established genera. For the present, however, it is referred to *Conochitina*, where it perhaps gives the least taxonomic offence. Some tests (cf. *Rhabdochitina*) are cylindrical (Pl. 5, figs. 5, 15); others (cf. *Conochitina*) are weakly tapering conical (Pl. 5, fig. 2); while yet others (cf. *Lagenochitina*) have swollen cylindrical chambers and cylindrical or slightly flaring oral tubes (Pl. 4, figs. 2–4). The base may be convex or flat with a rounded basal margin, and a basal process is commonly present. Some of the variation in shape shown by the base and basal process is illustrated in Plate 3 (figs. 11–22).

Material. Approximately 3000 single tests.

Occurrence. Sc651–Sc381, Sc281–Sc241, Sc201–Sc61, ?Sc41 (many questionably identified, broken specimens), ?Sc1 (questionably identified fragments). In the Baltic this species ranges from the Glaukonitkalk, B_2, to the Borkholm Beds, F_2 (Eisenack 1965), and is present in the Ostseekalk of north Germany and south Finland (Eisenack 1962*b*, 1965). It occurs also in the Dalby and 'Skagen' Formations (Caradoc) of central Sweden (Laufeld 1967) and the Herscheider Shale of Westphalia (Eisenack 1939). The type material is from the Decorah Formation (Trentonian; Twenhofel *et al.* 1954; Cooper 1956; Templeton and Willman 1963) of southern Minnesota.

Conochitina sp. aff. *C. elegans* Eisenack 1931

Plate 4, figs. 11–13

Dimensions (in microns). Based upon three complete but distorted single tests and five fragments.

	Total length (3 measurements)	*Maximum diameter (8 measurements)*	*Apertural diameter (3 measurements)*
Range:	375–82	63–99	58–81
Mean:	378	84	71

Remarks. About a dozen distorted or broken chitinozoans from four horizons are referred to *Conochitina* sp. aff. *C. elegans*, but they cannot be adequately compared with the north European material (Eisenack 1959, 1965; Jenkins 1967).

Occurrence. Sc361–Sc341, Sc261–Sc241.

Genus CYATHOCHITINA Eisenack 1955*b*

Type species. Conochitina campanulaeformis Eisenack 1931 (by original designation), Ordovician, Baltic.

Cyathochitina kuckersiana kuckersiana (Eisenack 1934)

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, fig. 8 (neotype); text-fig. 4 (neotype).
1967 *Cyathochitina kuckersiana* (Eisenack); Laufeld, p. 315, fig. 18.
1967 *Cyathochitina kuckersiana* (Eisenack); Jenkins (pars), p. 458.

Remarks. Three stratigraphically and morphologically distinct subspecies of *Cyathochitina kuckersiana* occur in the Viola Limestone. *C. kuckersiana patagiata* ssp. nov. (Pl. 5, figs. 6–14, 17) is characterized by a very narrow carina, but is otherwise indistinguishable from the type subspecies (Eisenack 1934, 1962*a*). Alone, it represents the

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EXPLANATION OF PLATE 4

Figs. 1–5. *Conochitina minnesotensis* (Stauffer 1933), all ×100. 1, Sc481/103/1/B, with cylindrical chamber and flaring neck. 2–3, Sc641/103/1/B and C, respectively, with swollen cylindrical chambers, flaring necks, and straight apertures. 4, Sc561/103/1/A, with markedly swollen cylindrical chamber. 5, Sc561/103/1/C, with cylindrical chamber and flaring neck.

Figs. 6–10. *Cyathochitina kuckersiana latipatagium* ssp. nov., all ×100. 6, Sc61/10/14/E. 7–8, Sc61/10/14/B and Sc61/10/14/D, respectively, oral polar views showing wide, translucent carinae. 9, Sc61/10/14/C. 10, Sc61/10/14/F.

Figs. 11–13. *Conochitina* sp. aff. *C. elegans* Eisenack 1931, all ×100. 11, Sc361/17/2/C, very short example. 12, Sc361/17/2/D, aboral end of test. 13, Sc241/17/2/D.

species in the lower Viola Limestone. *C. kuckersiana latipatagium* ssp. nov. (Pl. 4, figs. 6–10) is approximately as wide as long, has a very wide carina, and alone represents *C. kuckersiana* at the top of the Viola Limestone. At one horizon, Sc81, *C. kuckersiana* is represented by specimens which are indistinguishable from the European type material (Eisenack 1934, 1962*a*). These are designated *C. kuckersiana kuckersiana* (Eisenack 1934).

In all three subspecies, as in the British material (Jenkins 1967), a pronounced longitudinal ribbing is occasionally developed on the shoulders, flanks and the lower part of the neck; and faint striations, concentric with the basal margin, occur on the carinae of some specimens. As in Estonia (Eisenack 1962*a*, pl. 14, fig. 9), Sweden (Laufeld 1967, fig. 18*c*) and Shropshire (Jenkins 1967, p. 459, 479, pl. 72, figs. 8, 9; pl. 73, fig. 1) small holes in the test walls of some specimens of *C. kuckersiana* suggest the existence of unidentified boring organisms (?fungi) (Pl. 5, fig. 16). In British and Oklahoman assemblages these holes occur preferentially in a few species, most conspicuously in *C. kuckersiana.*

Twenty-six isolated bases, which were dissected from undamaged specimens of all three subspecies and mounted in polar view, show a pale, circular, relatively thin-walled zone situated about the centre of the base and approximately one-third of the maximum diameter in width (Pl. 5, figs. 12, 14). In no case, however, is the base perforated by a central pore.

Material. Approximately 200 single tests referable to *C. kuckersiana kuckersiana.*

Occurrence. Sc81. *C. kuckersiana kuckersiana* occurs throughout the Caradoc Series of Shropshire, England (Jenkins 1967); and ranges from the Kuckers Beds, C_2, to the Borkholm Beds, F_2, in Estonia (Eisenack 1962*b*; personal communication, March 1964). It occurs in small numbers at two middle Dalby horizons in the Caradoc of Dalarna, Sweden (Laufeld 1967, p. 317) and is present in the Ostseekalk of south Finland (Eisenack 1965).

Cyathochitina kuckersiana patagiata ssp. nov.

Plate 5, figs. 6–14, 17

Holotype. Plate 5, fig. 9. Specimen Sc561/10/14/A; Viola Limestone, 561 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. A subspecies of *C. kuckersiana* with a very narrow carina.

Dimensions. 35 specimens measured. This subspecies is virtually identical in size and general shape to the type subspecies. The width of its carina is only 4–12 μ, and contrasts with widths of about 20 μ for *C. kuckersiana kuckersiana*, and 25–55 μ for *C. kuckersiana latipatagium.*

Material. Approximately 3000 single tests.

Occurrence. Sc561–Sc501. *C. k. patagiata* is abundant at horizon C8/b (Cheney Longville Flags) in the Caradoc type section, Shropshire (Jenkins 1967, p. 459) but is unknown elsewhere in England.

Cyathochitina kuckersiana latipatagium ssp. nov.

Plate 4, figs. 6–10

1962*a* ?*Cyathochitina kuckersiana* forma *brevis* Eisenack, p. 299, pl. 14, fig. 9; text-fig. 5.

1967 *Cyathochitina kuckersiana* (Eisenack); Jenkins (*pars*), p. 458, pl. 72, figs. 4, 5 (holotype), 6–7.

Holotype. Jenkins 1967, pl. 72, fig. 5. Specimen C1/10/14/X; Onnia Beds, Caradoc Series, Shropshire, England.

Diagnosis. A subspecies of *Cyathochitina kuckersiana* with a short, wide test (maximum diameter and total length approximately equal) and a very wide carina.

Dimensions (*in microns*). The carina width in 15 specimens from the Viola Limestone is 30–55 μ.

	Total length	*Chamber length*	*Maximum diameter (excluding carina)*	*Oral tube diameter*	*Carina width*
Holotype:	180	100	154	*c*. 50	40

Remarks. This subspecies is highly distinctive and alone represents *Cyathochitina kuckersiana* in the upper Viola Limestone. Transitional forms linking it with *C. kuckersiana kuckersiana* were not found during the present study. In the Caradoc Series of Shropshire, England (Jenkins 1967), however, a continuous series of intermediate forms links it with the type subspecies. The specimens from the Jewe, Kegel, and Wasalemm Beds, D_1–D_3, of Estonia, which Eisenack (1962*a*, p. 299, pl. 14, fig. 9; text-fig. 5) informally designated *C. kuckersiana* forma *brevis*, may belong to this subspecies. They clearly agree with it in size and over-all shape, but it is not yet known whether they possess a consistently wide carina.

Material. Approximately 1000 single tests from the Viola Limestone; and approximately 5000 single tests from the Caradoc Series of Shropshire, England.

Occurrence. Sc61–Sc41, Sc1. The subspecies is present throughout the Caradoc Series of Shropshire, England (Jenkins 1967, pp. 458–9).

Genus DESMOCHITINA Eisenack 1931 emend. 1962*a*

Type species. *Desmochitina nodosa* Eisenack 1931 (by original designation), Ordovician, Baltic.

Desmochitina minor Eisenack 1931

Plate 6, figs. 1–18

1931 *Desmochitina*? *minor* Eisenack, p. 93, pl. 3, figs. 9 (holotype), 10–11.
1958 *Desmochitina minor* forma *typica* Eisenack, p. 398, pl. 2, fig. 29 (neotype).
1962*a* *Desmochitina minor* forma *typica* Eisenack; Eisenack, pp. 303–4, pl. 16, figs. 3–8.
1965 *Desmochitina minor* forma *typica* Eisenack; Taugourdeau, p. 471, pl. 3, fig. 70.
1965 *Desmochitina minor* forma *typica* Eisenack; Eisenack, p. 130, pl. 10, figs. 16–17.

EXPLANATION OF PLATE 5

Figs. 1–5, 15. *Conochitina minnesotensis* (Stauffer 1933), all × 100. 1, Sc501/103/1/D, with cylindrical chamber and cylindrical neck. 2, Sc481/103/1/C, with uniformly tapering, slender conical test; chamber and neck not differentiated. 3. Sc421/103/1/B, with swollen cylindrical chamber and flaring neck. 4–5, 15, Sc481/103/1/A, Sc441/103/1/B, and Sc441/103/1/A, respectively, with virtually cylindrical tests; chambers and necks not differentiated.

Figs. 6–14, 17. *Cyathochitina kuckersiana patagiata* ssp. nov., all × 100. 6–11, Sc561/10/14/M, D, E, A (holotype), K and L, respectively. 12, 14, Sc561/10/14/H and J, respectively, oral polar views of isolated bases, each showing the thin-walled, translucent central zone. 13, Sc561/10/14/G, oral polar view of isolated base showing the very narrow carina. 17, Sc561/10/14/C.

Fig. 16. *Cyathochitina kuckersiana* (Eisenack 1934), Sc81/10/14/A, polar view of a specimen perforated by circular holes, possibly the result of fungal attack, × 100.

1967 *Desmochitina minor* Eisenack; Laufeld, p. 328, fig. 25.
1967 *Desmochitina minor* forma *typica* Eisenack; Jenkins, p. 459, pl. 71, figs. 14–15, 18; pl. 72, fig. 2.

Dimensions (*in microns*). 50 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Minimum (neck) diameter*	*Apertural diameter*
Range:	64–94	58–84	51–69	29–41	30–48
Mean:	77	68	58	34	42

Remarks. This species corresponds precisely to Eisenack's *Desmochitina minor* forma *typica*. It occurs throughout the Viola Limestone, where many examples are identical with one or other of the Baltic specimens figured by Eisenack (1962*a*, pl. 16, figs. 1–8, 10; 1965, pl. 10, figs. 16–17), and with Taugourdeau's (1965, pl. 3, fig. 70) figured specimen from the lower part of the Maquoketa Formation of Iowa. They are closely similar in size to, but more quadrangular in lateral view than, the Swedish and most of the British Caradoc material described by Laufeld (1967) and Jenkins (1967). Tests with smooth walls occur throughout the Viola–Fernvale unit in association with tests having finely rugose walls (Pl. 6, figs. 8, 11*a*). The surface texture of the latter, however, is not sufficiently coarse for them to be assigned to *D. minor* forma *rugosa* Eisenack 1962*a*. Forms transitional to *D. erinacea* Eisenack 1931 occur in several populations (Pl. 6, figs. 4, 17) but at no horizon have typical examples of that species been recognized. Specimens (Pl. 6, figs. 15–16) approaching *D. minor* f. *elongata* Eisenack 1958 occur at several horizons (including Sc241, Sc181, Sc141, and Sc81) but typical examples of this informal taxon have not been found in Oklahoma. Some of the variation assumed by *D. minor* in the Viola Limestone is illustrated on Plate 5 (figs. 1–18).

Populations of *D. minor* in the Caradoc Series of Shropshire (Jenkins 1967) and the Sylvan Shale of Oklahoma (Jenkins, in preparation) contain numerous chains of up to twenty tests; in the Viola material, however, as in that from Sweden (Laufeld 1967, p. 328), chains of two tests are exceedingly rare, and chains of three or more tests are unknown. Generally the aperture is sealed by a disc-like operculum, which only rarely remains aborally attached as a basal appendage. *D. minor* and *D. lata* Schallreuter 1963 occur together in the Viola Limestone. They are quite distinct and intermediate forms have not been found.

Material. Several thousand single tests, three chains of two tests each, and one cluster (Pl. 6, fig. 18) of two tests.

Occurrence. Sc653·8–Sc541, Sc501, Sc461–Sc361, Sc321, Sc281–Sc61, ?Sc41, Sc1. The species is very common in the Ostseekalk (Eisenack 1965) and ranges from the Glaukonitkalk, B_2, to the Borkholm Beds, F_2, in Estonia (Eisenack 1958, 1962*a*, 1962*b*, 1965). It is present throughout the Caradoc Series in Shropshire, England (Jenkins 1967) and occurs in all but the youngest Caradoc strata in Dalarna, Sweden (Laufeld 1967).

Desmochitina lata Schallreuter 1963

Plate 6, figs. 19–27; Plate 7, figs. 1–5

1963 *Desmochitina lata* Schallreuter, p. 401, pl. 2, figs. 11, 12 (holotype).
1965 *Desmochitina monilis* Taugourdeau, p. 470, pl. 2, figs. 43, 49.
1967 *Desmochitina lata* Schallreuter; Laufeld, p. 325, fig. 23.

Dimensions (*in microns*). 50 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Minimum diameter*	*Apertural diameter*	*Diameter of membranous opercular flange*
Range:	55–83	41–68	74–110	36–74	54–87	2·5–8
Mean:	68	54	92	54	72	5
Holotype (Schallreuter 1963):	56	44	82	47	58	—

Remarks. Desmochitina lata Schallreuter 1963 can be distinguished from *D. monilis* Taugourdeau 1965 only on the basis of a small size difference, and I consider them conspecific. Populations from the Viola Limestone include forms which are identical to those described and figured by both Schallreuter and Taugourdeau. They consist almost entirely of single tests, and clusters (*sensu* Kozlowski 1963) of three to five tests are extremely rare (Pl. 6, figs. 24, 25). In the few chains found, tests are connected so that the aperture and operculum of one test is closely applied to the convex base of its orally adjacent neighbour. When tests in a chain separated, the operculum generally remained in place, sealing the aperture; occasionally, however, an operculum was found firmly attached to the base of a test, having apparently been torn from the aperture which it originally occupied. The precautions taken to avoid damaging these fossils while preparing them for microscopical examination, and their generally excellent state of preservation, lead me to believe that tests in chains generally separated prior to fossilization, and probably during life, rather than during the time between death and final burial or during laboratory preparation of the material.

EXPLANATION OF PLATE 6

Figs. 1–18. *Desmochitina minor* Eisenack 1931, all ×250. 1, Sc221/45/1/C. 2, Sc261/45/1/C. 3, Sc261/45/1/B. 4, Sc241/45/1/K, transitional to *D. erinacea* Eisenack 1931. 5, Sc221/45/1/A. 6, Sc221/45/1/B. 7, Sc201/45/1/C; 7*a*, focusing on outline of test; 7*b*, focusing on aperture. 8, Sc261/45/1/C, translucent example illustrating rugose surface texture of test wall. 9, Sc561/45/1/A, translucent example showing operculum fallen into chamber; 9*a*, focusing on outline of test; 9*b*, focusing on central prominence of the operculum; 9*c*, focusing on edge of operculum. 10, Sc141/45/1/B, example with operculum fallen into chamber; 10*a*, focusing on outline of test; 10*b*, focusing on operculum. 11, Sc241/45/1/B, translucent example illustrating finely rugose test wall surface texture (11*a*) and a partially detached operculum; the base of this specimen is slightly invaginated forming the lenticular dark area, which should not be mistaken for an opisthosome. 12, Sc201/45/1/B, focusing on aperture (12*a*) and outline of test. 13, Sc1/45/1/A, rare example with rectilinear test. 14. Sc141/45/1/C, with maximum diameter in oral half of chamber; this shape is relatively uncommon but occurs throughout the succession. 15–16, Sc81/45/1/A and Sc241/45/1/E, respectively, transitional to *D. elongata* Eisenack 1958. 17, Sc161/45/1/A, translucent example transitional to *D. erinacea* Eisenack 1931, illustrating very coarsely rugose surface texture of test wall. 18, Sc141/45/1/A, two tests joined shoulder-to-shoulder; their relationship is probably original and not the result of chance preservation.

Figs. 19–27. *Desmochitina lata* Schallreuter 1963, all ×250. 19, Sc521/65/2/A. 20, Sc261/65/2/A. 21, Sc421/65/2/B. 22, Sc241/65/2/A, small example. 23, Sc281/65/2/B, oral polar view of small specimen, focusing on aperture and operculum. 24, Sc581/65/2/D, cluster of three tests, each in lateral view. 25, Sc581/65/2/C, cluster of three tests, each in oral polar view. 26, Sc421/65/2/C, polar view; 26*a*, focusing on aperture; 26*b*, focusing on base to show small fragments left by previously attached test when the original chain or cluster dissociated. 27, Sc501/65/2/B, polar view; 27*a*, focusing on separating operculum and aperture; 27*b*, focusing on outline of test.

D. lata is larger than *Desmochitina scabiosa* (Wilson and Hedlund 1964) comb. nov. (= *Calpichitina scabiosa* Wilson and Hedlund 1964) (total length 50–73 μ, maximum diameter 60–80 μ) and *Desmochitina bransoni* (Wilson and Dolly 1964) comb. nov. (= *Hoegisphaera bransoni* Wilson and Dolly 1964) (total length 39–49 μ, maximum diameter 50–65 μ); and has a longer oral tube than *D. bransoni* (oral tube length 2–4 μ). In addition, *D. scabiosa* and *D. bransoni* are diagnosed, in part, according to the surface textures of their test walls, and in this respect may further differ from *D. lata*. The practice of distinguishing species on the basis of the surface texture of their test walls, however, is questionable and should perhaps be avoided, since the surface texture and apparent structure of the test wall may be related to preservation, and can readily be modified by various methods of preparation and intensities of bleaching.

Material. Several thousand single tests, a few chains of two and three tests, and rare clusters of three to five tests each.

Occurrence. Sc581–Sc381, Sc341–Sc321, Sc281–Sc181. In addition, a number of tests which may be interpreted as *D. lata* or as the inner bodies of *Pterochitina hymenelytrum* sp. nov. occur in Sc161–Sc61, and Scl. Schallreuter (1963) described this species from glacial boulders found near Stralsund, on the German Baltic coast, and since dated by ostracods (Laufeld 1967, p. 296) as Itfer or Jewe (Caradoc). It also occurs in the Caradocian 'Skagen' Formation of central Sweden (Laufeld 1967). Taugourdeau (1965) records *D. monilis*, here considered synonymous with *D. lata*, in the Viola Limestone of the Criner Hills, Oklahoma; the Criner Hills lie a few miles south of the Arbuckle Mountains.

Genus PTEROCHITINA Eisenack 1955*a*

Type species. *Bion perivelatum* Eisenack 1937 (by original designation), Silurian, Baltic.

Pterochitina hymenelytrum sp. nov.

Plate 7, figs. 6–18; text-fig. 7

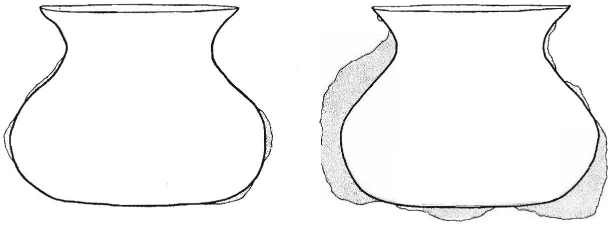
Holotype. Plate 7, fig. 6. Specimen Sc121/62/2/A; Viola Limestone, 121 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. Oblate spheroidal or wide depressed conical chamber; chamber length about 60% maximum diameter, about 80% total length; maximum diameter of chamber (excluding outer membrane) midway along chamber. Oral tube short, sharply flaring; about 60% maximum diameter at its narrowest point, about 80% maximum diameter at aperture; the latter may be sealed by a disc-shaped apertural cap with a narrow membranous flange. Thin outer membrane lacking consistent shape envelops the more rigid inner body, to which it is attached somewhere above and somewhere below the chamber's maximum diameter.

Dimensions (*in microns*). 50 specimens measured.

	Total length	*Chamber length*	*Maximum diameter (exclusive of outer membrane)*	*Minimum diameter*	*Apertural diameter*	*Diameter o, membranous opercular flange*
Holotype:	70	58	84	63	84	—
Range:	56–88	42–72	76–115	36–79	57–92	1·5–8
Mean:	72	57	96	55	74	5

Description. Generally the chamber is spheroidal, widest midway along its length, and probably has retained much of its original shape. Sometimes, however, it is conical, widest at its base, and has clearly been distorted by compression. A complete series of intermediate forms links individuals having spheroidal and conical chambers, and confirms the essential unity of each of several populations.



TEXT-FIG. 7. *Pterochitina hymenelytrum* sp. nov. Lateral profiles, illustrating slight (left) and almost complete separation of the inner and outer layers of the test wall, × 350. The thicker, relatively rigid inner layer consistently retains its shape, whereas the thin outer layer (stippled) lacks a particular shape of its own.

The inner body (i.e. the test exclusive of the outer membrane) is indistinguishable in both size and shape from *Desmochitina lata* Schallreuter 1963, and the presence of a loose outer membrane in *Pterochitina hymenelytrum* is the sole basis for distinguishing the two species. *D. lata* ranges from horizon Sc581 to Sc181, through which sequence *P. hymenelytrum* is absent, while in younger strata (Sc161 to Sc61 and Sc1) *P. hymenelytrum* occurs abundantly and in association with tests which, solely on the basis of

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EXPLANATION OF PLATE 7

Figs. 1–5. *Desmochitina lata* Schallreuter 1963, all ×250. 1, Sc421/65/2/E, polar view, broken specimen with incompletely detached operculum. 2, Sc501/65/2/D, polar view, showing the operculum of the once aborally adjacent test (prior to break up of original chain or cluster) firmly attached to the base; 2*a*, focusing on aperture; 2*b*, focusing on operculum and base; 2*c*, focusing on outline of test. 3, Sc421/65/2/D, chain of two tests. 4, Sc561/65/2/B, polar view focusing on aperture (4*a*) and outline of test. 5, Sc181/65/2/A, oral polar view of operculum fallen into chamber; oral half of test missing.

Figs. 6–18. *Pterochitina hymenelytrum* sp. nov., ×250. 6, Sc121/62/2/A, holotype. 7, Sc161/62/2/D, the translucent outer wall-layer in this specimen superficially resembles the carina in *Cyathochitina kuckersiana* (Eisenack 1934). 8, Sc161/62/2/A, polar view; unlike the carina in *Cyathochitina kuckersiana*, the outer wall-layer lacks striations concentric with the basal margin and is crossed by a multiplicity of secondary folds. 9–11, Sc101/62/2/H, Sc161/62/2/B, and Sc81/62/2/A, respectively, chains of two tests each. 12, Sc101/62/2/F, oral polar view, focusing on very thin outer wall-layer (12*a*) and on displaced operculum. 13, Sc101/62/2/A, polar view, focusing on junction of operculum and aperture (13*a*) and on opercular flange. 14, Sc101/62/2/J, polar view showing marked separation of the wall-layers. 15, Sc101/62/2/C, polar view, focusing on aperture (15*a*) and thin outer wall-layer. 16, Sc121/62/2/B, polar view, focusing on operculum and aperture (16*a*) and outline of test; the outer wall-layer has been lost. 17, Sc101/62/2/K, polar view, focusing on aperture (17*a*) and outline of test. 18, Sc101/62/2/D, polar view of detached operculum, showing very translucent opercular flange encircling the more opaque body of the operculum.

morphology, could be interpreted as *Desmochitina lata* or the inner bodies of *P. hymenelytrum*. The two species are closely related and a strong case could be made for considering them varieties of one species. Certainly the difference between them is grossly exaggerated by referring them to different genera, yet such distortion of natural relationships is an unavoidable consequence of following a strictly empirical system of classification.

The loose, enveloping membrane in *P. hymenelytrum* may have developed, phylogenetically, by the separation of the outer and inner layers in the possibly two-layered test wall of *Desmochitina lata*; such a phylogeny is suggested by a few specimens referred to *D. lata* from horizon Sc281, which have developed narrow equatorial flanges (*c*. 2 μ in width), which appear structurally the same as the outer membrane of *P. hymenelytrum*. The membrane extends up to 15 μ from the inner body and in lateral view is seen to envelop the chamber and oral tube; the points of its attachment to the inner body vary from one test to another. It is delicate and relatively thin, and its susceptibility to folding and distortion is responsible for the very variable over-all shape of this species. The inner body is relatively rigid and retains a fairly consistent shape.

The outer membrane is pale amber or yellow, and transparent, even in tests which have not been bleached and which are otherwise black and opaque. While one may confidently use the colour and transparency of this membrane in identifying *P. hymenelytrum* in the Viola and Fernvale Limestones of Oklahoma, these characteristics are not used to diagnose the species since they may be secondary features, resulting from the type of preservation which generally prevails in the Viola–Fernvale sequence, rather than wholly original characteristics.

Comparison. Pterochitina makroptera Eisenack 1959 (over-all diameter 180–347 μ) is larger than the new species and its membrane bears striations concentric with the margin of the test. In *P. retracta* Eisenack 1955*b* the outer membrane is a large umbrella-like structure.

Material. Approximately 1200 single tests, four chains each of two tests, and very rare clusters of three to five tests each.

Occurrence. Sc161–Sc61, Sc1.

Genus HERCOCHITINA Jansonius 1964 emend. Jenkins 1967

Type species. Hercochitina crickmayi Jansonius 1964 (by original designation), Vauréal Formation, Upper Ordovician, Anticosti Island, Quebec.

Remarks. Tappan (1966) placed *Belonechitina* Jansonius 1964 and *Hercochitina* Jansonius 1964 in synonymy. The present study confirms the propriety of Tappan's synonymy by demonstrating the very close phylogenetic relationship between *Conochitina robusta* Eisenack 1959 (= *Belonechitina robusta* [Eisenack 1959] Jansonius 1964) and *Hercochitina crickmayi* Jansonius 1964, which are the type species, respectively, of *Belonechitina* and *Hercochitina*. For the present, however, I favour retaining the separate identity of *Hercochitina* to include a group of species which, if only distantly related, are distinctively and similarly ornamented.

Hercochitina crickmayi Jansonius 1964 emend.

Plate 8, figs. 1–11; text-figs. 8, 10

1964 *Hercochitina crickmayi* Jansonius, p. 908, pl. 1, figs. 9 (holotype), 10–11.
1964 *Hercochitina* sp. A Jansonius, pl. 1, fig. 13.

Emended diagnosis. Chamber conical, about four-fifths total length; maximum diameter about one-third total length; base flat, margin rounded; small, cylindrical, or distally tapering basal process occasionally distinguishable. Oral tube slightly flaring, two-thirds to three-quarters maximum diameter in width; aperture straight, serrate or irregularly fimbriate. Twenty to thirty longitudinal rows of spines connected at their tips by longitudinal bars. Sometimes the spine rows are λ-spines up to 17 μ in length with numerous bases. Spines and bars commonly support perforate or imperforate membranes, which form narrow longitudinal ridges, up to 8 μ in height, rising abruptly, like fins, from the test wall. Spines and bar may loose identity in membrane. Ridges and spine rows short, or extending from basal margin to aperture.

Dimensions (*in microns*). 50 specimens measured.

	Total length	*Maximum diameter*	*Minimum diameter (at base of neck)*	*Apertural diameter*
Range:	204–364	86–117	54–84	63–90
Mean:	288	99	67	76
Holotype (Jansonius 1964):	290	—	—	—

Description. In size and general shape this species is virtually the same wherever it has been found. The character of its ornament varies considerably, however, and is the basis for distinguishing two informal taxa, *Hercochitina crickmayi* forma *spinetum* (Pl. 8, figs. 1*a*, *b*; text-fig. 8) and *H. crickmayi* forma *normalis* (Pl. 8, figs. 2–8, 10–11; text-fig. 8). In f. *spinetum* the ornament consists of λ-spines up to 17 μ in height, each with a blunt tip and numerous (5–15 or more) discrete bases arranged in a longitudinal row. In the older populations (Sc501 to Sc401) of f. *normalis* the ornament consists of twenty to thirty rows of short spines running the whole length of the test. The spines

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EXPLANATION OF PLATE 8

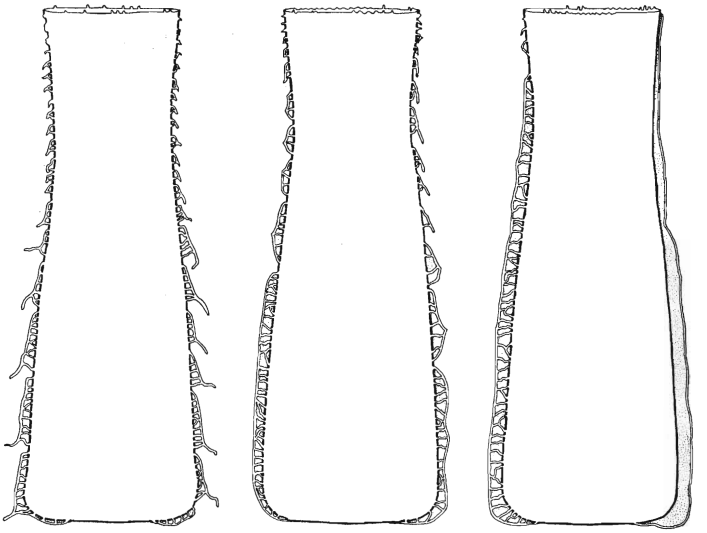
Fig. 1. *Hercochitina crickmayi* forma *spinetum*, Sc521/56/2/A; 1*a*, ×100; 1*b*, detail of ornament, ×250.

Figs. 2–8, 10–11. *Hercochitina crickmayi* forma *normalis*. 2, Sc461/57/2/C, with low longitudinal ridges, ×100. 3, Sc381/57/2/Y, ×100. 4, Sc381/57/2/U, ×100. 5, Sc441/57/2/P, with very low ridges, ×100. 6, Sc381/57/2/T, with strongly developed fin-like ridges, ×100. 7, Sc381/57/2/B; 7*a*, detail of ridge, ×250; 7*b*, ×100. 8, Sc381/57/2/W, ×100. 10, Sc381/57/2/X, ×100. 11, Sc381/57/2/A; 11*a*, ×100; 11*b*, detail of ornament, ×250.

Fig. 9. *Hercochitina crickmayi*, Sc461/57/2/B, transitional between f. *spinetum* and f. *normalis*; the ornament of f. *spinetum* (λ-spines with numerous proximal limbs) occupies the oral half of the test, the ornament of f. *normalis* (longitudinal ridges) the aboral half, ×250.

Figs. 12–17. *Hercochitina turnbulli* sp. nov., all but 12*b* ×250. 12, Sc241/70/6/D, holotype; 12*b*, ornament viewed through translucent upper oral tube, ×400. 13, Sc361/70/6/E. 14–16, Sc241/70/6/F, C, and B, respectively. 17, Sc241/70/6/G, translucent example photographed in three focal planes to illustrate ornament.

in each row stand normal to the test wall, are connected at their tips by a continuous longitudinal bar, and support a thin, generally unbroken membrane. The membranes, and the spines incorporated within them, stand out sharply, like fins, from the test wall and are up to 3–5 μ in height. In younger populations of f. *normalis* (Sc381–Sc321) the spines and bars are no longer differentiated within the membrane, and the ridges have become simple, more or less homogeneous membranes up to 8 μ in height.



TEXT-FIG. 8. *Hercochitina crickmayi* Jansonius 1964 emend. × 230. Lateral profiles of forma *spinetum* (left) showing λ-spines with numerous bases; forma *normalis* (right) showing longitudinal membranes in which spines may (left side of specimen) or may not be incorporated; and a transitional form having the ornament of f. *spinetum* on the neck and upper flanks, and the ornament of f. *normalis* toward the base. The presence of a membrane is indicated by stippling.

Morphologically, *H. crickmayi* f. *spinetum* is transitional between *Conochitina robusta* Eisenack 1959 and *H. crickmayi* f. *normalis*, and is linked with both by a continuous series of intermediate forms. Forms linking f. *spinetum* with f. *normalis* commonly include specimens which bear the ornament of f. *normalis* (membranous ridges) aborally, and the ornament of f. *spinetum* (λ-spines with numerous bases) toward the aperture (Pl. 8, fig. 9; text-fig. 8).

Comparison. *Conochitina robusta* and *Hercochitina crickmayi* are distinguished on the basis of whether their ornament consists largely of λ-spines (*C. robusta*), or of longitudinal ridges or rows of spines connected at their tips by a bar (*H. crickmayi*). *Hercochitina downiei* Jenkins 1967 is much smaller (mean total length 153 μ) than *H. crickmayi* and bears twelve to sixteen rows of relatively long spines up to 59 μ in length.

Remarks. The informal infraspecific taxa *Hercochitina crickmayi* forma *spinetum* and forma *normalis* comprise part of a continuous evolutionary series, and are distinguished somewhat arbitrarily. While certain stratigraphical considerations require that these forms be distinguished by name, I am unwilling to refer them to formal infraspecific taxa before their morphology and stratigraphical distribution, lateral and vertical, has been studied more closely.

Material. Several thousand single tests.

Occurrence. Sc521–Sc321. The type material is from the Upper Ordovician Vauréal Formation of Anticosti Island, Quebec.

Hercochitina turnbulli sp. nov.

Plate 8, figs. 12–17; Plate 9, figs. 1–5; text-fig. 9

Holotype. Plate 8, figs. 12*a*, *b*. Specimen Sc241/70/6/D; Viola Limestone, 241 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

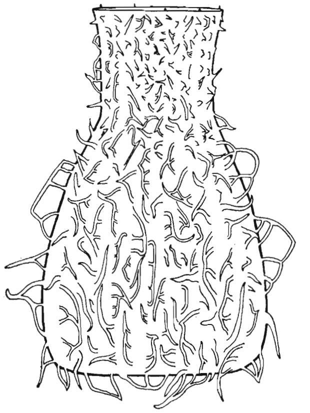
Diagnosis. Chamber conical, two-thirds to three-quarters total length; maximum diameter at base, 75–90% chamber length; base flat, margin bluntly rounded. Oral tube cylindrical or slightly flaring, half to two-thirds maximum diameter in width; aperture bearing few blunt spines (up to 3 μ in length). Ornament of slender, simple and λ-spines up to 15% maximum diameter in length; arranged in 20–30 longitudinal rows extending from basal margin to aperture; longitudinal bars connecting spine tips discontinuous, commonly lacking.

Dimensions (*in microns*). 35 specimens measured.

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Apertural diameter*	*Spine length*
Holotype:	122	82	66	39	46	< 8
Range:	99–132	66–102	59–86	30–46	35–51	< 12
Mean:	121	85	73	37	43	—

Description. The chief diagnostic characteristic is the dense ornament of short spines (ridges are not developed) arranged in 20–30 longitudinal rows. The multiple bases of each λ-spine lie in the same longitudinal row; the longitudinal bars are short, connect only a few spine tips and occur, at most, in only four or five spine rows. The neck and chamber are readily distinguishable.

Comparison. Hercochitina turnbulli sp. nov. (spines aligned in longitudinal rows) and *Conochitina hirsuta* Laufeld 1967 (spine bases not in longitudinal rows) are closely similar in size and shape. Their ornament consists of simple and λ-spines, and, in damaged material, where tests have lost much or all of their ornament, it may be difficult or impossible to determine which of these species is present. A few specimens transitional to *H. turnbulli* occur in each of five populations (Sc181, Sc161, Sc121, Sc101, Sc81) of *Conochitina hirsuta*; they perhaps correspond to those Swedish specimens (Laufeld 1967, p. 305) in which the bases of spines on the chamber are aligned in longitudinal rows. *Hercochitina downiei* Jenkins 1967 is larger (total length 135–188 μ) than *H. turnbulli*; its spines are longer,



TEXT-FIG. 9. *Hercochitina turnbulli* sp. nov. Lateral view showing ornament of π-spines, λ-spines, and simple spines, ×400.

arranged in fewer rows, and their tips are connected by continuous longitudinal bars running from the basal margin to the aperture. *H. crickmayi* Jansonius 1964 emend. is readily distinguished from *H. turnbulli* by its greater size (total length 204–364 μ) and the character of its ornament.

Material. Approximately 1500 single tests.

Occurrence. Sc361–Sc321, ?Sc281 and ?Sc261 (questionable identifications of damaged tests which have lost their ornament), Sc241–Sc221, Sc141.

Genus LAGENOCHITINA Eisenack 1931

Type species. Lagenochitina baltica Eisenack 1931 (by original designation), Baltic drift.

Lagenochitina sp. cf. *L. baltica* Eisenack 1931

Plate 9, fig. 6

Dimensions (in microns).

	Total length	*Chamber length*	*Maximum diameter*	*Oral tube diameter*	*Diameter of base*
Specimen Sc161/12/3/A:	217	142	87	44 → 37	72

Remarks. One chitinozoan from the Viola Limestone (Sc161) is referred to *Lagenochitina* sp. cf. *L. baltica* Eisenack 1931. Typical representatives of this species have not been recorded in North America.

Genus RHABDOCHITINA Eisenack 1931

Type species. Rhabdochitina magna Eisenack 1931 (by original designation), Baltic drift.

Rhabdochitina turgida Jenkins 1967

Plate 9, figs. 7–9

Rhabdochitina turgida Jenkins 1967, p. 467, pl. 74, figs. 16–19.

Dimensions (in microns). 3 specimens measured.

	Total length	*Maximum diameter*	*Apertural diameter*
Range:	79–93	33–9	19–24
Mean:	87	35	22

Remarks. Four single tests from two horizons (Sc121 and Sc81) in the Viola Limestone differ from the British type material (total length 146–362 μ, maximum diameter 69–131 μ) only by their smaller size.

Rhabdochitina usitata Jenkins 1967

Plate 9, figs. 10–12

Rhabdochitina usitata Jenkins 1967, p. 468, pl. 74, figs. 13–15; pl. 75, fig. 1.

Dimensions (*in microns*). 7 specimens measured.

	Total length	*Maximum diameter*	*Apertural diameter*
Range:	357–574	116–53	69–99
Mean:	469	139	86

Remarks. Seven single tests from three horizons (Sc641, Sc541, and Sc481) in the Viola Limestone compare closely with the British type material. The latter, however, includes both cylindrical and weakly conical tests, whereas all seven specimens from Oklahoma are weakly conical.

Genus SPHAEROCHITINA Eisenack 1955*a*

Type species. *Lagenochitina sphaerocephala* Eisenack 1932 (by original designation), Silurian, Baltic.

Sphaerochitina compactilis sp. nov.

Plate 9, figs. 13–17

Holotype. Plate 9, fig. 13. Specimen Sc621/102/1/C; Viola Limestone, 621 ft. stratigraphically below base of Sylvan Shale, Sycamore Creek.

Diagnosis. Chamber conical to spherical; maximum diameter at base or midway along chamber, about half total length; base flat or convex, margin bluntly rounded. Neck cylindrical or not differentiated from chamber, up to one-third total length; one-third to half maximum diameter in width. Wall smooth.

Dimensions (*in microns*). 20 specimens measured.

	Total length	*Maximum diameter*
Holotype:	117	65
Range:	114–35	56–72
Mean:	120	64

Description. While most tests occur singly with little or no evidence that they were at one time connected to other tests, some occur in clusters of two to four tests connected side-by-side (Pl. 9, fig. 17). These clusters are interpreted as derived from the break up of large clusters of chitinozoans comparable with those illustrated by Kozlowski (1963) and Jenkins (1967, p. 460, pl. 72, fig. 2). I have seen no evidence, however, for the existence of cocoons (*sensu* Kozlowski 1963) in this species.

EXPLANATION OF PLATE 9

Figs. 1–5. *Hercochitina turnbulli* sp. nov., ×250. 1–2, Sc241/70/6/A and L, respectively, showing relatively undamaged ornament through translucent test wall. 3–5, Sc361/70/6/N, P, and R, respectively, damaged examples showing stumps of spines arranged in longitudinal rows.

Fig. 6. *Lagenochitina* sp. cf. *L. baltica* Eisenack 1931, Sc161/12/3/A, ×100.

Figs. 7–9. *Rhabdochitina turgida* Jenkins 1967, Sc121/23/1/C, A, and B, respectively, ×100.

Figs. 10–12. *Rhabdochitina usitata* Jenkins 1967, Sc641/16/3/A, Sc481/16/3/G, and Sc541/16/3/C, respectively, ×100.

Figs. 13–17. *Sphaerochitina compactilis* sp. nov., ×250. 13, Sc621/102/1/C, holotype. 14, Sc621/102/1/E. 15, Sc621/102/1/A, cluster of two tests. 16, Sc621/102/1/J. 17, Sc621/102/1/B, cluster of four tests photographed in three focal planes.

Remarks. Within the Viola Limestone *S. compactilis* is recognized chiefly by its smooth, variably shaped, small test, and a tendency to occur in clusters.

Material. Approximately 150 single tests, and several clusters of two to four tests.

Occurrence. Sc651, Sc621.

CHARACTER AND AFFINITIES OF THE VIOLA–FERNVALE FAUNA

The chitinozoan fauna of the Viola and Fernvale Limestones has been examined at stratigraphical intervals of 20 ft. throughout the 654 ft. thick Viola–Fernvale sequence exposed in the bed and banks of Sycamore Creek, map reference NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 27, T. 3 S., R. 4 E., Johnston County, Oklahoma (text-fig. 1). Large numbers of well-preserved chitinozoans occur throughout the Viola Limestone, but material from the well-sorted Fernvale calcarenite is invariably broken or damaged. The relatively poor preservation of the chitinozoans in the Fernvale Limestone is consistent with this formation's high-energy depositional environment, which is evident from the fragmentary and abraded skeletal detritus and the dearth of mud-grade particles in the rock.

The fauna at any one horizon (known here as an assemblage) consists of few species, twenty-four of the thirty-three assemblages examined each containing from five to seven species. At only one horizon does the fauna comprise as many as nine species and at only one is it reduced to fewer than four species. These figures compare closely with those of Jenkins (1967, p. 480) for British Ordovician assemblages in Shropshire, England, and would support the view that chitinozoan assemblages characteristically are comprised of few species. The fauna has been referred to the following ten genera, and twenty-two species and subspecies of which eight are new:

Ancyrochitina corniculans sp. nov.
Angochitina capillata Eisenack 1937
Conochitina micracantha Eisenack 1931
Conochitina wesenbergensis Eisenack 1959
Conochitina seriespinosa sp. nov.
Conochitina hirsuta Laufeld 1967
Conochitina robusta Eisenack 1959
Conochitina tribulosa sp. nov.
Conochitina minnesotensis (Stauffer 1933)
Conochitina sp. aff. *C. elegans* Eisenack 1931 (about twelve distorted or broken specimens)
Cyathochitina kuckersiana kuckersiana (Eisenack 1934)
Cyathochitina kuckersiana patagiata ssp. nov.
Cyathochitina kuckersiana latipatagium ssp. nov.
Desmochitina minor Eisenack 1931
Desmochitina lata Schallreuter 1963
Hercochitina crickmayi Jansonius 1964
Hercochitina turnbulli sp. nov.
Lagenochitina sp. cf. *L. baltica* Eisenack 1931 (one specimen)
Pterochitina hymenelytrum sp. nov.
Rhabdochitina turgida Jenkins 1967
Rhabdochitina usitata Jenkins 1967
Sphaerochitina compactilis sp. nov.

Owing to their scarcity, poor preservation, and the possibility that they have been reworked from older deposits, *Conochitina* sp. aff. *C. elegans* and *Lagenochitina* sp. cf. *L. baltica* are ignored in the following discussion. Typical examples of *Conochitina elegans* occur in the Caradoc of Estonia (Eisenack 1962*b*), the Caradoc of Shropshire, England (Jenkins 1967), the Ostseekalk of north Germany and south Finland (Eisenack 1965), and the Sylvan Shale of Oklahoma (Jenkins, in preparation); typical examples of *Lagenochitina baltica* are known in the Ashgill of Estonia (Eisenack 1962*b*), the Caradoc of Shropshire (Jenkins 1967), the Caradoc of Dalarna, Sweden (Laufeld 1967), and the Ostseekalk of north Germany, Gotland, and south Finland (Eisenack 1965).

The twelve previously described species recognized in the Viola–Fernvale sequence (Table 1, column A) appear to be characteristic Ordovician forms, and reports of their occurrence outside this system would appear to require further documentation with respect to identity and/or stratigraphy. Ten of these species (Table 1, column B) are present in the Caradoc–Ashgill Series, C_2–F_2, of northern Europe (Eisenack 1962*b*, 1965; Laufeld 1967; Jenkins 1967), and six of them are possibly restricted to these series (Table 1, column C). (The Caradoc and Ashgill Series have been correlated by Twenhofel *et al.* (1954) with the Black River and Trenton Stages in New York, and the younger Eden, Maysville and Richmond Stages in the upper Ohio River valley. Berry's (1960*a*, tables 2 and 3; 1960*b*, table 1) correlation is essentially the same.)

TABLE 1. Listing previously described species (column A) found in the Viola and Fernvale Limestones; those of them (column B) which occur also in the Caradoc–Ashgill, C_2–F_2, succession of northern Europe; and those (column C) which, in northern Europe, may be restricted to the Caradoc and Ashgill Series

Previously described species in the Viola and Fernvale Limestones of Oklahoma	*Present in the Caradoc-Ashgill of northern Europe*	*Possibly restricted in northern Europe to the Caradoc and Ashgill Series*
Angochitina capillata	+	+
Conochitina micracantha	+	
Conochitina wesenbergensis	+	+
Conochitina hirsuta	+	+
Conochitina robusta	+	+
Conochitina minnesotensis	+	
Cyathochitina kuckersiana	+	+
Desmochitina minor	+	
Desmochitina lata	+	+
Hercochitina crickmayi (known only from North America)		
Rhabdochitina turgida (in northern Europe known only from the Llanvirn–Llandeilo)		
Rhabdochitina usitata	+	
Column A	B	C

The Viola–Fernvale chitinozoan fauna comprises two distinct elements, one cosmopolitan, the other provincial. The cosmopolitan element, consisting of eleven previously described species (Table 2, column A), bears a striking resemblance to faunas from the Caradoc–Ashgill of Estonia, Sweden, and Britain, and from the Ostseekalk of the Baltic region. It contains eight species (Table 2, column B) known in the Ostseekalk fauna of north Germany, Gotland, and south Finland (Eisenack 1965), seven (column C) in common with the C_2–F_2 fauna of Estonia (Eisenack 1962*b*), six (column D) recorded by Laufeld (1967) in the Caradoc of Dalarna, Sweden, and four (column E) recorded by Jenkins (1967) in the Caradoc of Shropshire, England. The large proportion of chitinozoan species that are shared between North America and northern Europe, in rocks of approximately the same age, indicates that correlation between the two continents is clearly feasible on the basis of these microfossils.

TABLE 2. Species comprising the cosmopolitan element in the Viola–Fernvale fauna, and their known geographical distribution in the Caradoc and Ashgill Series of northern Europe.

Species comprising the cosmopolitan element in the Viola–Fernvale fauna	*Ostseekalk of north Germany, Gotland, and south Finland*	C_2–F_2 *beds (Caradoc–Ashgill) of Estonia*	*Caradoc of Dalarna, Sweden*	*Caradoc of Shropshire, England*
Angochitina capillata	+	+		
Conochitina micracantha	+	+		
Conochitina wesenbergensis	+	+		
Conochitina hirsuta			+	+
Conochitina robusta	+	+	+	
Conochitina minnesotensis	+	+	+	
Cyathochitina kuckersiana	+	+	+	+
Desmochitina minor	+	+	+	+
Desmochitina lata	+		+	
Rhabdochitina usitata				+
Rhabdochitina turgida	(In northern Europe, this species is known only from the Llanvirn–Llandeilo of Shropshire.)			
Column A	B	C	D	E

The second, or provincial, element in the Viola–Fernvale fauna consists of seven species (*Ancyrochitina corniculans*, *Conochitina seriespinosa*, *C. tribulosa*, *Hercochitina crickmayi*, *H. turnbulli*, *Pterochitina hymenelytrum* and *Sphaerochitina compactilis*) known only from North America; the publication of future studies, however, may show that the provincial aspect of this faunal element is more apparent than real. The most striking feature about this faunal element is that four of the five ornamented species bear rows of processes, or ridges, running parallel with the length of the test. The ornament of *Ancyrochitina corniculans* includes λ-spines and, occasionally, π-spines, the proximal elements of which stand in longitudinal rows. *Hercochitina turnbulli* has rows of simple spines, λ-spines, and π-spines. *Hercochitina crickmayi* bears many rows of spines connected at their tips by longitudinal bars; commonly, the spines and bars support perforate or imperforate membranes forming narrow longitudinal ridges which rise abruptly, like fins, from the surface of the test. The spines in *Conochitina seriespinosa* stand in longitudinal rows, their bases characteristically expanded in a plane parallel with the test's length; thus, in lateral view the spine bases appear to merge with the test wall, while in polar view they appear to meet the test wall abruptly. This general style of ornamentation, in which processes are aligned in longitudinal rows, is peculiar to the Upper Ordovician and seems particularly common in North America. It is relatively rare in northern Europe, where it is known in *Hercochitina downiei* Jenkins 1967 from the Caradoc of Shropshire, England; some specimens of *Conochitina hirsuta* Laufeld 1967 from the Caradoc of Dalarna, Sweden; and *Cyathochitina stentor* (Eisenack

1937) from the Caradoc Kuckers Beds, C_2, of Estonia (Eisenack 1962*a*, 1962*b*), the Caradoc of Dalarna (Laufeld 1967), and the probably Caradocian Herscheider Shale of Westphalia (Eisenack 1939). It is unknown elsewhere.

CHITINOZOAN FAUNAS FROM ABOVE AND BELOW THE VIOLA–FERNVALE SUCCESSION

The Viola–Fernvale chitinozoan fauna is altogether different from that which succeeds it in the Sylvan Shale (Jenkins, in preparation) and the two faunas contain only one species, *Desmochitina minor*, in common. Chitinozoans occur in great abundance throughout the Sylvan Shale and the fauna there contains elements more frequently associated with Silurian than Ordovician sediments. The striking difference between the Viola–Fernvale and Sylvan faunas suggests that the unconformity between the two stratigraphical units probably represents a substantial period of time (although no reliable indication of its duration can presently be given) or that the character of chitinozoan faunas may be very much more subject to control by the environment of deposition than has hitherto been suspected.

Acid-insoluble residues from the Corbin Ranch Formation, which underlies the Viola–Fernvale unit, contain very little organic material, and several attempts to recover chitinozoans from this formation have failed. Unlike the Viola–Fernvale unit and Sylvan Shale, which contain large numbers of graptolites and chitinozoans, the Corbin Ranch Formation contains no graptolites (Harris 1957, p. 98) and, apparently, no chitinozoans. This is one more in a growing body of facts which tends to support the hypothesis that, in the Ordovician at least, there is an ecological and/or genetic relationship between the graptolites and the chitinozoans. Such a relationship, however, is by no means proven.

VERTICAL DISTRIBUTION AND STRATIGRAPHICAL SIGNIFICANCE OF CHITINOZOANS IN THE VIOLA–FERNVALE SUCCESSION

The stratigraphical distribution of the species, subspecies, and forms encountered in the Viola–Fernvale sequence, and the composition of the fauna at each horizon, is summarized in Table 3.

Only one important faunal break interrupts the general continuity of the faunal succession. At Sycamore Creek, it lies within the uppermost Viola Limestone and, as far as the spacing of the samples has enabled me to determine, some 60–80 ft. below the Fernvale–Sylvan Shale contact and 40–60 ft. below the lithological change separating the chert-bearing calcite mudstones of the Viola Limestone from the more massively bedded, coarse skeletal calcarenites of the Fernvale Limestone. The faunal break does not coincide with the base of the Fernvale Limestone, where there is no apparent faunal or stratigraphical evidence of a break in deposition. Seven species are present throughout the hundred or so feet of strata immediately below the faunal break; four of them occur for the last time at the break and three continue above it, where they are immediately joined by two forms which do not occur earlier. Of the five species present immediately above the faunal break, four continue to the top of the Viola–Fernvale succession. It is particularly relevant to note that two of the three species which continue without interruption through the break (*Conochitina minnesotensis* and *Desmochitina minor*) are known to range, in northern Europe, from the very early Ordovician Glaukonitkalk, B_2, to the topmost Ordovician Borkholm Beds, F_2 (Eisenack 1965, pp. 126, 130). One would scarcely expect such long-ranging forms to respond to a stratigraphical break, even a major one, within the Ordovician System.

This faunal break may correspond to the unconformity postulated to exist at the base of the Fernvale Limestone by Ulrich (1911, pl. 27; *in* Baker and Bowman 1917, pp. 89–92; summarized in Berry 1960, p. 30), Edson (1927, p. 970 and fig. 1; 1930), Wengerd (1948, pp. 2189, 2250) and Twenhofel *et al.* (1954). That it does not coincide precisely with the base of the Fernvale would seem relatively unimportant on the regional scale, particularly since the Viola–Fernvale contact is gradational, cannot always be located precisely, and may be marked by an alternation of Viola and Fernvale lithologies. Although it is difficult to deduce the magnitude of the hiatus it may represent, the break in the faunal succession seems very significant. It provides a palaeontological basis for believing that a major hiatus exists here, and indicates that the uppermost Viola–Fernvale strata (60–80 ft. thick at Sycamore Creek) are substantially younger than the beds immediately below them.

The application in southern Oklahoma of this aspect of my work should be avoided until adequate supporting data are available. For this reason it is emphasized that the hiatus has been recognized in only one section and that its lateral distribution has not been proved; it is quite possible that the hiatus is a local development, perhaps restricted to a very small part of south-central Oklahoma. Furthermore, since the stratigraphical ranges of the Viola–Fernvale chitinozoan species are not known in terms of the North American type sections, or other standards of stratigraphical reference, it is not presently possible to estimate the time represented by the faunal break at Sycamore Creek; possibly the break represents only a very short interval. It is hoped that future studies of the critical upper part of the Viola–Fernvale succession, at widely separate localities, will provide more information on the significance and lateral distribution of this hiatus.

With the single exception discussed above, no abrupt faunal changes occur in the Viola–Fernvale sequence, and only occasionally is a stratigraphical interval of 20 ft. marked by the appearance or disappearance of more than one species or subspecies. The general continuity of the faunal succession precludes the possibility that other significant hiatuses are present in the sequence, and suggests that, apart from the faunal and inferred stratigraphical break considered above, deposition of the Viola–Fernvale sediments was virtually continuous or interrupted only by breaks too short to be reflected in the fossil record. This view is strongly supported for the lower half of the sequence by the continuity of the evolutionary series *Conochitina robusta–Hercochitina crickmayi* f. *spinetum–H. crickmayi* f. *normalis*, which runs from horizon Sc621 to Sc321. The evolutionary and stratigraphical relationships between the forms comprising this series are discussed below and summarized in text-figure 10.

THE EVOLUTIONARY SERIES *CONOCHITINA ROBUSTA–HERCOCHITINA CRICKMAYI* F. *SPINETUM–H. CRICKMAYI* F. *NORMALIS*

In the lower half of the Viola Limestone an evolutionary series can be traced from *Conochitina robusta* Eisenack 1959 through *Hercochitina crickmayi* f. *spinetum* to *H. crickmayi* f. *normalis* (text-fig. 10). Appreciable morphological changes are limited to changes in the character of the ornamentation (by which means the three taxa are distinguished), and the test remains practically the same in size and general shape wherever these forms have been found (text-figs. 6 and 8).

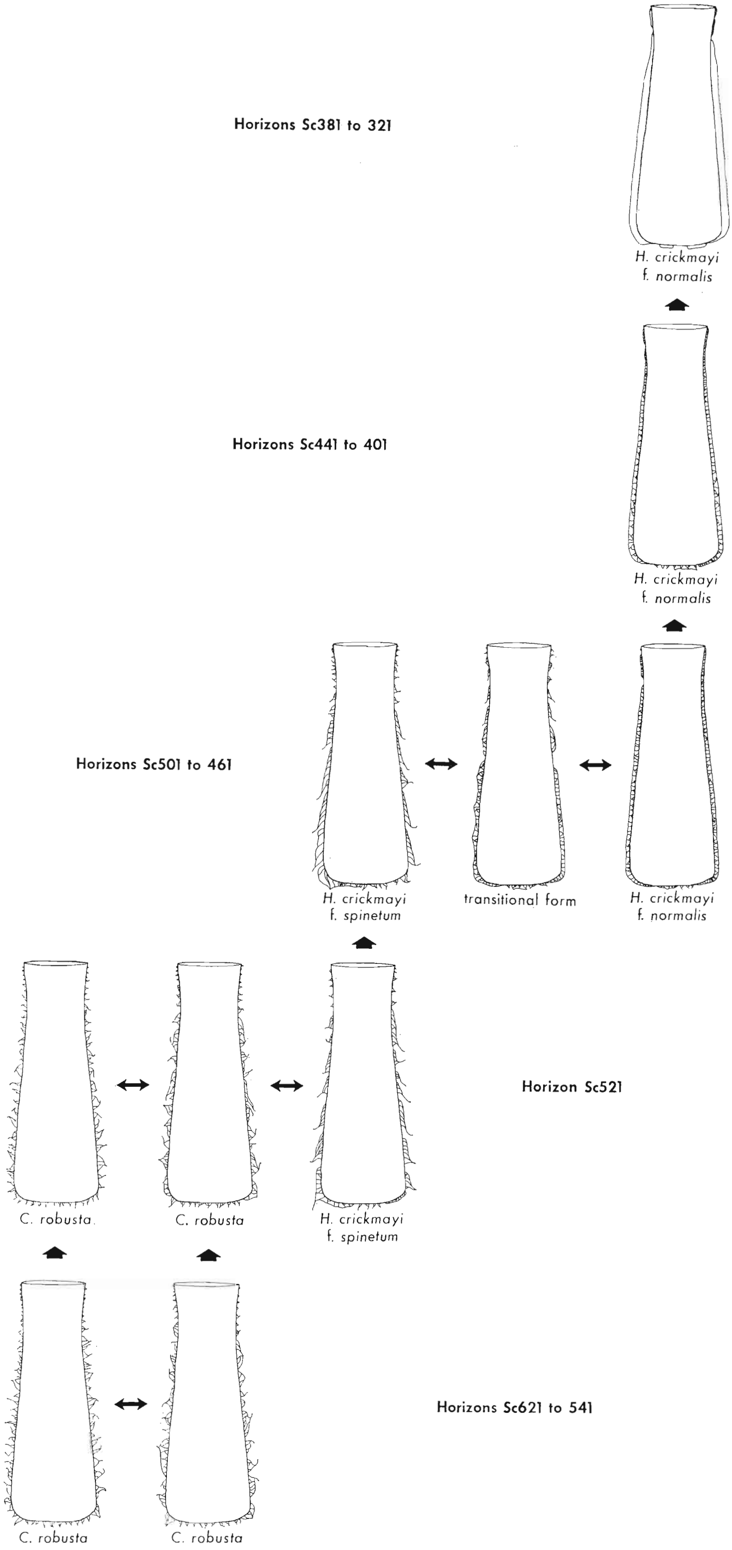
Pure populations of *Conochitina robusta* range from horizon Sc621 to Sc541, where *Hercochitina crickmayi* and forms transitional to it are lacking. The ornament of *C. robusta* consists almost exclusively of λ-spines up to 12 μ in length, each with a blunt tip and a row of two to five (occasionally eight) discrete proximal limbs aligned parallel with the length of the test.

At a younger horizon, Sc521, a population of continuously intergrading forms contains typical *C. robusta* predominating numerically over specimens of *H. crickmayi* f. *spinetum*. The latter is furnished with λ-spines up to 17 μ in height, each with a blunt tip and numerous (five to fifteen or more) discrete proximal limbs arranged in a row parallel with the length of the test. Morphologically, *H. crickmayi* f. *spinetum* is transitional between *C. robusta* and *H. crickmayi* f. *normalis*, and is linked with both by a continuous series of intermediate forms.

At still younger horizons, Sc501 to Sc461, *C. robusta* is lacking, and *H. crickmayi* f. *spinetum* occurs in conjunction with *H. crickmayi* f. *normalis*, which at these horizons is furnished with twenty to thirty longitudinal rows of short spines (up to 3·5 μ in length) running the whole length of the test. The spines in each row stand normal to the test wall, are connected at their tips by a continuous longitudinal bar, and support a thin, generally unbroken membrane. The latter and its incorporated spines stand out sharply, like fins, from the test-wall. Where f. *spinetum* and f. *normalis* occur together, they are linked by a continuous series of intermediate forms, which commonly bear the ornament of f. *normalis* (membranous ridges) aborally, and the ornament of f. *spinetum* (λ-spines with numerous bases) toward the aperture.

The lineage ends in pure populations of *H. crickmayi* f. *normalis* at horizons Sc441 to Sc321, where *C. robusta* and forms transitional to it are lacking. At the youngest of these horizons (Sc381–Sc321), the spines and longitudinal bars are no longer differentiated within the membrane, and the ridges have become simple, more or less homogeneous membranes up to 8 μ in height.

TEXT-FIG. 10. Illustrating the phylogenetic relationship between *Conochitina robusta*, *Hercochitina crickmayi* forma *spinetum* and *H. crickmayi* forma *normalis*, and showing the range of morphological variation in populations at successive stratigraphical levels in the Viola Limestone. Appreciable morphological changes in this lineage are limited to changes in the character of the ornamentation (by which means the three taxa are distinguished); the size and general shape of the test remain practically constant wherever these forms have been found. For the sake of clarity, ornament is shown only in profile. Drawings are approximately × 100.



TEXT-FIG. 10. EVOLUTIONARY SERIES

PROVISIONAL CHITINOZOAN ZONATION OF THE VIOLA AND FERNVALE LIMESTONES

On the basis of changes in the faunal succession, five biostratigraphical zones are recognized in the Viola–Fernvale sequence (Table 3). The zones are clearly distinguishable from each other, although they are admittedly somewhat arbitrary divisions of an essentially continuous faunal succession, whose unity is more apparent than its divisibility. While the zones are provisional and based upon evidence from only one section, it is becoming increasingly apparent that, in general, chitinozoan species are of wide lateral distribution and are affected relatively little by minor facies changes. For this reason it is hoped that the present provisional zonation will be verified by similar studies elsewhere in the Viola–Fernvale sequence or its correlatives, and that in turn the zonation will enable precise correlations to be effected within this stratigraphical unit and its correlatives, not only between isolated outcrops in southern Oklahoma but throughout the subsurface of the North American mid-continent. It is hoped, furthermore, that the zonation will provide an additional basis for correlating between the Viola–Fernvale unit and rocks of the same age throughout North America. The chief characteristics of the zones, which include two assemblage zones, two range zones, and one concurrent-range zone (American Commission on Stratigraphic Nomenclature, 1961) are outlined below.

Three species (*Desmochitina minor*, *Conochitina minnesotensis* and *Angochitina capillata*) are relatively long-ranging within the Viola–Fernvale sequence and may be considered characteristic of the unit as a whole.

Assemblage Zone of *Sphaerochitina compactilis*. The oldest beds of the Viola Limestone are characterized by *Desmochitina minor*, *Conochitina minnesotensis*, and *C. wesenbergensis*, and by the absence of forms which appear in the Zone of *Conochitina robusta–Hercochitina crickmayi*, in particular *Angochitina capillata* and *Conochitina robusta*. *Sphaerochitina compactilis*, a distinctive species with a tendency to occur in clusters, is characteristic of the basal Viola Limestone. While this species gives its name to the zone, it is not restricted to it and occurs in the lowermost beds of the succeeding zone. At Sycamore Creek the Zone of *Sphaerochitina compactilis* is between 13 and 33 ft. thick. It extends from the base of the Viola Limestone to horizon Sc641, and possibly includes younger strata between horizons Sc641 and Sc621.

Assemblage Zone of *Conochitina robusta–Hercochitina crickmayi*. This zone does not coincide with the total range of any one species or subspecies, but extends from the first occurrences of *Angochitina capillata* and *Conochitina robusta* to the last occurrence of *Hercochitina crickmayi* and first occurrence of *Conochitina micracantha*. At Sycamore Creek this zone is at least 300 ft. thick and extends from the top of the *Sphaerochitina compactilis* Zone to horizon Sc321. It possibly also includes younger strata up to,

TABLE 3. Summary of the stratigraphical distribution of chitinozoan taxa in one section through the Viola and Fernvale Limestones of Oklahoma. The single occurrence (in Sc161) of *Lagenochitina* sp. cf. *L. baltica* is not shown.

but not including, horizon Sc281. *Conochitina robusta*, *Hercochitina crickmayi* and *Cyathochitina kuckersiana patagiata* are each diagnostic of this zone, do not occur outside it, and may subsequently prove useful in subdividing it. *Conochitina wesenbergensis* and *Desmochitina lata* occur throughout most of this zone.

Concurrent-range Zone of *Conochitina micracantha*. This zone is characterized by the association of *Conochitina micracantha* and *Desmochitina lata*, and ranges from the first occurrence of the former to the last occurrence of the latter. At Sycamore Creek the zone ranges from between horizons Sc321 and Sc281 to a level somewhere between horizons Sc181 and Sc161. *Conochitina tribulosa* is restricted to this zone.

Range Zone of *Conochitina seriespinosa*. This zone is defined by the total range of *Conochitina seriespinosa*. Its base coincides also with the first occurrence of *Pterochitina hymenelytrum*, and lies immediately above the Zone of *Conochitina micracantha*. Seven species (*Angochitina capillata*, *Conochitina micracantha*, *C. seriespinosa*, *C. hirsuta*, *C. minnesotensis*, *Desmochitina minor*, and *Pterochitina hymenelytrum*) occur throughout this zone, but only one, *Conochitina seriespinosa*, is restricted to it. The upper limit, at Sycamore Creek, is marked by the last occurrences of *Angochitina capillata*, *Conochitina hirsuta*, and *C. micracantha* at the faunal break which separates the *Conochitina seriespinosa* Zone from the overlying Zone of *Ancyrochitina corniculans*.

Range Zone of *Ancyrochitina corniculans*. The *Conochitina seriespinosa* and *Ancyrochitina corniculans* Range Zones are separated by an abrupt change in the composition of the chitinozoan fauna. Of the seven species which are present throughout the *Conochitina seriespinosa* Zone, only three (*Conochitina minnesotensis*, *Desmochitina minor*, and *Pterochitina hymenelytrum*) continue through the faunal break into the *Ancyrochitina corniculans* Zone. *Ancyrochitina corniculans* and *Cyathochitina kuckersiana latipatagium* are both diagnostic of this zone. They first occur immediately above the faunal break and, accompanied by *Desmochitina minor* and *Pterochitina hymenelytrum*, range through the uppermost Viola Limestone and Fernvale Limestone and continue to the top of the succession. At Sycamore Creek the faunal break and the base of this zone lie 60–80 ft. below the Fernvale–Sylvan Shale contact.

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REFERENCES

AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE. 1961. Code of stratigraphic nomenclature. *Bull. Am. Ass. Petrol. Geol.* **45,** 645–65.

AMSDEN, T. W. 1957. Catalog of Middle and Upper Ordovician Fossils. *Circ. Okla. geol. Surv.* **43,** 41 pp.

BAKER, C. L. and BOWMAN, W. F. 1917. Geologic exploration of the south-eastern Front Range of Trans-Pecos Texas. *Bull. Univ. Tex. Bur. econ. Geol. Technol.* **1753,** 67–177, pl. 1–8.

BERRY, W. B. N. 1960*a*. Graptolite faunas of the Marathon region, west Texas. *Univ. Tex. Publs.* **6005,** 179 pp. 20 pl.

—— 1960*b*. Correlation of Ordovician graptolite-bearing sequences. *21st. Int. geol. Congr.* pt. 7, 97–108.

COLLINSON, C. and SCHWALB, H. 1955. North American Paleozoic Chitinozoa. *Rep. Invest. Ill. St. geol. Surv.* **186,** 33 pp. 2 pl.

COMBAZ, A. and POUMOT, C. 1962. Observations sur la structure des chitinozoaires. *Revue Micropaléont.* **5,** 147–60, pl. 1–5.

—— *et al.* 1967. Microfossiles organiques du Paléozoïque. Les chitinozoaires (2). Morphographie. Published for the Commission Internationale de Microflore du Paléozoïque by the Centre National de la Recherche Scientifique, Paris.

COOPER, C. L. 1942. North American Chitinozoa. *Bull. geol. Soc. Am.* **53,** 1828.

COOPER, G. A. 1956. Chazyan and related brachiopods. *Smithson. misc. Collns.* **127** (2 parts), 1245 pp. 269 pl.

CRAMER, F. H. 1964. Microplankton from three Palaeozoic formations in the province of León, NW-Spain. *Leid. geol. Meded.* **30,** 253–361, pl. 1–24.

DAKE, C. L. 1921. The problem of the St. Peter Sandstone. *Bull. Mo. Sch. Mines tech. Ser.* **6** (1), 228 pp. 30 pl.

DEAN, W. T. 1958. The faunal succession in the Caradoc Series of south Shropshire. *Bull. Brit. Mus. (nat. Hist.) Geol.* **3,** 191–231, pl. 24–6.

—— 1960. The Ordovician trilobite faunas of south Shropshire, I. Ibid. **4,** 71–143, pl. 11–19, 2 figs.

DECKER, C. E. 1933. Viola Limestone, primarily of Arbuckle and Wichita Mountain regions, Oklahoma. *Bull. Am. Ass. Petrol. Geol.* **17,** 1405–35.

—— 1935. Graptolites of the Sylvan Shale of Oklahoma and Polk Creek Shale of Arkansas. *J. Paleont.* **9,** 697–708.

—— 1936. Some tentative correlations on the basis of graptolites of Oklahoma and Arkansas. *Bull. Am. Ass. Petrol. Geol.* **20,** 301–11.

—— 1951. Preliminary note on age of Athens Shale. Ibid. **35,** 912–15.

DECKER, C. E. 1952. Stratigraphic significance of graptolites of Athens Shale. Ibid. **36,** 1–145, pl. 1–3.

—— and MERRITT, C. A. 1931. The stratigraphy and physical characteristics of the Simpson Group. *Bull. Okla. geol. Surv.* **55,** 112 pp. 15 pl.

ECHOLS, D. J. and LEVIN, H. L. 1966. Ordovician Chitinozoa from Missouri. *Okla. Geol. Notes*, **26,** 134–9, pl. 1–2.

EDSON, F. C. 1927. Ordovician correlations in Oklahoma. *Bull. Am. Ass. Petrol. Geol.* **11,** 967–75.

—— 1930. Lower Paleozoic unconformities. Ibid. **14,** 947 (1227).

EISENACK, A. 1931. Neue Mikrofossilien des baltischen Silurs I. *Palaeont. Z.* **13,** 74–118, pl. 1–5.

—— 1932. Neue Mikrofossilien des baltischen Silurs II. Ibid. **14,** 257–77, pl. 11–12.

—— 1934. Neue Mikrofossilien des baltischen Silurs III. und neue Mikrofossilien des böhmischen Silurs I. Ibid. **16,** 52–76, pl. 4–5.

—— 1937. Neue Mikrofossilien des baltischen Silurs IV. Ibid. **19,** 217–43, pl. 15–16.

—— 1939. Chitinozoen und Hystrichosphaerideen im Ordovicium des Rheinischen Schiefergebirges. *Senckenberg. leth.* **21,** 135–52, pl. A–B.

—— 1955*a*. Chitinozoen, Hystrichosphären und andere Mikrofossilien aus dem *Beyrichia*-Kalk. Ibid. **36,** 157–88, pl. 1–5.

—— 1955*b*. Neue Chitinozoen aus dem Silur des Baltikums und dem Devon der Eifel. Ibid. **36,** 311–19, pl. 1.

—— 1958. Mikrofossilien aus dem Ordovizium des Baltikums. 1. Markasitschicht, *Dictyonema*-Schiefer, Glaukonitsand, Glaukonitkalk. Ibid. **39,** 389–405, pl. 1–2.

—— 1959. Neotypen baltischer Silur-Chitinozoen und neue Arten. *Neues Jb. Geol. Palaeont. Abh.* **108,** 1–20, pl. 1–3.

—— 1962*a*. Neotypen baltischer Silur-Chitinozoen und neue Arten. Ibid. **114,** 291–316, pl. 14–17.

—— 1962*b*. Mikrofossilien aus dem Ordovizium des Baltikums. 2. Vaginatenkalk bis Lyckholmer Stufe. *Senckenberg. leth.* **43,** 349–66, pl. 44.

—— 1965. Die Mikrofauna der Ostseekalke. 1. Chitinozoen, Hystrichosphären. *Neues Jb. Geol. Palaeont. Abh.* **123,** 115–48, pl. 9–13.

ELLES, G. L. 1925. The characteristic assemblages of the graptolite zones of the British Isles. *Geol. Mag.* **62,** 337–47.

HAM, W. E. and WILSON, J. L. 1967. Paleozoic epeirogeny and orogeny in the central United States, *Am. J. Sci.* **265,** 332–407.

HARRINGTON, H. J. and LEANZA, A. F. 1957. *Ordovician Trilobites of Argentina.* Spec. Publs. 1, Univ. Kans. Press, Lawrence.

HARRIS, R. W. 1957. Ostracoda of the Simpson Group of Oklahoma. *Bull. Okla. geol. Surv.* **75,** 333 pp. 10 pl.

HSÜ, S. C. 1934. Graptolites of the lower Yangtze Valley. *Monogr. natn. Res. Inst. Geol. Shanghai*, Ser. A, **4** (4).

JAANUSSON, V. and STRACHAN, I. 1954. Correlation of the Scandinavian Middle Ordovician with the graptolite succession. *Geol. För. Stockh. Förh.* **76,** 684–96.

JACKSON, D. E. and LENZ, A. C. 1962. Zonation of Ordovician and Silurian graptolites of northern Yukon, Canada. *Bull. Am. Ass. Petrol. Geol.* **46,** 30–45.

JANSONIUS, J. 1964. Morphology and classification of some Chitinozoa. *Bull. Canad. Petrol. Geol.* **12,** 901–18, pl. 1–2.

JENKINS, W. A. M. 1967. Ordovician Chitinozoa from Shropshire. *Palaeontology*, **10,** 436–88, pl. 68–75.

JODRY, R. L. and CAMPAU, D. E. 1961. Small pseudochitinous and resinous microfossils: new tools for the subsurface geologist. *Bull. Am. Ass. Petrol. Geol.* **45,** 1378–91, pl. 1–3.

KAY, M. 1960. Classification of the Ordovician System in North America. *Int. geol. Congr.* 21 (7), 28–33.

KOZLOWSKI, R. 1963. Sur la nature des chitinozoaires. *Acta palaeont. pol.* **8,** 425–49.

LAPWORTH, C. 1879*a*. On the tripartite classification of the Lower Palaeozoic rocks. *Geol. Mag.* (2) **6,** 1–15.

—— 1879*b*–1880. On the geological distribution of the Rhabdophora. *Ann. Mag. nat. Hist.* (5) **3,** 245–57, 449–55; (5) **4,** 333–41, 423–31; (5) **5,** 45–62, 273–85, 358–69; (5) **6,** 16–29, 185–207.

LAUFELD, S. 1967. Caradocian Chitinozoa from Dalarna, Sweden. *Geol. För. Stockh. Förh.* 89, 275–349, figs. 1–34.

LOEBLICH, A. R. 1942. Bryozoa from the Ordovician Bromide Formation, Oklahoma. *J. Paleont.* **16,** 413–36, pl. 61–4.

MILLER, T. H. 1966. Techniques for processing and photographing chitinozoans. *Paleont. Contr. Univ. Kans. Paper*, **21,** 10 pp. 4 pl.

RUEDEMANN, R. 1925. The Utica and Lorraine formations of New York; Part I. Stratigraphy. *Bull. N.Y. St. Mus.* **258,** 175 pp.

—— and DECKER, C. E. 1934. The graptolites of the Viola Limestone. *J. Paleont.* **8,** 303–27, pl. 40–3.

SCHALLREUTER, R. 1963. Neue Chitinozoen aus ordovizischen Geschieben und Bemerkungen zur Gattung *Illichitina*. *Palaeont. Abh.* **1,** 391–405, pl. 1–2. Also in *Mitt. geol. pal. Inst. Univ. Greifswald.* **47.**

SCHRAMM, M. W. 1964. Paleogeologic and quantitative lithofacies analysis, Simpson Group, Oklahoma. *Bull. Am. Ass. Petrol. Geol.* **48,** 1164–95, figs. 1–18.

SKEVINGTON, D. 1963. A correlation of Ordovician graptolite-bearing sequences. *Geol. För. Stockh. Förh.* **85,** 289–319.

SOKOLOV, B. S. *et al.* 1960. Stratigraphy, correlation, and paleogeography of the Ordovician deposits of the U.S.S.R. *21st. Int. geol. Congr.* pt. 7, 44–57.

STAUFFER, C. R. 1933. Middle Ordovician Polychaeta from Minnesota. *Bull. geol. Soc. Am.* **44,** 1173–1218, pl. 59–61.

TAFF, J. A. 1903. Description of the Tishomingo Quadrangle [Indian Territory]. *Geologic Atlas U.S. Folio* **98,** 1–8.

TAUGOURDEAU, P. 1962. Associations de chitinozoaires dans quelques sondages de la région d'Édjelé (Sahara). *Revue Micropaléont.* **4,** 229–36, pl. 1.

—— 1965. Chitinozoaires de l'Ordovicien des U.S.A.; comparaison avec les faunes de l'ancien monde. *Revue Inst. fr. Pétrole* **20,** 463–85, pl. 1–3.

—— and JEKHOWSKY, B. DE. 1960. Répartition et description des chitinozoaires siluro-dévoniens de quelques sondages de la C.R.E.P.S., de la C.F.P.A. et de la S.N. REPAL au Sahara. Ibid. **15,** 1199–1260, pl. 1–13.

TEMPLETON, J. S. and WILLMAN, H. B. 1963. Champlainian Series (Middle Ordovician) in Illinois. *Bull. Ill. St. geol. Surv.* **89,** 260 pp. 41 figs.

TWENHOFEL, W. H. *et al.* 1954. Correlation of the Ordovician formations of North America. *Bull. geol. Soc. Am.* **65,** 247–98.

ULRICH, E. O. 1911. Revision of the Paleozoic systems. Ibid. **22,** 281–680.

—— 1927. Fossiliferous boulders in the Ouachita 'Caney' Shale and the age of the shale containing them. *Bull. Okla. geol. Surv.* **45,** 48 pp. 6 pl. 3 figs.

WENGERD, S. A. 1948. Fernvale and Viola Limestones of south-central Oklahoma. *Bull. Am. Ass. Petrol. Geol.* **32,** 2183–2253, pl. 1–12.

WHITTINGTON, H. B. 1954. A new Ordovician graptolite from Oklahoma. *J. Paleont.* **28,** 613–21, pl. 63.

—— 1955. Additional new Ordovician graptolites and a chitinozoan from Oklahoma. Ibid. **29,** 837–51, pl. 83–4.

—— and WILLIAMS, A. 1964. The Ordovician period. *Q. Jl. geol. Soc. Lond.* **120 S,** 241–54.

WILSON, L. R. and DOLLY, E. D. 1964. Chitinozoa in the Tulip Creek Formation, Simpson Group (Ordovician), of Oklahoma. *Okla. Geol. Notes* **24,** 224–32, pl. 1.

—— and HEDLUND, R. W. 1964. *Calpichitina scabiosa*, a New Chitinozoan from the Sylvan Shale (Ordovician) of Oklahoma. Ibid. **24,** 161–4, pl. 1.

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APPENDIX: DESCRIPTION OF SAMPLES

The samples used in this study are listed below in descending stratigraphical order. They are numbered according to their original stratigraphical positions (measured in feet) below the Fernvale–Sylvan Shale contact. Thus sample Sc581, for example, represents a horizon 581 ft. stratigraphically below this datum.

The total thickness of the Viola and Fernvale Limestones in Sycamore Creek was measured as 653 ft. 9 in.

Sc1	Coarse-grained calcarenite; light grey with numerous rusty-weathering fragments; containing cryptolithid trilobites, crinoids, and bryozoans.
Sc21	Coarse-grained calcarenite; light grey; containing crinoids.
Sc41	Fine-grained sandy and silty calcarenitic calcite mudstone; light greyish-brown with thin impersistent and irregularly distributed brown laminae; containing a few unidentified shelly fragments. Small quantity of yellow and dove-grey nodular chert.
Sc61	Calcite mudstone; brownish grey with black flecks; containing abundant cryptolithid trilobites.
Sc81	Calcarenitic calcite mudstone; brownish-grey with black flecks; containing cryptolithid trilobites and crinoids. Small quantity of white, brown, and dove-grey, opaque nodular chert.
Sc101	Calcite mudstone with small proportion of medium-grained calcarenitic material distributed irregularly (and occasionally in clots up to 0·5 in. diam.) throughout the mudstone. Greyish-brown; containing rare crinoid stems.
Sc121	Calcarenitic calcite mudstone; greyish-brown. Patches of very coarse spar (up to 1·5 in. diam. and containing crystals up to 0·5 in. in length) and veins, up to 0·05 in. wide, indicate recrystallization of $CaCO_3$. Light orange-brown, opaque, nodular chert cut by veins of spar.
Sc141	Calcarenitic calcite mudstone; greyish-brown. Dove-grey opaque nodular chert (nodules up to 5 in. in length), commonly intrabedded as more or less continuous sheets, or as rows of small nodules (up to 0·5 in. diam.) running parallel with the bedding.
Sc161	Calcarenitic calcite mudstone; greyish-brown; containing rare cryptolithid trilobites.
Sc181	Calcarenitic calcite mudstone; greyish-brown.
Sc201	Skeletal calcarenitic calcite mudstone; greyish-brown; containing crinoid stems and black carbonaceous graptolites.
Sc221	Skeletal calcarenitic calcite mudstone; light grey to greyish-brown; containing abundant crinoids and uncommon, locally rose-pink, brachiopods.
Sc241	Coarse-grained calcarenitic calcite mudstone; greyish-brown to brown; fauna of brachiopods, cryptolithid trilobites, some crinoid stems, and a species of small gastropod. Small quantity of buff to greyish-brown, opaque chert.
Sc261	Calcarenitic calcite mudstone; brown; containing a few brachiopods and crinoids.
Sc281	Siliceous calcite mudstone with rare shelly fragments; brown.
Sc301	Calcarenitic calcite mudstone; brown; containing rare brachiopods.
Sc321	Coarse skeletal calcarenitic sandy calcite mudstone; light grey to light brownish-grey, weathering to yellowish-buff; containing abundant cryptolithid trilobites and a few brachiopods.
Sc341	Calcarenitic calcite mudstone containing sandy and coarse-grained skeletal material; light grey to light brownish-grey, buff weathering; containing abundant brachiopod and trilobite fragments.
Sc361	Calcarenitic calcite mudstone; grey; containing fragmentary brachiopods (fragments up to 0·5 in. diam.).
Sc381	Calcarenitic calcite mudstone; olive-grey; containing cryptolithid trilobites and rare brachiopods.
Sc401	Slightly sandy calcite mudstone; grey and brown; containing rare graptolites.
Sc421	Calcite mudstone; grey, mottled, and streaked with olive-brown; containing rare broken brachiopods.

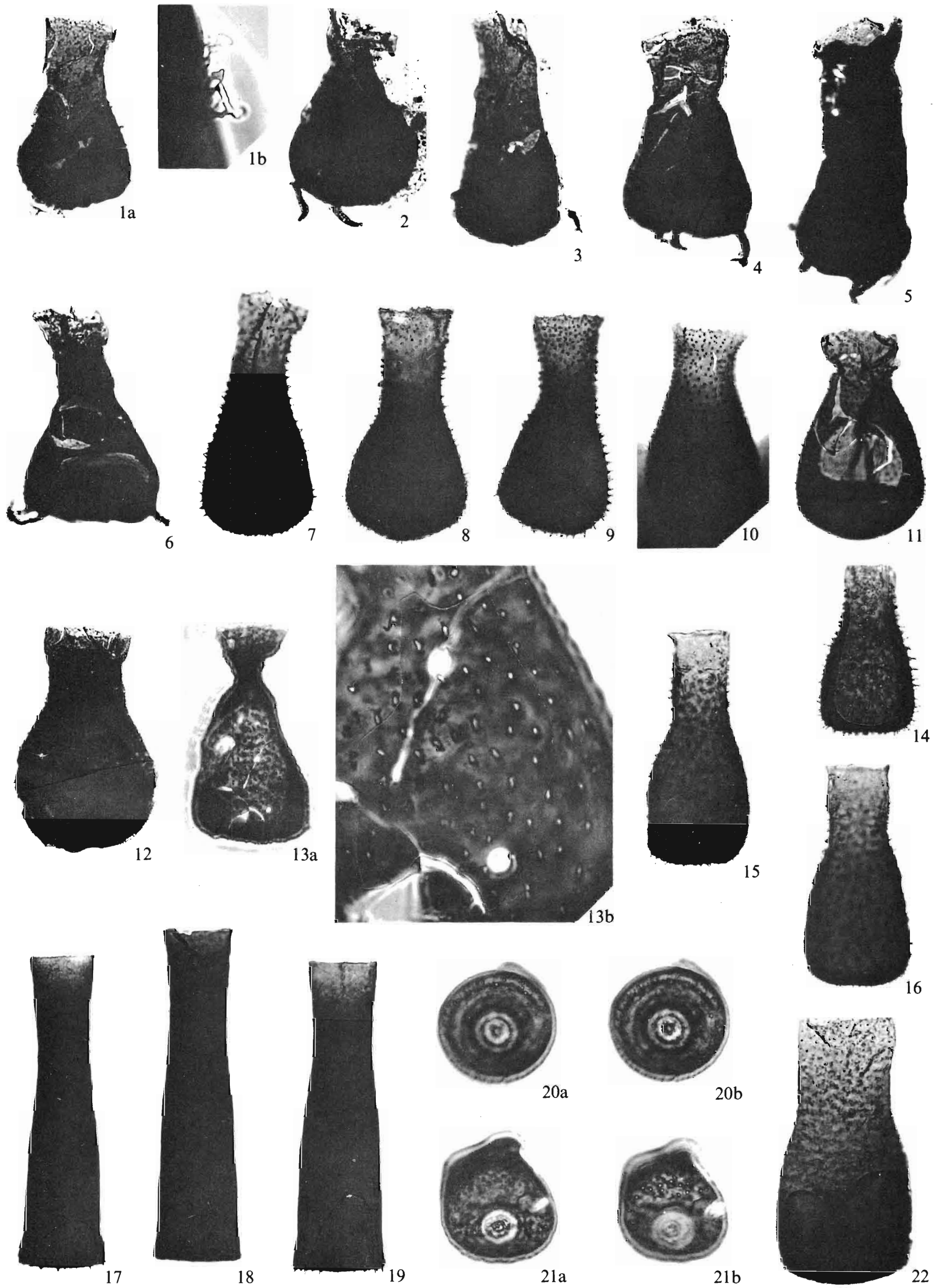
Sc441	Skeletal calcarenitic calcite mudstone; grey; containing much fragmentary shelly material.
Sc461	Calcarenitic calcite mudstone; grey to light olive-brown; containing large fragments of brachiopods and much broken shelly material. Perfectly formed small pyrite cubes scattered throughout the rock.
Sc481	Siliceous calcite mudstone; grey to olive-brown or buff.
Sc501	Siliceous calcite mudstone; greyish-brown, buff weathering.
Sc521	Siliceous calcite mudstone; brown.
Sc541	Slightly sandy calcite mudstone; buff; containing rare, black carbonaceous graptolites.
Sc561	Siliceous calcite mudstone; brown; containing abundant, black carbonaceous graptolites, some brachiopods and cryptolithid trilobites.
Sc581	Siliceous calcite mudstone; brown; containing rare red-stained, black carbonaceous graptolites.
Sc601	Siliceous calcite mudstone; brown; containing red-stained, black carbonaceous graptolites.
Sc621	Siliceous calcite mudstone; brown.
Sc641	Siliceous calcite mudstone; brown.
Sc651	Siliceous sandy and silty calcite mudstone; very dark brown to brown, weathering to light brown, buff, or orange.
Sc653·8	Thinly laminated, calcareous siltstone from 1 in. above the base of the Viola Limestone; brown, weathering to pale buff or orange.

	HORIZON \ CHITINOZOAN	*Desmochitina minor*	*Conochitina minnesotensis*	*Conochitina wesenbergensis*	*Sphaerochitina compactilis*	*Angochitina capillata*	*Conochitina robusta*	*Desmochitina lata*	*Cyathochitina kuckersiana patagiata*	*Hercochitina crickmayi* f. *spinetum*	*Hercochitina crickmayi* f. *normalis*	*Rhabdochitina usitata*	*Conochitina tribulosa*	*Cyathochitina kuckersiana kuckersiana*	*Conochitina* sp. aff. *C. elegans*	*Hercochitina turnbulli*	*Rhabdochitina turgida*	*Conochitina hirsuta*	*Conochitina micracantha*	*Conochitina seriespinosa*	*Pterochitina hymenelytrum*	*Cyathochitina kuckersiana latipatagium*	*Ancyrochitina corniculans*	CHITINOZOAN ZONE
Fernvale Lst	Sc1	+	?																		+	+	+	Range Zone of *Ancyrochitina corniculans*
	Sc 21																							
	Sc41	?	?																			+	?	
	Sc61	+	+																		+	+	+	
	Sc81	+	+			+								+			+	+	+	+	+			Range Zone of *Conochitina seriespinosa*
	Sc101	+	+															+	+		+			
	Sc121	+	+			?											+	+	+	+	+			
	Sc141	+	+			?										+			+	+	+			
	Sc161	+	+			+												+	+	+	+			
	Sc181	+	+			+		+										+	+					Concurrent–range Zone of *Conochitina micracantha*
	Sc201	+	+			+		+											+					
	Sc221	+				+		+								+		+	+					
	Sc241	+	+			+		+					+		+	+		+	+					
	Sc261	+	+			+		+					+		+	?			+					
	Sc281	+	+			+		+					+			?			+					
	Sc301																							
	Sc321	+				+		+			+					+								Assemblage Zone of *Conochitina robusta – Hercochitina*
la Limestone	Sc341					+		+			+				+	+								
	Sc361	+				+					+				+	+								
	Sc381	+	+	+		+		+			+													
	Sc401	+	+	+		+		+			+													
	Sc421	+	+	+		+		+			+													
	Sc441	+	+	+		+		+			+													
	Sc461	+	+	+		+		+		+	+													
	Sc481		+	+		+		+		+	+	+						+						

Viola Li

Sc481		+	+		+		+		+	+	+			+			*robusta – Hercochitina crickmayi*
Sc501	+	+	+		+		+	+	+	+				+			
Sc521		+	+		+	+	+	+	+								
Sc541	+	+	+		+	+	+	+			+						
Sc561	+	+	+		+	+	+	+									
Sc581	+	+	+		+	+	+										
Sc601	+	+	+		+	+											
Sc621	+	+	+	+	+	+											
Sc641	+	+	+								+						Assemblage Zone of *Sphaerochitina compactilis*
Sc651	+	+	+	+													
Sc653-8	+		+														

PLATE 1



JENKINS, *Ancyrochitina*, *Angochitina* and *Conochitina*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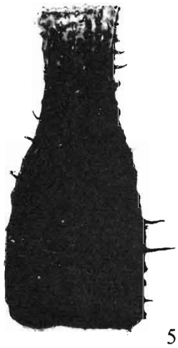
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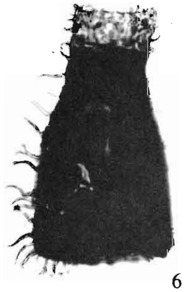
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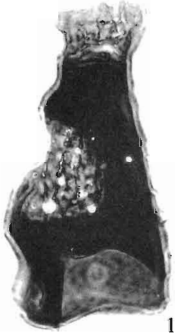
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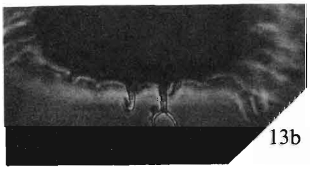
13a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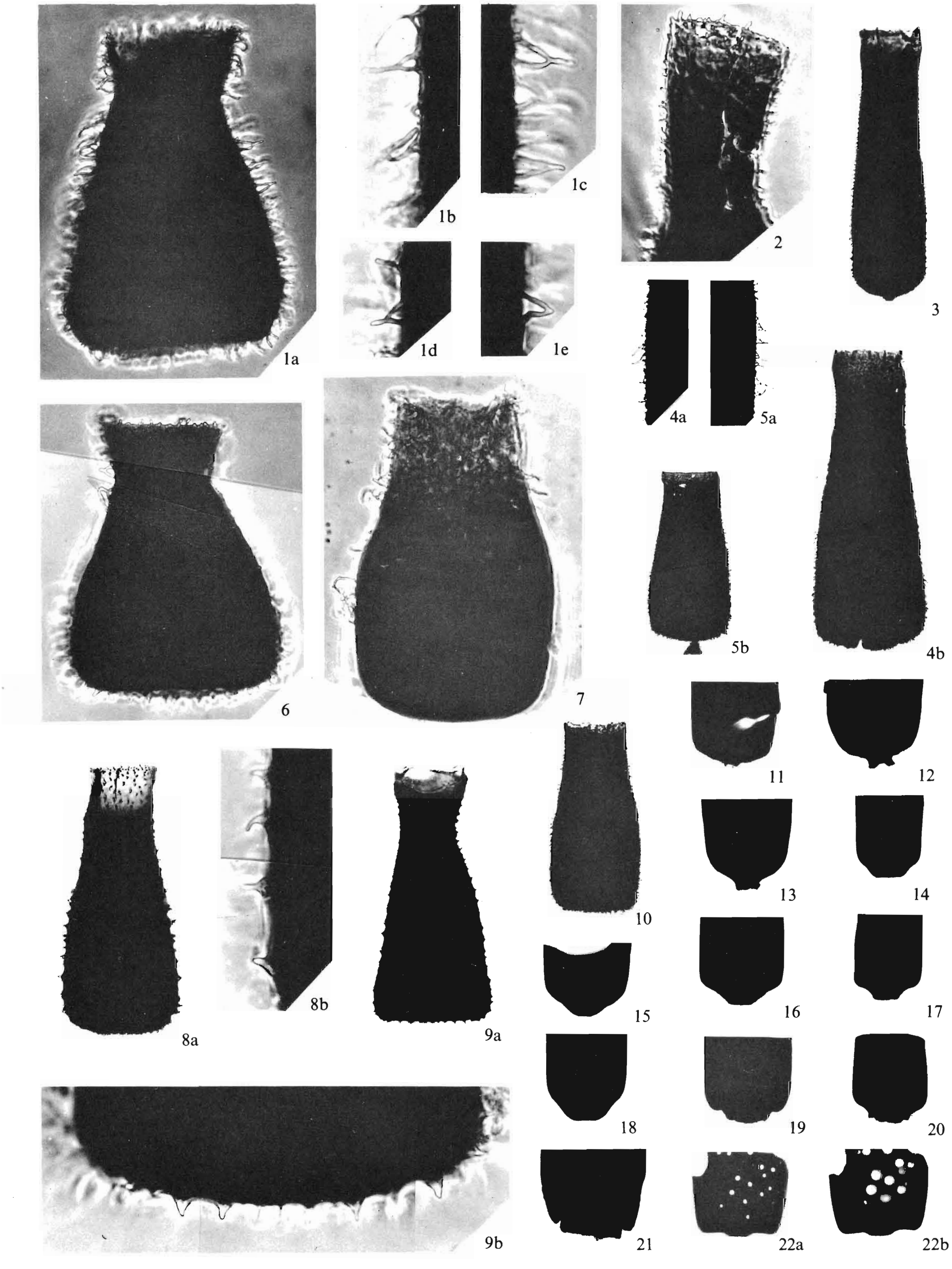
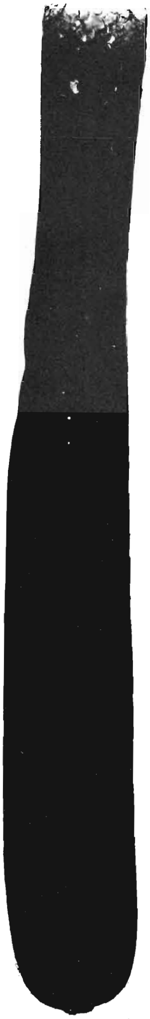
JENKINS, *Conochitina*



JENKINS, *Conochitina*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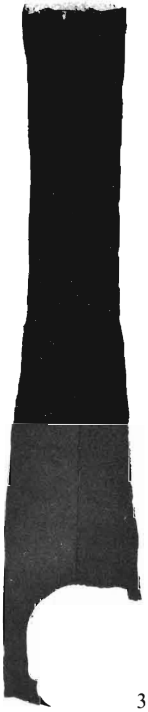
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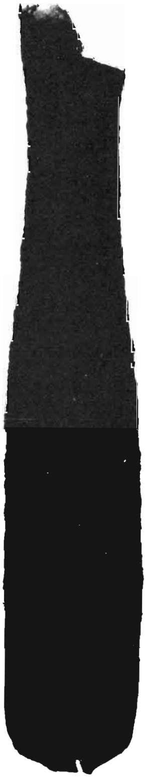
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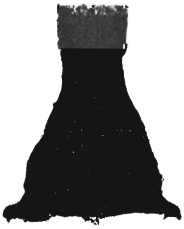
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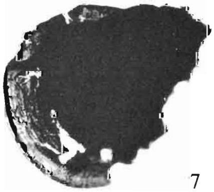
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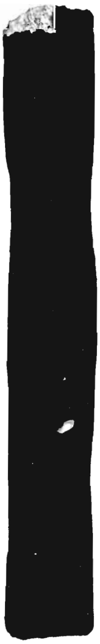
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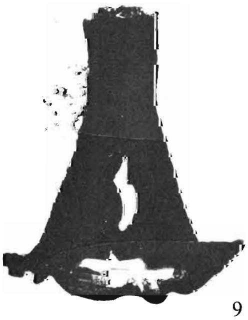
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JENKINS, *Conochitina* and *Cyathochitina*


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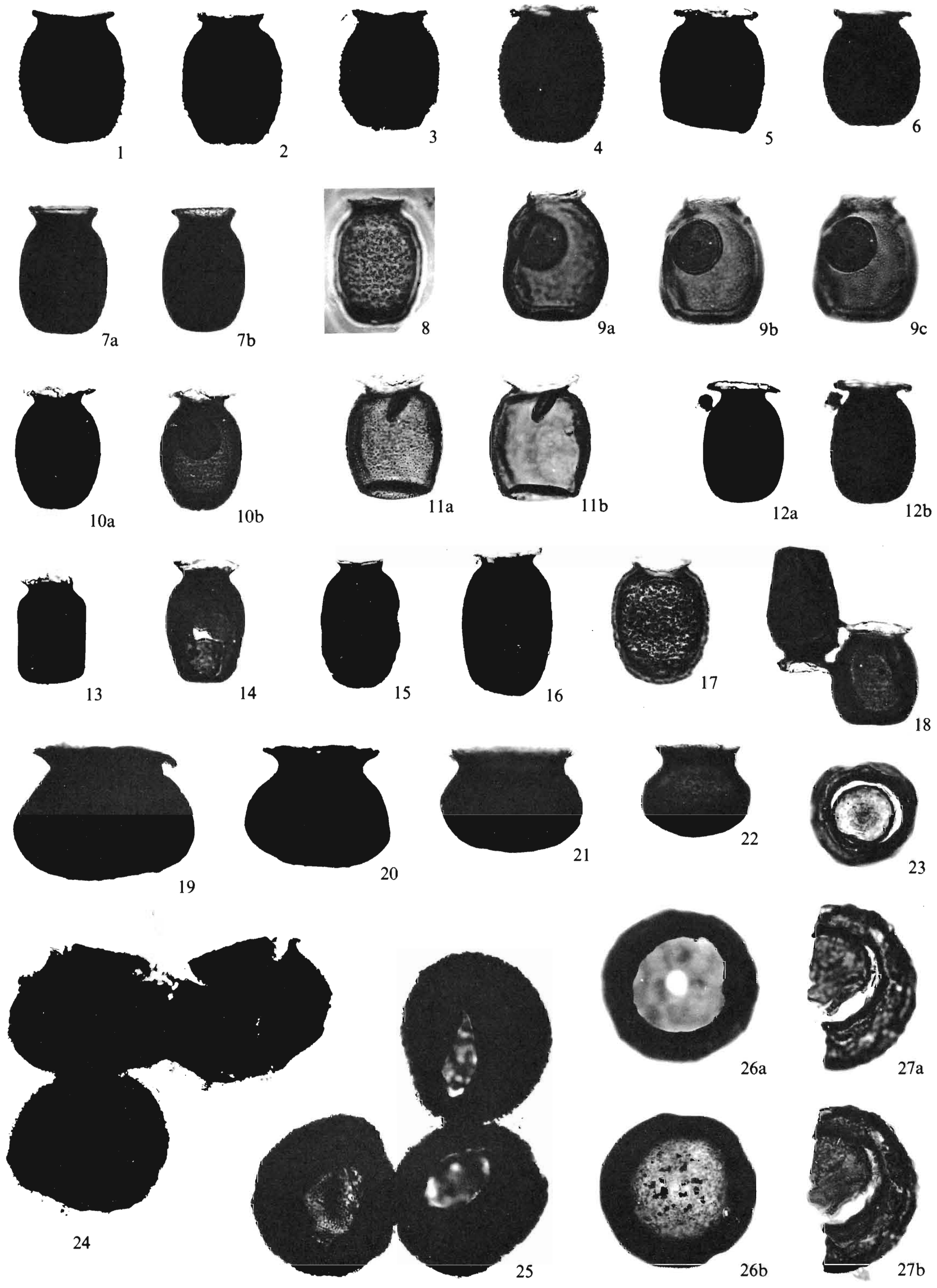
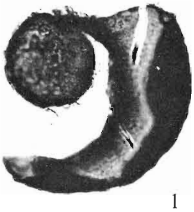
JENKINS, *Conochitina* and *Cyathochitina*



JENKINS, *Desmochitina*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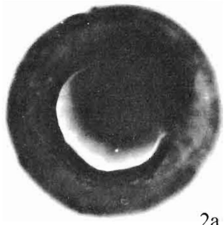
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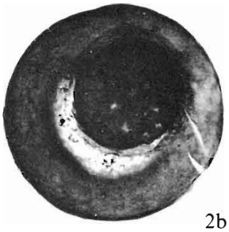
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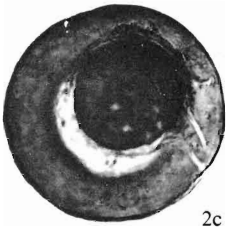
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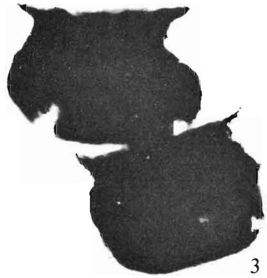
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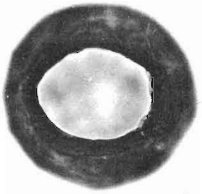
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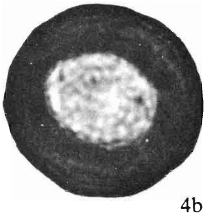
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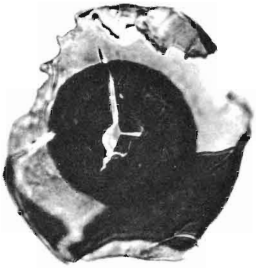
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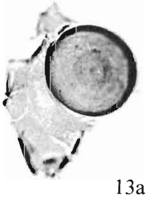
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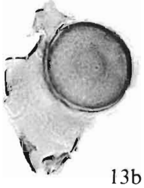
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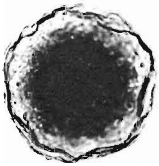
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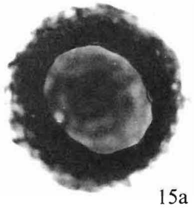
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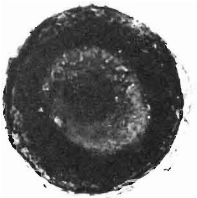
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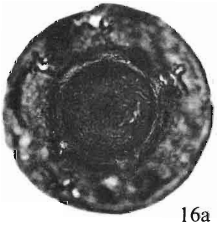
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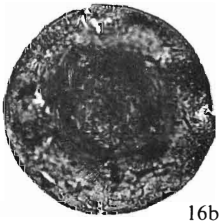
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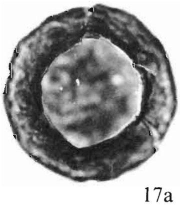
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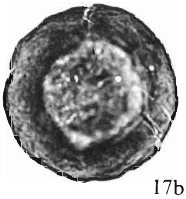
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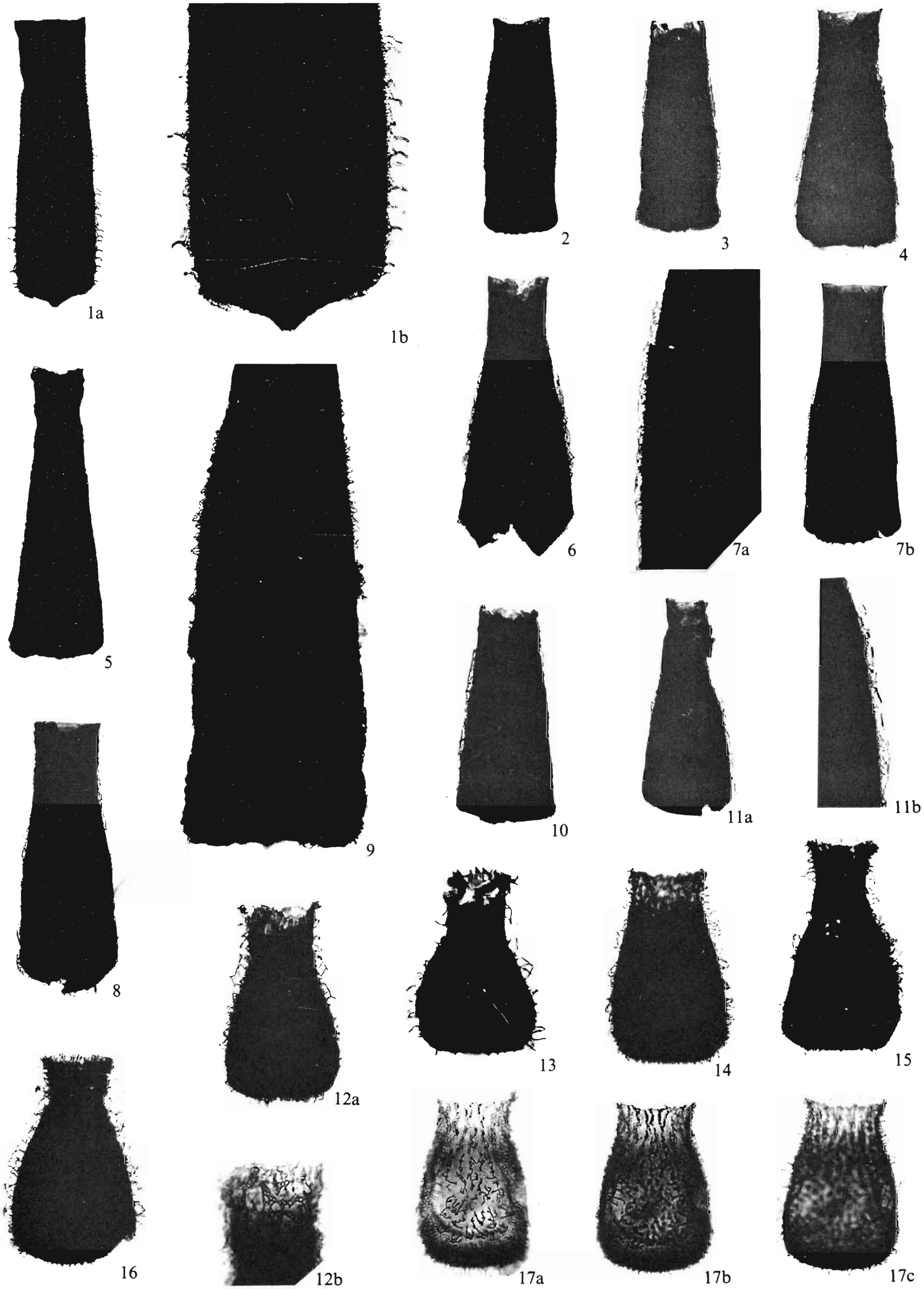
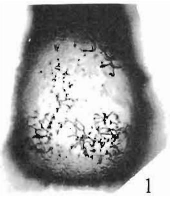
JENKINS, *Desmochitina* and *Pterochitina*



JENKINS, *Hercochitina*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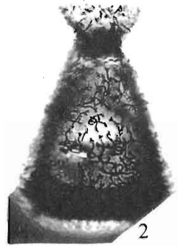
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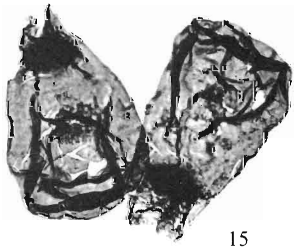
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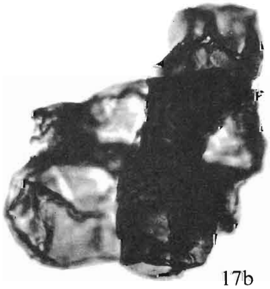
17a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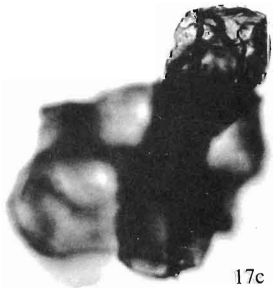
17c

JENKINS, *Hercochitina*, *Lagenochitina*, *Rhabdochitina* and *Sphaerochitina*