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The age of the *Euconochitina symmetrica* Zone and implication for Lower Ordovician chitinozoan and graptolite zonations of Laurentia

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Abstract

An *Euconochitina symmetrica* Zone was defined in the G-locality at Lévis, Quebec, within an interval belonging to Zone A of Raymond that contains *Paratetragraptus approximatus.* The interval was consequently attributed to the Floian. *E. symmetrica* was also recognized in Northern Gondwana, and the species was considered an undisputed marker for the base of the Floian. During the past decades, several occurrences of *E. symmetrica* have been reported from Avalonia, southern China, and even from Northern Gondwana in Tremadocian strata casting doubt on the Floian age of the Zone.

Revisions of the graptolites in the G locality and N section at Lévis provides a frame on which the age of the *E. symmetrica* Zone can be precisely documented. At both localities the *E. symmetrica* chitinozoan assemblage is older than the base of the *Paratetragraptus approximatus* graptolite Zone. Therefore, the presence of *E. symmetrica* can no longer be correlated with the graptolite *P. approximatus* Zone as it was initially suggested. It rather characterizes the upper Tremadocian *Sagenograptus murrayi* Zone, its upper part could however reach the Floian.

An older assemblage characterized by a *Lagenochitina gigas* n. sp. assemblage (previously designated *Lagenochitina maxima*) occurs in strata correlated with the Tremadocian *Aorograptus victoriae* graptolite Zone.

Correlation of the biostratigraphic ranges of the chitinozoan and graptolite faunas in the lower part of the Lévis Formation allowed for a better positioning of the Lower Ordovician Laurentian chitinozoan zones on the Ordovician time scale.

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Keywords: Ordovician, Tremadocian, Chitinozoans, Graptolites, Laurentia, biostratigraphy.

1. Introduction

The chronostratigraphy of the Ordovician is based on a number of GSSP's (Global Stratotype sections and Points), based on the FAD (First Appearance Datum) of carefully selected fossil occurrences (see Goldman et al., 2020 for the latest information). Conodont and graptolite taxa have been used for the definition of all boundaries and in most cases correlation with other fossil groups (e.g., acritarchs, chitinozoans, brachiopods) have been attempted. Due to the restriction of certain fossil groups to special lithologies or palaeogeographic regions, these correlations are not invariable precise and problems have been reported. Thus, correlations had to be revised accordingly in the past. Especially, the precise age of the *Euconochitina symmetrica* chitinozoan Zone has been under scrutiny (Lefebvre et al., 2018) as it was supposed to characterize the base of the Arenig, Lower Ordovician. Its early Arenig (now Floian) age in North America (Achab, 1980) and South-West Europa (Paris, 1981) has subsequently been questioned, as this particular fauna was found in definitively upper Tremadocian successions in other regions. Thus, the boundary between the Tremadocian and Floian stages of the Ordovician System has to be re-evaluated based on chitinozoan records. Unfortunately, chitinozoans have not been described from the GSSP section at Diabasbrottet, Västergötland, Sweden, but the graptolite faunas can easily be correlated between Baltica and Laurentia.

Chitinozoans have been used as an important microfossil group to correlate Lower Ordovician rock successions (cf. Paris, 1990; Webby et al., 2004; Goldman et al., 2020), but problems still exist as the discussion of Lefebvre et al. (2018) shows. One serious problem was the correlation of the *E. symmetrica* chitinozoan Zone with the basal Floian *Paratetragraptus approximatus* graptolite Zone (Achab, 1980, 1986; Paris, 1981, 1990) based on the record from the G-locality at Lévis, Québec, Canada and from Northern Gondwana.

The North American Lower Ordovician Series are referred to the Ibexian Series in the USA and to the Canadian Series in Eastern Canada. The Lévis area on the southern

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shore of the St-Lawrence River, in front of Quebec City, is the type area of the Canadian Series. The area is rich in graptolites and has long attracted the interest of geologists (Logan, 1863, 1865) and paleontologists (Hall, 1865; Dana, 1874; Raymond, 1914; Osborne and Berry, 1966). Several sections are type localities of some of the biostratigraphically most important Lower Ordovician graptolite species.

Since these pioneer works, more paleontological studies have been undertaken. Achab (1980) documented the stratigraphic distribution of the chitinozoans in the lower part of the Levis Formation at the G-locality, which crops out at the foot of Rue du Fleuve in the town of Lévis. Based on Raymond (1914), she assigned the *E. symmetrica* Zone, which lies within the interval of zone A of Raymond containing *P. approximatus,* to the Lower Arenig.

In more recent work on the graptolites of the Pointe-de-Lévy slice, Maletz (1992, 1997) confirmed the report of *Sagenograptus murrayi,* initially referred as *Dictyonema' murrayi* by Clark (1924), within zone A of Raymond (1914) in the G-locality and its equivalent in the N-section of Osborne and Berry (1966). This occurrence demonstrates that strata at these sites range downward into the Tremadocian.

The equivalence between the chitinozoan *E. symmetrica* Zone and the graptolite *P. approximatus* Zone was adopted by the chitinozoan community and *E. symmetrica* was for long considered indicative of the time slice TS2a, which marks the base of the Floian and the species was used for global correlations (Webby et al., 2004; Paris et al., 2004).

Surprisingly, *E. symmetrica* was subsequently reported from late Tremadocian strata in many regions. As chitinozoans are understood to be excellent biostratigraphic fossils with a wide geographic distribution and short biostratigraphic ranges, these unexpected occurrences created a debate within the chitinozoan community; a debate that requires a reconsideration of the Floian age of the strata in which the *E. symmetrica* Zone was originally defined. Maletz's (1997) detailed stratigraphic information on the graptolite faunas allows to compare and correlate the stratigraphic ranges of graptolites with that of the chitinozoans in the sections of the Lévis Formation and to review the age of the strata on which the age of the *Euconochitina symetrica* chitinozoan Zone was based.

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2. The Lower Ordovician rocks of the Lévis area

The Lévis area, the type locality of the Canadian Series, is located on the southern shore of the St-Lawrence River just opposite of Quebec City. The area is situated at the junction of three major geological domains: the Canadian Shield to the north, the St. Lawrence platform along the St. Lawrence River valley and the Appalachian Orogen on the southern shore of the St. Lawrence River. The rocks of the Lévis area belong to the Appalachians front and are part of a belt of allochthonous slices of Cambrian-Ordovician age.

The Pointe-de-Lévy slice (Fig. 1), intercalated between the Promontoire de Quebec slice and the Bacchus slice, is composed of shales, limestone intervals and conglomerates. It was divided into two units: The Lauzon Formation overlain by the Levis Formation. Both units are well known for their graptolite and trilobite faunas. Maletz (1997) noted that both the Lévis and the Lauzon formations were not adequately defined, as their bases and their tops were unknown. He suggested to abandon the name Lauzon Formation and refer the entire succession of the Pointe-de-Lévy slice to the Lévis Formation.

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3. Chitinozoan and graptolite correlation of the Lévis succession

Chitinozoan and graptolite data are available for two sections in the Lévis area covering the Tremadocian-Floian boundary interval. The *E. symmetrica* Zone was defined in one of the G-localities (graptolite localities) of Logan (1863), the one later recognized as the Rue du Fleuve section. The second section corresponds to the N-section of Osborne and Berry (1966) and Maletz (1992, 1997) on the northern border of the Lauzon cemetery at Lauzon. Chitinozoans and graptolites of these two sections will be discussed in this study.

3.1. The G-Locality at Lévis

The G-Locality is actually only one of the G-localities of Logan (1863), marked on his map. It was situated at the foot of Rue du Fleuve at Lévis, but is not available any more, as a bike-path has been constructed covering the succession. The G-locality (see Maletz, 1997, p. 736) is the type locality for *P. approximatus, Phyllograptus typus* and other graptolites, thus has been a very important place for collecting early Ordovician graptolites in the past (Raymond, 1914; Clarke, 1924; Maletz, 1997). It was called the RC locality by Landing et al. (1992), based on the color of the 'Rusty Conglomerate' (Logan 1863, Raymond, 1914; Clarke, 1924, 1926), dominating the section. Graptolites were present at several levels, but in the middle of the succession, a covered interval was recognized (Fig. 2). Maletz (1992) provided a range chart for the G-locality showing that *Clonograptus rigidus* can be found below and above the conglomerate layer and that this interval can be included in the uppermost part of the *Sagenograptus murrayi* Zone, while *Sagenograptus murrayi* was recognized in the interval later on (Maletz, unpublished). Maletz (1997, fig. 4) indicated that the base of the *P. approximatus* Zone was above the top of the 'Rusty Conglomerate' or conglomerate 4 of Logan (1863) with the index species found at 1.5 m above the top of the conglomerate (see Maletz, 1992, fig. 4). This level, thus can be used to define the *P. approximatus* Zone in the section.

Above a covered interval, the succession continues with siltstones, mudstones and carbonaceous mudstones in which *Expansograptus nitidus* and *Phyllograptus typus* are the most common faunal elements of Zone B of Raymond. This interval, in the past formed a small cliff on the steep slope, but is not preserved today. Maletz (1997, fig. 4) regarded the interval as the upper part of the *Tshallograptus fruticosus* Zone, as he was able to correlate it with the succession of the Begin's Hill section. Raymond (1914) identified the lower interval as his Zone A and the upper one above the covered interval as his Zone B.

Achab (1980) initially studied the chitinozoans of the G-locality section (Fig. 2). She investigated six samples from the lower part (Zone A of Raymond, 1914) and four samples from the upper part (Zone B of Raymond, 1914). The lower of the two defined chitinozoan assemblages is characterized by *E. symmetrica*, a small and very distinctive chitinozoan species. Because the assemblage lies within Raymond's Zone A that contains *P. approximatus*, the *E. symmetrica* Zone was equated with the graptolite *P. approximatus* Zone that marks the base of the Arenig (Achab, 1980), or now the base of the Floian (Maletz et al., 1996; Bergström et al., 2004). The correlation of graptolite and chitinozoan samples (Fig. 2) clearly show that the base of the *E. symmetrica* Zone is below the base of the *P. approximatus* Zone. As per fig. 4 of Achab (1980), the thickness of the *E. symmetrica* Zone at the G-locality can be estimated at about 3 meters, so its base is clearly of late Tremadocian age. However, subject to the correctness of the estimated thickness of the zone and the accuracy of the position and the spacing of the samples on the lithological column, its upper part could reach the *P. approximatus* Zone. The base of the *E. symmetrica* Zone is therefore older than previously suggested by Achab (1980). Fossils from the interval below the 'Rusty Conglomerate' have not been investigated, however, in the G-locality.

A similar occurrence for *E. symmetrica* can be observed in the Bégin's Hill section. Achab (1986) documented two levels exclusively with *E. symmetrica* from the lowermost samples of the Bégin's Hill section, which were referred to the Zone C of Raymond (1914). The interval with *E. symmetrica*, however, can be correlated with the Zone A of Raymond (1914) in the G-locality based on the lithology and graptolite content (see Maletz, 1997, figs. 4, 8). The contact with the underlying conglomerate (the 'Rusty Conglomerate' or conglomerate 4 of Logan, 1863) is not exposed at Bégin's Hill.

3.2. The N-section at Lauzon

The N-section (Fig. 3) is poorly known and has never been investigated or described in detail. Osborne and Berry (1966) studied the graptolites of the N-section, however, they were not able to clearly establish the age of the strata and only concluded that the rocks can possibly be attributed to the Tremadocian. Maletz (1992; 1997, fig. 4) illustrated the lower part of the succession with a distinct conglomerate bed in the center of the section. He correlated this conglomerate with the 'Rusty Conglomerate' of the G-locality, based on the recovered graptolite fauna. There is a considerable discrepancy in the thicknesses between the various lithological units in the N-section and the G-locality. The conglomerate bed is about 5.5 m thick in the G-locality, but reaches more than 18 m in the N-section. Also the record of *P. approximatus* in the G-locality and the N-section appears to show considerably

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differences in thickness of the units. The species appears at ca. 1.5 m above the conglomerate in the G-locality is at ca. 7 m above the conglomerate in the N-section. The reason for these differences may be seen in the tectonic displacement and shearing of lithological units as slickenslides are common in the sediments and not represent true changes in lithological thickness of the units. Osborne & Berry (1966) commented on the variable thickness of the lithological units and suggested that even conglomerate beds present in one locality may be missing in another nearby locality.

Lindholm & Maletz (1989) illustrated *Clonograptus rigidus* (Hall, 1858) for the N-section, but additional material has not been published. A number of important specimens are illustrated herein (Fig. 4) to show the poor quality of the graptolite preservation. The interval below the conglomerate includes a fauna referred to the *Aorograptus victoriae* Zone (cf. Williams & Stevens, 1991). Robust clonograptids or adelograptids (Fig. 4K) are present in one layer and *Paratemnograptus magnus* (Williams & Stevens, 1991) is common in juvenile specimens (Fig. 4H, J), characterized by the strongly undulating dorsal side of the stipes. Common four-stiped specimens may belong to the same species (Fig. 4F, I), as distal branching appears only in larger specimens. Fairly robust stipes fragments (Fig. 4K) cannot referred to a certain taxon. The graptolites above the conglomerate are quite different and include fragments of *Sagenograptus murrayi* (Fig. 4A), *Clonograptus rigidus* (Fig. 4B) and numerous specimens of *Paratemnograptus magnificus* (Figs. 4C-E) lacking the conspicuous undulating dorsal side of the stipes found in the older *Paratemnograptus magnus*. Juveniles (Fig. 4C) are only tentatively referred to the species. The lateral origin of the thecae is less obvious in the few relief specimens and bithecae are not recognized (Fig. 4D).

The chitinozoans of this section were studied in 1979 by Achab who was, at that time, trying to develop an Eastern Canada chitinozoan biozonation on the basis of strata that were well-dated by graptolites or other fossils. The results of this work however were never published mainly because the age of the strata was not firmly established, but also because the observed chitinozoan assemblages did not resemble any of those then reported in the literature. It was not possible, therefore, to assign an age to the Lauzon strata on the basis of chitinozoans. Two chitinozoan assemblages were nevertheless easily distinguished (Fig. 3). The first assemblage, extracted from strata below the conglomerate (also identified as band 4 of Logan, 1863), was dominated by large, bottle shaped chitinozoans belonging to the genus *Lagenochitina*. The second assemblage, present above the conglomerate, was essentially composed of specimens of *E. symmetrica* comparable to those observed in the lower part of the section at the G-locality (Achab, 1980).

Twenty years later, the largest bottle-shaped forms of the lower assemblage appeared to be very similar to specimens identified *Lagenochitina maxima* in Williams et al. (1999a, b) from the *victoriae* graptolite Zone of the Cow Head Group of western Newfoundland. Williams et al. (1999b) illustrated the specimens from sample CHN8.32 (Cow Head, the Ledge section) in an unpublished report to the IUGS/ICS subcommission on Ordovician stratigraphy. This similarity supported the Tremadocian age of the material from the N-section at Lévis, presumed by Osborne and Berry (1966) and allowed to add a Tremadocian *Lagenochitina maxima* zone to the lower Ordovician chitinozoan biozonation of Laurentia (Achab et al., 2003).

A comparison however indicates that the specimens from Lauzon and Newfoundland are different from the single specimen of *L. maxima* illustrated by Taugourdeau and de Jekhowsky (1960) and designated as holotype. This later does not exhibit the conspicuous flexure diagnostic of the genus *Lagenochitina* as established in the classification of Paris et al. (1999) and was consequently attributed to the genus *Conochitina*. In the taxonomic notes below, the specimens that had been attributed to *L. maxima* in the chitinozoan zonation of Laurentia (Achab, 2003; Williams et al., 1999a, b) are now identified as *Lagenochitina gigas* n. sp.

The age of the *L. gigas* n. sp. assemblage probably corresponds to the *A. victoriae* Zone as recognized by Maletz (1997) at Lévis, but the graptolite fauna from this interval has not been described due to the poor preservation of the material (Fig. 4F-K). The assignment is in line with the presence of specimens of *L. maxima (*now *L gigas* n. sp) in the A. victoriae Zone of the Cow Head Group of Newfoundland (Williams et al. 1999a, b).

The second assemblage, found above the conglomerate (Fig. 3), can be identified as the *E. symmetrica* assemblage and, as in the G-locality, the base of the *E. symmetrica* assemblage is below the local or regional FAD (First Appearance Datum) of

P. approximatus and corresponds to a level belonging to the upper Tremadocian *S. murrayi* Zone.

4. Material

4.1 Chitinozoans

Results of this study are mainly based on material collected in the late 1970s and for which only optical photographs are available. It is unfortunately not possible to attain new palynological preparations because there are no more samples left, it is impossible to re-sample, to access laboratory facilities and to an SEM. We believe, however, that the optical photographs and the associated comments will provide a general idea of the chitinozoan assemblages discussed in this paper.

Fig. 2 is adapted from the chitinozoan ranges in the G locality at Lévis published by Achab in her review in 1980. Fig. 3 presents 21 chitinozoans extracted from 8 samples collected in the N-section at Lauzon, along the cemetery path departing between 61 and 65 Boulevard Jacques Cartier.

Out of the 8 samples 4 revealed productive. The 21 specimens illustrated are deposited at the Geological Survey of Canada under the number GSC 142491 to GSC 142511 (inclusively). The other slides are part of the palynological collections of the centre INRS Eau Terre Environnement, at Québec.

4.2 Graptolites

All graptolites used during this investigation were from the research of Maletz (1992, 1997). The specimens presented in Fig. 4 are preserved at the Geological Survey, Ottawa, Canada under the numbers GSC 142639-142648. Most of the additional graptolite material remains unpublished and is preserved in the collection of Jörg Maletz (FU Berlin, Germany). Revisions of the biostratigraphically important material of the collection were made in 2020.

4.3. Taxonomic Notes

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Euconochitina symmetrica (Taugourdeau and de Jekhowsky, 1960)

Fig. 3, 1-4 (GSC 142491 TO 142 494)

1960 *Conochitina symmetrica* Taugourdeau and de Jekhowsky, 1960, pl. IV, 59

1980 *Conochitina symmetrica* Taugourdeau and de Jekhowsky, 1960; Achab, pl. 3, figs. 7-10.

1986 *Conochitina symmetrica* Taugourdeau and de Jekhowsky ,1960; Achab, pl. 3, figs. 1-4.

2000 *Conochitina symmetrica* Taugourdeau and de Jekhowsky, 1960; Batten, p. 93, pl. 2, fig. 11-12.

2008 *Euconochitina fenxiangensis* n. sp. Chen et al., pl. 6, 10, 11.

2009 *Euconochitina paschaensis* n. sp. de la Puente and Rubinstein, pl. 1, 1-10.

Remarks. The dimensions of *E. symmetrica* Taugourdeau and de Jekhowsky, 1960 are based on a single specimen, the holotype. When comparing the sizes (Table 1) and stratigraphic ranges of the reported populations of *E. symmetrica* Taugourdeau and de Jekhowsky 1960, *Euconochitina fenxiangensis* Chen et al. 2008 and *Euconochitina paschaensis* de la Puente and Rubinstein 2009, it appears that these three species are quite similar, have roughly the same stratigraphic range and are considered difficult to differentiate.

E. fenxiangensis and *E. paschaensis* have the same shape and size, they were defined at about the same time in two different regions. Chen et al. (2008) described *E. fenxiangensis* as a new species from China, while de la Puente and Rubinstein (2009) did the same for *E. paschaensis* from Argentina. This temporal coincidence may explain why neither of the two articles mentioned or compared the two species, the authors did not seem to be aware of the creation of the other species.

In some regions, including the Lévis area, the *E. symmetrica* assemblages show a continuum from specimens with a flared collarette (diabolo shape), similar to the holotype and easily assignable to *E. symmetrica* to more conoid specimens with a small or without a collarette, assignable to *E. paschaensis* and considered by Nowak et. al. (2016) and Lefebvre et al. (2018) to form a *symmetrica/paschaensis* group. In other

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localities (Wang et al., 2013), *E. symmetrica, E. paschaensis* and *E. fenxiangensis* were recognized through roughly the same stratigraphic interval.

Considering the morphological continuum observed from specimens with flared collarette to more conoid silhouettes, their roughly comparable size, and their similar biostratigraphical range, we propose to consider the three species as synonyms.

Lagenochitina gigas **n. sp.**

Fig. 3, 5-9 (GSC 142-95 to142-499)

cf. 1999 *Lagenochitina maxima* Taugourdeau and de Jekhowsky, 1960; Williams et al., fig. 9, a-i

non 2000 *Lagenochitina maxima* Taugourdeau & de Jekhowsky, 1960; Batten, pl. 6, figs. 1-7

? 2000 *Amphorachitina* sp. Batten, pl. 6, fig. 21

Locality: Lauzon Cemetery, between 61 and 65 Boulevard Jacques Cartier

Holotype: Fig. 4, 5 (GSC 142495)

Stratigraphic horizon: Levis Formation, Locality N200 of Osborne and Berry 1966

Diagnosis: *Lagenochitina* species characterized by a very large test with well-differentiated neck and chamber, exhibiting a distinct flexure and prominent shoulders, a cylindrical neck with a slightly flaring collarette. The maximum width is observed just below the shoulder at the upper part of the elongated subcylindrical to ovoid chamber. These distinctive features allow the assignation to a new species of the genus *Lagenochitina*.

Description: With a test length of about 1 mm, the specimens attributed to this species are among the largest known chitinozoans. Prominent shoulders differentiate the neck, which represents almost 40% of the total length, from an elongated chamber approximately 3 times higher than it is wide.

Dimensions: Length=800-1280 µm, chamber length = 550-800 µm, chamber width 180-240 µm, neck width 100-120 µm, aperture 90-160 µm.

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Remarks and comparisons. Specimens assigned to this new species are almost identical to those called *L. maxima* by Batten in Williams et al. (1999b) from bed CHN8.32 of the Ledge section of the Cow Head Group of western Newfoundland, Canada, assigned to the *A. victoriae* graptolite Zone. The specimens from Lauzon and those from the CHN8.32 bed of Newfoundland share all the features of the new species. The other specimens figured in Batten's thesis (Batten 2000, Pl. 6, figs 1-7) seem quite different with their shorter neck and less slender silhouette, they do not share the typical morphology of *L. gigas* n. sp. They also originated from Floian strata.

Eisenack (1968) illustrates, beside a short form, an elongated form of *Lagenochitina esthonica* (650 - up to 1360 µm) from the Expansus Limestone of Sweden and the Vaginatenkalk of Öland. The silhouette of the Baltic specimen (Eisenack, 1968 pl. 29, ph. 2) recalls *Lagenochitina gigas*, it however differs from it by its flat base, less prominent shoulders and less elongated chamber.

The holotype of *Lagenochitina maxima* illustrated by Taugourdeau and de Jekhowsky (1960) lacks the distinct flexure of the genus *Lagenochitina* and was therefore transferred to the genus *Conochitina*. Unfortunately, material comparable to *Conochitina maxima* was never found again, casting doubt on its usefulness for biostratigraphic purposes. Further material identified by this name needs to be re-evaluated.

Lagenochitina **cf.** ***longiformis*** **Obut, 1995**

Fig. 3, 14-19 (GSC 142504 to 142509)

Remarks: The Lauzon specimens (560-580 µm) do not exactly conform with the holotype of *L. longiformis* Obut, 1995 from the Moscow Syncline, but are morphologically close to, although larger of those later identified as *Lagenochitina* cf. *longiformis* from Estonia by Hints and Nõlvak (2006, pl. 4, figs. 15, 19–25) (330-445 µm) and those from northwestern Argentina documented by de la Puente and Rubinstein (2009) (368-452 µm). Liang et al. (2017) noted that Obut's holotype shares the same vesicle outline and size with the specimen of *Lagenochitina destombesi* illustrated in Elaouad-Debbaj (1988, pl. 7, fig. 5) (approx. 659 µm), suggesting that *L. longiformis* might be a senior synonym of *L. destombesi*. The overall outline of the specimen is however different from that of the holotype designated by Elaouad-Debbaj (1988)

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which bears a more ovoid chamber which shows a gradual differentiation toward the neck. The overall shape of the *L. destombesi* figured by Amberg et al. (2017; pl.1 fig. 9) with a neck representing almost half of the total length, a flaring collarette, and a well differentiated chamber share some characters with *L.* cf. *longiformis*.

Lagenochitina destombesi Elaouad-Debbaj, 1987

Remarks: *L. destombesi* is the index species of the oldest chitinozoan zone in northern Gondwana. It was first described by Elaouad-Debbaj (1987) from Morocco.

The species was not identified at Lauzon but some Tremadocian specimens shown by Batten (2000, pl. 5, figs: 12-15, 21) from western Newfoundland recall the general outline of some of the specimens illustrated by Elaouad-Debbaj (1987) However, the various specimens illustrated by Elaouad-Debbaj (1987) show such a large variation in morphology that it is difficult to determine the boundaries of the species. These morphological variations are such that several Tremadocian lagenochitinids can be assigned to the species. This is the case of the forms identified as *L. destombesi* in South China (Chen et al., 2008; Wang et al., 2013). Liang et al. (2017) undertook a careful review of these specimens and put the specimens identified *L. destombesi* by Wang et al. (2013) in synonymy with *L. pestovoensis* Obut, 1995. They considered the other specimens to be atypical and reassigned them to *L. destombesi?.*

Amberg et al., (2017) reported the species from northern England (see the remarks above regarding *Lagenochitina longiformis*).

Only specimens identified as *L.* cf. *destombesi* have been reported in the Fezouata Formation which proves the difficulty of identifying the species even in its stratum typicum (Nowak et al., 2016, Lefebvre et al., 2017).

Although the *L. destombesi* Zone is cited as the oldest zone of Baltica by Nõlvak (1999), the index species was not illustrated.

***Lagenochitina* cf. *pestovoensis* Obut, 1995**

Fig. 3, 10-13 (GSC142500 to 142503)

Remarks: The species was first figured without description by Obut (1973, pl. 10, fig 9) from the Drill-hole Pesto Novgorod district, Moscow at the depth of 1184-1192 m.

Liang et al. (2017) recognized the species in South China and provided a precise description, biometrics and illustrations (L = 158-360 µm). The specimens from Lauzon (360 - 450µm) (Fig. 5, 10-13) although larger, share the morphology, the relatively well developed neck representing near half of the vesicle length, the ovoid to sub-ovoid chamber with rounded basal edge and the maximum diameter located in the middle part of the chamber.

Lagenochitina esthonica Eisenack, 1955

Remarks: Wang et al. (2013) defined a *L. esthonica* Zone in levels underlying the *E. symmetrica* Zone, referable to the Tremadocian *S. murrayi* Zone of southern China. Achab (1980) defined at Lévis, Québec, Canada in Raymond's Zone A, a *L. esthonica* Zone above her *C. symmetrica* Zone, in levels belonging to the Floian. Specimens of *L. esthonica,* figured by Wang et al. (2013) are also reported from South China by Liang et al. (2018). A comparison of the material from these localities shows that they can easily be differentiated and are unlikely to represent the same species. The Chinese specimens are more globulous and considerably smaller (170–220 µm) than the Lévis ones (400–675 µm), which feature also a taller than wide ovoid chamber. Therefore, these two forms probably represent two different species.

In the Fezouata Shale, Nowak (2016) also noted the presence of small forms of *L. esthonica* Eisenack, 1955, similar to those identified *L.* cf. *longiformis* by Hints and Nõlvak (2006) from Estonia and by de la Puente and Rubinstein (2009) from Argentina.

The above observations and remarks underline the difficulties encountered in the identification of Tremadocian chitinozoans, more particularly the identification of forms related to the genus *Lagenochitina*. The difficulties are due in large part to a fairly broad definition of certain species and an obvious lack of discriminating criteria. This has led to the attribution to the same species of specimens having only a more or less comparable silhouette or even specimens with a great variety of sizes and silhouettes. An in-depth review leading to a precise definition of the different species is necessary. Clearly defined criteria that are easy to observe and use will help distinguish between the different species of *Lagenochitina*. These species could then be fully used, as they certainly have the potential, as important biostratigraphic tools for the Tremadocian.

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5. Important occurrences and age of the *Euconochitina symmetrica* interval

The age of *E. symmetrica* Zone has been discussed variously as of late Tremadocian or early Floian age (Fig. 4). New information from the Lévis localities of Quebec, Canada are here evaluated and compared to published references, providing a better understanding on the precise biostratigraphic correlation of the interval.

The chitinozoan *E. symmetrica* was first described by Taugourdeau and de Jekhowsky (1960) from the Algerian Sahara (Northern Gondwana). Although the type horizon was not specified, *E. symmetrica* was probably extracted from the El Atchane Member of the Oued Mya Formation in well Af.2 at the depth of 2565 m, in strata tentatively attributed to the early Arenig by Legrand (1965). Consequently, Paris (1981) and Paris and Mergl (1984) attributed an early Arenig age to the *E. symmetrica* assemblages observed in the Northern Gondwana domain especially those from Algerian Sahara and Bohemia.

Achab (1980) originally defined the *E. symmetrica* Zone as the basal Arenig chitinozoan zone in Laurentia, based on the information from the G-section at Lévis, Quebec. This age was also adopted by Paris (1990) in his Ordovician chitinozoan biozonation of the Northern Gondwana Domain and later by Webby et al. (2004) and Paris et al. (2004). From then the *E. symmetrica* Zone was considered to represent the undisputed diagnostic marker of the basal Arenig and the time slice TS.2a and was intensively used for global correlations.

Subsequently however, *E. symmetrica* was repeatedly reported from Tremadocian strata of almost all paleocontinents, casting doubt on the precise age of this zone and its usefulness.

Baltica. The Ordovician chitinozoan biozonation of Baltoscandia (Nõlvak, 1999) shows two zones, the *L. destombesi* and *Euconochitina primitiva* zones that cover the Tremadocian-Floian boundary interval. The author however, mentioned the possible presence of *E. symmetrica* in the *E. primitiva* Zone (Hunneberg Stage) of Baltoscandia. Later, Hints and Nõlvak (2006) reported the presence of *E. symmetrica* in the lower part of the Leetse Formation of the Tallin area of Estonia, correlated with the *Paroistodus proteus* conodont Zone and referred to the late Tremadocian (Hunnebergian). This age assignment was based on the fact that in the Diabasbrottet GSSP section, the base of the Floian falls within the upper part of the topmost subzone of the *P. proteus* Zone (Maletz et al., 1996; Bergström et al., 2004) and main parts of the *P. proteus* conodont Zone fall into the late Tremadocian. Goldman et al. (2020) indicated a *L. destombesi* Zone in the Tremadocian, followed by the *Euconochitina primitiva* Zone ranging through the whole Floian and into the higher part of the Dapingian. The zonation is identical to that of Webby et al. (2004), based on Nõlvak (1999). Nõlvak (1999) correlated the *L. destombesi* Zone with the late Tremadocian *Kiaerograptus supremus* graptolite Zone and indicated a correlation of the base of the Hunnebergian which contains *S. murrayi* with the base of the Arenig. The base of the Hunnebergian is now, however, correlated with the mid- to late Tremadocian (Goldman et al., 2020). Thus, the *L. destombesi* Zone cannot be identified as latest Tremadocian in age, as was done by Nõlvak (1999).

West Gondwana, Argentina. De la Puente and Rubinstein (2009) described a chitinozoan microfauna containing small chitinozoans recalling *E. symmetrica* as *E. paschaensis* from the upper Tremadocian Saladillo and Parcha formations of Argentina. The authors correlated the range of this taxon with the *Kiaerograptus, S. murrayi* and *Hunnegraptus copiosus* graptolite zones, thus covering the upper half of the Tremadocian stage (see Goldman et al., 2020). De la Puente and Rubinstein (2013) discussed the *E. paschaensis* Zone for an extensive interval in the Tremadocian (*Anisograptus matanensis* Zone to *H. copiosus-S. murrayi* zones of the Central Andean Basin of Argentina, but did not recognize the typical forms of *E. symmetrica* with a flaring collarette and did not report any chitinozoans from intervals directly below or above the *E. paschaensis* Zone. Their *E. paschaensis* Zone does not reach into the Floian.

China. Chen et al. (2008) recognized the *L. destombesi* and *E. symmetrica* zones in the Fenxiang Formation, Chenjiahe section, Hubei Province (South China). They stated that the *E. symmetrica* Zone starts in the late Tremadocian and ranges possibly into the lowermost part of the Honghuayuan Formation, belonging to the *Prioniodus elegans* conodont Zone of Floian age (Chen et al. 2008, p. 289). Zhen et al. (2005) discussed *Acodus triangularis* as indicative of a Floian age, a species found in the higher part of the Fenxiang Formation in the Chenjiahe section by Baliński et al. (2012). Zhen et al. (2009) suggested that the top of the Fenxiang Formation may be Floian in age based on conodont records. This info was used by Maletz & Kozłowska (2013) and thus, the correlation with the graptolites is indirect and may be wrong.

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Also in South China, *E. paschaensis* was found associated with *E. symmetrica* in levels correlatable with part of the *S. murrayi* Zone in the Nanba section, but does not reach the *H. copiosus* Zone (Wang et al., 2013). The interval is underlain by the *L. esthonica* Zone in the lower-middle part of the *S. murrayi* Zone and the *L. destombesi* Zone beneath, ranging downwards through the *A. victoriae* Zone into the *Adelograptus tenellus* Zone. Younger chitinozoans from the latest Tremadocian and basal Floian were too poorly preserved for a detailed investigation.

Liang et al. (2017) defined In the upper part of Tungtzu Formation and the lower part of the Hunghuayuan Formation of South China, a *Lagenochitina pestovoensis* Zone and an *E. symmetrica* Zone. The considered interval corresponds to a late, but not latest Tremadocian age. Liang et al. also questioned the Chinese occurrences of *L. destombesi* Elaouad-Debbaj 1988, the index species of the first chitinozoan zone of northern Gondwana and Baltica. They concluded that the Chinese specimens of *L. destombesi* are not typical and consequently recommended to no longer use the *L. destombesi* Zone in southern China; they also put *L. destombesi* as identified by Wang et al. (2013) in synonymy with *L. pestovoensis*.

In South China, the *E. symmetrica* Zone can be correlated with the uppermost *Tripodus proteus, Triangulodus bifidus* and lowermost *Serratognathus diversus* conodont zones, which corresponds to a late, but not latest Tremadocian age at Houtan (Liang et al., 2017). It is necessary to emphasize that the base of the *S. diversus* Zone of the Yangtze Platform provided by Zhen et al. (2015) corresponds to the base of the Floian. However, Liang et al. (2017) documented that the Tremadocian–Floian boundary is located in the lower part of the *S. diversus* Zone in the Houtan section. Thus the upper boundary of the *E. symmetrica* Zone is found in the uppermost Tremadocian, similarly to its occurrence in the Yiyang area, Hunan Province (Wang et al., 2013). However, Liang et al. (2017) did not provide any chitinozoan data from younger intervals, leaving some doubt on the precise position of the top of the *E. symmetrica* Zone in South China.

Avalonia. Amberg et al. (2017) described *E. symmetrica* and *E. paschaensis* from the Watch Hill Formation (Skiddaw Group) of North England. The authors identified the *symmetrica-destombesi* chitinozoan assemblage and correlated it with the upper part of the British *S. murrayi* graptolite Zone (Fig. 5) and the *Lagenochitina conifundus* Zone of Webby et al. (2004). They discussed the extension of the biostratigraphic range of *E.*

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symmetrica into the upper Tremadocian and regarded it as an important index for the Tremadocian-Floian boundary interval. The Watch Hill Formation is reported to include the *S. murrayi* Zone (Cooper et al., 2004), ranging into the overlaying Hope Beck Formation. Thus, a range into the Floian cannot be suggested by the record.

Peri-Gondwana (N-Gondwana). Paris (1990) indicated the presence of an *Amphorachitina conifundus* (now *Lagenochitina*: Paris et al., 1999) Zone below the *E. symmetrica* Zone (Fig. 5) in Bohemia and cited Paris & Mergl (1984) for the record. He correlated the interval with the late Tremadocian to early Arenigian (Paris, 1990; fig. 4). In Bohemia, *L. conifundus* was reported to be common in the basal Klabava Formation. However, *L. conifundus* was not even mentioned in Paris & Mergl (1984) and a revision of the material does not exist, questioning this record. *E. symmetrica* is found in the *Clonograptus* interval of Bohemia (Paris, 1990). The age of the graptolite fauna of the *Clonograptus* Zone from the basal Klabava Formation (Kraft and Mergl, 1979) might be of basal Floian age (cf. Kraft and Kraft, 2003), but as *Paratetragraptus* has not been recognized in the fauna, a late Tremadocian age cannot be ruled out. The connection of the *L .conifundus* and *E. symmetrica* zones is unclear in the Bohemican succession.

Nowak et al. (2016) reported, from the Fezouata Formation of Morocco, an assemblage of small chitinozoans showing a morphological continuum between *E. paschaensis* and *E. symmetrica* designated as the *E. paschaensis-symmetrica* group. The associated graptolites and acritarchs of the succession suggest a Tremadocian age and can be referred to the *S. murrayi* Zone. Lefebvre et al. (2018) also discussed the *E. symmetrica* Zone of the Fezouata Biota from the *S. murrayi* graptolite Zone. Lefebvre et al. (2018, fig. 4) indicated the presence of an *Eremochitina brevis* Zone above the *E. symmetrica* Zone, correlated with the higher part of the *S. murrayi* Zone. The authors indicated the presence of *L. esthonica* in the *paschaensis-symmetrica* Zone, possibly ranging higher in/through (?) the *E. brevis* Zone. They also mentioned that the small forms of *L. esthonica* are similar to *L. cf. longiformis* reported by Hints and Nõlvak (2006) from north Estonia and by de la Puente and Rubinstein (2009) from Argentina. They did not indicate the presence of any younger chitinozoans, but the graptolite succession of the Fezouata Biota ranges into the '*Azygograptus* interval', thus, possibly into the Dapingian, but not all biostratigraphic intervals are recognized. Thus, the *P. approximatus* Zone is not represented by graptolites.

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Realizing a discrepancy to the data of Paris (1990), who considered the *E. symmetrica* Zone of Gondwana to be of Floian age, Lefebvre et al. (2018) recommended to carefully re-evaluate the biostratigraphy of Early Ordovician chitinozoan zones and asked for a better, more precisely defined biozonation.

Laurentia, (this study). The updated stratigraphic ranges of the graptolites of the Lévis Formation and their comparison with that of the chitinozoans made it possible to revisit the Lower Ordovician chitinozoan zonation of Laurentia as it had been proposed earlier (Fig. 5) by Achab (1980) and Achab et.al (2003) and to equate, at least the lower part of the *E. symmetrica* Zone with the *S. murrayi* graptolite Zone. The *L. maxima* Zone is replaced by the *L. gigas* n. sp. Zone which can be correlated with the A. victoriae Zone.

6. Conclusions

The chitinozoan record from the Québec Canadian successions, easily allows a precise integration of chitinozoan and graptolite biozonations and provides a better global correlation of the Tremadocian and the base of the Floian stages.

Initially, the *E. symmetrica* chitinozoan Zone was referred to the Floian (Arenig, Lower Ordovician) based on the studies in Laurentia (Achab, 1980) and North-Gondwana (Paris, 1981, 1990). However, subsequent works in various regions of the world and detailed investigations in Laurentia clearly show a late Tremadocian age based on correlatable graptolite faunas. These correlations demonstrate that, in Laurentia, the base of the *E. symmetrica* chitinozoan assemblage is older than the base of the *P. approximatus* graptolite Zone, which defines the base of the global Second Stage of the Ordovician, the Floian. Therefore, the presence of *E. symmetrica* can no longer be regarded as indicative of the *P. approximatus* Zone as it was initially suggested. *E. symmetrica* characterizes the upper Tremadocian *S. murrayi* graptolite Zone and possibly ranges into the Floian *P. approximatus* graptolite Zone.

The integration of graptolite and chitinozoan data from the lower part of the Levis Formation at the G-locality and in the N-section also shows that the *E. symmetrica* Zone is not directly underlain by the *L. gigas* n. sp. assemblage that may be correlated with the A. victoriae graptolite Zone. A gap in the succession can be seen and the intervening interval, characterized by a massive conglomerate that may have removed a

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considerable lithological interval, probably even the lower part of the *E. symmetrica* Zone. More research is needed to precisely demonstrate the development of early Ordovician chitinozoan assemblages in Laurentia and the correlation with other fossil groups.

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Conflicts of interests: None

Table 1. Dimensions of *E. symmetrica, E. fenxiangensis and E. paschaensis.* Values in parenthesis are those of the holotypes.

***Euconochitina symmetrica* (Taugourdeau and de Jekhowsky 1960)**			
	Lenght	**Chamber diameter**	**Neck diameter**
C. symmetrica Taugourdeau and de Jekhowsky 1960	(250)	(140)	
C. symmetrica Taugourdeau and de Jekhowsky 1960; Achab 1980	L=200-275	Dp=160-220	Dc=110-150
E. symmetrica (Taugourdeau and de Jekhowsky 1960); Wang et al. 2013	L=117-238	Dp=92-140	Dc=58-116
E. symmetrica (Taugourdeau and de Jekhowsky 1960); Chen et al. 2018	L=117-286	Dp=66-165	Dc=37-102
***Euconochitina fenxiangensis* Chen et al. 2008**			
E. fenxiangensis Chen et al. 2008	L=131-(181)-245	Dp=75-(112)-165	Dc=50-(65)-96
***Euconochitina paschaensis* de la Puente and Rubinstein 2009**			
E. pashaensis de la Puente and Rubinstein 2009	L=134-(167)-209	Dp=71-(88)-109	Dc=45-

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			(59)-87
E. pashaensis de la Puente and Rubinstein 2009; Wang et al. 2013	L=125-180	Dp=90-140	Dc=55-80

Fig. 1. Simplified geological map of the Quebec City and Lévis areas and the allochtonous belt of Cambro-Ordovician slices.

Fig. 2. Chitinozoan and graptolite ranges in the G-locality at Lévis (adapted from Achab, 1980; Maletz, new).

Fig. 3. Graptolite and chitinozoan ranges in the N-section at Lévis. All figured chitinozoans are from samples collected on the path departing between 61 and 65 Boulevard Jacques Cartier: specimen 1 = sample 6, specimens 2-4 = sample 8. Specimens 5, 11-13, 20 = sample 1; specimens 6-10, 14-18, 21 = sample 2.

Fig. 4. Graptolites from the N-section at Lévis. A. *Sagenograptus murrayi*, GSC 142639. B. *Clonograptus rigidus*, GSC 142640. C-E. *Paratemnograptus magnificus*. C. GSC 142641, proximal end. D. GSC 142642, stipe fragment with plaited overlap, no bithecae. E. GSC 142643, specimen with distal branching. F, H-J, ?K. *Paratemnograptus magnus*. F, I. GSC 142644, tetragraptid proximal end (I) and latex cast of fragment with plaited overlap, lacking bithecae (F). H. GSC 142647, proximal end. J. GSC 142648, four-stiped proximal end showing undulation of dorsal side of stipes. K. GSC 142645, long and wide stipe fragment. G. *Adelograptus* sp. or *Clonograptus* sp., GSC 142646, large specimen with considerably webbing. A, E. ca. 2.5 m above conglomerate. B-D. ca. 5.5 m above conglomerate. F, I. ca. 2.0 m below base of conglomerate. G, H, J, K. ca. 1.5 m below base of conglomerate.

Fig. 5. Reported occurrences of the *Euconochitina symmetrica* Zone

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Highlights

- Lower Ordovician chitinozoans and graptolites of the Lévis Formation
- The *Euconochitina symmetrica* Zone is not Floian as initially suggested

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- It is rather Tremadocian and corresponds to the *Sagenograptus murrayi* graptolite Zone
- A new *L. gigas* n. sp. Zone replaces the previously designated *L. maxima* Zone
- The *L. gigas* n. sp. Zone corresponds to the *Aorograptus victoriae Zone*

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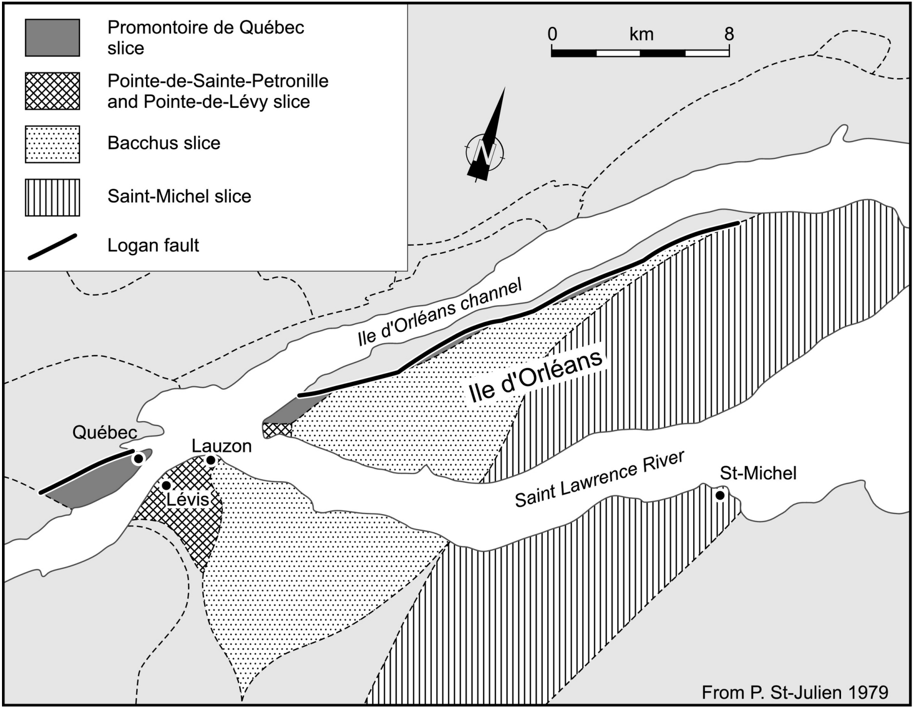


Promontoire de Québec slice
Pointe-de-Sainte-Petronille and Pointe-de-Lévy slice
Bacchus slice
Saint-Michel slice
Logan fault
0
km
8
N
Ile d'Orléans channel
Ile d'Orléans
Québec
Lauzon
Lévis
Saint Lawrence River
St-Michel
From P. St-Julien 1979

Figure 1

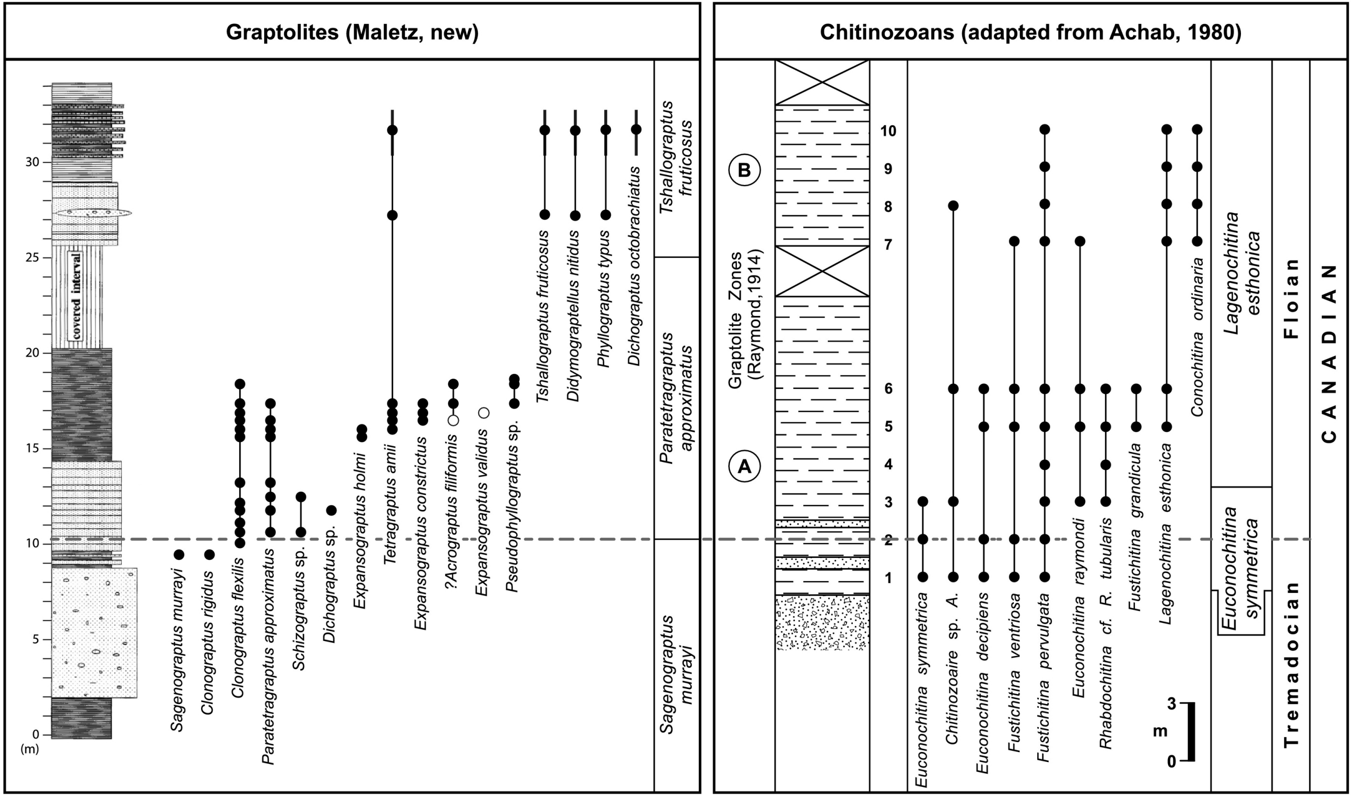
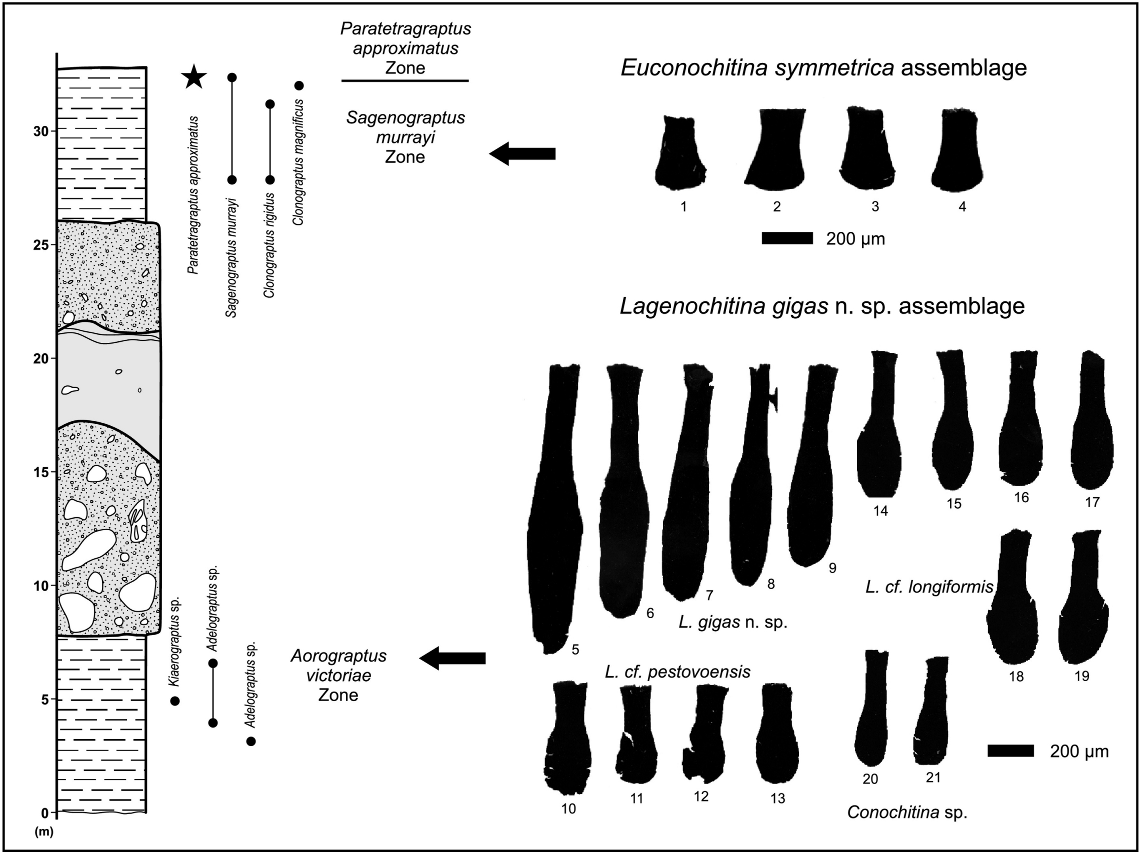

Graptolites (Maletz, new)
Chitinozoans (adapted from Achab, 1980)
covered interval
(m)
Sagenograptus murrayi
Clonograptus rigidus
Clonograptus flexilis
Paratetragraptus approximatus
Schizograptus sp.
Dichograptus sp.
Expansograptus holmi
Tetragraptus amii
Expansograptus constrictus
?Acrograptus filiformis
Expansograptus validus
Pseudophyllograptus sp.
Tshallograptus fruticosus
Didymograptellus nitidus
Phyllograptus typus
Dichograptus octobrachiatus
Tshallograptus fruticosus
Paratetragraptus approximatus
Sagenograptus murrayi
Graptolite Zones (Raymond,1914)
A
B
Euconochitina symmetrica
Chitinozoaire sp. A.
Euconochitina decipiens
Fustichitina ventriosa
Fustichitina pervulgata
Euconochitina raymondi
Rhabdochitina cf. R. tubularis
Fustichitina grandicula
Lagenochitina esthonica
Conochitina ordinaria
Lagenochitina esthonica
Euconochitina symmetrica
Floian
Tremadocian
CANADIAN
m

Figure 2



Paratetragraptus approximatus Zone
Sagenograptus murrayi Zone
Aorograptus victoriae Zone
Paratetragraptus approximatus
Sagenograptus murrayi
Clonograptus rigidus
Clonograptus magnificus
Kiaerograptus sp.
Adelograptus sp.
Adelograptus sp.
30
25
20
15
10
5
0
(m)
Euconochitina symmetrica assemblage
1
2
3
4
200 µm
Lagenochitina gigas n. sp. assemblage
5
6
7
8
9
L. gigas n. sp.
10
11
12
13
L. cf. pestovoensis
14
15
16
17
18
19
L. cf. longiformis
20
21
Conochitina sp.
200 µm

Figure 3

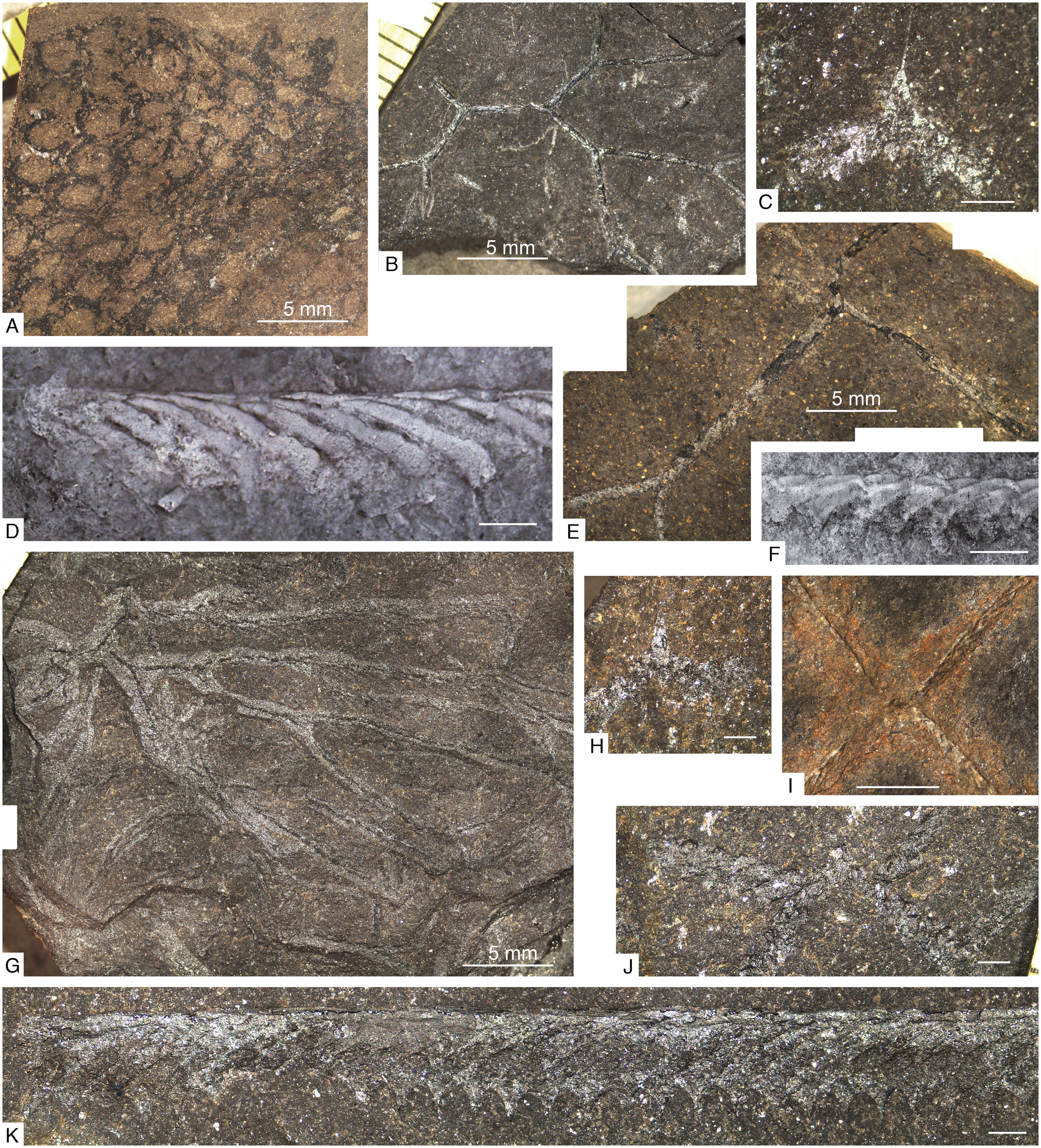


Figure 4

			Until 2004		Since 2004						This Study	
Time slices	Graptolite Zones: Britain	Graptolite Zones: North America	Achab' 1980 and Achab et al. 2003 **LAURENTIA**	Paris, 1980 Webby *et al.*, 2004 **N. GONDWANA**	Hints& Nolvak 2006 **ESTONIA**	de la Puente & Rubinstein 2009, 2013 **ARGENTINA**	Wang *et al.*,2013 **S. CHINA (Yiyang)**	Liang *et al.*,2017 **S. CHINA (Yiangtse)**	Ambert *et al.*,2017 **AVALONIA**	Lefebvre *et al.*,2017 **N. GONDWANA**	**LAURENTIA (Levis and Lauzon)**	**Global Stages**
2b	varicosus	fruticosus	esthonica/ raymondi	baculata	primitiva						esthonica / raymondi	FLOIAN
2a	phyllograptoides	approximatus	symmetrica	symmetrica							?	
1d	murrayi	copiosus / murrayi		conifundus	symmetrica cf. longiformis	symmetrica cf.longiformis cf.conifundus	symmetrica	symmetrica	symmetrica	brevis symmetrica	symmetrica	TREMADOCIAN
1c		victoriae	maxima		destombesi		esthonica	pestovoensis			gigas	
1b	???? / tenellus	tenellus		destombesi			destombesi	????				
1a	flabelliformis	flabelliformis										

Figure 5