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Calibration of Chitinozoa *versus* graptolite biozonation in the Wenlock of Builth Wells district (Wales, U.K.), compared with other areas in Avalonia and Baltica

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ABSTRACT – The Wenlock sections around Builth Wells, recently used to establish a revised Wenlock graptolite biozonation have been here studied for Chitinozoa. Fifty-five samples have been collected from four sections containing three to five graptolite biozones; samples were taken from the same slabs of rocks used for the redefinition of the graptolite biozonation. The index species of three globally recognised chitinozoa biozones are present, *Margachitina margaritana*, *Cingulochitina cingulata*, and *Conochitina pachycephala*, together with several other characteristic species. These global biozones can be divided into several local biozones. In levels with the *centrifugus* and *murchisoni* graptolite biozones, a local *margaritana* biozone is defined; within the *riccartonensis* graptolite biozone two biozones are defined, the *mamilla* and *burdinalensis* biozones with a third, the *tuba* biozone at the top. The *cingulata* biozone starts at the base of the *dubius* graptolite biozone; the *pachycephala* biozone commences halfway up the *rigidus* graptolite biozone and at the base of the (newly defined) *lundgreni* graptolite biozone, is the *subcyatha* biozone. Halfway through the *lundgreni* graptolite biozone the *cribrosa* biozone begins and continues into the uppermost samples which are referred to the *nassa-ludensis* graptolite biozones.

In five areas of Avalonia and Baltica a calibration between chitinozoa and graptolite biozonations has been established for the Wenlock: Builth Wells district (U.K.), Brabant Massif (Belgium), Estonia and northern Latvia, Gotland (Sweden) and mainland Sweden. For the chitinozoa a similar succession of nine biozones and two interzones (as the expression of extinction events) is present in at least three of the five areas. From bottom to top: the Wenlock part of the local *margaritana* biozone coincides with the *centrifugus* and *murchisoni* graptolite biozones. The *mamilla* and *burdinalensis* biozones are present respectively in the lower and upper part of the *riccartonensis* graptolite biozone. The lower extinction event is either located in the topmost part of the *riccartonensis* graptolite biozone (Builth Wells district) or in the *dubius* graptolite biozone (other areas). The main part of the *tuba* biozone and the *cingulata* biozone are found in the *dubius* graptolite biozone and the *lagena* and *pachycephala* biozones in the *rigidus* graptolite biozone. The *subcyatha* and the *cribrosa* biozones are found in the *lundgreni* graptolite biozone. An interzone and the *indecora/lycoperdoides* biozone starts within the *nassa* biozonal complex. The apparent minor differences between the calibrations of biozonations of the two groups could be explained by differences in sample density, by the discontinuous or condensed sedimentation in the sections or differences in biozone definition. Eight new taxa are described, named *Cingulochitina angusta*, *C. bouniensis*, *C. burdinalensis*, *C. dreyensis*, *C. pitetensis*, *Eisenackitina anulifera*, *E. causiata*, and *E. ithoniensis*.

RIASSUNTO – [Calibrazione della biozonazione a chitinozoi rispetto a quella a graptoliti nel Wenlock del distretto di Builth Wells (Galles, Inghilterra) e confronto con altre aree in Avalonia e Baltica] – Le sezioni del Wenlock intorno a Builth Wells, recentemente usate per stabilire una aggiornata biozonazione a graptoliti del Wenlock, sono state qui studiate per i chitinozoi. Cinquantacinque campioni sono stati raccolti da quattro sezioni contenenti da tre a cinque biozone a graptoliti; i campioni sono stati presi dagli stessi spezzoni di roccia usati per la ridefinizione delle biozone a graptoliti. Sono presenti le specie indice di tre biozone a chitinozoi riconosciute a livello globale: *Margachitina margaritana*, *Cingulochitina cingulata*, e *Conochitina pachycephala*, insieme a numerose altre caratteristiche specie. Queste biozone globali possono essere suddivise in numerose biozone locali. In livelli appartenenti alle biozone a graptoliti *centrifugus* e *murchisoni*, viene definita una biozona locale a *margaritana*; entro la zona a graptoliti *riccartonensis*, vengono definite due zone locali a chitinozoi, la *mamilla* e la *burdinalensis*, seguite da una terza, la biozona *tuba*. La biozona *cingulata* comincia alla base della biozona a graptoliti *dubius*; la biozona *pachycephala* comincia a metà della biozona a graptoliti *rigidus* e la biozona *subcyatha* comincia alla base della zona a graptoliti *lundgreni*, recentemente definita. A metà della biozona a graptoliti *lundgreni* comincia la biozona *cribrosa*, che continua nei campioni più alti, attribuiti alla biozona a graptoliti *nassa-ludensis*.

Una calibrazione tra le biozone a graptoliti e a chitinozoi è stata stabilita per il Wenlock di cinque aree di Avalonia e Baltica: Builth Wells (Inghilterra), Massiccio del Brabant (Belgio), Estonia e Lituania, isola di Gotland (Svezia) e Svezia continentale. Per i chitinozoi, una simile successione di nove biozone e due interzone (espressione di eventi di estinzione) è presente in almeno tre delle cinque aree. Dalla base al tetto: la parte wenlockiana della biozona locale *margaritana* coincide con le biozone a graptoliti *centrifugus* e *murchisoni*. Le biozone *mamilla* e *burdinalensis* sono presenti rispettivamente nella parte bassa ed alta della biozona a graptoliti *riccartonensis*. Il più antico evento di estinzione è collocato nella parte sommitale della biozona a graptoliti *riccartonensis* (Builth Wells district) o nella biozona a graptoliti *dubius* (in altre aree). La maggior parte della biozona *tuba* e la biozona *cingulata* sono state trovate nella biozona a graptoliti *dubius* e le biozone *lagena* e *pachycephala* nella biozona a graptoliti *rigidus*. Le biozone *subcyatha* e *cribrosa* si trovano nella biozona a graptoliti *lundgreni*. Una interzona e le biozone *indecora/lycoperdoides* cominciano all'interno del complesso biozonale *nassa*. Le apparenti differenze secondarie nella calibrazione delle biozone dei due gruppi possono essere spiegate con differenze nella densità di campionamento, con la sedimentazione discontinua o condensata in alcune sezioni o con differenze nella definizione di biozone. Sono qui descritti anche otto nuovi taxa, chiamati *Cingulochitina angusta*, *C. bouniensis*, *C. burdinalensis*, *C. dreyensis*, *C. pitetensis*, *Eisenackitina anulifera*, *E. causiata* e *E. ithoniensis*.

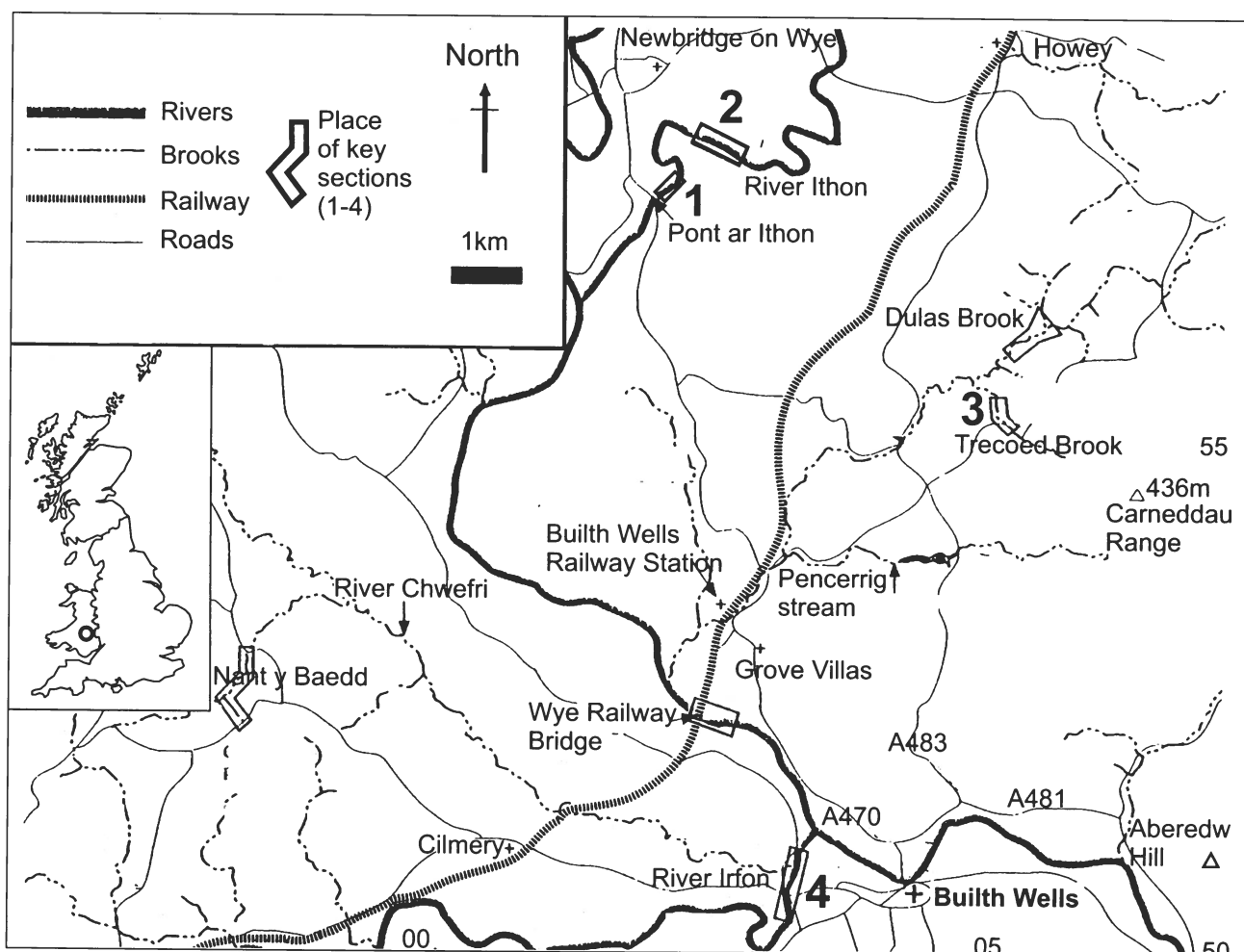
INTRODUCTION

The Builth Wells district (central south Wales, U.K.; Text-fig. 1) lies 75 km from the Wenlock type area, around Much Wenlock, in the Welsh Borderland. The Wenlock sections around Builth Wells are classic because Elles (1900) used these as the basis for her Wenlock graptolite biozonation, a scheme which has been widely applied.

Recently Zalasiewicz & Williams (1999) have restudied the graptolites from Elles (1900) and from other previous collections, together with their own new collections. A reassessment of the Wenlock graptolite biostratigraphy showed that the lower part of the Wenlock contains the *centrifugus*, *murchisoni* and *riccartonensis* graptolite biozones, essentially the same as recognised widely elsewhere in the world. However, the middle to late Wenlock graptolite biostratigraphy differs from that recognised elsewhere. Above the *riccartonensis* graptolite biozone, the *dubius*, *rigidus* and

lundgreni graptolite biozones are distinguished, while separate *flexilis* and *ellesae* graptolite biozones are not recognised. *Monograptus flexilis* appears earlier than, then largely co-exists with *Cyrtograptus rigidus*. *Cyrtograptus ellesae* appears later than *C. lundgreni* and not earlier as previously accepted. The same study indicates that the Sheinwoodian-Homerian boundary, as currently defined, might occur within, rather than at the base of the *lundgreni* graptolite biozone. The late Wenlock of the Builth Wells district is sparsely fossiliferous and is placed within an undivided *nassa-ludensis* graptolite biozone interval (Zalasiewicz *et al.*, 1998; Zalasiewicz & Williams, 1999).

In their study, four sections proved to be the most continuous, with the presence of three to five graptolite biozones in which the index and other characteristic species are recognised (Text-fig. 1). In this paper the results of a palynological study on the Chitinozoa of 55 samples from these four sections (Text-fig. 2) are presented. The samples were taken from the same



Text-fig. 1 - Sketch map of study area and location of the studied sections of the Builth Wells district, Wales, U.K. 1) River Ithon East, SE of Newbridge on Wye; 2) River Ithon West, SE of Newbridge on Wye; 3) Trecoed Brook; 4) River Irfon. The numbers (A481, etc.) indicate road numbers. (after Zalasiewicz & Williams, 1999).

Sections		Graptolite biozones		Chitinozoa species		Local Chitinozoa biozonation	
Samples (0 = barren)							
Irfon	E10	ludensis nassa					cribrosa
	E7						
	E6						
	E1						
	E16	lundgreni					subcyatha
	E18						
	E20						
	E21						
	E29	rigidus					pachycephala
	E32						
	E32A						
	E33						
	E34						
Trecoed	N41	?					cingulata
	N40						
	N39	rigidus					tuba
	I17 0						
	N42	?					burdinalensis
	I18						
	N38 0	dubius					mamilla
	N37						
	N36	riccarton- ensis					margaritana
	N33C						
Ithion East	N33B	?					margaritana
	N33A						
	K35	riccarton- ensis					margaritana
	K34C						
	K34B						
	K34A						
	K33	murchisoni					margaritana
	K32						
	K31						
	K30						
	K29	centrifugus					margaritana
	K28						
	K27						
	K26C						
Ithion West	K26B	murchisoni					margaritana
	K26A						
	K26						
	K21B						
	K21C	centrifugus					margaritana
	K21A						
	K21						
	K15 0						
	K22	murchisoni					margaritana
	K25						
	K11 0						
	K8						
	K7	centrifugus					margaritana
	K6 0						
	K4 0						
	K3 0						
	K2 0						
	K1						

Text-fig. 2 - Chitinozoa content in 55 samples from four sections of the Wenlock of the Builth Wells district, Wales, U.K. Corresponding graptolite biostratigraphy established in the same samples by Zalasiewicz & Williams (1999) and local Chitinozoa biostratigraphy are indicated.

slabs of rock containing the graptolites studied by Zalasiewicz & Williams (1999). The aim of this study is to present an accurate calibration of the newly defined graptolite biozonation with the Chitinozoa biozonation. In addition, this calibration is compared with other areas of the palaeocontinents Avalonia, Baltica and Perunica (Bohemia), where at least a partial calibration between graptolite and Chitinozoa biozonations has been established.

MATERIAL AND METHODS

LITHOSTRATIGRAPHY AND SAMPLING

The Wenlock sediments of the Builth Wells district, were deposited in an offshore, deeper marine continental shelf setting or shelf edge; they are about 600 m thick and are divided into two formations (Text-fig. 3). The Dolfawr Mudstones Formation, starting in the upper Llandovery and containing the lower two graptolite biozones of the Wenlock (*centrifugus* and *murchisoni*), comprises alternating green and grey burrowed, mottled, mudstones and dark grey laminated graptolitic mudstones. It is covered by a much thicker Builth Mudstones Formation, consisting of calcareous, finely laminated graptolitic mudstones with burrows in the upper part. It contains the remainder of the Wenlock graptolite biozones (Zalasiewicz & Williams, 1999).

The location of the four sections is given on a map (Text-fig. 1) and the location of sample horizons is partly summarised in Zalasiewicz & Williams (1999).

a) *The Ithon West section*, along the River Ithon, 50 to 350 m NE of Pont ar Ithon, south of Newbridge on Wye, was studied but not published in Zalasiewicz & Williams (1999). It contains the *centrifugus* graptolite biozone (7 samples) and the *murchisoni* graptolite biozone (1 sample) (Zalasiewicz & Williams, pers. comm.).

b) *The Ithon East section* is situated 800 m NE of Pont ar Ithon and contains the graptolite biozones *centrifugus* (8 samples), *murchisoni* (2 samples) and *riccartonensis* (11 samples).

c) *The Trecoed section* along a tributary brook of the Dulas brook, 4.5 km north of Builth Wells contains the graptolite biozones *riccartonensis* (3 samples), *dubius* (3 samples) and *rigidus* (3 samples).

d) *The Irfon section* is situated along the River Irfon, close to its confluence with the River Wye, about 1 km west of Builth Wells. It contains the graptolite biozones *rigidus* (3 samples), *lundgreni* (8 samples) and *nassa-ludensis* (2 samples).

The naming of samples (e.g., E10) is the same as those of the graptolite levels of Zalasiewicz & Williams (1999).

PALYNOLOGICAL TECHNIQUES

The Chitinozoa were prepared (Text-fig. 2) according to standard palynological techniques

(Paris, 1978, 1981; Verniers, 1982), and studied either under optical light microscopy (Leitz-Orthoplan under transmitted and reflected light) or with Scanning electron microscopy (JEOL6400, emission current 10 kV, focal distance 10 mm). The Chitinozoa are mostly dark brown or opaque, indicating a moderate thermal alteration. They are poorly to moderately well preserved, with moderate diversity (2 to 16 species per sample) and abundance (0.1 to 70 Chitinozoa per gram of rock with 20–41 g of rock dissolved).

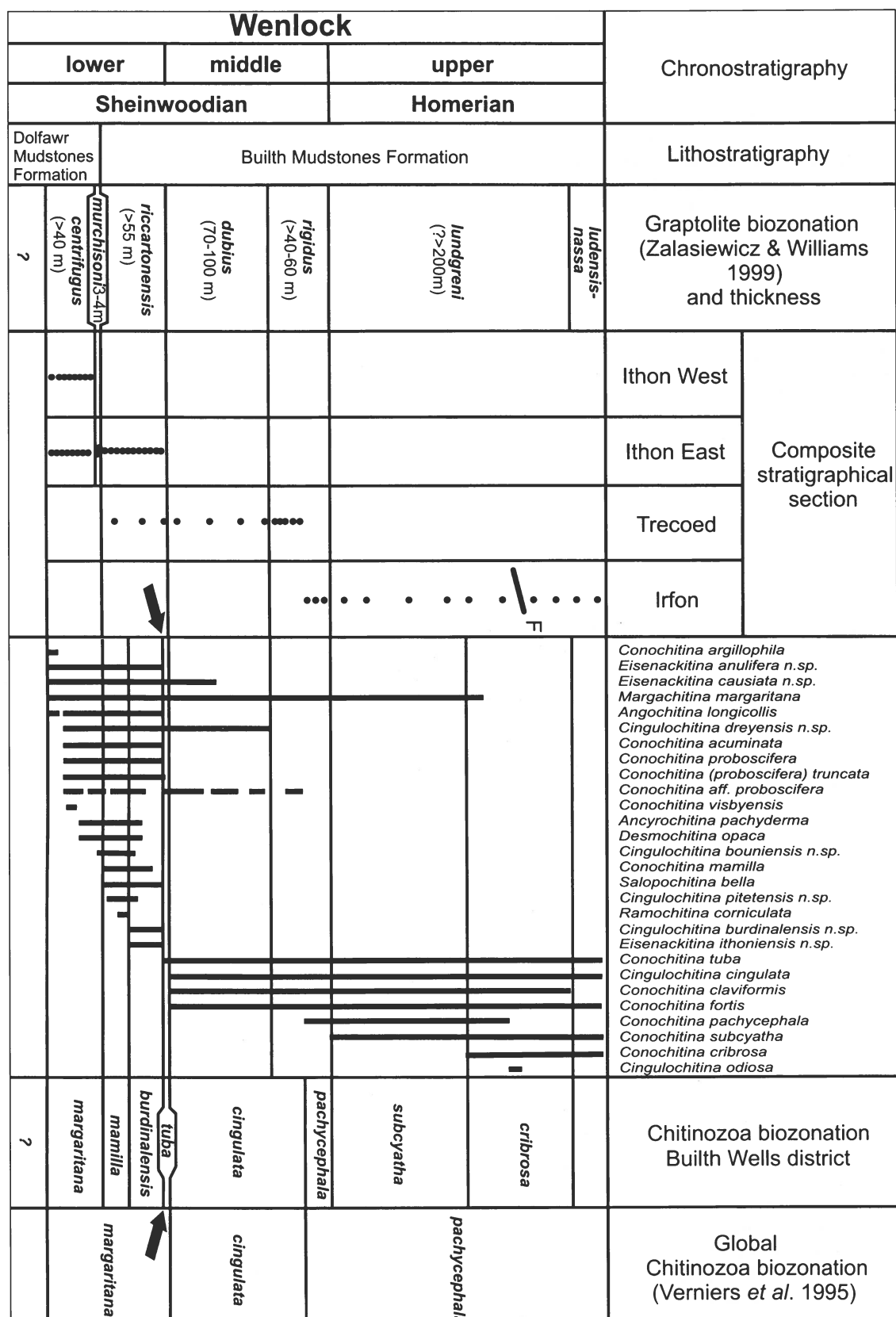
BIOSTRATIGRAPHY OF THE CHITINOZOA OF THE BUILTH WELLS DISTRICT

In the lower to middle upper Wenlock strata exposed in the study area, a succession of eight local biozones and two interzones can be distinguished (Text-fig. 3). The lower three biozones are grouped in a lower superzone and the upper five biozones in an upper superzone (see below). Between the two superzones, an extinction event occurs (see below and arrow in Text-fig. 3).

THE LOWER SUPERZONE

At the base of the sequence the lower superzone includes the following species, some first appearing in the uppermost Llandovery but all disappearing before or at the extinction event above the superzone: *Ancyrochitina pachyderma* Laufeld, 1974, *Angochitina longicollis* Eisenack, 1959, *Conochitina acuminata* Eisenack, 1959, *Conochitina proboscifera* Eisenack, 1937, *Conochitina (proboscifera) truncata* Laufeld, 1974, *Conochitina visbyensis* Laufeld, 1974, *Desmochitina opaca* Laufeld, 1974, *Eisenackitina anulifera* sp. nov., *Ramochitina corniculata* (Laufeld, 1974), *Salopochitina bella* Swire, 1990. Some other species continue upwards as *Margachitina margaritana* (Eisenack, 1937), *Cingulochitina dreyensis* sp. nov., *Conochitina* aff. *proboscifera* Laufeld, 1974, and *Eisenackitina causiata* sp. nov.

This superzone can be divided into three biozones: in ascending order: (1) the *margaritana* biozone, containing the index species *Margachitina margaritana* and the above-mentioned main species of the superzone; (2) the *mamilla* biozone, whose base is defined by the first appearance of the index species *Conochitina mamilla* Laufeld, 1974, and also of *Cingulochitina pitetensis* sp. nov. and *Cingulochitina bouniensis* sp. nov. (the latter appears a little lower, down in the top of the underlying biozone); (3) the *burdinalensis* biozone whose base is defined by the first occurrence of the index species, *Cingulochitina burdinalensis* sp. nov., and also of *Eisenackitina ithoniensis* sp. nov. Towards the upper part of this superzone this assemblage becomes rare and poorly diverse and most species have disappeared in an extinction event.



Text-fig. 3 - Chitinozoa ranges in a composite section of the Wenlock in the Builth Wells district, with sample location within the lithostratigraphy, the graptolite and the Chitinozoa biozonation. The arrow below the base of the *tuba* Chitinozoa biozone indicates a Chitinozoa extinction event.

THE UPPER SUPERZONE

The upper superzone is characterised by a succession of appearances of taxa. *Conochitina tuba* Eisenack, 1932 is the first species to appear and is the index species of the *tuba* biozone. It is followed by the joint appearance of *Cingulochitina cingulata* (Eisenack, 1937), index species of the *cingulata* biozone, *Conochitina claviformis* Eisenack, 1931, and *Conochitina fortis* Nestor, 1982. The appearance of *Conochitina pachycephala* Eisenack, 1964 marks the base of the third biozone; the appearance of *Conochitina subcyatha* Nestor, 1982 the base of the fourth biozone and the appearance of *Conochitina cribrata* Nestor, 1982 the base of the fifth biozone. The uppermost two samples contain the characteristic species of the second superzone (*Cingulochitina cingulata*, *Conochitina cribrata*, *C. fortis*, *C. subcyatha* and *C. tuba*). The (post-) *lundgreni* extinction event, also described for Chitinozoa (Kaljo *et al.*, 1995), is not encountered in the Builth Wells samples possibly because it is situated higher in the sequence above the sampling range. *Margachitina margaritana* although rare is present throughout this second superzone.

According to the graptolite biozonation three sections (Ithon East, Ithon West and Trecoed) partly overlap (see Text-fig. 3). The Chitinozoa biozonation confirms these overlaps. It was even possible to locate the two graptolite samples within the *riccartonensis* graptolite biozone of the Trecoed section, in relation to the 11 samples of the same graptolite biozone in the River Ithon East section. Each of the former series of samples could be attributed to one of the three Chitinozoa biozones within the *riccartonensis* graptolite biozone in the latter section. Sample N33A belongs to the *mamilla*, sample N33B to the *burdinalensis* and sample N33C to the *tuba* biozone. The latter is not present in the Ithon East section.

CORRELATION WITH THE GLOBAL CHITINOZOA BIOZONATION

In the Builth Wells district three global Chitinozoa biozones (Verniers *et al.*, 1995) are present with their index species: *Margachitina margaritana*, *Cingulochitina cingulata* and *Conochitina pachycephala*. The overlying global biozone *Sphaerochitina lycoperdoides* was not found.

CALIBRATION AND COMPARISON OF CHITINOZOA AND GRAPTOLITE BIOZONATIONS IN AVALONIA, BALTICA, NORTHERN GONDWANA AND LAURENTIA

As described in Verniers *et al.* (1995) the four global biozones of the Wenlock are present in most of the areas described below. However, this study allows subdivision of these global biozones into several local biozones for Avalonia and Baltica. In the following discussion, only the taxa shared with the Builth Wells district, will be used for comparison.

AVALONIA

United Kingdom

Aldridge *et al.* (1979) and Dorning (1981) described in their overviews of the Chitinozoa composition in the Wenlock and Ludlow of Shropshire, the succession of two different assemblages. The first characterizes the lower Wenlock Buildwas Formation and comprises *Ancyrochitina pachyderma*, *A. gutnica* Laufeld, 1974, *Angochitina longicollis*, *Conochitina acuminata*, *C. proboscifera*, and *Margachitina margaritana*; the second is present in the middle to middle upper Wenlock Coalbrookdale Formation and includes *Cingulochitina cingulata*, *Conochitina pachycephala*, *C. gutta* Laufeld, 1974, with *C. tuba* and *Linochitina erratica* (Eisenack, 1931) appearing higher in the formation. However, no detailed correlation with the graptolite biozonation is provided.

Mabillard & Aldridge (1985) studied the international stratotype (Global Stratotype Section and Point, G.S.S.P.) of the Llandovery-Wenlock boundary at Leasows Farm, Wenlock Edge, Shropshire, U.K. According to the definition of this G.S.S.P., the base of the Buildwas Formation is taken as the base of the Wenlock (Holland, 1980a; Bassett, 1989). In the definition it is assumed that the lower part of the formation is the base of the *centrifugus* graptolite biozone, even in the absence of the index species at the G.S.S.P. A typical Chitinozoa assemblage is present with *Margachitina margaritana*, *Conochitina proboscifera*, *Angochitina longicollis*, *Ancyrochitina gutnica*, *Conochitina visbyensis* and also *Cingulochitina cingulata*; the last could possibly be a synonym of either *Cingulochitina dreyensis* sp. nov. or *C. pitetensis* sp. nov. One should note that not all specimens were determined to the species level, and more species might be present.

Swire (1990, 1993) described the acritarchs and some Chitinozoa from two places around Wenlock Edge: the Lower Hill Farm borehole in the type area of the Wenlock, and the Whitwell Coppice outcrop, at the G.S.S.P. of the Sheinwoodian-Homerian boundary within the same area. He also studied a third locality, the Eastnor Park borehole in the Malvern Hills. Graptolites are present in several parts of the boreholes and outcrops and calibration of graptolites and Chitinozoa is possible. Two total-range biozones are proposed, i.e. *Calpichitina* (*Densichitina*) *densa* (Eisenack, 1932) and *Cingulochitina cingulata*. Unfortunately, the former zone was not recovered from the Builth Wells district and could not be used for correlation. *Cingulochitina cingulata* appears from a level within the *riccartonensis* graptolite biozone and ranges up to the section top within the *lundgreni* graptolite biozone. This is the only reported occurrence of *Cingulochitina cingulata* at a level so low in the Wenlock. As mentioned by Verniers *et al.* (1995), this determination should be compared with similar forms (see, e.g., *Cingulochitina pitetensis* sp. nov. or *C.*

dreyensis sp. nov., herein, which do occur in strata below the occurrence of *Cingulochitina cingulata*). *Margachitina margaritana* is present throughout the Lower Hill Farm borehole from the base of the Buildwas Formation (base of the Wenlock by definition) up to the *lundgreni* graptolite biozone, as shown in the section at Whitwell Coppice. This range is identical in the Builth Wells district. *Salopochitina bella* is found in the Lower Hill farm borehole only in the *centrifugus* graptolite biozone, while in the Builth Wells district it occurs higher, only in the *riccartonensis* graptolite biozone. Hence its range is longer than first observed, but restricted to the lower Wenlock.

Mullins (1998a, b) studied the Chitinozoa from the Banwy River section in mid Wales, where Loydell & Cave (1996) established a refined graptolite biozonation for the Telychian and the Llandovery-Wenlock transition. Mullins (1998a, b) could demonstrate that *M. margaritana* appears in the uppermost Llandovery *insectus* graptolite biozone and not at the base of the Wenlock as indicated by Mabillard & Aldridge (1985) based on the presence of this species at the international stratotype of the Llandovery-Wenlock boundary (Leasows section).

Belgium

The Wenlock sequence in the Meuse area is more than 1050 m thick and is the best studied Wenlock sequence in the Brabant Massif. The Chitinozoa from sixty samples through this sequence, show a succession of two different assemblage zones, C and D, divided into subzones (Verniers, 1981, 1982, figs. 3 and 8).

Subzone C1, in member MB3D, containing the first occurrence of *Margachitina margaritana*, can more precisely be dated (Mullins, 1998b) as latest Telychian *insectus* graptolite biozone, early Wenlock.

Subzone C2 in member MB3E - containing small specimens of *Conochitina proboscifera* and *C. truncata* in association with *Angochitina longicollis*, *Eisenackitina anulifera* sp. nov., *Cingulochitina angusta* sp. nov., *C. dreyensis* sp. nov., *C. pitetensis* sp. nov., *Conochitina acuminata*, and *Ramochitina corniculata* - resembles the *margaritana* local biozone of Builth Wells, which occurs at the level of the *centrifugus* graptolite biozone, lowermost Wenlock. Because of the presence of *Margachitina margaritana* it could, however, also belong to the uppermost Telychian (see above).

Graptolites in most of the Formation MB4 indicate the *centrifugus* or *murchisoni* graptolite biozone, high in the formation (outcrop CD22E) the *riccartonensis* graptolite biozone, and at the very top (outcrop CD22G) post-*riccartonensis* and *flexilis* graptolite biozones (Verniers & Rickards, 1979). The last biozones can be approximately correlated with the middle Wenlock *dubius* and/or *rigidus* graptolite biozones, as defined by Zalasiewicz & Williams (1999). The Chitinozoa subzone C3 occurs in most of the forma-

tion up to outcrop CD22E and is similar to C2, except for the presence of well developed *Conochitina proboscifera* and *C. truncata* and the successive appearance of *Cingulochitina bouniensis* sp. nov. and of *C. burdinalensis* sp. nov. The lower part of the subzone C3 can be correlated with the *margaritana* local biozone; the middle part of the same subzone can be correlated with the *mamilla* biozone by the appearance of *Cingulochitina bouniensis* sp. nov.; and the upper part with the *burdinalensis* biozone, by the presence of the index taxon.

The assemblage in the uppermost part of the Formation MB4 (outcrop CD22G) was described as an impoverished C3 subzone, with absence of most species that normally are present in subzones C2 and most of C3. It cannot be correlated convincingly with either the impoverished top of the *burdinalensis* biozone or with the *tuba* biozone of Builth Wells. Hence, no comparison is possible between both calibrations owing to the scarcity of Chitinozoa in those samples of the Meuse area which contain middle Wenlock graptolites.

In the first sample, at +3.2 m above the base of Formation MB5, *Conochitina* sp. cf. *C. armillata* occurs (subzone C4), from a level between two unspecified middle Wenlock graptolite horizons. It shows the lowest observed occurrence of the middle Wenlock Chitinozoa "fauna renewal" in the Meuse area. Higher up, one level in the Formation MB6 contains middle Wenlock graptolites and the Chitinozoa assemblage subzone D1, characterized by the frequent occurrence of the index taxon of the *cingulata* biozone of Builth Wells. The graptolite horizon, dated as mid Wenlock, is too imprecisely constrained to enable comparison with the Builth Wells district. The rich assemblages of subzones D1 and D2 can be correlated with the *cingulata* biozone of Builth Wells and possibly with the higher *pachycephala* biozone of that area, but the index species of the latter biozone was not observed in the Meuse area.

From one third up in Formation MB7, *Conochitina subcyatha* and *Conochitina gutta* are present; the last-named is frequent in the upper third of the MB7 Formation, allowing a correlation of subzone D2 with the *subcyatha* biozone of Builth Wells. Subzone D3 in the uppermost part of Formation MB7 and lower part of Formation MB8 contains the index species of the *Sphaerochitina lycoperdoides* biozone, a level not reached in the Builth Wells district.

Poland

Four graptolite-dated samples from the Holy Cross Mountains broadly confirm some of the calibrations between the graptolite and Chitinozoa biozonations. Characteristic species - such as *Conochitina pachycephala*, *Cingulochitina cingulata*, and *Linochitina erratica* - occur in what was called upper *nassa* and basal *ludensis* zones. They indicate the *pachycephala*

global biozone. A similar assemblage occurs at a similar graptolite bearing level in the Prague Basin (see below). A sample from the middle *ludensis* graptolite biozone contains, according to Rombouts (1982), *Sphaerochitina lycoperdoides* Laufeld, 1974, the index species of the homonym global biozone.

BALTICA

The island of Gotland

The Chitinozoa from the Wenlock of the island of Gotland (Sweden) were studied in detail by Laufeld (1974) who described a succession similar to Bülth Wells and to Estonia. Laufeld (1974) established eight Chitinozoa assemblages, named after their index species or without names for the interzones: *margaritana*, *mamilla*, interzone, *tuba*, *cingulata*, *pachycephala*, interzone, *lycoperdoides*. This succession of Chitinozoa assemblages is calibrated here (Text-fig. 4) with the graptolite biozonation of Gotland provided by Jeppsson *et al.* (1994). The Lower and Upper Visby Beds, containing the lowermost assemblage (*margaritana*) do not contain any indicative graptolite. *Conochitina mamilla* appears low in the Högklint Beds, at the base of the *riccartonensis* graptolite biozone. In the higher parts of the Högklint, in the Tofta, and members a and b of the Slite Beds, no specific or only transient Chitinozoa are present (interzone); this interval corresponds to the top of the *riccartonensis* and supposed *antennularius* graptolite biozones. Five incoming events characterise five biostratigraphical divisions in the Slite Beds. The *tuba* biozone starts at the base of *belophorus* graptolite biozone and the *cingulata* biozone within the same *belophorus* graptolite biozone, where *Conochitina gutta* also appears. *Conochitina pachycephala* first occurs, according to Laufeld (1974), from the uppermost part of the Slite Beds (*Pentamerus gothlandicus* Beds and Slite Siltstone member). The relation of the level of this first appearance of *C. pachycephala* to the graptolite biozonation is unclear. The exact sampling level cannot be situated within the correlation scheme of Jeppsson *et al.* (1994). It could correspond to any level in the middle Wenlock to lower upper Wenlock. Within the Halla Beds, an impoverished Slite assemblage is present, some new species appear, including *Linochitina erratica*, a situation which is similar to that of the Prague Basin (see below); in the upper part of the Mulde beds *Sphaerochitina lycoperdoides* appears. Both levels contain the *nassa* or *praedeubeli* graptolite biozones. At the *nassa-ludensis* transition an important Chitinozoa renewal event is present, as there are several extinction events and appearances within the *ludensis* graptolite biozone.

Grahn (1995) studied lower Silurian boreholes from Gotland in detail, amongst others the När-1 borehole which extended from the Llandovery to the Wenlock (*centrifugus* graptolite biozone). Graptolites

were determined by H. Jaeger (pers. comm.). The Chitinozoan assemblage commences in the upper Telychian *spiralis* graptolite biozone; it is unclear if the higher Telychian graptolite biozones are included. The assemblage is typical for strata containing *spiralis* or higher Telychian graptolite biozones; in this case, *M. margaritana* could start at the base of the *spiralis* graptolite biozone, i.e. earlier than elsewhere, where it appears at the base of the *insectus* graptolite biozone (see Mullins, 1998a). The presence of *Desmochitina densa*, together with *Angochitina longicollis*, *Conochitina acuminata*, *Conochitina proboscifera*, *Conochitina (proboscifera) truncata* and *Margachitina margaritana* at the base of the Wenlock corresponds to the occurrence of these species in Shropshire, as observed by Swire (1993).

Mainland Sweden

In a similar study, Grahn (1998) investigated lower Silurian boreholes from mainland Sweden in detail, several of which range into the Wenlock and contain rare graptolite levels. Nederberga 1 (trench S2°W) contains in the upper part of its sequence the typical assemblage of the *margaritana* biozone as defined in the Bülth Wells district (similar to the När 1 borehole assemblage: see above); however, the index species rarely occurs.

The Röstanga 3 and 4 boreholes, which penetrate strata dated as *rigidus* graptolite biozone, contain *Conochitina tuba*, *Margachitina margaritana*, *Euconochitina praeclaviformis* Grahn, 1998 and *Conochitina proboscifera*, and can be correlated with a middle Wenlock assemblage, though the characteristic species, needed for a more detailed division, are absent.

Grahn (1998) proposed a local biozonation for the Wenlock of mainland Sweden, including four biozones (*Angochitina longicollis*, *Euconochitina praeclaviformis*, *Cingulochitina cingulata* and *Sphaerochitina lycoperdoides*) and two subzones. Unfortunately, the index species of the subzones *Ramochitina nestorae* Grahn, 1995 and *Ancyrochitina gutnica* are not observed in the Bülth Wells district. As Grahn stated in 1995, the *margaritana* biozone starts within the *spiralis* graptolite biozone, lower than observed in other areas (see Mullins, 1998b). Grahn (1998) described *Euconochitina praeclaviformis* as a new species for early forms of what was previously determined as *C. claviformis*; this Grahn's species can not yet be used for comparison. *Conochitina tuba* and *Cingulochitina cingulata*, index species for biozones of the Bülth Wells district, appear together at the same level in the *belophorus* graptolite biozone, possibly corresponding to the *dubius* graptolite biozone as defined by Zalasiewicz & Williams (1999) in Bülth Wells. One should note that in the latter area the first index species appears at the top of the *riccartonensis* graptolite biozone and the second index species at the base of the *dubius* graptolite biozone.

Avalonia Builth Wells, Wales, U.K. (This study)	Avalonia Mehaigne, Brabant M (Verniers, 1980, 1982)	Baltica Estonia & N. Latvia (Nestor, 1990, 1994)	Baltica Gotland (Sweden) (Laufeld, 1974)	Baltica Mainland Sweden (Grahn, 1995; in press)	Baltica & Avalonia Calibration Graptolites Chitinozoa	Global Chitinozoa Biozonation
<i>ludensis-nassa</i>	?	<i>ludensis-nassa</i>	<i>ludensis-nassa</i>	<i>ludensis-nassa</i>	<i>ludensis-nassa</i>	<i>lycoperdoides</i>
		interzone V	<i>lycoperdoides</i>		<i>indecora/lycoperdoides</i>	
	<i>lycoperdoides</i>	<i>indecora</i>	interzone		interzone	
		<i>cribrosa</i>			<i>cribrosa</i>	
<i>lundgreni</i>	<i>lundgreni</i>	<i>testis</i>	<i>testis</i>	<i>lundgreni</i>	<i>lundgreni</i>	<i>pachycephala</i>
		<i>radians</i>	<i>radians</i>			
	<i>subcyatha</i>	<i>subcyatha</i>			<i>subcyatha</i>	
	to		<i>pachycephala</i>		<i>pachycephala</i>	
<i>(ellesae)</i>		<i>pachycephala</i>	<i>(ellesae)</i>	<i>ellesae</i>		
		?	?			
<i>rigidus</i>	<i>rigidus</i>	<i>pre-radians</i>	<i>rigidus</i>	<i>rigidus</i>	<i>rigidus</i>	
	<i>pachycephala</i>	<i>post-flexilis</i>			<i>pachycephala</i>	
		<i>lagena</i>			<i>lagena</i>	
			<i>cingulata</i>		<i>cingulata</i>	<i>cingulata</i>
<i>dubius</i>	<i>dubius</i>	<i>belophor./flex.</i>	<i>belophor./antennular.</i>	<i>dubius</i>	<i>dubius</i>	
	<i>tuba</i>	<i>tuba</i>	<i>tuba</i>		<i>tuba</i>	
	(interzone)	<i>et mamilla</i>			(interzone)	
<i>riccarton.</i>	<i>riccarton.</i>	<i>riccarton.</i>	<i>riccarton.</i>	<i>riccarton.</i>	<i>riccarton.</i>	<i>margaritana</i>
	<i>burdinalensis</i>	interzone IV	<i>mamilla</i>	<i>praeclaviform.</i>	<i>burdinalensis</i>	
	<i>murchisoni</i>	<i>murchisoni</i>	<i>murchisoni</i>	<i>murchisoni</i>	<i>murchisoni</i>	
	<i>margaritana</i>	<i>margaritana</i>	<i>margaritana</i>	<i>margaritana</i>	<i>margaritana</i>	
<i>centrifugus</i>	<i>centrifugus</i>	<i>centrifugus</i>	<i>centrifugus</i>	<i>centrifugus</i>	<i>centrifugus</i>	

Text-fig. 4 - Calibration of the Wenlock graptolite and Chitinozoa biozonations in the Builth Wells district and in different other areas from Avalonia and Baltica, where such calibrations were studied (Brabant Massif in Belgium, Gotland and mainland Sweden, and Estonia-Latvia). Stippled lines between the left five columns indicate correlation of the lower boundaries of the Chitinozoa biozones. The right column is the summary of the calibrations as known by now in Avalonia and Baltica. Lines indicate where all authors agree about the calibration. Triangles indicate the range of disagreement by the different authors in the calibration of the lower boundary of the biozones.

Conochitina pachycephala - the index species of a biozone in the Builth Wells district - starts in mainland Sweden at the base of the *rigidus* graptolite biozone, as in the Builth Wells district. The appearance of *Linochitina erratica* at the base of the *dubius-nassa* interregnum is similar as in the Prague Basin. *Sphaerochitina lycoperdoides* starts in the middle of the same interregnum.

One can conclude that, although different index species are used to define the biozonation in mainland Sweden, the ranges of the index species of the Builth Wells biozonation occur at the same levels in relation to the graptolite biozonation (see Text-fig. 4).

Estonia and Latvia

Nestor (1990, 1994), based on more than 2000 samples from the Silurian of East Baltic area, described a formal Chitinozoa biozonation of 26 biozones and 5 interzones. For the Wenlock there are nine biozones and two interzones defined in the Ohesaare reference section, where a graptolite biozonation was presented by Kaljo (1970), and has been recently refined by Loydell *et al.* (1998). The Ventpils borehole allows calibration of the Chitinozoa and the graptolite biozonations, the latter studied by Ulst (*in Gaillite et al.*, 1987). The Chitinozoa biozones are mostly defined as interval zones, with the bases defined by the first occurrences of the index species (*margaritana*, cf. *mamilla*, *tuba*, *cingulata*, *lagena*, *pachycephala*, *cribrosa*). Some biozones are defined as total range zones (*subcyatha* and

indecora), and interzones (IV and V) as intervals with scarce or atypical Chitinozoa species.

The *Margachitina margaritana* biozone is established in levels of the *centrifugus-murchisoni* graptolite biozones in the Ohesaare borehole and in the *murchisoni* graptolite biozone of the Ventpils borehole. The interzone IV is present in the Ohesaare borehole, within the *riccartonensis* and *dubius* graptolite biozones (the latter in the sense of Storch 1994; Loydell *et al.*, 1998) and in the Ventpils borehole, at a lower level in the graptolite biozonation, *i.e.* in the lower half of the *riccartonensis* graptolite biozone. The *Conochitina* sp. cf. *mamilla* biozone is found at levels between the *dubius* and *belophorus/flexilis* graptolite biozones in the Ohesaare borehole, but seemingly lower in the Ventpils borehole, *i.e.* in levels corresponding to the upper half of the *riccartonensis* graptolite biozone. The beginning of the *Conochitina tuba* biozone occurs in the *belophorus/flexilis* graptolite biozones in the Ohesaare borehole. Higher levels are too sparse in graptolites, and contain only long-ranging species which range into overlying Ludlow (Loydell *et al.*, 1998, p. 777). In the Ventpils borehole, however, the graptolite biozonation is described to the top of the Wenlock by Ulst (*in Gaillite et al.*, 1987). The *Conochitina tuba* biozone is found at levels containing successively the *antennularius* and the lowermost *flexilis* graptolite biozones; the *Cingulochitina cingulata* biozone in levels containing the uppermost *flexilis* graptolite biozone; and the *Conochitina lagena* biozone in levels between the *flexilis* and the *radians* (= lower part of the *lundgreni*) graptolite biozones,

believed to roughly correspond to the *perneri* graptolite biozone. The *pachycephala* biozone is found partly below and partly within an interval that roughly corresponds to the lower half of the *radians* graptolite biozone. Hence, in Estonia the base of the *Conochitina pachycephala* biozone can only be calibrated versus the graptolite biozonation within a broad interval situated above the *flexilis* and below the *lundgreni* graptolite biozones. The *Conochitina subcyatha* biozone is found in an interval containing the upper half of the *radians* to the lower part of the *testis* (= upper part of the *lundgreni*) graptolite biozone. The *Conochitina cribrata* biozone is found at levels comprising the upper part of the *testis* graptolite biozone and the basal part of the *nassa* graptolite biozone. The *Sphaerochitina indecora* biozone is encountered at levels with the upper part of the *nassa* graptolite biozone; at the top of the Wenlock, the interval zone V is situated at levels correlated with the *ludensis* graptolite biozone.

NORTH GONDWANA

Perunica (Bohemia)

Several studies by Dufka in the Silurian of the Prague Basin presented a calibration between the graptolite and Chitinozoa biozonations. In a preliminary study of 9 samples through the Wenlock, Dufka (1992) could determine several taxa but left other taxa under an open nomenclature. However, the association of *Margachitina margaritana* and *Conochitina proboscifera* with *Conochitina (proboscifera) truncata* is typical for the lower three graptolite biozones in the Wenlock. Following the present study, a possible synonymy of *Eisenackitina?* sp. (Pl. 3, fig. 3) with *E. causiata* sp. nov., and of *Belonechitina?* sp. (Pl. 3, fig. 4) with *Cingulochitina dreyensis* sp. nov. is suggested. Both new species occur in the same assemblage. *Conochitina proboscifera* and related forms are described from graptolite levels dated as mid Wenlock, which is an unusually high occurrence for this species. One would expect only *C. spp.* aff. *C. proboscifera* here, but they are not mentioned at these levels in Dufka *et al.* (1995). In the *lundgreni* graptolite biozone *Conochitina tuba* is found (as in the Builth Wells district, although it appears much earlier in this last locality; see above), together with *Sphaerochitina sphaerocephala* (Eisenack, 1932), a form which is normally found in the uppermost Ludlow and Pridoli. The only figured specimen (Pl. 3, fig. 12) could be a synonym of *Sphaerochitina lycoperdoides*. The data are too limited to allow a detailed comparison with Builth Wells.

The Chitinozoa from graptolite-dated sections of the upper Wenlock (*lundgreni* graptolite biozone and higher) and Ludlow were first studied in detail by Dufka (*in* Kriz *et al.*, 1993). There is a drastic change in Chitinozoa composition at the transition between the *lundgreni* and the *dubius-parvus* graptolite biozones. *Margachitina margaritana* has its last occur-

rence at the top of the *testis* subzone (*lundgreni* graptolite biozone), while new species appear which are not encountered at Builth Wells. *Conochitina pachycephala* is reported to appear at the top of the *lundgreni* graptolite biozone, but it appears lower in the Builth Wells district (in the upper *rigidus* graptolite biozone), showing an apparent diachronic first occurrence in comparison with the graptolite biozonation.

Dufka (1995) studied the Chitinozoa from the middle Wenlock to lower part of the upper Wenlock (*belophorus* to *lundgreni* graptolite biozones) in the graptolite dated Kosov section. The *belophorus* graptolite biozone, which may be correlated with the *dubius* graptolite biozone of the Builth Wells district (Zalasiewicz & Williams, 1999), contains *Margachitina margaritana* and *Conochitina* sp. cf. *C. proboscifera* as well as two *Cingulochitina* species (listed under open nomenclature) which are not present at Builth Wells or in Belgium. Questionable determinations of *Cingulochitina cingulata* are mentioned at the base of the sequence, but the species is definitely present midway through the *rigidus* graptolite biozone and continues until the *radians* subzone of the *lundgreni* graptolite biozone. Questionable determinations of *Conochitina tuba* are mentioned midway through the *rigidus* graptolite biozone, while the species is definitely present from the base of the *perneri/ramosus* graptolite biozone upwards; i.e., higher than in Builth Wells district. *Linochitina* sp. cf. *L. erratica* and *L. sp.* cf. *L. odiosa* (Laufeld, 1974) appear at the top of the *perneri/ramosus* graptolite biozone and continue to the top of the Wenlock, but are not observed in the U.K. ?*Urnochitina* sp. A of Dufka (1995), starting at the base of the *testis* graptolite biozone, is a form similar to *Conochitina cribrata*, which starts in Builth Wells at the same level in the graptolite biozonation, midway through the *lundgreni* graptolite biozone. If this synonymy can be confirmed by subsequent studies, this could mark another corresponding calibration between the two biozonations.

The Chitinozoa of the lower Wenlock were studied by Dufka *et al.* (1995) from three boreholes (B48, B57, B71) containing graptolites from the Llandovery-Wenlock transition (*insectus-centrifugus* graptolite biozone) to the middle Wenlock (*belophorus* graptolite biozone). A lower assemblage, in layers of the *insectus* or *centrifugus* graptolite biozone, contains, among others, *Margachitina margaritana*, *Conochitina proboscifera* and a species which is here interpreted as a possible synonym of *Cingulochitina dreyensis* sp. nov. or *Eisenackitina causiata* sp. nov. Higher within the same assemblage, *Conochitina (proboscifera) gracilis* (Laufeld, 1974) and a *Cingulochitina* (listed under open nomenclature) appear; but both these species are not observed in Builth Wells. This assemblage typically occurs in the uppermost Llandovery and lower Wenlock graptolite biozones (*insectus* to *riccartonensis* graptolite biozone interval). Levels from the *dubius* and *belophorus* graptolite bio-

zones contain *Margachitina margaritana*, *Conochitina* sp. aff. *C. proboscifera* and *Linochitina* sp. cf. *L. odiosa*.

Hence, similarities - but also many differences - are observed between the calibrations of the biozonations in the Builth Wells district and the Prague Basin. To clarify the discrepancies, more studies are needed to fill stratigraphical gaps in the Prague Basin.

LAURENTIA

White *et al.* (1992) described some Chitinozoa from graptolite-dated sequences in the Wenlock turbidites of the southwestern Southern Uplands, Scotland. They found *Cingulochitina cingulata* at a level tentatively dated as *lundgreni* graptolite biozone, and *Margachitina margaritana* at a level dated as *centrifugus* to *murchisoni* graptolite biozones. This corroborates the previous calibrations as shown above and also those in Verniers *et al.* (1995).

CONCLUSIONS RELATING TO CALIBRATION OF WENLOCK GRAPTOLITE AND CHITINOZOA BIOZONATIONS

In five areas, on eastern Avalonia and southwestern Baltica, an at least partial calibration between Chitinozoa and graptolite biozonations for the Wenlock has been established: Builth Wells district (U.K.), Brabant Massif (Belgium), Estonia and northern Latvia, Gotland (Sweden) and mainland Sweden (Text-fig. 4). For Chitinozoa, a similar succession of nine biozones and two interzones (the latter two being the expression of extinction events), is present in at least three of the five areas. From bottom to top: three lower Wenlock biozones (*margaritana*, *mamilla*, and *burdinalensis*) - followed by an important, lower extinction event - and six middle to lower upper Wenlock biozones (*tuba*, *cingulata*, *lagna*, *pachycephala*, *subcyatha*, and *cribrosa*). The *margaritana* biozone is here a local biozone with a range shorter than the global biozone; the *mamilla* biozone is different from the Estonian cf. *mamilla* biozone of Nestor (1990).

Higher in the upper Wenlock but not in the study area, after a second extinction event, several *Sphaerochitina* spp. appear in the *indecorallycoperdoides* biozone, and higher up more extinctions in the uppermost Wenlock (Kaljo *et al.*, 1995).

If we compare this Chitinozoa succession with the graptolite succession, we observe that the Wenlock part of the local *margaritana* biozone coincides with the *centrifugus* and *murchisoni* graptolite biozones. The *mamilla* and *burdinalensis* biozones are present respectively in the lower and upper part of the *riccartonensis* graptolite biozone. The lower extinction event is either located in the topmost part of the *riccartonensis* zone (Builth Wells district) or in the *dubius* graptolite biozone (other areas). The *mamilla* and the *burdinalensis* biozones are not recognised in Estonia where only an interzone is observed. In

Gotland only the *burdinalensis* biozone is unknown. This absence can possibly be explained by the eustatic sea level low at that time, with the beginning of extensive reef building in different regions (see Nestor & Einasto, 1997), the shallow turbiditic MB4 Formation in Belgium (Verniers, 1983), and the very shallow to supra-tidal deposits of the top of the Höglint and Tofta Beds in Gotland (Laufeld, 1974). This resulted in an environment in the Baltic area which was too shallow for the chitinozoan mode of life.

The middle to lower upper Wenlock Chitinozoa and graptolite biozones do not correlate as accurately as those of the lower Wenlock. The slight shifts between the calibrations of biozonations of the two groups can possibly be explained by the differences in sample density between the areas, discontinuous or condensed sequences or also by differences in the definition of the graptolite biozones in the various regions, prior to the redefinition of the middle and low upper Wenlock graptolite biozones by Zalasiewicz & Williams (1999). More detailed sampling in the study areas and other localities could clarify whether the apparent diachronous appearances (Text-fig. 4) are real or an artefact. Furthermore, a possible explanation for the later appearances can be given by deeper water species (e.g., *Cingulochitina cingulata*, see Rombouts, 1982) which will appear later in shallower waters during transgressions. The calibration of the upper part of the upper Wenlock biozones is beyond the scope of this study, due to the scarcity of graptolites in the studied levels. However, the Chitinozoa in the upper two samples of the Builth Wells district, only generally dated as *nassa-ludensis* graptolite biozones, are (by comparison with the other areas mentioned above) still antecedent the post-*lundgreni* extinction event, and possibly very low in the *nassa-ludensis* graptolite biozone interval.

The lower extinction event is not recognised by Kaljo *et al.* (1995) as a generalized Silurian bio-event, but only as an extinction event of Chitinozoa, which they place in the *riccartonensis* graptolite biozone. As a result of the present study, this event can be more accurately located at the very top of the *riccartonensis* graptolite biozone as defined by Zalasiewicz & Williams (1999).

SYSTEMATIC PALAEONTOLOGY

SYNONYMIES

The Chitinozoa assemblages of the Builth Wells district are similar to those of the Mehaigne area (Brabant Massif, Belgium, Avalonia) studied by Verniers (1982). In the latter paper, many species were classified under open nomenclature because of the moderate to poor state of preservation, even though the abundance was rather high. Some researchers described several of them as new species

from studies of their own material; these and other systematic studies call to propose a synonymy list as follows: *Conochitina fortis* Nestor, 1984, is the same form as *Conochitina* sp. D Verniers, 1982 and a senior synonym of *Conochitina fumaliensis* Verniers, 1998. *Angochitina longicollis* Eisenack, 1959 includes *Sphaerochitina* sp. A Verniers, 1982, on which the ornamentation has disappeared. *Conochitina acuminata* Eisenack, 1959 includes *Conochitina flamma* Laufeld, 1974 in Verniers, 1982, because its length is too short to be included in *C. flamma*. *Conochitina subcyatha* Nestor, 1982 is the same form as *Conochitina* sp. C Verniers, 1982, but also incorporates *Conochitina* sp. E Verniers, 1982. The forms called *Conochitina armillata*? Taugourdeau & de Jekhowsky, 1960 in Verniers, 1982 are now classified as either *Conochitina pachycephala* Eisenack, 1964, (when they have an orally constricted basal edge) or *Conochitina claviformis* Eisenack, 1931 (when they have not). The form *Conochitina brevis brevis*? Taugourdeau & de Jekhowsky, 1960 in Verniers, 1982 is considered now as *Conochitina lagena* Eisenack, 1968. Two forms in this study are probably identical to the *nomina nuda* from the Wenlock of Sardinia (Pittau, 1998: unpublished Excursion guide of the C.I.M.P. - Pisa '98 Symposium and Excursion). *Ancyrochitina* sp. A could correspond to *Sphaerochitina serpaglii* Pittau, 1998 and *Ancyrochitina* sp. B to *Sphaerochitina jaegeri* Pittau, 1998.

ABBREVIATIONS, REPOSITORY, GRAPTOLITE BIOSTRATIGRAPHY

Abbreviation used in descriptions below: elongation = maximal width divided by the maximal length of the Chitinozoa. Measurements are sometimes given by three numbers; i.e., the minimum, the average and the maximum value observed. All specimens studied are stored in the collections of the Laboratory for Palaeontology, University of Ghent, Belgium. Graptolite biostratigraphy for the Builth Wells district is according to Zalasiewicz & Williams (1999).

Incertae sedis group CHITINOZOA Eisenack, 1931

Order OPERCULATIFERA Eisenack, 1972

Family DESMOCHITINIDAE Eisenack, 1931 emend.
Paris, 1981

Subfamily PTEROCHITININAE Paris, 1981

Genus CINGULOCHITINA Paris, 1981

Type species – *Desmochitina cingulata* Eisenack, 1937.

CINGULOCHITINA ANGUSTA sp. nov.

1981 *Linochitina* sp. A VERNIERS, pl. 2, fig. 30.

1982 *Cingulochitina* sp. A VERNIERS, p. 23, pl. 7, figs. 138-142.

Derivation of name – Latin *angustus*, narrow, referring to the small width-length relation.

Holotype – Illustrated in Verniers, 1982, pl. 7, fig. 185, Section IF-9, sample 11.5 m above logged section, slide IF-9/11.5 m, specimen Ch423, England-Finder co-ordinates E39.

Type locality and stratum – Section IF-9, Les Falihottes, Fallais, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 86, 98); Formation MB3, member MB3D, upper Telychian, Llandovery.

Material – 11 specimens in the Mehaigne area.

Diagnosis – The small elongation (maximal width divided by the maximal length) between 0.32 and 0.37, the very convex base and the ridge-like, low carina in the middle of the basal edge is characteristic.

Description – A cylindrical, slightly ovoid general shape; indistinct shoulders and flexure, a fine and small collarette, the neck passing gradually into the slightly ellipsoid chamber; the basal edge very rounded and a very convex base; a mucron or the impression of one is present; in the middle of the large basal edge a ridge-like low carina is visible and the basal edge does not change its curve under this carina; the tegument is smooth and very thin (about 1 µm).

Occurrence – In the Mehaigne area: rare in the late Llandovery to early Wenlock; members MB3D to basal MB4A.

Biometry – Measurements on 11 specimens from the Mehaigne area: length 141-153-163 µm, max. width 43-53-57 µm, width at the collarette 32-38-55 µm; elongation 0.32-0.34-0.37; opening of the pseudostome 0.59-0.71-0.92; Builth Wells: length 130 µm, max. width 43 µm, width at the collarette: 31 µm; elongation: 0.33.

Discussion – It clearly differs from the other *Cingulochitina* species by its slender shape and very convex base.

Stratigraphical range – Rare in the Mehaigne area, in the late Llandovery and early Wenlock: in certain samples from members MB3D and the base of MB4A; in Ithon East, Wales: sample K30.

CINGULOCHITINA BOUNIENSIS sp. nov.

1979 *Linochitina* sp. B VERNIERS & RICKARDS, p. 157, pl. 1, figs. 9-10.

1981 *Linochitina* sp. B VERNIERS, p. 171, pl. 2, fig. 24.

1982 *Cingulochitina* sp. B VERNIERS, pp. 23-24, pl. 7, figs. 143-147, 150-156.

Derivation of name – From the old water mill Bounia, where the stratotype section of the MB4 Formation is situated, Burdinale valley, Mehaigne area, Brabant Massif, Belgium.

Holotype – Illustrated in Verniers, 1982, pl. 7, fig. 146; section CD-22E, bed 35, upper shale part, slide CD-22E/35, specimen Ch283, England-Finder co-ordinates O48.

Type locality and stratum – Bounia, Lamontzée, Burdinale valley, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 78, 102); Formation MB4, member MB4B, lower Wenlock.

Material – 106 specimens in the Mehaigne area.

Diagnosis – A small *Cingulochitina* with a short ridge-like carina, very rounded basal edge and longitudinal folds as ornamentation, making it dissimilar to all other *Cingulochitina* sp.

Description – A slightly cono-ovoid shape, with a short or no neck; no shoulders and an indistinct flexure; an ovoid chamber, a very rounded basal edge and a round convex base where a low mucron is present; frequently in chains. In solitary specimens a ridge-like carina is present under the basal edge. The tegument is thin and seems to fold, in most cases, parallel to the longitudinal axis.

Biometry – Measurements on more than 88 specimens from the Mehaigne area material: length 84–98–117 µm, max. width 48–62–70 µm, width at the collarete 30–47–57 µm; elongation 0.38–0.63–1.05; opening of the pseudostome 0.56–0.71–0.91.

Stratigraphical range – Mehaigne area: atypical in the late Llandovery member MB3, rare to dominant in the early Wenlock Formation MB4 (especially dominant in samples 29 and 30); Builth Wells: Ithon East and Trecoed, samples containing the index species of the *murchisoni* and *riccartonensis* graptolite biozones.

CINGULOCHITINA BURDINALENSIS sp. nov.
Pl. 1, figs. 3–4

1979 *Linochitina* sp. G VERNIERS & RICKARDS, p. 157, pl. 1, figs. 3, 4.

1981 *Linochitina* sp. F VERNIERS, p. 171, pl. 2, fig. 23.

1982 *Cingulochitina* sp. F VERNIERS, p. 27, pl. 6, figs. 129–132.

Derivation of name – From the name of the valley and river La Burdinale, Mehaigne area, Belgium, where the holotype occurs.

Holotype – Illustrated in Verniers, 1982, pl. 6, fig. 130; section CD-22E, bed 35, upper shale part, slide

CD-22E/35, specimen Ch329, England-Finder co-ordinates L53/3.

Type locality and stratum – Bounia, Lamontzée, Burdinale valley, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 78, 102); Formation MB4, member MB4B, lower Wenlock.

Paratypes – Illustrated in Verniers, 1982, pl. 6, fig. 131 and 132, section CD-22E, bed 35, upper shale part, slide CD-22E/35, specimens Ch48 and Ch291, England-Finder co-ordinates O54/1 and V48/4, respectively.

Material – More than 32 specimens in the Mehaigne area.

Diagnosis – A large, wide *Cingulochitina* with very short neck and an obvious carina.

Description – Large ovoid forms, no collarete, very short neck, no flexure, slight shoulders, the chamber is orally conical and ovoid in the middle; the basal edge is sharp with a carina (3–5 µm wide) on it; the base, concave with an impression of the mucron; an operculum is sometimes observed on top of the pseudostome.

Biometry – Two size variants occur in the same samples of the Mehaigne area. The smaller variety, measurements on 9 specimens from the Mehaigne area: length 65–99–120 µm, max. width 74–88–100 µm, width at the collarete 40–47–55 µm; elongation 0.77–0.94–1.15; opening of the pseudostome 0.44–0.54–0.59. The larger variety, measurements on 8 specimens from the Mehaigne area: length 94–128–177 µm, max. width 102–117–145 µm, width at the collarete 57–69–85 µm; elongation 0.75–0.94–1.26; opening of the pseudostome 0.50–0.59–0.68. Measurements on 6 specimens from Builth Wells: length 86–150 µm, max. width 76–88 µm, width at the collarete 40–45 µm; elongation 0.66–0.89; opening of the pseudostome 0.46–0.58.

Discussion – The larger variant slightly resembles *Cyathochitina* cf. *dispar* Benoit & Taugourdeau, 1961, in Cramer, 1967 (p. 85) and ?*Cyathochitina dispar* Benoit & Taugourdeau, 1961, in Cramer, 1964 (p. 344 and pl. 23, figs. 8, 13–14) but differs by its smaller size, the lack of a long neck and the presence of an operculum.

Stratigraphical range – In the Mehaigne area: early Wenlock (*riccartonensis* graptolite biozone) to middle Wenlock; rare to frequent (up to 18%) in member MB4B and the base of Formation MB5, also rare but atypical in the middle of the late Wenlock, at the base of Formation MB7. In Builth Wells: in the upper half of the *riccartonensis* graptolite biozone only.

CINGULOCHITINA DREYENSIS sp. nov.

Pl. 1, fig. 7

- 1979 *Linochitina* sp. C VERNIERS & RICKARDS, p. 157, pl. 1, figs. 11, 12.
 1979 *Linochitina* sp. D VERNIERS & RICKARDS, p. 157, pl. 1, figs. 13-14.
 1981 *Linochitina* sp. C VERNIERS, p. 171, pl. 2, fig. 20.
 1981 *Linochitina* sp. D VERNIERS, p. 171, pl. 2, fig. 25.
 1982 *Cingulochitina* sp. C VERNIERS, pp. 24-25, pl. 6, fig. 125; pl. 7, figs. 170-182.
 1982 *Cingulochitina* sp. D VERNIERS, pp. 25-26, pl. 6, figs. 123; pl. 7, figs. 183-190.
 1992 *Belonechitina?* sp. DUFKA, p. 119, pl. 3, fig. 4.
 1995 *Cingulochitina* sp. C Verniers 1982 - GRAHN, fig. 6K.

Derivation of name – From the small village Dreye, in the Mehaigne area, where the best outcrop (KF-2) of the type stratum occurs.

Holotype – Illustrated in Verniers, 1982, pl. 7, fig. 185; section CD-1A, bed 33, slide CD-1A/33, specimen Ch193, England-Finder co-ordinates L20/1.

Type locality and stratum – Rue de Rochée, Lamontzée, Burdinale valley, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 77, 100); Formation MB4, member MB4A, lowermost Wenlock.

Paratype – Illustrated in Verniers, 1982, pl. 7, fig. 173, section CD-1A, bed 6, slide CD-1A/6, specimen Ch186, England-Finder co-ordinates: V24/1-U24/3, repository: Laboratory for Palaeontology, University of Ghent, Belgium.

Material – 757 specimens in the Mehaigne area.

Diagnosis – The species has a trapezoid form with or without neck, short ridge-like carina, sharp basal edge.

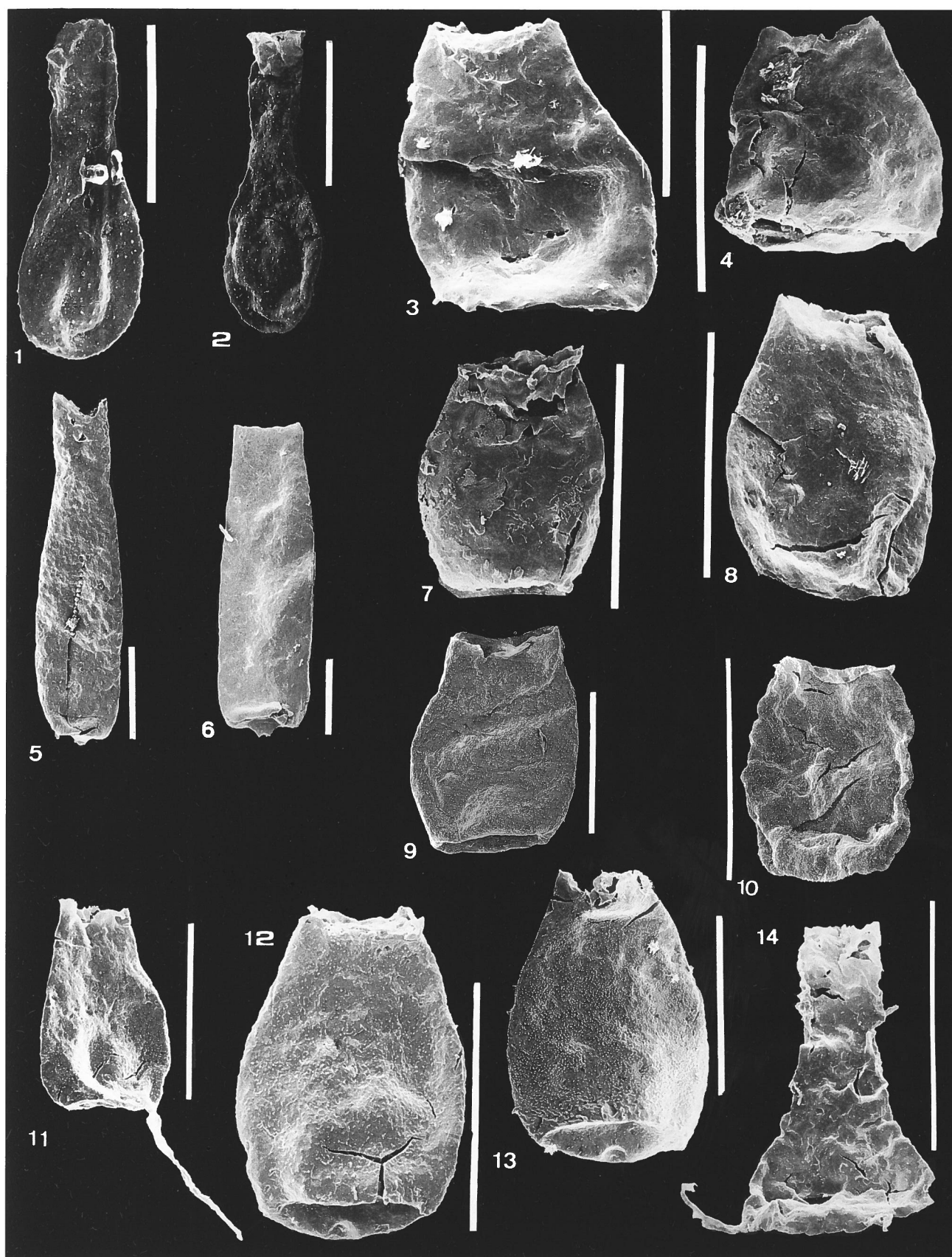
Description – The short forms are ovoid, slightly conical with a short to very short neck and a short, simple, thin collarette; often the neck narrows quite abruptly when it passes into the collarette in which case the specimen usually has an operculum on top of the pseudostome; in several cases, the impression of a thin prosome can be seen in flattened specimens about ten μm aboral of the pseudostome; the prosome can sometimes stick out of the neck (Verniers, 1982, pl. 7, fig. 170). In other cases no operculum or prosome have been observed; in this last case the neck together with the collarette is cylindrical and subconical (Verniers, 1982, pl. 7, fig. 172); the chamber is generally ovoid and slightly conical; the basal edge is usually rounded, and the base convex, or rarely flat; in the middle of the basal edge a ridge-like low carina occurs; the basal edge does not change its curvature under the carina; a low mucron sometimes occurs but mostly only an opening is seen; the tegument is thin and usually smooth, or sometimes covered with fine spines or granules or very vague concentric rings oblique to the longitudinal axis; no chains were observed.

The longer forms are cono-ovoid to cylindro-ovoid with a medium-long to long neck and a thin collarette in the prolongation of the neck; in some cases the neck narrows just below the collarette; the

EXPLANATION OF PLATE 1

- Figs. 1, 2 - *Angochitina longicollis* Eisenack, 1959. 1) sample K21C, preparation 95028, S.E.M. stub K21C, specimen Ch2, River Ithon east section, x335; 2) sample K21B, preparation 95027, S.E.M. stub K21B, specimen Ch8, River Ithon east section, x270.
 Figs. 3, 4 - *Cingulochitina burdinalensis* sp. nov. 3) sample K34B, preparation 970083, S.E.M. stub K34B, specimen Ch1, River Ithon east section, x350; 4) sample K34B, preparation 970083, S.E.M. stub K34B, specimen Ch20, Ithon east section, x465.
 Fig. 5 - *Conochitina (proboscifera) truncata* Laufeld, 1974, sample K34C, preparation 970082, S.E.M. stub K34C, specimen Ch19, River Ithon east section, x180.
 Fig. 6 - *Conochitina proboscifera* Eisenack, 1937, sample K34C, preparation 970082, S.E.M. stub K34C, specimen Ch8, River Ithon east section, x140.
 Fig. 7 - *Cingulochitina dreyensis* sp. nov., sample K34C, preparation 970082, S.E.M. stub K34C, specimen Ch13, River Ithon east section, x465.
 Figs. 8, 9 - *Eisenackitina anulifera* sp. nov. 8) sample K34B, preparation 970083, S.E.M. stub K34B, specimen Ch2, River Ithon east section, x465; 9) sample K29, preparation 970043, S.E.M. stub K29, specimen Ch19, River Ithon east section, x265.
 Fig. 10 - *Eisenackitina causiata* sp. nov., sample K29, preparation 970043, S.E.M. stub K29, specimen Ch4, River Ithon east section, x420.
 Fig. 11 - *Salopochitina bella* Swire, 1990, sample K31, preparation 970076, S.E.M. stub K31, specimen Ch7, River Ithon east section, x330.
 Fig. 12 - *Eisenackitina ithoniensis* sp. nov., sample K34C, preparation 970082, S.E.M. stub K34C, specimen Ch3, River Ithon east section, x465.
 Fig. 13 - *Eisenackitina ithoniensis* sp. nov., holotype, sample K34B, preparation 970082, S.E.M. stub K34B, specimen Ch3, River Ithon east section, x465.
 Fig. 14 - *Ancyrochitina ancyrea* (Eisenack, 1931), sample K34C, preparation 970082, S.E.M. stub K34C, specimen Ch12, River Ithon east section, x465.

Provenance: River Ithon east section, SE of Newbridge on Wye, Bulth Wells district, U.K.; repository: Laboratory for Palaeontology, University of Ghent, Belgium; scale: white bar = 100 μm .



flexure and shoulders are indistinct; the chamber is slightly cono-ovoid or ovoid, the basal edge, sharp or very sharp, with a low, ridge-like carina occurring on it; a slight constriction of the chamber can occur orally of the carina; the base is slightly convex or flat with an opening in the middle; only seldom is a low mucron observed; the tegument is thin, covered with fine spines or granules, or sometimes smooth.

Biometry – Small variety, measurements on 60 specimens from the Mehaigne area: length 79–101–117 μm , max. width 54–65–72 μm , width at the collarete 26–42–49 μm ; elongation 0.50–0.64–0.92; opening of the pseudostome 0.46–0.61–0.69. Large variety, measurements on 65 specimens from the Mehaigne area: length 89–118–143 μm , max. width 55–64–72 μm , width at the collarete 27–47–64 μm ; elongation 0.48–0.54–0.65; opening of the pseudostome 0.43–0.68–0.81. Measurements in Builth Wells, on 6 specimens: length 75–115 μm , max. width 55–90 μm , width at the collarete 35–54 μm ; elongation 0.67–1.06.

Discussion – *Cingulochitina dreyensis* sp. nov. slightly resembles *Cingulochitina cingulata* by its general form and because sometimes a faint constriction of the chamber just orally of the carina is present; it differs from the latter by its more elongated ovoid chamber, its maximal width close to the basal edge, indistinct shoulders and flexure and by the low ridge-like carina and the possible point ornamentation. *Cingulochitina dreyensis* sp. nov. can be differentiated from *Cingulochitina pitetensis* sp. nov. on a width/length diagram; the latter is slightly more slender, longer and has a clear mucron and a more pronounced carina.

Stratigraphical range – In the Mehaigne area: rare to present in the late Llandovery members MB3C and MB3D; rare to dominant in the late Llandovery or early Wenlock member MB3E and the base of member MB4A, and rare to present in the rest of the early Wenlock Formation MB4. In the Builth Wells district: at least from *centrifugus* to *dubius* graptolite biozones.

CINGULOCHITINA PITETENSIS sp. nov.

- 1979 *Linochitina* aff. *cingulata* Eisenack 1937 - MARTIN & RICKARDS, p. 194, pl. 1, fig. 7.
 1981 *Linochitina* sp. E VERNIERS, p. 171, pl. 2, fig. 28.
 1982 *Cingulochitina* sp. E VERNIERS, pp. 26–27, pl. 6, figs. 133–137.

Derivation of name – The hamlet Pitet, in Fallais, Mehaigne area, Belgium, locality of the holotype.

Holotype – Illustrated in Verniers, 1982, pl. 6, fig. 134; section IF-9, sample 11.5 m above logged section, slide IF-9/2.5 m, specimen Ch280, England-Finder co-ordinates N21/1-3.

Type locality and stratum – Locality IF-9, Les Falihtottes, Pitet, Fallais, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 86, 98); Formation MB3, member MB3D, upper Telychian, Llandovery.

Paratypes – Illustrated in Verniers, 1982, pl. 6, fig. 136; section IF-9, sample 11.5 m above logged section, slide IF-9/11.5 m, specimens Ch442–443, England-Finder co-ordinates: E44, repository: Laboratory for Palaeontology, University of Ghent, Belgium.

Material – 60 specimens in the Mehaigne area.

Diagnosis – The species has a slender and elongated, ovoid chamber, vague flexure and indistinct shoulders, a small protruding mucron and the lack of constriction, orally of the carina.

Description – A cylindro-ovoid general shape, with a medium-long neck, ending in an ample or widening collarete; a slight flexure and indistinct shoulders, an elongated ovoid chamber, a very sharp basal edge on which a ridge-like carina occurs; the base is flat or slightly convex with a small protruding mucron; in several specimens the collarete of the underlying individual still hangs on to the basal edge and hides the base; the tegument is thin and smooth; quite often observed in chains of two specimens.

Biometry – Measurements on 37 specimens from the Mehaigne area: length 94–118–156 μm , max. width 50–56–60 μm , width at the collarete 32–41–50 μm ; elongation 0.36–0.45–0.59; opening of the pseudostome 0.55–0.72–0.92. Measurements on 2 specimens from Builth Wells district: length 106–126 μm , max. width 59–60 μm , width at the collarete 40–47 μm ; elongation: 0.47–0.56.

Discussion – *C. pitetensis* sp. nov. differs from *C. cingulata* by its much shorter carina, by its more slender and more elongated, ovoid chamber, by its vague flexure and indistinct shoulders, its small protruding mucron and the lack of constriction, orally of the cingulum. *C. pitetensis* sp. nov. differs from *C. dreyensis* sp. nov. by its more slender form, the presence of a small protruding mucron and the always smooth tegument. Both last species can be differentiated on a width-length diagram.

Stratigraphical range – In the Mehaigne area: rare to present in the late Llandovery and early Wenlock, in members MB3C, MB3D and MB3E and the base of MB4A. In the Builth Wells district: present in the middle part of the *riccartonensis* graptolite biozone; from the base of *dubius* graptolite biozone upwards the similar form *Cingulochitina cingulata* appears.

Order OPERCULATIFERA Eisenack, 1972
Family DESMOCHITINIDAE Eisenack, 1931, emend.
Paris, 1981

Subfamily EISENACKITININAE Paris, 1981

Genus EISENACKITINA Jansonius, 1964

Type species – *Eisenackitina castor* Jansonius, 1964.

EISENACKITINA ANULIFERA sp. nov.
Pl. 1, figs. 8-9.

- 1979 *Eisenackitina concava* Eisenack 1972 - VERNIERS & RICKARDS, pl. 2, fig. 11.
1981 *Eisenackitina* sp. A VERNIERS, pl. 2, figs. 18-19.
1982 *Eisenackitina* sp. A VERNIERS, pp. 42-43, pl. 5, figs. 89-97, 102.

Derivation of name – Latin *anulus* and *-fera*: bearing rings, referring to the ring-like thickenings of the wall.

Holotype – Illustrated in Verniers, 1982, pl. 5, fig. 93; section CD-20, bed 33, slide CD-20/33, specimen Ch132, England-Finder co-ordinates: P27/2.

Type locality and stratum – Locality CD-20, near Bounia, Lamontzée, Burdinale valley, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 78, 101); Formation MB4, member MB4A, lower Wenlock.

Paratype – Illustrated in Verniers, 1982, pl. 5, fig. 89AB; section CD-1A, bed 33, lower Wenlock, S.E.M. stub CD-1A/33 (1979), specimen Ch3.

Material – 294 specimens in the Mehaigne area.

Diagnosis – Thick walled *Eisenackitina* with clear shoulders, often smooth and ring-like thickening on the chamber and bottom.

Description – A medium-sized *Eisenackitina* species with a cono-ovoid form, a short neck, no collarette, a distinct flexure and shoulders, a conical or ovoid chamber; the basal edge is round to sharp, and the base, usually flat, sometimes convex, with a mucron or the impression from one on it; in some cases an operculum is observed on top of the pseudostome or in the neck. The tegument inside is smooth, and outside, slightly rugose or covered with felt; in several cases concentric rings also occur around the shoulders (Verniers, 1982, pl. 5, figs. 93-95). In broken specimens the internal structures, the internal decorations of the tegument, and the changes in thickness of the tegument can be observed (Verniers, 1982, pl. 5, figs. 95-96). Verniers' (1982) fig. 96 shows a thin operculum that starts from an internal layer of the tegument and sits in the middle of the neck. The tegument is thick at the chamber and begins to thin

halfway up the chamber towards the pseudostome, and also at the base towards the mucron (Verniers, 1982, pl. 5, fig. 95). Concentric rings can occur around the mucron on the base. Occasionally instead of a mucron, a sudden thinning of the tegument can be observed where normally the mucron is situated.

Biometry – Measurements on 203 specimens from the Mehaigne area: length 84-139-210 µm, max. width 80-114-145 µm, width at the collarette 28-59-91 µm; elongation: 0.63-0.89-1.33; opening of the pseudostome 0.31-0.53-0.68. Measurements on 22 specimens from Buih Wells: length 90-129-175 µm, max. width 62-91-130 µm, width at the collarette 32-45-63 µm; elongation 0.56-0.77-0.92.

Discussion – *E. anulifera* sp. nov. is similar to *E. dolioliformis* Umnova, 1976, but smaller and thinner walled. It differs from *Eisenackitina causiata* sp. nov. which is smaller and has no concentric rings but more often a rugose ornamentation on a thin wall.

Stratigraphical range – In the Mehaigne area: rare in Formation MB2; rare to frequent (up to 44%) in Formations MB3 and MB4 (middle and late Llandovery, early Wenlock) atypical forms occur infrequently in the top of Formation MB4 (sample 33), and Formations MB5, MB6 and MB7 (middle and late Wenlock). In the Buih Wells district: from *centrifugus* to *riccartonensis* graptolite biozones.

EISENACKITINA CAUSIATA sp. nov.
Pl. 1, fig. 10

- 1971 *Conochitina* sp. nov. 1 LAUFELD, p. 295, Pl. I D.
1979 *Eisenackitina bursa* Taugourdeau & De Jekhowsky 1960 - VERNIERS & RICKARDS, p. 154, pl. 2, figs. 9, 10.
1981 *Eisenackitina* sp. C VERNIERS, p. 171, pl. 2, fig. 22.
1982 *Eisenackitina* sp. C VERNIERS, pp. 44-45, pl. 5, figs. 103-119; pl. 6, figs. 120-121.
1992 *Eisenackitina?* sp. DUFKA, p. 119, pl. 3, fig. 3.
1995 *Cingulochitina* sp. C Verniers 1982 - GRAHN, figs. 6K & L.

Derivation of name – Greek, *causia*, sun hat, due to the conical form of the operculum.

Holotype – Illustrated in Verniers, 1982, pl. 5, fig. 106; section CD-1A, bed 33, S.E.M. stub CD-1A/33 (1979), specimen Ch7.

Type locality and stratum – Locality CD1A, rue de Rochée, Lamontzée, Burdinale valley, Mehaigne area, Belgium (exact location: Verniers, 1983, pp. 77, 100); Formation MB3, member MB3E, uppermost Telychian, Llandovery.

Paratypes – Illustrated in Verniers, 1982, pl. 5, fig. 105, and pl. 6., fig. 120; section CD-1A, bed 33, lowermost Wenlock, S.E.M. stub CD-1A/33 (1979), specimens Ch4 and Ch5.

Material – 365 specimens in the Mehaigne area.

Diagnosis – Cono-ovoid form, no shoulders nor neck, thin walled with fine ornamentation of spines, verrucae or rugae, a conical operculum with a small protruding central part.

Description – A small cono-ovoid form, no shoulders and nearly no neck, only a collarette and in many cases an operculum, often with an elevation in the middle; in some flattened specimens, the impression from an operculum is seen inside the neck (Verniers, 1982, pl. 5, fig. 109); in other specimens no prosome or operculum is observed; the flexure is indistinct shoulders are seldom observed; the chamber is ovoid and the basal edge gentle to sharp; in some cases, there is a small depression on the tegument in the centre of the base which does not connect with the interior; the base is flat or gently convex; the tegument is thin and usually decorated with fine spines, granules, or an irregular, reticular, rugose ornamentation; this decoration is usually found around the basal edge and the lower part of the chamber, and decreases towards the pseudostome and the centre of the base. Some specimens are smooth, possibly due to abrasion.

Most specimens form a concentrated cluster on a length-width diagram, but some variants also occur: very wide and small forms (pl. 5, fig. 113), elongated and small forms (pl. 5, fig. 101), much taller forms with the same shape (pl. 5, figs. 117-118) and elongated taller forms (pl. 5, fig. 119). These last two variants have about the same size as *E. anulifera* sp. nov., but are differentiated from this last species by their thin tegument, the absence of shoulders, and their slight flexure.

Biometry – Normal variety, measurements on 38 specimens from the Mehaigne area: length 69-91-106 µm, max. width 66-89-102 µm, width at the collarette 32-57-72 µm; elongation 0.77-1.03-1.72; opening of the pseudostome 0.43-0.64-0.82.

Large variety, measurements on 22 specimens from the Mehaigne area: length 119-139-173 µm, max. width 93-109-132 µm, width at the collarette 40-70-88 µm; elongation 0.67-0.79-0.99; opening of the pseudostome 0.36-0.67-0.91. Measurements on 26 specimens from Builth Wells district: length 76-108-143 µm, max. width 55-82-120 µm, width at the collarette 32-48-82 µm; elongation 0.52-0.77-0.97.

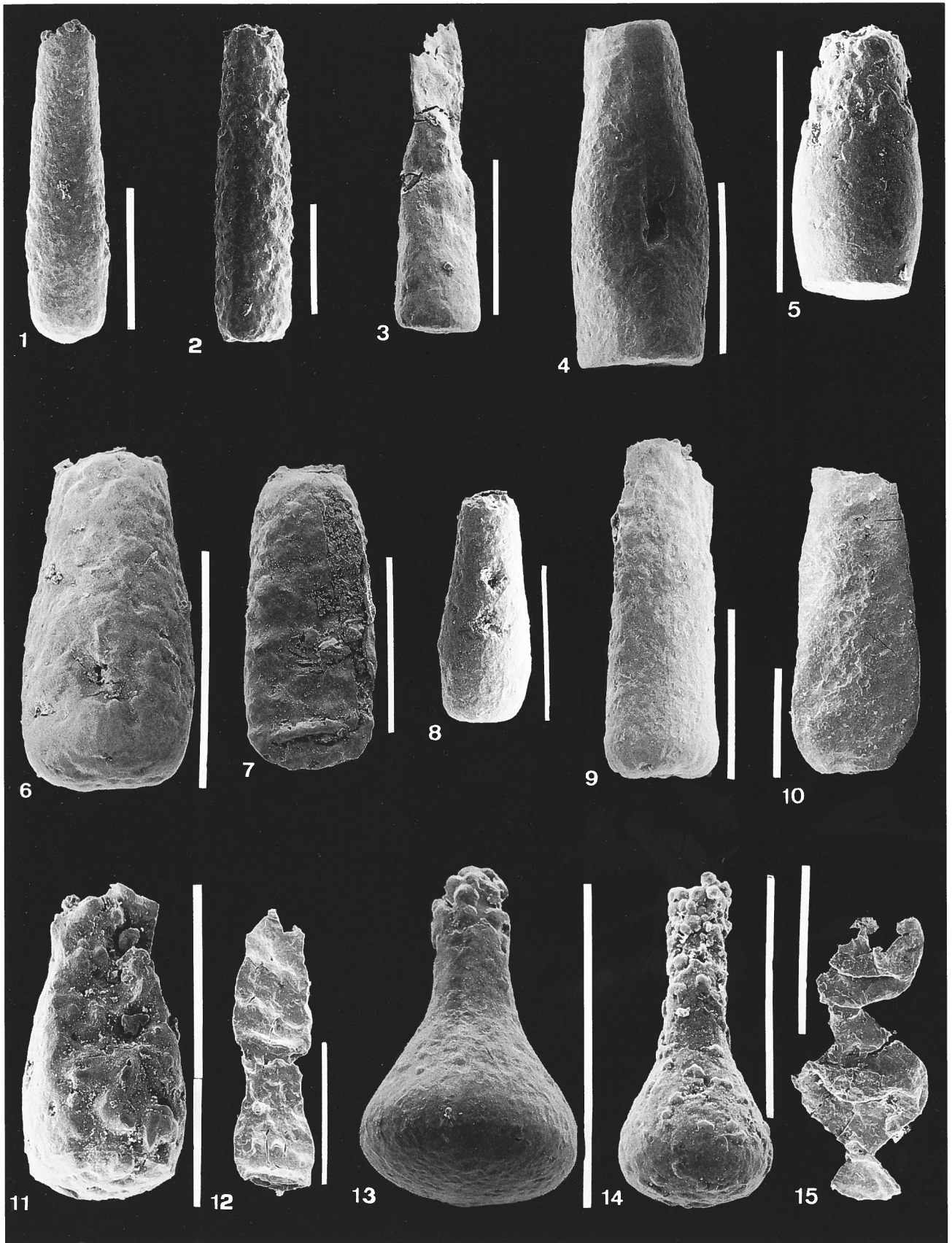
Discussion – The thin wall and the small size easily differentiate this species from *E. dolioliformis*. *E. causiata* sp. nov. resembles *E. varireticulata* Swire, 1990 in size and form of the operculum, but differs from this species by its reticulate ornamentation, never observed in fossils from the Mehaigne area.

Stratigraphical range – In Podolia (in the former USSR, Ukraine) a similar species was found in the basal conglomerate of the Restevo Beds, which was palynologically dated (Chitinozoa) as middle Llandovery (Laufeld, 1971). In the same paper it is mentioned that the species listed under open nomenclature occurs in Dalarna (Sweden) only in middle Llandovery rocks (*M. gregarius* and *M. convolutus* zones). In the Mehaigne area: rare to present in the formations MB2 and MB3A; present to frequent (up to 45%) in members MB3C and MB3D; rare to present in member MB3E and Formation MB4. The large variety occurs mainly during the apogee of *E.*

EXPLANATION OF PLATE 2

- Figs. 1-3 - *Conochitina claviformis* Eisenack, 1931. 1) sample E16, preparation 970144, S.E.M. stub E16, specimen Ch14, River Irfon section, x270; 2) sample E32A, preparation 970147, S.E.M. stub E32A, specimen Ch1, River Irfon section, x210; 3) sample E16, preparation 970144, S.E.M. stub E16, specimen Ch58, River Irfon section, x300.
- Figs. 4-5 - *Conochitina subcyatha* Nestor, 1982. 4) sample E32A, preparation 970147, S.E.M. stub E32A, specimen Ch14, River Irfon section, x330; 5) sample E16, preparation 970144, S.E.M. stub E16, specimen Ch78, River Irfon section, x465.
- Fig. 6 - *Conochitina cribrosa* Nestor, 1982, sample E16, preparation 970144, S.E.M. stub E16, specimen Ch34, River Irfon section, x465.
- Fig. 7 - *Conochitina pachycephala* Eisenack, 1964, sample E16, preparation 970144, S.E.M. stub E16, specimen Ch51, River Irfon section, x335.
- Fig. 8 - *Conochitina fortis* Nestor, 1984, sample E16, preparation 970144, S.E.M. stub E16, specimen Ch89, River Irfon section, x300.
- Figs. 9, 10 - *Conochitina tuba* Eisenack, 1932. 9) sample E16, preparation 970144, S.E.M. stub E16, specimen Ch10, River Irfon section, x330; 10) sample N42, preparation 960038, S.E.M. stub N42, specimen Ch3, Trecoed Brook section, x210.
- Figs. 11, 12 - *Cingulochitina cingulata* (Eisenack, 1937). 11) sample E16, preparation 970144, S.E.M. stub E16, specimen Ch59, River Irfon section, x270; 12) chain of two specimens, sample N42, preparation 960038, S.E.M. stub N42, specimens Ch2, Trecoed Brook section, x270.
- Fig. 13 - *Ancyrochitina* sp. A, sample E16, preparation 970144, S.E.M. stub E16, specimen Ch25, River Irfon section, x620.
- Fig. 14 - *Ancyrochitina* sp. B, sample E16, preparation 970144, S.E.M. stub E16, specimen Ch15, River Irfon section, x465.
- Fig. 15 - *Margachitina margaritana* (Eisenack, 1937), chain of two specimens, sample N42, preparation 960038, S.E.M. stub N42, specimens Ch4, Trecoed Brook section, x330.

Provenances: River Irfon section, W of Builth Wells, and Trecoed Brook section, N of Builth Wells, both from Builth Wells district, U.K.; repository: Laboratory for Palaeontology, University of Ghent, Belgium; scale: white bar = 100 µm.



causiata sp. nov. in members MB3C and MB3D. In the Builth Wells district: present at least from the *centrifugus* zone upwards, till the *dubius* graptolite biozone.

EISENACKITINA ITHONIENSIS sp. nov.

Pl. 1, figs. 12-13

Derivation of name – From the river Ithon, Builth Wells district, U.K., where the type stratum is located.

Holotype – Pl. 1, fig. 13, section along the river Ithon east, SE of Newbridge on Wye, Builth Wells district, U.K., sample location in Zalasiewicz & Williams (1999, p. 283), S.E.M. stub K34B, specimen Ch3.

Type locality and stratum – Outcrop along the river Ithon, SE of Newbridge on Wye, Builth Wells district, U.K.; level K34B, sampled for graptolites by Zalasiewicz & Williams (1999); Builth Mudstones Formation, lower Wenlock.

Material – More than 23 specimens.

Diagnosis – Cono-ovoid silhouette, (very) sharp basal edge, granules or spines on a medium-thick wall, mostly on the aboral half and no ornamentation on the base.

Description – A medium-sized *Eisenackitina* species with a cono-ovoid form, a short neck, sometimes short flaring collarette, faint flexure and shoulders, an elongated ovoid chamber, sharp to very sharp giving the impression of a ridge-like carina; a flat or slightly convex base, with a small depression as mark of a mucron; the tegument is covered with granules or rugae on the whole body but increasingly and mostly on the aboral half. Close to the basal edge are the largest granules or rounded spines. No ornamentation on the base. The tegument is 3-4 µm thick on the chamber.

Biometry – Measurements on 11 specimens from Builth Wells district: length 100-134-160 µm, max. width 57-83-135 µm, width at neck below the collarette 37-45-65 µm; elongation 0.45-0.58-0.76.

Discussion – *Eisenackitina ithoniensis* sp. nov. differs from *E. anulifera* sp. nov. because it has spines and a very sharp basal edge; from *E. causiata* sp. nov. which is smaller, thin walled and has a different operculum; from *Salopochitina bella* owing to its few, very long appendices and not ornamented vesicle; from *Eisenackitina dolioliformis*, by the ornamentation on its bottom; from *Cingulochitina burdinalensis* sp. nov. which carries a carina and is not so elongated and from *Conochitina visbyensis* which can have vaguely

the same silhouette but has no granules nor the sharp basal edge.

Stratigraphical range – Builth Wells district: basal Builth Mudstones Formation, upper half of the *riccartonensis* graptolite biozone, lower Sheinwoodian, lower Wenlock.

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