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CHITINOZOANS FROM THE ORDOVICIAN-SILURIAN BOUNDARY BEDS IN THE EASTERN CINCINNATI REGION IN OHIO AND KENTUCKY[1]

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ABSTRACT. Representatives of seven species of chitinozoans, one of which is new (*Ancyrochitina belfastensis* n. sp.), were isolated from samples of the lowermost Silurian Belfast Member and of slightly younger beds of the Brassfield Formation and of the Upper Ordovician Preachersville Member of the Drakes Formation at two localities in southern Ohio and north-central Kentucky in an attempt to determine the size of the stratigraphic gap at the Ordovician-Silurian paraconformity. Based on comparisons with successions in Estonia and on Anticosti Island, Quebec, the chitinozoans suggest that the stratigraphic gap between the systems, which is likely to be due to a global sea level drop associated with the Gondwana glaciation, represents an interval from the Ashgillian *D. complanatus* Zone to the early Llandoverian *C. cyphus* Zone and hence corresponds to about four graptolite zones. The present study is the first record of Silurian chitinozoans from Ohio.

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INTRODUCTION

The outcrop area of richly fossiliferous Ordovician rocks in southwestern Ohio and adjacent parts of Indiana and Kentucky, commonly referred to as the Cincinnati Region, is the type area for the North American reference standard of the Upper Ordovician, the Cincinnatian Series. Its varied faunas have been studied extensively for more than 150 years, and most fossil groups are now reasonably well known. However, a few groups are still little investigated and one of these is the chitinozoans, a group of organic-walled microfossils with enigmatic affinities. Despite the fact that chitinozoans are common throughout the Cincinnatian succession, and have been shown to be excellent guide fossils elsewhere in the world, very little has been published on Cincinnatian chitinozoans. Indeed, the available information includes only the description of two new species by Eisenack (1959) and a few abstracts (Schopf and Schopf 1961, Miller 1975, Bergström et al. 1981) along with two unpublished theses (Miller 1976, Knabe 1980). No chitinozoans have been recorded previously from Silurian rocks in Ohio.

An interesting and important aspect of the geology of the Cincinnatian succession is its boundary relations to the overlying Silurian rocks. Whereas there is a lithically well-marked unconformity at the systemic boundary in the western Cincinnati Region (see, for instance, Rexroad et al. 1965, Rexroad 1967) this boundary is rather inconspicuous lithically on the eastern flank of the Cincinnati arch in Highland, Brown, and Adams counties in Ohio and adjacent parts of Kentucky where the Ordovician-Silurian contact has been described as conformable and gradational locally (Peck 1966). Yet fossil evidence indicates the presence of a significant stratigraphic hiatus in this area also, and the systemic boundary is apparently a paraconformity.

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Despite several recent studies (Rexroad et al. 1965, Rexroad 1967, Rexroad in Berry and Boucot 1970, Gray and Boucot 1972, Cooper 1975), there is considerable uncertainty about how much of the basal Silurian is missing. Further, there is no evidence of preservation of youngest Ordovician (Hirnantian or Gamachian) rocks anywhere in the Cincinnati Region, and so the gap at the systemic boundary is likely include also the uppermost Ordovician. The purpose of the present study was to determine if chitinozoans could clarify the controversial biostratigraphy at this systemic boundary.

STRATIGRAPHIC FRAMEWORK

The oldest Silurian unit in the study area in Adams Co., Ohio, and Lewis Co., Kentucky, (fig. 1) is the Brassfield Formation, which contains fossils of early to middle Llandoverian (Early Silurian) age (Rexroad 1967, Berry and Boucot 1970, Cooper 1975, Rexroad and Kleffner 1984). The lowermost part of the Brassfield is a lithically distinct unit of silty dolomitic limestone and shale, up to 3 m thick, that was described as the Belfast Bed by Foerste (1896). This unit, now classified as a member of the Brassfield, crops out along the east-central flank of the Cincinnati arch where it rests on Late Ordovician rocks mapped as the Preachersville Member of the Drakes Formation (fig. 2). Rexroad (1967) reported abraded reworked Ordovician conodonts from the lowermost Belfast at some localities, and Silurian ones, including *Icriodina* (=*Distomodus*), throughout the unit. In his revision of the Brassfield conodonts, Cooper (1975) identified *Distomodus kentuckyensis, Icriodella discreta,* and *Ozarkodina hassi,* among others, from the Belfast and referred it, as well as the rest of the Brassfield, to the *D. kentuckyensis* Zone. Cramer and Díez de Cramer (1972) recognized acritarchs of their *Veryhachium valiente*-subfacies in the Belfast and suggested correlation of the unit with the upper part of the *Coronograptus cyphus* Zone. Unfortunately, no data supporting that biostratigraphic dating are presented in their paper, and no graptolites are known from the Belfast. Although the Belfast has yielded no stratigraphically diagnostic megafossils, the microfossil evidence just mentioned clearly suggests an early Silurian, perhaps early Llandoverian, age.

Only relatively limited biostratigraphic information is available from the Preachersville Member of the Drakes Formation. Kohut and Sweet (1968) reported conodonts from a locality close to ours in Adams Co. According to a recent evaluation of these and other conodont data (Sweet 1979, fig. 3), perhaps as much as half of the late Cincinnatian Richmondian Stage is missing in our study area, and this suggests the presence of a substantial hiatus in the uppermost Ordovician.

METHODS AND MATERIALS

Six samples from the Belfast, two samples from the underlying Drakes, and two samples from the post-Belfast Brassfield were investigated. Five samples were collected from the well-known road cuts along Ohio Route 41 S.W. of Ohio Brush Creek, Adams Co., Ohio, and five samples from a road cut E.N.E. of Tollesboro, Lewis Co., Kentucky (fig. 1). The samples, which had a weight of 0.1-0.4 kg, were treated following the laboratory methods described by Grahn (1980). Most of the samples yielded very few chitinozoans (fig. 1). This is in agreement with the conditions in other areas where the relative abundance, as well as species diversity, of chitinozoans are low in the uppermost Ordovician and lowermost Silurian. The Belfast samples yielded fewer than 0.5 specimen per gram of rock except for a single sample from the Tollesboro section which contained 15.3 specimens per gram of rock. The frequency in the Preachersville was 0.09 and in the post-Belfast Brassfield 0.44-1.9 specimens per gram of rock. All chitinozoans show some degree of distortion, probably caused by compaction of the sediment. Micrographs were taken of selected gold-coated specimens on a Cambridge S4-10 SEM at 5 kV. All illustrated specimens are kept under OSU numbers in the type collection of the Orton Geological Museum at The Ohio State University.

CHITINOZOAN BIOSTRATIGRAPHY

Detailed evaluation of the biostratigraphic significance of the seven chitinozoan species encountered is somewhat hampered by the lack of useful information

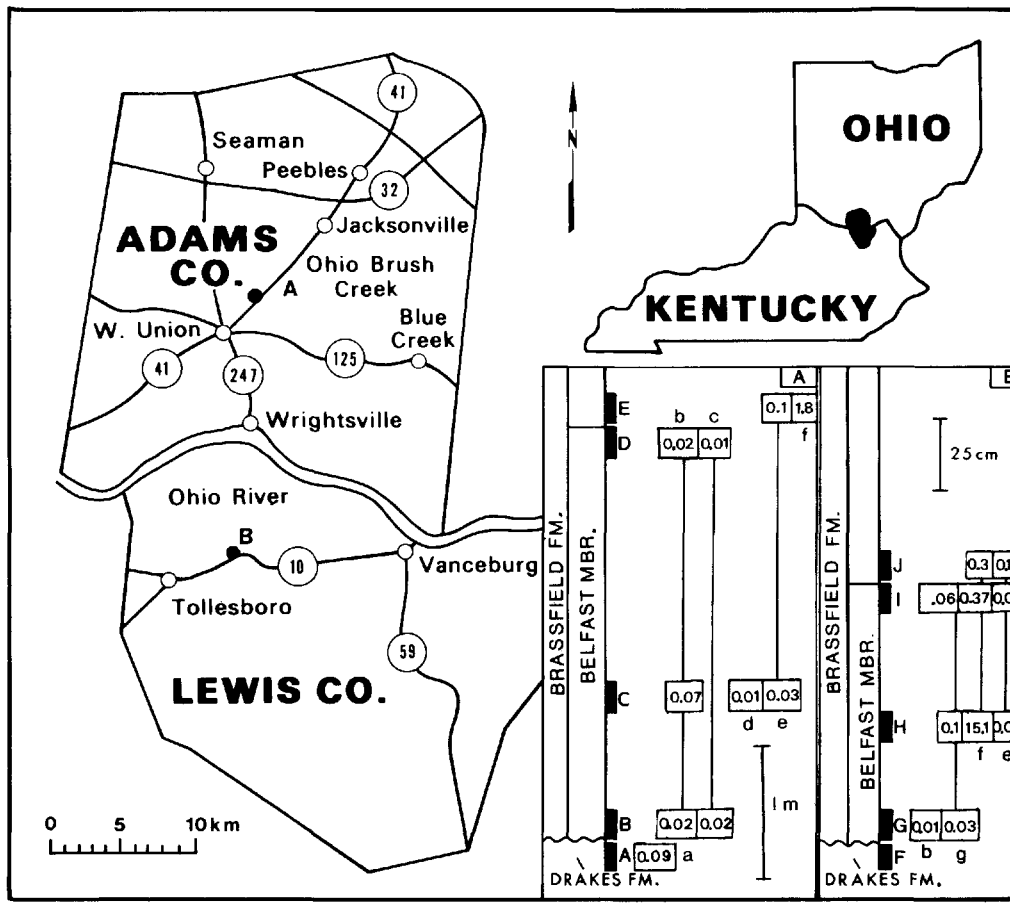

FIGURE 1. Location of sections studied, stratigraphic level of each sample, and frequency of chitinozoans. The Ohio Brush Creek section (inset diagram A) is a high road cut along the west side of State Route 41 at road curve with small intermittent stream forming a waterfall across the cliff face about 3.4 km (2.1 miles) N.E. of West Union and 9.8 km (6.1 miles) S.W. of the Ohio Brush Creek bridge, Adams Co., Ohio. Sample A is from the top 10 cm of the Drakes; B, C, and D from basal 10 cm, 100 cm above the base, and top 10 cm of the Belfast, respectively; and E from basal 10 cm of the post-Belfast Brassfield. Figures in boxes on vertical lines denote number of specimens of a particular species per gram of rock sample. The Tollesboro section (inset diagram B) is a road cut along Kentucky Highway 10 on hill S.W. of Cabin Creek 4 km (2.5 miles) E. of junction with Kentucky Highway 57 in Tollesboro, Lewis Co., Kentucky. This is section 4A of Rexroad and Kleffner (1984). Sample F is from top 10 cm of the Drakes; G, H, and I from B basal 10 cm, 42 cm above the base, and top 10 cm of the Belfast, respectively; and J from basal 10 cm of the post-Belfast Brassfield. Species designations in diagrams A and B are as follows: a, *Ancyrochitina merga;* b, *Conochitina* cf. *C. iklaensis;* c, *Cyathochitina campanulaeformis;* d, *Conochitina* sp.; e, *Ancyrochitina* sp.; f, *A.* cf. *A. primitiva;* g, ***A. belfastenis.***

about the chitinozoan succession in the Ordovician-Silurian boundary interval in several key sequences in North America and abroad. However, such successions have been documented from Sweden (Eisenack 1968, Grahn 1978), Estonia (Nestor 1976, 1980, Nõlvak 1980) and Podolia, USSR (Laufeld 1971), Belgium (Martin 1973), and Anticosti Island, Quebec (Achab 1977b, 1981). Remarks on the dis-

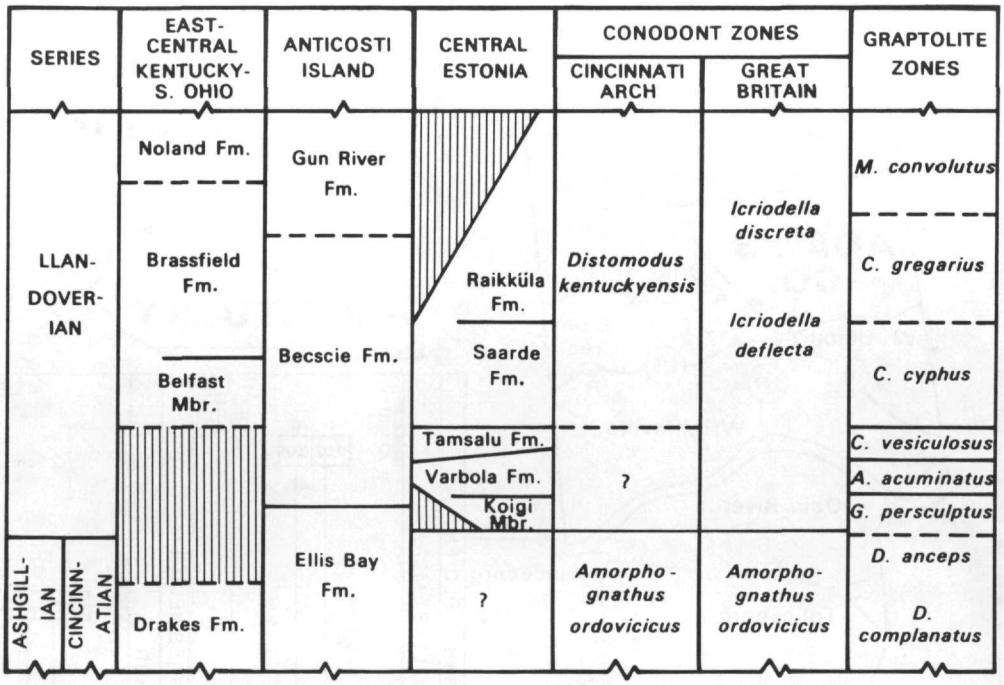

FIGURE 2. Correlation of the Belfast and associated strata with units on Anticosti Island and in Estonia, and cosmopolitan conodont and graptolite zones.

tribution of our taxa are given in the Appendix, and here we summarize their biostratigraphic significance.

The chitinozoans from the Belfast do not show any clear provincial affinity. Collectively, they confirm an Early Silurian age for the unit. The specimens herein referred to as *Conochitina* cf. *C. iklaensis* are very similar to, although not quite typical of, representatives of the nominal species from the *C. cyphus* to *M. convolutus* zones in Estonia (Nestor 1980) and coeval strata in the Gun River Formation of Anticosti Island (Achab 1981). We interpret the occurrence of this form, which also is in the basalmost Belfast, as indicating that this unit in its entirety is probably not older than the *C. cyphus* Zone. Although not very diagnostic biostratigraphically, the other chitinozoans present in the Belfast are in general agreement with this conclusion (see Appendix). Furthermore, a chitinozoan species-assemblage typical of the *C. gregarius* Zone in Estonia appears in the Brassfield somewhat above the Belfast (Grahn in prep.). Because there is no indication of a stratigraphic break between the Belfast and the latter level, the appearance of this assemblage may be viewed as additional evidence of an early Llandoverian age for the Belfast. This is in good agreement with, and confirms, the dating of the unit by means of conodonts (Rexroad 1967, Cooper 1975, Rexroad and Kleffner 1984) and acritarchs (Cramer and Díez de Cramer 1972).

The only species recovered from the Preachersville, *Ancyrochitina merga,* is previously known from the *Dicellograptus companatus* Zone in the Sylvan Shale of Oklahoma (Jenkins 1970) and the Vauréal Formation on Anticosti Island (Achab 1977a) as well as coeval strata in the Maquoketa Shale of Kansas (Wright and Meyers 1981). Older occurrences are recorded from the Maysvillian of Indiana and Ohio (Miller 1976) and Kentucky (Knabe 1980). The known range of this

species suggests that the uppermost Preachersville is not younger than the *D. complanatus* Zone, that is, the middle Ashgillian. This is in agreement with data from megafossils and conodonts that suggest that late Ashgillian strata are missing in the entire Cincinnati Region.

Accordingly, as summarized in fig. 2, we conclude that in our study area the stratigraphic gap of the Ordovician-Silurian paraconformity corresponds to the upper Ashgillian (Hirnantian or Gamachian stages) as well as an interval of three graptolite zones in the lowermost Llandoverian. Although this is a significant hiatus, the corresponding one on the western flank of the Cincinnati arch may be even larger (Rexroad and Kleffner 1984).

REMARKS ON PALEOECOLOGY

The Ordovician-Silurian systemic boundary break in the Cincinnati Region has a counterpart in many cratonic successions around the world and is likely to be due to a eustatic sea level drop, perhaps as much as 100 m., which was caused by the Gondwana glaciation (Brenchley and Newall 1984). The Belfast was deposited during the transgression following this large-scale regression. At our Ohio Brush Creek locality, the interval of the systemic contact is beautifully exposed for considerable distances in several long road cuts. In view of the fact that the stratigraphic gap may represent a time interval of several million years, it is remarkable that the contact is not marked by a conglomerate, channelled surface, or other lithic evidence of erosional activity. The Preachersville and the Belfast appear to be perfectly conformable; indeed, even at very close inspection, it is locally not easy to pinpoint the precise level of the paraconformity within a few cm thick interval that has been described as lithically transitional (Peck 1966). This masking of the contact is possibly due to reworking of argillaceous material from the Preachersville into the basalmost Belfast. This possibility is supported by the fact that reworked Ordovician conodonts are present locally in the lowermost Belfast (Rexroad 1967).

Although the position of the Belfast immediately above a major stratigraphic break suggests that the unit was laid down in shallow water, the precise water depth in the depositional environment is uncertain. No mudcracks, stromatolites, flat-pebble conglomerates, or other structures suggesting very shallow water have been reported from the Belfast, but the absence of a varied megafossil fauna may be taken as an indication of restricted and perhaps stressed conditions. Gray and Boucot (1972) found spore tetrads to dominate among the organic-walled microfossils in the upper Preachersville and lower Belfast whereas acanthomorphic acritarchs occur commonly in the upper Belfast indicating an increase in water depth during deposition of the unit. In all likelihood the Cincinnati Region was above sea level during latest Ordovician and earliest Silurian time, and non-marine conditions prevailed during Belfast time in the Appalachian region to the southeast of the study area. Yet the presence of Silurian conodonts, acritarchs, and chitinozoans throughout the Belfast proves the marine nature of the entire unit. Right above the Belfast, the Brassfield contains brachiopods of the *Cryptothyrella* or *Platymerella* Communities (*Eocoelia* or *Pentamerus*) Benthic Marine Life Zones (Gray and Boucot 1972) along with a diversified fauna of other shallow-water organisms indicating the existence of shallow-water marine conditions (Gordon and Ettensohn 1984). Chitinozoans are known to be scarce, or absent, in rocks deposited in very shallow water, especially under intertidal or supratidal conditions (Laufeld 1974, Grahn 1981, 1982, Grahn and Bergström 1984). Their presence throughout the Belfast, albeit in low numbers in most samples, suggests deposition in a subtidal environment. Alternatively, these fossils, along with conodonts and acritarchs, might have been transported by currents from the normal life environment of the organisms and deposited in very

shallow and possibly intertidal waters although, as noted above, lithic evidence of intertidal or supratidal deposition has not been found. Our chitinozoan assemblages are strongly dominated (99%) by representatives of *Ancyrochitina* with long hollow appendices. It has been suggested that such appendices served as floating devices and that these forms were planktic (Laufeld 1967, Chaiffetz 1972, Grahn 1978). If this interpretation is correct, it is obvious that such chitinozoans could be transported relatively easily from the normal life environment of the chitinozoophorans into more specialized environments such as that in which the Belfast was deposited. Unfortunately, the conodonts recorded from the Belfast are widespread in rocks representing a variety of shallow-water environments and their paleoecologic significance is uncertain. Gordon and Ettensohn (1984) suggested that the Belfast was deposited in a low-energy lagoonal environment but additional sedimentologic study of the unit throughout its area of occurrence, particularly in Ohio, is likely to add the data needed for a detailed assessment of its depositional environment.

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APPENDIX

REMARKS ON TAXONOMY

Brief comments on the chitinozoan taxa found are given below but to conserve space, we have omitted lists of synonyms and extensive descriptions. All the taxa discussed are illustrated in fig. 3-15.

Ancyrochitina belfastensis n. sp. (fig. 3-5)

HOLOTYPE: OSU 38451.

ETYMOLOGY: Named for the Belfast Member, the type stratum.

TYPE LOCALITY: Tollesboro section (see fig. 1 for location), 1.1 m above base of the Belfast.

DESCRIPTION: An *Ancyrochitina* species with a cylindrical neck half as long as the total vesicle length, and a subconical body with a convex base. The rounded basal edge carries about six appendices with their bases divided into two parts. The vesicle wall is smooth orad of the basal edge.

DIMENSIONS: Total length 100-188 μm; max. width 75-88 μm; width of aperture 31-43 μm; max. length of appendices 31 μm.

REMARKS: The branching of the appendices in the present species is similar to that in *A. spongiosa* Achab 1977, but our species is distinguished by having much more slender appendices that do not have the spongy structure present in those of *A. spongiosa*. Furthermore, the latter species has five to 10 appendices.

KNOWN OCCURRENCE: The Belfast Member (early Llandoverian), Tollesboro, Kentucky. MATERIAL: 16 specimens.

Ancyrochitina merga Jenkins 1970 (fig. 8-9)

This species, the only chitinozoan recovered from the uppermost part of the Preachersville, has a small fungiform vesicle with almost straight flanks that taper in a gentle curve into a neck that widens at the aperture. Most of the appendices are broken, but those present are bifurcate. The vesicle wall is smooth or covered with very small spines. Jenkins (1970) recorded this form as common in the upper part of the lower Sylvan Shale of Oklahoma (*D. complanatus* Zone), and it has also been reported from coeval strata in the Vauréal Formation on Anticosti Island (Achab 1977a) and the Maquoketa Shale of Kansas (Wright and Meyers 1981). Other occurrences include the Maysvillian of Indiana and Ohio (Miller 1976) and Kentucky (Knabe 1980).

Ancyrochitina cf. *A. primitiva* Eisenack 1964 (fig. 6-7)

At the Ohio Brush Creek section, specimens of this species appear in the middle Brassfield where they dominate the chitinozoan fauna. In the Tollesboro section it has been recovered also in the Belfast. Our specimens differ from typical specimens of *A. primitiva* in having appendices that are curved aborally. No ornamentation has been observed on the neck. Typical specimens of Eisenack's species are present in somewhat younger beds in southern Ohio than those discussed here (Grahn, unpubl. data). Eisenack (1964) noted that this species exhibits great intraspecific variation. The species is recorded from the upper Llandoverian to upper Ludlovian and is known from Baltoscandia (Eisenack 1964, 1968, 1970, Laufeld 1974, Nestor 1982), Podolia, USSR (Laufeld 1971), Great Britain (Eisenack 1977), and Portugal (Paris 1981).

Ancyrochitina sp. (fig. 10)

This species is sparingly represented in the Belfast and in younger parts of the Brassfield. It has the cylindro-conical vesicle typical of *Ancyrochitina,* but because the appendices are incompletely preserved,

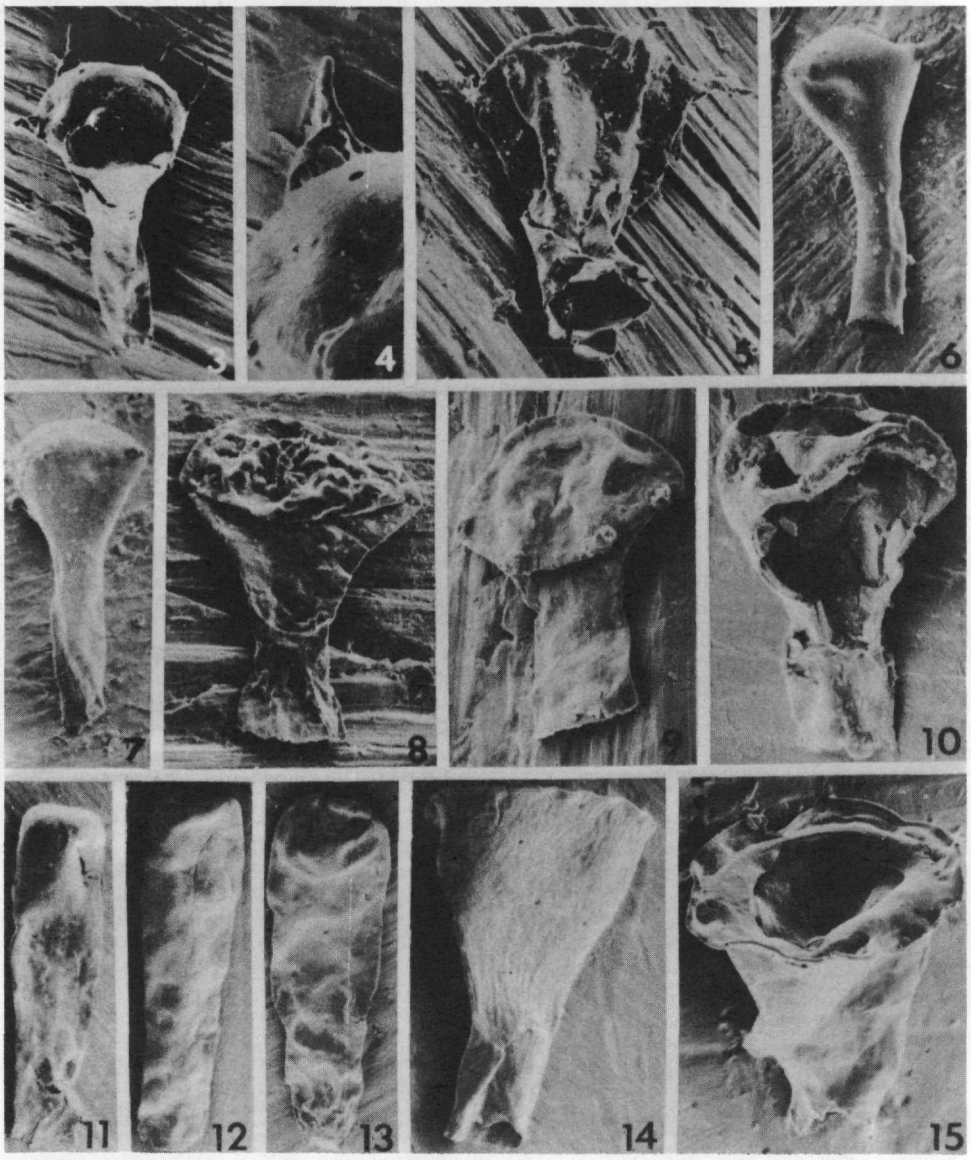

FIGURE 3-15. SEM micrographs of chitinozoans from the Belfast and the Preachersville. 3-5 ***Ancyrochitina belfastensis*** n. sp. 3, oblique aboral view of OSU 38451 (holotype), sample H, 250×; 4, detail of same specimen. Note the appearance of the appendix base 625×; 5, lateral view of OSU 38452, sample H, 290×. 6-7. *Ancyrochitina* cf. *A. primitiva* Eisenack 1964. 6, lateral view of OSU 38453, sample H, 200×; 7, lateral view of OSU 38454, sample I, 245×. 8-9. *Ancyrochitina merga* Jenkins 1970. 8, lateral view of OSU 38455, sample A, 275×. Note appearance of appendix; 9, lateral view of OSU 38456, sample A, 215×. 10, *Ancyrochitina* sp., lateral view of OSU 38457, sample C, 300×. Note appearance of appendix. 11-12, *Conochitina* cf. *C. iklaensis* Nestor 1980. 11, lateral view of OSU 38458, sample C, 135×; 12, lateral view of OSU 38459, sample B, 130×. 13, *Conochitina* sp., lateral view of OSU 38460, sample C, 145×. 14-15, *Cyathochitina campanulaeformis* (Eisenack 1931). 14, lateral view of OSU 38461, sample B, 205×. Note longitudinal thickenings at flexure. 15, oblique aboral view of OSU 38462, sample D, 200×.

specific determination is difficult. However, in size and overall morphology it shows similarity to specimens of *Ancyrochitina* described from the upper Ashgillian and lower Llandoverian of Sweden (Grahn 1978, 1982), the Llandoverian Medina Group, New York (Miller and Eames 1982), and the Llandoverian Becscie Formation, Anticosti Island (Achab 1981).

Conochitina cf. *C. iklaensis* Nestor 1980 (fig. 11-12)

This form, which was found only in the Belfast, has a smooth subcylindrical vesicle with a broadly rounded basal edge and a flat to concave base. We compare our specimens with Nestor's species because the basal scar described by Nestor has not been observed in the Belfast specimens. The size and length:width ratio are, however, the same as in the Estonian species. In Estonia this species occurs in the Raikküla Stage (*C. cyphus* to *M. convolutus* zones) and similar specimens have been described from the Gun River Formation of Anticosti Island (Achab 1981). Specimens of *C. iklaensis* exhibit overall similarity to those of the *C. proboscifera* group but differ in not having a protruding basal process and a concave base. Also, the latter occur in younger strata than the former species.

Conochitina sp. (fig. 13)

A *Conochitina* species similar to those noted by Achab (1981, pl. 3:1) as characteristic of the Gun River Formation on Anticosti Island occurs in the middle portion of the Belfast at the Ohio Brush Creek section. Compared to *C.* cf. *C. iklaensis* this form has a broader basal part and the flanks taper into a narrower aperture.

Cyathochitina campanulaeformis (Eisenack 1931) (fig. 14-15)

This species, which is represented in both the Belfast and in the overlying part of the Brassfield at the Ohio Brush Creek locality, has the typical bell-shaped vesicle and longitudinal thickenings at the flexure. Similar specimens are common in Caradocian through Wenlockian strata, the stratigraphically youngest known ones being probably those from the uppermost Wenlockian of Scania, Sweden (Grahn, unpubl. data).

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