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Chitinozoans of the Plöcken Formation (Hirnantian) and Kok Formation (upper Llandovery–lower Ludlow) in the Cellon section (Carnic Alps, Austria)

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Kok Formation
Telychian/lower Silurian

Contents

Abstract

Forty five samples from the Upper Ordovician–lower Silurian sedimentary successions of the Cellon section (Carnic Alps, Austria) are palynologically processed for investigation of chitinozoans within the Valbertad Formation (Katian), the Uqua Formation (late Katian–?lowermost Hirnantian), the Plöcken Formation (Hirnantian) and the Kok Formation (upper Llandovery–lower Ludlow). However, taxonomically assignable chitinozoans are only found in the Plöcken Formation (12 taxa) and in the lower part of the Kok Formation (25 taxa) and these are discussed herein in detail. Due to their generally poor state of preservation many taxa are left in open nomenclature. In the Plöcken Formation, the following taxa are identified: *Armoricochitina nigerica*, *Desmochitina minor*, *Rhabdochitina* cf. *gracilis* and *Tanuchitina elongata*; moreover, occurrence of representatives of the genera *Conochitina*, *Euconochitina* and *Spinachitina* is documented although these could not be identified at species level. This chitinozoan assemblage is herein assigned to the Hirnantian *Tanuchitina elongata* chitinozoan biozone. An independent confirmation of this Late Ordovician age assignment is provided by the occurrence in the lower part of the succession of the Plöcken Formation of the index-fossil of the *Metabolograptus persculptus* graptolite biozone, the uppermost graptolite biozone of the Ordovician, and of the *Hirnantia* Fauna. Evidence of the *Spinachitina oulebsiri* chitinozoan biozone, the uppermost chitinozoan biozone of the Ordovician, is not, however, found within the Cellon section samples.

The chitinozoans of the Plöcken Formation show close relationships to the chitinozoan assemblages of the cold-water realms of Northern Gondwana.

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In recent literature considerable confusion has arisen concerning the stratigraphical position of the base of the Hirnantian Stage in the Bou Ingarf section (central Anti-Atlas, Morocco), which is the type section of several Ordovician chitinozoan biozones such as the *A. merga* and *T. elongata* biozones. The main reason for this may be linked to the incorrect application in previous studies of the zonal definitions to the latter biozones.

In the lower part of the Kok Formation, which unconformably succeeds the Plöcken Formation after a significant hiatus (Rhuddanian–lower Telychian), the following taxa were recorded: *Bursachitina conica*, *Eisenackitina causiata*, *E. dolioliformis*, *E.* cf. *inanulifera*, *Ancyrochitina* gr. *ancyrea*, *Angochitina longicollis*, *Conochitina* cf. *armillata*, *C.* cf. *elongata*, *C.* cf. *iklaensis*, *C. leviscapulae*, *C. praeproboscifera*, *C.* sp. 1 sensu MULLINS & LOYDELL, 2001, *Euconochitina* sp. 2 sensu NESTOR, 1994? and *Euconochitina* sp. 3 sensu NESTOR, 1994? In addition, the presence of numerous taxa identifiable only at generic level as *Bursachitina*, *Calpichitina* (without description), *Eisenackitina*, *Cyathochitina*, *Lagenochitina*, *Plectochitina*?, *Sphaerochitina* and *Conochitina* is established. The chitinozoans of the lower part of the Kok Formation are assigned herein to the global *Angochitina longicollis* chitinozoan biozone, the base of which is correlated on a global scale with the base of the *Oktavites spiralis* graptolite biozone and the lower *Pterospathodus amorphognathoides angulatus* conodont biozone, respectively. The presence of the succeeding global *Margachitina margaritana* chitinozoan biozone, the base of which is located in the uppermost Telychian, could not be proven within the succession due to the absence of chitinozoans from this level upwards.

The chitinozoans of the lower part of the Kok Formation show – in contrast to the Plöcken Formation – a close relationship to the chitinozoan assemblages of the warm-water areas of the palaeocontinents of Baltica and Avalonia.

Chitinozoen der Plöcken-Formation (Hirnantium) und Kok-Formation (oberes Llandovery–unteres Ludlow) aus dem Cellon-Profil (Karnische Alpen, Österreich)

Zusammenfassung

Im Cellon-Profil wurde das Chitinozoen-Vorkommen in der Valbertad-Formation (Katium), der Uqua-Formation (oberes Katium–?unterstes Hirnantium), der Plöcken-Formation (Hirnantium) und der Kok-Formation (oberes Llandovery–unteres Ludlow) untersucht, und dafür wurden 45 Proben palynologisch aufbereitet. Nur in der Plöcken-Formation (12 Taxa) und im unteren Teil der Kok-Formation (25 Taxa) sind bestimmbare Chitinozoen vertreten, die hier eingehend beschrieben werden. Da die Fossilien überwiegend schlecht erhalten sind, mussten viele Taxa in offener Nomenklatur gehalten werden.

In der Plöcken-Formation treten folgende Taxa auf: *Armoricochitina nigerica*, *Desmochitina minor*, *Rhabdochitina* cf. *gracilis* und *Tanuchitina elongata* und weiters nicht genauer bestimmbare Vertreter der Gattungen *Conochitina*, *Euconochitina* und *Spinachitina*.

Diese Chitinozoen-Gesellschaft wird der *Tanuchitina elongata* Chitinozoen-Biozone des Hirnantiums zugewiesen. Dieses Alter wird bestätigt durch das Vorkommen des Index-Fossils der *Metabolograptus persculptus* Graptolithen-Biozone, der jüngsten Graptolithen-Zone des Ordoviziums, sowie der *Hirnantia* Fauna, beide im unteren Teil der Plöcken-Formation auftretend. Die *Spinachitina oulebsiri* Chitinozoen-Biozone, die jüngste Chitinozoen-Zone des Ordoviziums, kann im Cellon-Profil jedoch nicht nachgewiesen werden.

Die Chitinozoen der Plöcken-Formation zeigen enge Beziehungen zu den Chitinozoen-Gesellschaften der Kaltwassergebiete von Nord-Gondwana.

Für die in der jüngeren Literatur entstandene Konfusion hinsichtlich der stratigrafischen Position der Basis des Hirnantiums im Bou Ingarf Profil (zentraler Anti-Atlas, Marokko), dem Typusprofil mehrerer Ordovizischer Chitinozoen-Biozonen wie die *A. merga* und die *T. elongata* Biozone, konnte die Anwendung fehlerhafter Zonendefinitionen auf die beiden genannten Biozonen in früheren Arbeiten als Ursache identifiziert werden.

Im unteren Teil der Kok-Formation, die nach langer Sedimentationsunterbrechung (Rhuddanium–unteres Telychium) diskordant über der Plöcken-Formation folgt, sind folgende Chitinozoen-Taxa vertreten: *Bursachitina conica*, *Eisenackitina causiata*, *E. dolioliformis*, *E.* cf. *inanulifera*, *Ancyrochitina* gr. *ancyrea*, *Angochitina longicollis*, *Conochitina* cf. *armillata*, *C.* cf. *elongata*, *C.* cf. *iklaensis*, *C. leviscapulae*, *C. praeproboscifera*, *C.* sp. 1 sensu MULLINS & LOYDELL, 2001, *Euconochitina* sp. 2 sensu NESTOR, 1994? und *E.* sp. 3 sensu NESTOR, 1994?; weiters finden sich nicht näher bestimmbare Vertreter der Gattungen *Bursachitina*, *Calpichitina* (ohne Beschreibung), *Eisenackitina*, *Cyathochitina*, *Lagenochitina*, *Plectochitina*?, *Sphaerochitina* und *Conochitina*.

Die Chitinozoen der unteren Kok-Formation werden der globalen *Angochitina longicollis* Chitinozoen-Biozone zugeordnet, deren Basis mit der Basis der *Oktavites spiralis* Graptolithen-Biozone bzw. der unteren *Pterospathodus amorphognathoides angulatus* Conodonten-Biozone korreliert. Die darüber folgende globale *Margachitina margaritana* Chitinozoen-Biozone, deren Basis im obersten Telychium liegt, kann aufgrund des Fehlens von Chitinozoen ab diesem Bereich nicht nachgewiesen werden.

Die Chitinozoen-Gesellschaften der unteren Kok-Formation zeigen, im Gegensatz zu jenen der Plöcken-Formation, deutliche Beziehungen zu den Gesellschaften der Warmwasserareale der Paläokontinente Baltica und Avalonia.

Introduction

Early Palaeozoic palynomorphs (acritarchs, chitinozoans and spores) are used in numerous studies worldwide as they are excellent tools for stratigraphical dating as well as for environmental and palaeogeographical interpretation of their depositional settings. A further advantage of these fossil groups is the resistance of their vesicle walls, composed of organic matter, non-degradable to the harsh extraction techniques which are necessary for dissolving the clastic rocks surrounding the fossils. Unfortunately, such techniques tend to destroy the remnants of other stratigraphically useful organisms (MILLER, 1996; MOLYNEUX et al., 1996; PLAYFORD & DETTMANN, 1996; PARIS, 1996; RICHARDSON, 1996; STROTHER, 1996).

The Lower Palaeozoic of Austria is rich in clastic sequences whose age is sometimes insufficiently known. Notwithstanding this lack of data, palynological investigations have been rarely employed for dating purposes here in recent decades. The Austrian pioneers in this field were BACHMANN & SCHMID (1964) who published studies of chitinozoans and acritarchs from thin sections of a Silurian lydite breccia from the Rudniggraben area in the Carnic Alps. More than a decade later, MARTIN (1978) examined several samples from the sequence ranging from the former Uggwa Shales (now termed the Valbertad Formation) to the basal Kok Formation at the Cellon section and found a rich acritarch assemblage in one of the samples from the lowermost Kok Formation of Silurian age.

After the confirmation of the presence of palynomorphs in the Carnic Alps, it seemed worthwhile to evaluate their stratigraphical value for the Carnic sedimentation area within a well dated succession such as the Cellon section which had become famous due to the conodont zonation established there in the study by Walliser (1964). Thus 95 samples were collected ranging from the Katian Valbertad Formation up to the lower Lochkovian Rauchkofel Formation and these have been palynologically processed. The results of the taxonomical and stratigraphical studies on acritarchs were already published in Priewalder (1987).

The examination of the chitinozoans from the Cellon section became part of a broader scientific project. The aim was to give an initial overview of the geographical and stratigraphical distribution of acritarchs, chitinozoans and spores within the four Silurian facies zones of the Carnic Alps. According to Schönlaub (1997), these facies zones comprise the near-shore Wolayer Facies with calcareous shallow-water deposits (palynomorphs not studied due to the unfavourable environment), the Plöcken Facies with mainly calcareous deposition upon a shallow shelf, the Bischofalm Facies with siliciclastic basinal sediments and the transitional Findenig Facies positioned between the latter two settings.

In none of these facies did spores occur. Rich and diverse acritarch assemblages were present solely in the upper Llandovery–lowermost Wenlock sequence of the Cellon section which belongs to the Plöcken Facies. The chitinozoans, however, proved to be the geographically and stratigraphically most widespread palynomorph group: they were more or less continuously present in all studied facies zones. 79 samples from the Findenig and the Bischofalm Facies (sections Oberbuchach 1–3) have been randomly screened, and 60 % of them contain chitinozoans.

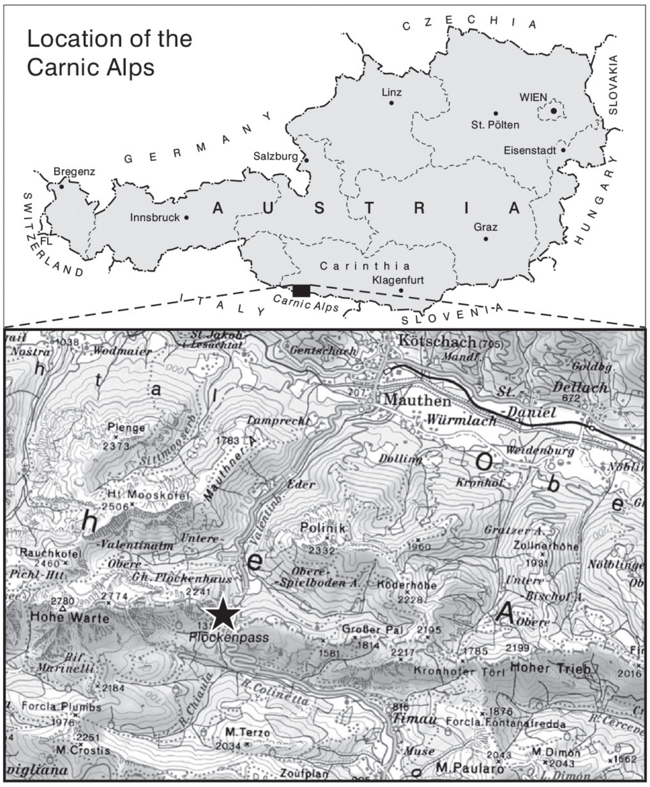
Preliminary results of the studies on the chitinozoans from the whole Cellon section (Katian–lower Lochkovian) were presented in Priewalder (1994, 1997, 2000). The topic of the present study are the chitinozoans from the lower part of the Cellon section. Unfortunately samples from the Valbertad Formation (Katian), Uqua Formation (late Katian–?lowermost Hirnantian) and the upper part of the Kok Formation (Wenlock–lower Ludlow) yielded only poorly preserved or no chitinozoans. Therefore, the main emphasis of this paper is on the rather diverse chitinozoan assemblages from the Plöcken Formation (Hirnantian) and the lower part of the Kok Formation (Telychian) which are discussed herein in detail.

Geological setting

The Carnic Alps

The Carnic Alps are located in the south of Austria and in the north of Italy on both sides of the border (Text-Fig. 1). They extend in a W–E direction over more than 140 km with a width of up to 15 km. They now form part of the Southern Alps and are separated by the Gailtal Fault (part of the Periadriatic Line) from the Eastern Alps to the north. The Carnic Alps formerly belonged to the pre-Variscan basement of the latter (Schönlaub & Histon, 2000; Corradini et al., 2015b).

Concerning the lithology, the Carnic Alps can be divided into two areas, separated by a prominent fault: a western portion is composed of low-grade metamorphic rocks, while an eastern portion contains an almost complete succession of fossiliferous sediments of Middle Ordovician to Permian age (Corradini et al., 2015b).



Text-Fig. 1.
Location map of the Carnic Alps. Black star = position of the Cellon section.

During the Cambrian, the Carnic Alps are postulated to have been part of the northern margin of the African sector of East Gondwana. Based on basic volcanism in parts of the Eastern Alps, rifting started in the Early Ordovician and led to the separation of small microcontinents, the Peri-Gondwana terranes and arcs, comprising the Carnic Alps (Apulia Terrane), Avalonia, Armorico-Iberia, Perunica and many others. Some of these terranes drifted northward with different rates and, starting in Devonian times, collided and accreted with Laurentia and Baltica during the course of the Variscan Orogeny (see in Schönlaub & Histon, 2000; Brett et al., 2009).

Based on faunal, sedimentological and palaeomagnetic data, the palaeogeographic position of the Carnic Alps in the Late Ordovician is approximately at 50° S, in the Silurian at 35° S and in the Devonian at 30° S. By the Lower Carboniferous the Apulia microterrane had arrived at the humid equatorial belt. With a continued northward drift, semiarid and arid conditions arose during the Guadalupian (Middle Permian) (Schönlaub & Histon, 2000).

The pre-Variscan successions in the Carnic Alps (Middle Ordovician–lower Upper Carboniferous) accumulated at the southern border of the Rheic Ocean and were affected by the Variscan Orogeny during the late Bashkirian and the Moscovian when the Rheic Ocean closed in the course of the collision of Gondwana and Laurussia. These successions are unconformably overlain by strata of Upper Carboniferous to Lower Permian (Cisuralian) age, and are then succeeded by the "Alpine" sequence of which the basal part (Middle Permian–Middle Triassic) is preserved in the Carnic Alps (Corradini et al., 2015c).

General lithostratigraphy

Up until the Katian, as much as 100 m of clastic sediments were deposited in the marine environments of the Carnic Alps. In the late Katian–?earliest Hirnantian, these are followed by near-shore massive pelmatozoan limestone, quartz arenite and greywacke, and coeval off-shore shale and bedded wackestone from slightly deeper water. In the Hirnantian, local non-deposition and/or erosion took place due to a widespread global marine low-stand, and diamictites within the coarse-grained impure limestone and calcareous pyritiferous sandstone point to the influence of the Gondwana glaciation (Brett et al., 2009; Corradini et al., 2015c; Schönlaub & Ferretti, 2015). According to Schönlaub (1988), in the Late Ordovician the Carnic Alps were affected by vertical block movements leading during the Silurian to different thicknesses in adjacent sections and to a great diversity of depositional environments.

The Silurian transgression in the Carnic Alps is first recognised at localities representative of the deep-water facies close to the base of the Llandovery, whereas in many shelf facies areas significant gaps occur between Ordovician and Silurian deposits. In extreme cases, Pridolian rocks may rest upon Late Ordovician strata (Schönlaub & Histon, 2000; Brett et al., 2009; Corradini et al., 2014).

The Silurian of the Carnic Alps is characterised by four lithofacies which depict different depth of deposition and hydrodynamic conditions. These range from the shoreline to the basin in a SW–NE direction: (1) the high energy Wolayer Facies with shallow marine limestone; (2) the shallow to moderately deep shelf Plöcken Facies with mainly “Orthoceras limestone”, as represented at the Cellon section; (3) the Findenig Facies reflecting the slope setting with alternating limestone, marl and black graptolitic shale; (4) the low-energy basinal Bischofalm Facies with euxinic deep-water sediments (black graptolitic shale alternating with chert and clayey “alum” slate) (Brett et al., 2009; Corradini et al., 2014; Hubmann et al., 2014).

In the Devonian, the depositional area of the Carnic Alps was even more differentiated with a shallow-water facies in the Southwest (intertidal, back reef, reef and reef debris limestones) flanked to the Northeast by a slope facies, a pelagic limestone facies, a distal pelagic siliciclastic facies and a northern shallow-water facies (Hubmann et al., 2014). In the Late Devonian the basin collapsed and caused the drowning of the reefs while in the latest Devonian a uniform pelagic environment was established which lasted until the Early Carboniferous. Subsequently from the late Early Carboniferous onwards, up to 1,000 m of arenaceous pelitic turbidites were deposited, and are interpreted as being a Variscan flysch sequence. The Variscan Orogeny in the late Bashkirian–Middle or Late Moscovian (early Late Carboniferous) brought the pre-Variscan sedimentation in the Carnic Alps to an end (Schönlaub & Histon, 2000; Corradini et al., 2015c).

The post-Variscan transgression started in the Carnic Alps in the late Late Carboniferous with the deposition of 600–800 m shallow-marine molasse-type sediments which rest with a distinct angular unconformity upon strongly deformed pre-Variscan units of different ages. They are succeeded by more than 1,000 m of Cisuralian (Lower Permian) carbonates and clastics deposited on a differently subsiding inner and outer shelf. This whole sequence was influenced by transgressive-regressive cycles which may be induced by the glaciations on the Southern Hemisphere. At the base of the Guadalupian (Middle Permian) there is a facies change to transgressive marine clastics which marks the beginning of the so-called “Alpine” sequence in the Carnic Alps with evaporite, dolomitic rock and finally ostracode and radiolarian wackestone (Schönlaub, 1992; Schönlaub & Histon, 2000). On top of this succession, South-alpine marine sediments of Triassic age accumulated (Bauer, 1980).

The Palaeozoic and Triassic strata of the Carnic Alps have been affected by the Variscan, as well as by the Alpine Orogeny. During the Variscan Orogeny in the early Late Carboniferous, the pre-Variscan depositional area became strongly compressed which resulted in a thrust sheet complex of isoclinally folded anchi- to epimetamorphic rocks and in shortening of the area of 75–80 % of the original width. The Variscan deformation produced nine north-verging nappes and was stronger than the tectonic forces during the Alpine Orogeny, as the post-Variscan cover is less intensely folded. The epizonal metamorphism during the Variscan Orogeny was also slightly higher than the mainly anchizonal Alpine overprint on the Upper Carboniferous to Triassic rocks. The Alpine tectonics, however, generated a complex deformation pattern in the Southern Alps, including the Carnic Alps (Schönlaub & Histon, 2000).

During the last decade, the pre-Variscan lithostratigraphic units of the Austrian and Italian parts of the Carnic Alps, of which the majority had previously been inadequately defined and documented, have been subjected to a re-evaluation und a formalisation according to the rules of the International Commission on Stratigraphy by an Italian-Austrian working group (Corradini & Suttner, 2015). This effort resulted in a variety of measures, amongst others in the reduction of the number of units and in several cases also in the substitution of unit names.

In the Cellon section succession, three lithostratigraphic units were affected by these adjustments: the former Uggwa Shale of Katian age was renamed the Valbertad Formation; the name of the succeeding former Uggwa Limestone (late Katian) was changed to the Uqua Formation; and finally, the former *Megaerella* Limestone (Pridoli–lowermost Lochkovian) was abandoned and incorporated within the Alticola Formation (Ludfordian–lowermost Lochkovian), however, elsewhere in the Carnic Alps the uppermost Pridolian portion became part of the newly established Seekopf Formation (Corradini et al., 2015c: 10).

The Cellon section

The Cellon section is located in the Carnic Alps in southwestern Carinthia, SSW of Kötschach-Mauthen, close to the Austrian/Italian border, in the more southern of the two avalanche gorges on the eastern flanks of Mount Cellon (Frischenkofel) (Text-Fig. 1). The altitude of the section ranges from 1,480–1,560 m, the coordinates are 46°36’32”N, 12°56’31”E.

The classical Cellon section comprises an almost complete Upper Ordovician to Lower Devonian succession. The strata in the steep avalanche gorge, moreover, continue upwards until the lower Carboniferous. The section is the stratotype for the Silurian of the Eastern and Southern Alps as well as for the Plöcken Facies, and it is a global reference section for the Silurian (Schönlaub & Histon, 2000; Corradini et al., 2014, 2015b).

Tectonically, the section belongs to the Cellon Nappe, one of nine nappes in the Carnic Alps, generated during the course of the Variscan orogeny.

The depositional environment of the Cellon succession was a relatively shallow to moderately deep marine shelf. Starting with siliciclastic sediments in the Katian (Valbertad Formation) and succeeded by limestones and siltstones in the late Katian–?earliest Hirnantian (Uqua Formation), the Ordovician sedimentation ended in the Hirnantian with the deposition of the glacially influenced impure limestones and calcareous sandstones of the Plöcken Formation. The succeeding Silurian to lowermost Devonian rocks were deposited in the so-called "Plöcken Facies". Compared to coeval and more basinal sections, the overall thickness of this transgressive sequence is considerably reduced with several gaps in sedimentation of varying lengths which suggests eustatic sea level changes. The oldest Silurian strata are of Telychian age and rest unconformably with a significant gap upon the Hirnantian Plöcken Formation. The transgression took place from the upper Llandovery (Telychian) to the Ludlow (Ludfordian) in a steadily subsiding basin, where the Kok Formation (nautiloid-bearing limestone, in the lower part alternating with shale) and the Cardiola Formation (alternating black cephalopod limestone, marl and shale) were deposited. In the upper Ludlow and Pridoli, however, more stable conditions were established leading to the deposition of the uniform carbonate succession of the Alticola Formation. The latter is succeeded by the dark platy offshore limestone of the Lochkovian Rauchkofel Formation (Schönlaub & Histon, 2000; Brett et al., 2009; Štorch & Schönlaub, 2012; Corradini et al., 2014; Corradini et al., 2015a, b).

The well-known Cellon section has been studied for more than a century. Geyer (1903) was the first to give a lithological description of the succession and Gaertner (1931) published the results of his detailed lithological and palaeontological studies. Since then, the section has been the subject of numerous investigations.

One of the most important investigations was the bed-by-bed sampling of the Upper Ordovician to basal Devonian succession and the subsequent description of the conodont fauna by Otto H. Walliser, which resulted in the publication of the first conodont zonation of the Silurian Period (Walliser, 1964). Decades later, Ferretti & Schönlaub (2001) restudied the conodonts of the Upper Ordovician part of the sequence, while Corradini et al. (2014) revised the Silurian conodont stratigraphy of the section.

Since it was stratigraphically well dated by conodonts, the Cellon section became an important site of investigation for many fossil groups and topics: acritarchs (Martin, 1978; Priewalder, 1987); bacteria and nannobacteria-like particles (Priewalder, 2013a, b); bivalves (Kříž, 1974, 1979, 1999); brachiopods (Plodowski, 1971, 1973; Jaeger et al., 1975; Cocks, 1979); chitinozoans (Priewalder, 1994, 1997, 2000); corals (Pickett, 2007); foraminifers (Langer, 1969; Kristan-Tollmann, 1971); graptolites (Jaeger, 1975; Jaeger et al., 1975; Štorch & Schönlaub, 2012); nautiloids (Ristedt, 1969; Histon, 1999, 2002; Histon & Schönlaub, 1999); ostracods (Schallreuter, 1990); trilobites (Haas, 1969; Santel, 2001).

K-bentonites were studied by Histon et al. (2007), carbon isotopes by Wenzel (1997) and Jeppson et al. (2012).

Results of detailed lithological analyses of the Cellon Section were published by Flügel (1965); Schönlaub (1985); Dullo (1992); Kreutzer (1992); Histon (1997a, 2012); Kreutzer & Schönlaub (1997); Schönlaub et al. (1997); Histon & Schönlaub (1999); Histon et al. (1999); Schönlaub et al. (2004); Brett et al. (2009); Corradini et al. (2015b). Brett et al. (2009) used the Cellon section to establish a sequence stratigraphy of the Silurian of the area.

The majority of the above listed studies are concerned with the Silurian to lowermost Devonian succession, whereas the Upper Ordovician strata of the Cellon section, particularly those influenced by the Hirnantian glaciation have been investigated by Schönlaub (1971, 1988), Schönlaub & Sheehan (2003, 2004) and Hammarlund et al. (2012). Similarly, in the late Katian–Hirnantian part of the section, an interdisciplinary team of geoscientists carried out studies on lithostratigraphy, K-bentonites, radiometry, carbon isotope chemistry, iron and sulphur chemistry, as well as on graptolites, conodonts, brachiopods, acritarchs and chitinozoans focusing on bringing together different lines of evidence for the Late Ordovician glaciation event in the Carnic Alps (Schönlaub et al., 2011).

For more details concerning the previous studies on the Cellon section see Corradini et al. (2014: 3–4).

The Cellon section comprises seven formations, which are from bottom to top: the Valbertad Formation (Katian), the Uqua Formation (late Katian–?basal Hirnantian), the Plöcken Formation (Hirnantian), the Kok Formation (Telychian–Ludfordian), the Cardiola Formation (Ludfordian), the Alticola Formation (Ludfordian–lowermost Lockovian) and the Rauchkofel Formation (Lochkovian).

In the next chapter, only two formations are described lithostratigraphically more in detail, the Plöcken and the Kok formations, because they are the only two containing stratigraphically significant chitinozoans. The Valbertad Formation and the Uqua Formation will only be briefly discussed, since they were devoid of identifiable chitinozoans.

The Valbertad Formation

The Valbertad Formation (the former Uggwa Shale), being at least 100 m in thickness, forms the base of the Cellon section. It is made up of greenish to greyish claystone to siltstone, deposited in a moderately deep-marine environment. It grades conformably into the overlying Uqua Formation (Schönlaub et al., 2011; Schönlaub & Simonetto, 2015).

The fossil content of the Valbertad Formation comprises acritarchs (unidentifiable), brachiopods, bryozoans, cephalopods (nautiloids), cystoids, gastropods, hyoliths, tentaculites, trilobites (Schönlaub & Simonetto, 2015).

The chronostratigraphic age is Katian, based on the *Foliomena* brachiopod fauna (Schönlaub & Simonetto, 2015). No identifiable chitinozoans are present in this sequence.

For more information concerning the Valbertad Formation in the Carnic Alps refer to Suttner et al. (2014a); Corradini et al. (2015b); Schönlaub & Simonetto (2015).

The Uqua Formation

At the base of the formation (the former Uggwa Limestone) (Text-Fig. 2) 4.11 m of greyish bedded wackestone (*Beds 1–4*; numbering after Walliser, 1964) occurs. It is overlain by 20 cm of greenish siltstone, followed by 25 cm of more compact argillaceous limestone to marlstone and 40 cm of unfossiliferous greenish siltstone at the top. The overall thickness of the Uqua Formation in the Cellon section, which is the stratotype of this formation, is 4.96 m (Schönlaub et al., 2011).

The contact with the overlying Plöcken Formation, which has greyish siltstone at the base and thus marks a distinct change in colour, is disconformable.

The depositional environment of the Uqua Formation was the deeper water area where allochthonous material from shallow water high-energy limestone strata (Wolayer Formation) accumulated. Geochemical investigations indicate deposition within an oxic water column (Schönlaub & Ferretti, 2015).

According to Schönlaub & Sheehan (2004), the upper greenish siltstone which follows the intercalated limestone to marlstone bed may reflect the regressive trend in the lower and middle Hirnantian. Due to the glaciation on the southern hemisphere, an area of about 30 million km^2 was covered by ice and the sea-level dropped about 100 m (Schönlaub & Sheehan, 2004). The latter change in sea-level considerably affected the depositional environment around the Cellon section. The greenish pelitic sediments may thus represent glacio-marine deposits in a distal position to the glaciation in northern Gondwana.

The fossil content of the Uqua Formation comprises acritarchs (unidentifiable), brachiopods, conodonts, cephalopods, crinoids, foraminifers, gastropods, ostracods, sponge spiculae, and trilobites (Schönlaub & Ferretti, 2015).

At present the chronostratigraphic age of the Uqua Formation is considered as being Late Katian (Ka3–4 Stage slices sensu Bergström et al., 2009) to (?)basal Hirnantian.

The sequence was correlated to the *Amorphognathus ordovicicus* conodont biozone by Ferretti & Schönlaub (2001) (Schönlaub & Ferretti, 2015).

The presence of the index-graptolite of the lower Hirnantian, *Normalograptus extraordinarius* (Sobolevskaya, 1974), which is correlated with the glacial period, has as yet not been proved in the Carnic Alps. There are two levels in the Cellon section which might represent the *N. extraordinarius* graptolite biozone: these are either the unfossiliferous greenish siltstone at the top of the Uqua Formation and/or the unconformity separating the Uqua Formation and the Plöcken Formation (Schönlaub et al., 2011: 524).

No identifiable chitinozoans are found in this sequence.

For more information concerning the Uqua Formation in the Carnic Alps refer to Suttner et al. (2014b); Schönlaub & Ferretti (2015); Corradini et al. (2015b).

The Plöcken Formation

At the base of this transgressive unit (Text-Fig. 2), a shaly sequence is developed with a thickness of 0.77 m (*Bed 5* – numbering after Walliser, 1964) and a distinctive colour change occurs compared to the greenish siltstone below. This basal bed comprises a greyish siltstone with intercalations of impure greyish to blackish bioclastic limestone lenses. In *Bed 5* – about 25 cm above the base of the formation – the index-graptolite of the uppermost Ordovician graptolite biozone, *Metabolograptus persculptus* (Elles & Wood, 1907) is recorded (Schönlaub et al., 2011; Štorch & Schönlaub, 2012). The *M. persculptus* graptolite biozone is correlated to the period of the melting of the Gondwana ice sheet and indicates the upper part of the Hirnantian Stage (for notes on the lower Hirnantian *N. extraordinarius* graptolite biozone in the Cellon section refer to the preceding chapter “The Uqua Formation”). In the same bed as well as slightly higher at the base of *Bed 6*, the presence of the *Hirnantia* brachiopod fauna, typical of the Kosov Brachiopod Province, is documented. In addition the trilobite *Mucronaspis mucronata* (Brongniart, 1822) is also recorded in *Bed 6*.

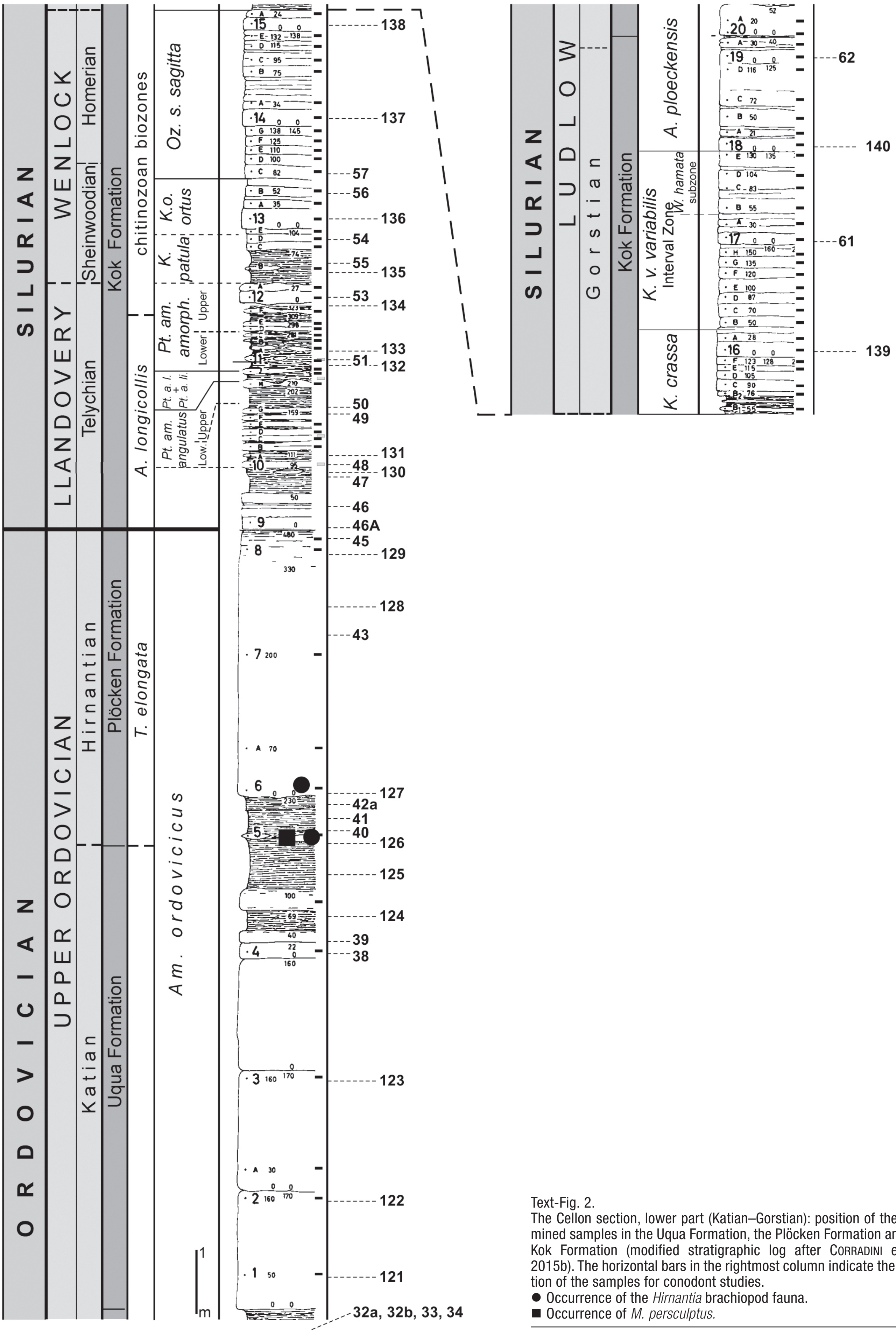
The shaly sequence is overlain by 5.4 m of a more massive impure pyritiferous limestone and calcareous sandstone with layers of bio- and lithoclasts (*Beds 6–8*). At the top of the formation thin layers of greenish silty shale occur (Schönlaub et al., 2011). Throughout the whole sequence bioturbation, channelling, convolute bedding, erosion and local non-deposition are evident (Schönlaub, 1988).

At other locations in the Carnic Alps (e.g., Rauchkofel South Section, Nölblinggraben Section) diamictites are present within the Plöcken Formation which demonstrate the influx of icebergs and cold water to the Carnic depositional area during the course of the melting of the Gondwana ice-cap (Schönlaub, 1988; Schönlaub et al., 2011). Diamictites are widely distributed in the North Gondwana realm where they all occur within the *Tanuchitina elongata* chitinozoan biozone of late Hirnantian age (Oulebsir & Paris, 1995; Paris et al., 2000a). These deposits themselves, however, are missing at the Cellon section.

The lithology of the Plöcken Formation in the Cellon section indicates a storm-dominated shallow water environment formed during the melting of the N-Gondwana ice-cap within the time range of the *M. persculptus* graptolite biozone which resulted in a global sea-level rise and transgression (Schönlaub & Sheehan, 2004).

In the Cellon section, the contact of the Plöcken Formation with the overlying Silurian Kok Formation is disconformable and characterised by a major sedimentological gap, which lasts until the upper Llandovery.

Recently a series of studies provided new data for the Upper Ordovician sequences in the Cellon section: at the unconformity between the underlying Uqua Formation and the covering Plöcken Formation, the stable isotopic values of carbon show a prominent excursion of +2.8 ‰, while the remaining samples in both formations display constantly low values (Schönlaub et al., 2011). Furthermore, geochemical investigations suggest that the Plöcken Formation was deposited within a reducing water column, at first under ferruginous conditions which later became richer in sulphide but not euxinic (Schönlaub et al., 2011: 522;



Text-Fig. 2.
The Cellon section, lower part (Katian–Gorstian): position of the examined samples in the Uqua Formation, the Plöcken Formation and the Kok Formation (modified stratigraphic log after Corradini et al., 2015b). The horizontal bars in the rightmost column indicate the position of the samples for conodont studies.
● Occurrence of the *Hirnantia* brachiopod fauna.
■ Occurrence of *M. persculptus.*

HAMMARLUND et al., 2012: 136). HISTON et al. (2007) and SCHÖNLAUB et al. (2011) reported four thin K-bentonite horizons within the Plöcken Formation with a thickness of a few millimetres to 3 cm at most. The one in the lower part of the formation (in the base of *Bed 6*) is located within the Hirnantia Fauna interval, the remaining three horizons were identified within *Bed 8* in the upper part of the sequence. These were probably derived from neighbouring peri-Gondwana terranes, which were separated from the Carnic Alps by an oceanic realm or an open sea of unknown width (HISTON et al., 2007).

The fossil content of the Plöcken Formation comprises acritarchs (unidentifiable), bivalves, brachiopods, cephalopods, chitinozoans, conodonts, echinoderms, foraminifers, gastropods, graptolites, ostracods, sponge spiculae, and trilobites (SCHÖNLAUB & FERRETTI, 2015).

The chronostratigraphic age of the Plöcken Formation is upper Hirnantian, due to the identification of the *Metabolograptus persculptus* graptolite biozone, the *Tanuchitina elongata* chitinozoan biozone and the *Amorphognathus ordovicicus* conodont biozone.

The *Conodont Fauna 2* within the Plöcken Formation of the Cellon section (FERRETTI & SCHÖNLAUB, 2001) is the first confirmed presence of conodonts in the Hirnantian of the North Gondwana realm.

Chitinozoans occur from the base to the top of the Plöcken Formation, but stratigraphically important taxa are only present in the upper part of the succession.

For more information concerning the Plöcken Formation in the Carnic Alps it is referred to SCHÖNLAUB et al. (2011); SUTTNER et al. (2014c); CORRADINI et al. (2015b); SCHÖNLAUB & FERRETTI (2015).

The Kok Formation

The Kok Formation (Text-Fig. 2) consists of a transgressive carbonate succession and it unconformably succeeds the Hirnantian Plöcken Formation with a long-lasting hiatus (Rhuddanian–lower Telychian) in between. The Silurian sedimentation started in the late Llandovery (Telychian) and continued until the middle Ludlow (Ludfordian) within a constantly subsiding basin. The contact with the succeeding Ludfordian Cardiola Formation is sharp and conformable. The whole sequence measures 13.5 m, is strongly condensed and shows several gaps in sedimentation (KLEFFNER & BARRICK, 2010). According to CORRADINI et al. (2014) the lower Sheinwoodian and the upper Homerian are missing.

The Kok Formation comprises *Beds 9–19*, numbering after WALLISER (1964). In the lower part of the sequence the “Lower shales and ferruginous limestone member” (BRETT et al., 2009; *Beds 9–11B*) consist of c. 3 m of alternating dark-grey to black shale and thin brownish and dark grey ferruginous limestone. In the upper part of the formation *Beds 11C–19* are referred to as the “Kok Limestones (lower, middle, upper)” by BRETT et al. (2009) and are mainly made up of brown-red ferruginous nautiloid wackestone and packstone deposited at low sedimentation rates and with numerous stylolitic and discontinuity surfaces, hardgrounds and evidences of reworking. A common feature is the presence of small scale depositional cycles which point to frequent changes in the hydrodynamic energy ranging from quiet sedimentation to storm related events (HISTON, 2012). The upper part of this succession (*Beds 13–19*) is characterised by thicker and more massive layers, a reddish colour of the rocks, intensive bioturbation and stromatolitic structures and microbial mats. Dark grey to black shaly layers are intercalated within the overall limestone sequence of the formation at the base of the Wenlock (overlying *Bed 12A*) and at the transition from the Wenlock to the Ludlow (overlying *Bed 15A*). For detailed lithologic descriptions of the Kok Formation in the Cellon Section see HISTON (1997a); HISTON & SCHÖNLAUB (1999); BRETT et al. (2009).

The Kok Formation was deposited in a shallow to moderately deep, steadily subsiding marine shelf environment. It accumulated below the normal wave base within the carbonate dominated Plöcken Facies where the sea bottom periodically was ventilated by surface currents. This overall transgressive Llandovery to Ludlow succession is characterised by intervals of reduced deposition and non-sedimentation, in particular during the Wenlock and Ludlow which is suggestive of sea level changes (SCHÖNLAUB & HISTON, 1999). BRETT et al. (2009) and HISTON (2012) documented several sea-level lowstands in the Cellon section during the deposition of the Kok Limestones and two pronounced deepening events concluded from the dark grey to black shale intercalations at the beginning of the Wenlock and the Wenlock–Ludlow transition. Moreover, they identified four sequence boundaries in the upper Llandovery to basal Ludlow interval. Taphonomic studies on the nautiloid fauna revealed frequent changes in the hydrodynamic regime and the oxygen content of the sediment (HISTON & SCHÖNLAUB, 1999; HISTON et al., 1999; HISTON, 2012).

As in the underlying Plöcken Formation, HISTON et al. (2007) identified various K-bentonite horizons in the Kok Formation: two in the Telychian *Pterospathodus celloni* conodont superzone and three in the Sheinwoodian *Cyrtograptus rigidus* graptolite biozone.

The Kok Formation is rich in fossils: acritarchs, bacteria, bivalves, brachiopods, cephalopods, chitinozoans, conodonts, conularids, corals, crinoids, foraminifers, gastropods, graptolites, machaeridians, ostracods, trace fossils and trilobites occur in varying frequencies at numerous stratigraphic levels (SCHÖNLAUB et al., 1997; FERRETTI et al., 2015).

The chronostratigraphic age of the Kok Formation in the Cellon section is Llandovery (Telychian) to Ludlow (Ludfordian). The Ordovician/Silurian boundary is located between *Bed 8* (Plöcken Formation, Hirnantian) and *Bed 9* with a large hiatus documented in between since the Silurian sedimentation started in the Telychian. According to the present study, this basal Silurian sequence can now be correlated with the global *Angochitina longicollis* chitinozoan biozone and thus with the lower part of the *P. a. angulatus* conodont biozone and the *O. spiralis* graptolite biozone, respectively. The boundary between the Telychian and the Sheinwoodian (Llandovery/Wenlock boundary) has been identified within the short black shale interval between *Beds 12A–12B* as *Bed 12B* yielded conodonts of the *Kockella patula* biozone, and JAEGER (1975) identified the graptolite *M. rigidus* in the shales above *Bed 12B*. This indicates that most of the Sheinwoodian and thus several conodont zones are missing. The position of the Sheinwoodian/

Homerian boundary is not precisely known, it might be located around *Bed 13E* in the lowermost part of the *Ozarkodina sagitta sagitta* biozone. The definition of the Homerian/Gorstian boundary (Wenlock/Ludlow boundary) is also tentative because only the lower part of the Homerian is present. However, since *Kockelella crassa* occurs in *Bed 15B1*, the boundary may be located within the black shales immediately below. The boundary between the Gorstian and the Ludfordian is determined only approximatively within the *Ancoradella ploeckensis* conodont biozone (Corradini et al., 2015b).

The global Silurian conodont zonation of Walliser (1964) was mainly based on data from the Cellon section. Corradini et al. (2014) revised the conodont communities of the whole sequence from the upper Llandovery to the end of the Pridoli according to the most recent zonation schemes. In the Kok Formation, nine conodont zones are distinguished, however, in the Sheinwoodian and Homerian several zones are missing. The first conodonts occur in *Bed 10*, thus the Kok Formation in the Cellon section comprises the following conodont zones (Corradini et al., 2014: Figs. 4, 5):

- [*Pterospathodus celloni* superzone [Männik, 2007] (*Beds 10–10J*; Telychian)].
- *Pterospathodus amorphognathoides angulatus* biozone [Männik, 2007] (*Beds 10–10H*; Telychian).
- *Pterospathodus amorphognathoides lennarti* and *Pterospatodus amorphognathoides lithuanicus* biozones [Männik, 2007] (*Bed 10J*; Telychian).
- *Pterospatodus amorphognathoides amorphognathoides* biozone [Walliser, 1964] (*Beds 11–12A*; Telychian).
- *Kockella patula* biozone [Walliser, 1964] (*Beds 12B–12D*; late Sheinwoodian).
- *Kockelella ortus ortus* biozone [Jeppson, 1997] (*Beds 12E–13B*; late Sheinwoodian).
- *Ozarkodina sagitta sagitta* biozone [Aldridge & Schönlaub, 1989] (*Beds 13C–15A*; late Sheinwoodian–early Homerian).
- *Kockelella crassa* biozone [Walliser, 1964] (*Beds 15B1–16A*; early Gorstian).
- *Kockelella variabilis variabilis* Interval biozone [Cramer et al., 2011] (*Beds 16B–17E*; Gorstian).
- *Ancoradella ploeckensis* biozone [Walliser, 1964] (*Beds 18–20*; late Gorstian–early Ludfordian).

Graptolites are rare in the Kok Formation. Jaeger (1975) obtained a *Monograptus priodon* community from *Bed 11C* as well as graptolites diagnostic of the *Cyrtograptus rigidus* biozone from the black shales immediately below *Bed 12C*.

The chitinozoans occur from the very base of the Kok Formation (*Bed 9*) up to the lower part of *Bed 11* in varying frequency and diversity. The succeeding interval up to *Bed 19* reveals only badly preserved chitinozoans or they are entirely missing. The interval from *Bed 9 to Bed 11* is assigned to the global *Angochitina longicollis* chitinozoan biozone.

For more information concerning the Kok Formation in the Carnic Alps refer to Histon (1997a, b; 2012); Kreutzer & Schönlaub (1997); Histon et al. (1999); Histon & Schönlaub (1999); Brett et al. (2009); Ferretti et al. (2012, 2015); Corradini et al. (2015b).

Material and methods

The collecting of the samples was carried out at intervals as small as possible within the shaly sequences, while in the calcareous parts the distances were further apart (Text-Fig. 2). Several pieces of the rocks were taken along the lateral extent of a layer in order to increase the probability of obtaining the required fossils.

A total of 45 samples ranging from the Valbertad Formation to the top of the Kok Formation (weight: 70 or 100 g; rarely 130–200 g) were palynologically processed by the extraction method of Laufeld (1974: 4), using the HCl – HF – HCl – HNO_3 treatment. Then the residue was gently rinsed with tapwater through a 50 µm nylon sieve. The chitinozoans were then picked under a binocular microscope and mounted on cover slides for SEM-investigations which subsequently were converted to permanent slides according to the procedure of Paris (1978: Fig. 55).

Introduction to the chitinozoan research

Chitinozoans are an extinct group of exclusively marine microfossils whose actual affinity is still under debate. Their vesicles are composed of organic material resistant to the action of strong mineral acids except that of nitric acid. Eisenack (1930, 1931) detected and first described them, and as he assumed that chitin was the main component of the vesicle walls, he named them Chitinozoa.

The chitinozoan tests are hollow and rod-, club-, bottle-, urn-shaped or globular/lenticular in form with one open and one closed pole. The former was originally sealed by a simple operculum or a complex plug which was lost at the end of their ontogeny. Surfaces are smooth or covered with ornamentation of great variety. Length can vary between c. 50 and 2,000 µm, however, they usually measure on average a few hundred µm. In most instances the chitinozoans occur as single individuals, sometimes they are seen as chains of a few to numerous vesicles and very rarely clusters of tests are also found that are held together by an organic material or a cocoon-like structure. Chitinozoans first appeared in the lowermost Ordovician and after rapid evolution and dispersion throughout the ancient oceans they had disappeared again from the fossil record by the end of the Devonian (Miller, 1996).

Neither the affinity of the chitinozoans, nor the composition of their vesicle walls has as yet been resolved completely. Over the years since their discovery, they have been assigned to various groups of organisms, such as the protozoans, metazoans, protists and fungi. The main criterion for these classifications was – beside the morphology of the vesicles – their assumed chemical composition of chitin or "pseudochitin". Voss-Foucart & Jeuniaux (1972) carried out chemical analyses of chitinozoan vesicles but did not find any chitin. The investigations of Jacob et al. (2007) and Dutta et al. (2007) provided the same results (no chitin), however, they found that they were composed mainly of highly aromatic macromolecules (Servais et al., 2013).

Today the majority of chitinozoan researchers believe that the chitinozoans were reproductive stages (eggs or egg capsules) of marine metazoans. The first to put forward this “egg theory” was Kozlowski (1963). Subsequently, when knowledge of this fossil group grew the theory was supported by various authors (e.g. Laufeld, 1974; Paris, 1981; Grahn, 1981; Jaglin & Paris, 1992; Gabbott et al., 1998; Paris & Nõlvak, 1999). They supposed that the parent organisms of the chitinozoans presumably were worm-like soft-bodied invertebrates with a length of a few millimetres living a planktonic or nektonic mode of life in the uppermost layers of the oceans, which had been concluded from the common occurrence of chitinozoans within euxinic black shale deposits. Furthermore, they assumed that the main food source of the chitinozoan producing animals may have been phytoplankton, the basic element of the food chain within the seas (Grahn & Paris, 2011; Paris & Nõlvak, 1999; Servais et al., 2013).

However, Liang et al. (2020) questioned this “egg theory”. In their studies they analysed the inner ultrastructure of rare exceptional Ordovician chitinozoan specimens, previously interpreted as teratological tests and all belonging to the chitinozoan order Prosomatifera (vesicles showing a neck and a prosom). The application of advanced imaging techniques (near-infrared microscopy, focused ion beam scanning electron microscopy, field emission scanning electron microscope and X-ray computed micro-tomography) revealed a „test-in-test“ morphology (a complete vesicle has one or several less-complete tests at the base) and structural details which were interpreted as new asexual reproductive stages producing either one or several offsprings at a time. These structures, however, were not found among the Operculatifera (chitinozoans with an operculum and without a neck) whose vesicles are frequently arranged in long chains and occasionally in cocoon-like structures. According to this new hypothesis, the chitinozoans were individual single celled microorganisms and belong to a new isolated group of protists.

The first classification of the chitinozoans was created by its discoverer Eisenack (1931). It followed the International Rules of Zoological Nomenclature and even though now slightly modified, it is still in use. Paris (1981) adopted the division into order, family, genus and species, as proposed by Eisenack (1931, 1972) and Taugourdeau (1966). He emended their scope and introduced the new category “subfamily”. This concept became a standard in chitinozoan research. As the biological affinities of the chitinozoans remain unknown, the classification is merely artificial and is based upon a “logical hierarchy of morphologic features” which, nonetheless, has proved feasible and has since been applied effectively in taxonomic work for decades. It is a parataxonomy with (morpho-)genera and (morpho-)species (Servais et al., 2013).

The chitinozoans have been part of the biosphere for about 130 Ma. The first representatives of this fossil group were simple, large, smooth individuals, appearing in the early Tremadocian (early Ordovician) of Morocco. In the late Tremadocian, they were already present on every palaeocontinent. They evolved rapidly and by Middle Ordovician time more than 50 % of the morphological innovations of the group had been developed. During the melting of the Gondwana ice-cap during the late Hirnantian (late Ordovician), almost all of the Ordovician genera and species became extinct, only a few genera made it across the Ordovician/Silurian boundary. The first Silurian related taxa appeared already in the late Ordovician, shortly before the extinction of the Ordovician species. However, they experienced their full development only from the basal Rhuddanian (early Llandovery) onward. In the Silurian, the group recovered rapidly and had an even more widespread distribution than in the early Ordovician. The gradual decline of the chitinozoans started already in the early Devonian and by the end of the Devonian they had completely disappeared from the fossil record. The last chitinozoan communities were monospecific and have been reported from the late Famennian of Brasil and Algeria, respectively (Paris & Nõlvak, 1999; Grahn & Paris, 2011).

Today, chitinozoans have a global distribution and are known from Lower Palaeozoic strata of all present-day continents. The habitat of the chitinozoans was controlled by the temperature and chemistry of the oceanic surface waters, by food supply, sea currents, etc. Their wide distribution, however, was most probably caused by drifting of the tests within ancient currents and does not necessarily reflect their original living space. Thus, chitinozoan communities may have identical compositions across a distance of thousands of kilometres as is the case in the Ordovician deposits of North Gondwana. However, the palaeogeographical distribution of individual chitinozoan taxa may vary, some are distributed across different climatic belts, while others are ecologically or biogeographically restricted (Miller, 1996; Paris, 1996; Achab & Paris, 2007; Vandenbroucke et al., 2014).

Chitinozoans occur exclusively within marine deposits. As a group, they are independent of lithology and are found in sediments of both nearshore environments, as well as in off-shelf deposits (mudstones, black shales, siltstones, wackestones, micritic or terrigenous limestones, cherts, ironstones, phosphatic rocks) from which they are extracted by the palynological preparation technique. Unfavourable rocks as to the deposition and/or preservation of chitinozoans are sediments from high-energy environments (well-sorted sandstones, bioclastic limestones) and from oxygenated environments (reefs, red nearshore sediments), as well as weathered and middle- to high grade metamorphic rocks. On the other hand, the taxonomic composition of some chitinozoan communities seems to be influenced by environmental factors (see in Paris, 1992, 1996; Nestor, 1994, 1998).

Eisenack (1930, 1931, 1932, 1934, 1937) was the first to study chitinozoans and to publish their descriptions with photographs, recorded with a transmitted light microscope. He extracted them from erratic boulders originating from Ordovician and Silurian bedrocks in Scandinavia, which had been carried to the beach of the former East Prussia by glaciers during the last ice ages. After these first references to the newly discovered fossil group, for a long time only sporadic papers dealing with chitinozoans appeared.

Comprehensive stratigraphical applications of the chitinozoans began at the end of the 1950s when oil companies started prospection of the largely undated subsurface Palaeozoic strata in the Sahara. Subsequently, scientific interest in chitinozoans increased enormously. Already in the 1960s, numerous studies were carried out all over the world, comprising detailed taxonomic investigations from well dated sections that demonstrated for the first time the stratigraphic value of the chitinozoans.

However, until the end of the 1960s only examination under the transmitted light microscope was available for the study of chitinozoans. The latter practise usually did not reveal suitable morphological details due to insufficient magnification levels and the common dark brown or even opaque appearance of the fossils. The introduction of the Scanning Electron Microscope (SEM) for the morphological examination of the chitinozoans therefore constituted a revolutionary progress affecting all fields of chitinozoan research. Only at sufficiently high magnifications is it possible to illustrate the great morphological diversity of these microfossils. This improved investigation technique led to a reliable classification of the chitinozoan taxa, which is fundamental for their accurate application in biostratigraphy. The first paper based exclusively upon SEM photographs was published by LAUFELD (1974) on Silurian chitinozoans from Gotland.

A further improvement in chitinozoan research practises was provided by the outstanding and fundamental publication of PARIS (1981) on chitinozoans from the Palaeozoic of southwestern Europe. In this extensive work all aspects of this fossil group (morphology, biometry, taxonomy, biology/affinity, palaeoecology, evolution/phylogeny, biostratigraphy/biozonations, quantification of data, palaeobiogeography) were discussed and thus established the basis for comprehensive investigations of chitinozoans.

The biostratigraphical potential of the chitinozoans, comparable to that of graptolites and conodonts, is reflected by the chitinozoan biozones which were set up from the end of the 1980s onward. They are precisely correlated within the geological time scale, as they have been adjusted to the graptolite and conodont biozones and they thus permit local, regional and long-distance correlations. The Ordovician chitinozoan biozonation for North Gondwana was established by PARIS (1990, 1999), that for Baltica by NÕLVAK & GRAHN (1993) and that of Laurentia by ACHAB (1989). The global Silurian chitinozoan biozonation was prepared by VERNIERS et al. (1995) and the global Devonian chitinozoan biozonation by PARIS et al. (2000c). Furthermore, as in the case of the graptolites and conodonts, the chitinozoans of which many taxa have short stratigraphical ranges are used nowadays to define international boundary stratotypes. A fundamental advantage of the chitinozoans is their resistance to mineral acids, therefore, they can be extracted from argillaceous as well as from calcareous rocks, unlike the graptolites and conodonts, due to their chemical composition.

During recent decades, chitinozoans of Ordovician, Silurian and Devonian age from France, Portugal, Spain, Great Britain, Belgium, Baltoscandia, Bohemia, Austria, Germany, Russia, North Africa (Algeria, Libya, Morocco), Mauretania, Niger, South Africa, Jordan, Turkey, Saudi Arabia, Iran, China, Australia, Brazil, Argentina, USA and Eastern and Northern Canada have been examined. The majority of these studies have dealt with taxonomy and biostratigraphy, other fields of investigation have included biogeochemistry, biology/affinity, evolution, palaeobiodiversity, palaeobiogeography and palaeogeographical reconstructions, palaeoclimate and palaeoecology.

In Austria, the first studies on chitinozoans were carried out under the transmitted light microscope by BACHMANN & SCHMID (1964). They examined thin-sections of a Silurian sample from the Carnic Alps. The first SEM investigations were done by PRIEWALDER (1994) who published the preliminary results of her studies on the chitinozoans from the Cellon section in the central Carnic Alps.

For more details concerning the history of chitinozoan research see MILLER (1996); PARIS (1996); SERVAIS et al. (2013).

The chitinozoans of the Plöcken Formation

The Hirnantian Plöcken Formation succeeds the subjacent Uqua Formation (late Katian–?basal Hirnantian) disconformably and the transition is marked by a distinct change in colour.

The distribution of the fossils in the succession

Although 20 samples have been examined from the Upper Ordovician succession of the Cellon section with four from the Valbertad Formation, seven from the Uqua Formation and nine from the Plöcken Formation (Text-Fig. 2), only four samples from the Plöcken Formation yielded identifiable chitinozoans. Of these, only the uppermost three samples [sample **128** from *Bed 7*, sample **129** from the base of *Bed 8*, both from pyritic limestone and sandstone, and sample **45** from the top of *Bed 8* (silty shale)] contain stratigraphically relevant fossils.

The reasons for the absence of chitinozoans from the Valbertad and Uqua formations are unknown. Their depositional environments apparently are not in contrast with the normal habitat of the chitinozoans or the preservation of these fossils. It remains unclear if it is a matter of original absence, or loss due to preservation at burial or in the outcrop or during preparation.

Besides chitinozoans, the palynological residues also revealed representatives of several other fossil groups which are similarly restricted to the Plöcken Formation: melanosclerites, scolecodonts, spiculae, foraminifers and large sphaeromorphs.

A remarkable phenomenon is the special preservation of large flattened circular objects of clearly organic origin (sphaeromorphs?, foraminifers?): a part of their tests shows a crumpled mica-like appearance whereas the remaining areas are undamaged (Pl. 11, Figs. 9, 11). This feature obviously results from severe impressions of mineral grains which points to a derivation of these fossils from more intensely altered rocks. Another conspicuous feature is the presence of thin crumpled graphitic particles which sometimes show a striking similarity to chitinozoans (Pl. 11, Figs. 7, 8) or scolecodonts (Pl. 11, Fig. 10). Some of them could actually be of biological origin as their crumpled mica-like structure is similar to that in the above mentioned sphaeromorphs/foraminifers. The graphitic particles are frequent in the palynologic residues from the Valbertad Formation, while in the Uqua and Plöcken formations they are rather rare except in sample 45 at the top of the Plöcken Formation.

The phytoplankton in the Upper Ordovician sequence is, however, only represented by poorly preserved and unidentifiable specimens (Priewalder, 1987).

Besides the fact that specimens were found in only a few of the samples, also the number of chitinozoans per sample is small though relatively large amounts of rock had been dissolved (130–190 g). This suggests that at least the depositional environment was unfavourable for the presence of the chitinozoans.

The chitinozoans of the Plöcken Formation are opaque under the transmitted light microscope and their state of preservation is poor. All of them are broken and missing a variable part of the apertural area. Most of the Conochitinidae (*Conochitina*, *Euconochitina*, *Rhabdochitina*, *Spinachitina*, *Tanuchitina*) are preserved three-dimensionally, at least the aboral part, the remaining part of the vesicle is frequently flattened. The Desmochitinidae (*Armoricochitina*, *Desmochitina*) are either flattened or preserved three-dimensionally.

Furthermore, the chitinozoans from sample **128** (*Bed 7*) and **129** (base of *Bed 8*) are usually deformed by imprints of pyrite crystals and by an intense decomposition activity by bacteria. Many specimens in these samples show internal casts of pyrite, sometimes the vesicle walls have been removed and only the pyritic casts are left. Occasionally, small pyrite framboids had grown inside the vesicles leading to a knobby appearance of the fossils. Moreover, the chitinozoans are frequently covered with amorphous organic material.

The increased occurrence of pyrite in the sediments also became obvious during the treatment of the samples with nitric acid which lead to the formation of typical dark-orange vapours. The latter reaction was first noticed while processing sample **42a** (*Bed 5*: intercalation of greyish limestone within greyish siltstone) and continued up to sample **45** (Top of *Bed 8*: greenish silty shales).

The breaking of the chitinozoan vesicles, the damage caused by pyrite-crystal growth and an extensive bacterial activity are in accordance with the shallow water anoxic environment deduced by Schönlaub (1988), Schönlaub & Sheehan (2004) and Hammarlund et al. (2012). However, also the destructive effects of the Variscan and/or Alpine Orogeny on the preservation of the chitinozoans have to be taken into consideration.

Characterising the environmental impacts recognised in the Plöcken Formation, Schönlaub (1988) reported small-scale channelling, layers with internal erosional surfaces, beds with contorted deformation structures, reworking of sediments and fossils with signs of displacement. Schönlaub & Sheehan (2004) interpreted the lithology of the Plöcken Formation in the Cellon section as formed in a storm-dominated shallow-water environment when a global transgression started during the course of the melting of the North Gondwana ice-cap in late Hirnantian time.

Hammarlund et al. (2012) on the other hand assumed that the anoxic zone which had developed on the lower slope and in the basin in the early Hirnantian, had been raised along with the sea level rise in the late Hirnantian and hence spread to the shallow water areas. It thus affected also the upper Hirnantian Cellon section sediments (Hammarlund et al., 2012: Fig. 6).

The concurrence of all these factors might be responsible for the damage to the chitinozoan vesicles and even for their sparsity or absence in several samples of the Plöcken Formation.

Concluding from the poor state of preservation of the extant chitinozoans it is assumed that part of the original fossil assemblage has been destroyed, especially the thinner-walled forms. For this reason, no numbers of chitinozoans per gram of sample will be indicated.

The maximum number of individuals was obtained from sample **129** (79 chitinozoans), followed by sample **128** with

Graptolite biozones	?		***M. persculptus***			
Chitinozoan biozones	?			***T. elongata***		
Species // Samples	**32a–125**	**126**	**40–43**	**128**	**129**	**45**
Euconochitina? sp.	-	1				
Conochitina sp. 1	-	1	-	5	7	
Euconochitina sp.	-	-	-	1		
Conochitina sp. 2	-	-	-	9	8	
Conochitina sp. 3	-	-	-	1	2	
Rhabdochitina cf. *gracilis*	-	-	-	3	6	
Tanuchitina elongata	-	-	-	10	7	1
Armoricochitina nigerica	-	-	-	6	-	5
Conochitina sp. 4	-	-	-	-	1	
Conochitina? sp.	-	-	-	-	1	
Spinachitina sp.	-	-	-	-	1	
Desmochitina minor	-	-	-	-	1	1
Number of species	-	2	-	7	9	3
Number of specimens	-	2	-	35	34	7
Undeterminable chitinozoans	-	5	1	26	45	5

Tab. 1.
Distribution of the chitinozoans within the Plöcken Formation. For the position of the samples in the Cellon section see Text-Figure 2.

61 chitinozoans, however, about half of these specimens are too poorly preserved for taxonomic classification. The concentration of the remaining two samples is even less: sample **126** (*Bed 5*) yielded two and sample **45** (top of *Bed 8*) seven identifiable chitinozoans.

The lowest occurring chitinozoans in the Cellon section (Text-Fig. 2, Tab. 1) appear in the greyish siltstone of *Bed 5* (sample **126**) of the Plöcken Formation with documentation of two species (*Conochitina* sp. 1, *Euconochitina*? sp.). More diverse communities with typical Hirnantian taxa were obtained from the pyritiferous limestone and sandstone in the upper part of the succession. *Bed 7* (sample **128**) yield seven species [*Armoricochitina nigerica* (BOUCHÉ, 1965), *Conochitina* sp. 1, *C.* sp. 2, *C.* sp. 3, *Euconochitina* sp., *Rhabdochitina* cf. *gracilis* EISENACK, 1962 and *Tanuchitina elongata* (BOUCHÉ, 1965)]. Nine species were extracted from the basal *Bed 8* (sample **129**) [*Conochitina* sp. 1, *C.* sp. 2, *C.* sp. 3, *C.* sp. 4, *C.*? sp., *Desmochitina minor* EISENACK, 1931, *R.* cf. *gracilis*, *Spinachitina* sp., *T. elongata,* plus a *Calpichitina*-fragment]. The silty shale at the top of *Bed 8* (sample **45**) contain three species (*A. nigerica*, *D. minor*, *T. elongata*). All these taxa are restricted to the Plöcken Formation, as the basal layers of the succeeding Kok Formation yield a completely different chitinozoan community (upper Telychian *Angochitina longicollis* chitinozoan biozone).

Altogether, about 80 chitinozoan vesicles have been assigned herein to seven genera and 12 species. The most frequent taxa are: *T. elongata* (18 specimens), *Conochitina* sp. 2 (17 specimens), *Conochitina* sp. 1 (13 specimens), *A. nigerica* (11 specimens) and *R.* cf. *gracilis* (9 specimens).

The chitinozoan communities of the Plöcken Formation have obviously been diminished and consist mainly of representatives of the Conochitinidae, with the exception of *Armoricochitina nigerica* and *Desmochitina minor*. Important elements which are usually present in North Gondwanan deposits of Hirnantian age are missing here, such as *Acanthochitina barbata* EISENACK, 1931, *Belonechitina micracantha* (EISENACK, 1931), *Calpichitina lenticularis* (BOUCHÉ, 1965), *Euconochitina lepta* (JENKINS, 1970), *Lagenochitina baltica* EISENACK, 1931, *Lagenochitina prussica* EISENACK, 1931. However, the most indicative taxa of the uppermost Ordovician (*Tanuchitina elongata* and *Armoricochitina nigerica*) are present.

The chitinozoan biozones

PARIS (1990) defined 22 chitinozoan biozones for the Ordovician of Northern Gondwana, which at that time was located at high southern latitudes, and subsequently extended them to 28 biozones (PARIS, 1999). The three uppermost Ordovician chitinozoan biozones are from the older to the younger: the *Ancyrochitina merga* biozone, the *Tanuchitina elongata* biozone and the *Spinachitina oulebsiri* biozone.

The ***Ancyrochitina merga*** **chitinozoan biozone** (PARIS, 1990: 201) was defined as a total range biozone, that means by the total range of the index species *Ancyrochitina merga* JENKINS, 1970.

- *Type stratum*: From the Upper Ktaoua Formation to the lower part of the Lower 2nd Bani Formation in the Bou Ingarf section in the Central Anti-Atlas (Morocco) (PARIS, 1990: 202; 1996: Fig. 4).
- *Age*: Latest Katian (*Paraorthograptus pacificus* graptolite biozone), it represents the pre-glacial period (LOI et al., 2010; VIDET et al., 2010).

The ***Tanuchitina elongata*** **chitinozoan biozone** (PARIS, 1990: 202) was originally defined by the interval from the last occurrence of *Ancyrochitina merga* to the last occurrence of *Tanuchitina elongata* (BOUCHÉ, 1965). However, when the succeeding *Spinachitina oulebsiri* chitinozoan biozone was newly established by PARIS et al. (2000a), also the upper boundary of the *T. elongata* biozone had to be newly defined by the first appearance of *Spinachitina oulebsiri*.

- *Type stratum*: Major part of the Lower 2nd Bani Formation up to the topmost Upper 2nd Bani Formation in the Bou Ingarf section in the Central Anti-Atlas (Morocco) (PARIS, 1990: 203; 1996: Fig. 4).
- *Age*: Basal – late Hirnantian (*Normalograptus extraordinarius* – lower *Metabolograptus persculptus* graptolite biozone). It represents the glacial period and the period just after the glacial period because it frequently occurs within glacio-marine diamictites, deposited during the melting of the North Gondwana ice-cap (PARIS, 1990; OULEBSIR & PARIS, 1995; PARIS et al., 2000a; VANDENBROUCKE et al., 2009; GRAHN & PARIS, 2011).

The ***Spinachitina oulebsiri*** **chitinozoan biozone** (PARIS et al., 2000a: Fig. 5) has never been formally defined and is problematic due to various uncertainties. According to VANDENBROUCKE et al. (2009: 55) the biozone is defined by the total range of *Spinachitina oulebsiri* PARIS et al., 2000a, a taxon that has Silurian affinity. Due to the ambiguous taxonomic relationship between *Spinachitina oulebsiri* and *Spinachitina fragilis* (NESTOR, 1980a), which is a similar taxon and the index-species of the succeeding first Silurian chitinozoan biozone, the stratigraphical value of the *S. oulebsiri* biozone is uncertain (VANDENBROUCKE et al., 2009). Moreover, in none of the North Gondwana localities where *Spinachitina oulebsiri* has been proven, independent sources of biostratigraphical age determinations, e.g. by graptolites, are available. This could have clarified whether the biozone is restricted to the uppermost Ordovician or continues into the lowermost Silurian (THUSU et al., 2013).

- *Type stratum*: *S. oulebsiri* was first described from samples of the Upper Member of the M'Kratta Formation in well NI-2, Northeast Algerian Sahara (PARIS et al., 2000a: Fig. 5).
- *Age*: Latest Hirnantian (upper *Metabolograptus persculptus* graptolite biozone), however, an earliest Rhuddanian age cannot be excluded (VANDENBROUCKE et al., 2009; LE HÉRISSÉ et al., 2013; THUSU et al., 2013). The *Spinachitina oulebsiri* chitinozoan biozone is typical for the short post-glacial period immediately below the Ordovician/Silurian boundary when the holomarine shelf conditions had been re-established by the end-glacial sea level rise (PARIS et al., 2000a; VANDENBROUCKE et al., 2009).

Although the chitinozoan communities of the Plöcken Formation are missing numerous uppermost Ordovician taxa (see above), the available species clearly point to the *Tanuchitina elongata* chitinozoan biozone. The index-species, though poorly preserved, has been unequivocally identified. The subjacent *Ancyrochitina merga* chitinozoan biozone can be excluded since representatives of the Ancyrochitininae and hence also *A. merga* whose total range defines the biozone are completely absent. Moreover the *A. merga* biozone is characteristic for the pre-glacial period (see below). Another indicator for the *T. elongata* biozone is the frequent occurrence of *Armoricochitina nigerica* which according to Paris (1990) is typical for the *T. elongata* biozone since this biozone also correlates with the acme biozone of *A. nigerica*.

Evidence of the succeeding *Spinachitina oulebsiri* chitinozoan biozone, the uppermost biozone of the Ordovician, could also not be proven in our samples. In the lower part of the *S. oulebsiri* biozone, chitinozoan taxa of the *T. elongata* biozone may still occur, however, the index-species whose FAD (first appearance datum) indicates the base of the biozone is not present in the Plöcken Formation. That means that the uppermost part of the Ordovician which corresponds to the short post-glacial period just below the Ordovician/Silurian boundary (Paris et al., 2000a) may be missing in the Cellon section.

The Hirnantian age of the chitinozoan community has been confirmed by the occurrence of *Metabolograptus persculptus* (Elles & Wood, 1907) in *Bed 5* in the lower part of the Plöcken Formation (Text-Fig. 2), as well as by the *Hirnantia* Brachiopod Fauna in *Bed 5* and in the basal part of *Bed 6*. It is important to point out here that this is one of the rare cases which allows the documentation of the Hirnantian age of the *Tanuchitina elongata* chitinozoan biozone by independent biostratigraphical dating.

When Paris (1990) established the *Ancyrochitina merga* and *Tanuchitina elongata* biozones, he designated the Bou Ingarf section in the Central Anti-Atlas (Morocco) as their type section because it exhibits an almost complete Upper Ordovician succession. In fact, since the centre of the Upper Ordovician ice-shield was located in present-day northern-central Africa, the area of the Bou Ingarf section was not directly affected by the glaciation disregarding a short period when the glaciers reached the sedimentary basins in the north of Gondwana. In the Bou Ingarf section a complete cycle could be demonstrated from a storm-dominated terrigenous shelf-facies (uppermost Katian) to a first less pronounced Hirnantian glaciation and a subsequent short interglacial transgression. This was followed by the Hirnantian glaciation climax with deep subglacial erosion, succeeded by the final melting of the ice-caps on the North Gondwana platform and the restauration of holomarine conditions close to the Ordovician/Silurian boundary (Loi et al., 2010: Fig. 12; Videt et al., 2010; Ghienne et al., 2014).

Loi et al. (2010) and Ghienne et al. (2014) reported minor glaciations already in the Katian which, however, did not leave any recognisable deposits. In the early Silurian glaciation shifted to the South American domain of Gondwana.

According to Loi et al. (2010), who studied the Bou Ingarf area in terms of the glacio-eustatic record, the upper part of the Upper Ktaoua Formation and the lower part of the Lower 2nd Bani Formation (Shaly Member) in the lower part of the Bou Ingarf section belong to the pre-glacial shelf-facies. In contrast, the succeeding upper part of the Lower 2nd Bani Formation (Sandstone Member, i.e. Unit 1 of the glaciation related succession in Loi et al., 2010: Fig. 12) represents a glaciogenous sequence which was deposited during the first (minor) Hirnantian glaciation and shows a sharp contact with the underlying shelf-succession. The Upper 2nd Bani Formation is also a glaciogenous sequence: Unit 2 in the lower part of the Upper 2nd Bani Formation indicates a short interglacial transgression, while Unit 3 in the middle part shows deposits of e.g. glacial erosion and infilled palaeo-valleys. Unit 4 exhibits transgressional sediments accumulated during the course of the final melting of the North Gondwana ice-shield (Loi et al., 2010: Fig. 12).

Bourahrouh et al. (2004) studied the chitinozoans of the Bou Ingarf section and assigned the Upper Ktaoua Formation to the *Ancyrochitina merga* biozone, and the lower part of the Lower 2nd Bani Formation (Shaly Member) to the *Tanuchitina elongata* biozone based on the biozonal definitions in Bourahrouh et al. (2004) which differ from those of Paris (1990):

> *A. merga* biozone (in Bourahrouh et al., 2004: 25): “This biozone was defined (Paris, 1990) as the *interval-range biozone* between the *FAD* (first appearance datum) of *Ancyrochitina merga* and the *FAD* of *Tanuchitina elongata*, which is the index species of the succeeding biozone” (**instead of**: „*total range zone*“ of *A. merga* in Paris, 1990: 201).
>
> *T. elongata* biozone (in Bourahrouh et al., 2004: 25): “......the *elongata* biozone is now restricted to the interval-range biozone between the *FAD* of *Tanuchitina elongata* and the *FAD* of *Spinachitina oulebsiri*” (**instead of**: the interval-range zone between the *LAD* (last appearance datum) of *A. merga* and the *FAD* of *Spinachitina oulebsiri*).

If the definition of the *A. merga* biozone of Paris (1990) is applied correctly (i.e. total range of the index-species), then the complete lower part of the Lower 2nd Bani Formation (i.e. the Lower 2nd Bani Shaly Member) belongs to the *A. merga* biozone (latest Katian), as *A. merga* in Bourahrouh et al. (2004: Fig. 4) occurs from sample 19 to sample 42 in the Bou Ingarf section, that is until immediately below the Lower 2nd Bani Sandstone Member, which was deposited during the first Hirnantian glacial episode (Unit 1 in Loi et al., 2010: Fig. 12).

The application of this incorrect zonal definition in Bourahrouh et al. (2004) led to the fact that in the Bou Ingarf section the *base* of the *Hirnantian*, which actually correlates with the base of the *T. elongat*a biozone, came to lie within the holomarine shelf-facies to which the Lower 2nd Bani Shaly Member belongs, instead of at the beginning of the glaciation (i.e., at the base of the Lower 2nd Bani Sandstone Member, i.e. at the base of Unit 1 in Loi et al., 2010). This erroneous dating found its way into other studies dealing with or referring to the Bou Ingarf section/the Anti-Atlas (Vandenbroucke et al., 2009; Delabroye & Vecoli, 2010; Loi et al., 2010; Videt et al., 2010; Thusu et al., 2013; Colmenar & Alvaro, 2015; Ghienne et al., 2014; Villas et al., 2016; Alvaro et al., 2019; Colmenar et al., 2019) [and further locations in the North Gondwana Domain (Ghavidel-Syooki, 2017a, b; Ghavidel-Syooki & Borji, 2018)]. The above demonstrated extension of the *A. merga* biozone (total range of *A. merga*) up to the top of the Lower 2nd Bani Shaly Member, however, removes the discrepancy between the sedimentological and biostratigraphical data concerning the base of the Hirnantian in the Bou Ingarf section, a discrepancy which also had been addressed by Delabroye & Vecoli (2010). Moreover, Villas et al. (2016: 52) wrote: “The age of the lower part of the *T. elongata* chitinozoan biozone should be re-evaluated, and the suggested delayed onset of the Hirnantian glaciation reconsidered”.

Due to the above delineated modifications of the chitinozoan biozonation in the Bou Ingarf section, considerable uncertainties arose concerning the stratigraphical position of the *T. elongat*a biozone (and also the *S. oulebsiri* biozone) within this important section.

BOURAHROUH et al. (2004: 27) reported on representatives of *S. oulebsiri* from the shaly member in the lower part of the Upper 2nd Bani Formation (i.e., Unit 2 of the glaciation related succession in LOI et al., 2010: Fig. 12) immediately above the glacial floor which forms the top of the Lower 2nd Bani Sandstone Member (Unit 1 in LOI et al., 2010: Fig. 12). Elsewhere (on page 37) they remarked that these shale and diamictite beds belong to the *T. elongata* biozone or possibly to the *S. oulebsiri* biozone.

According to VIDET et al. (2010: 369), the transgressive marine dark shale and siltstone in the Bou Ingarf section (i.e., Unit 2 in LOI et al., 2010) which rests upon the Lower 2nd Bani Sandstone Member (i.e., Unit 1 in LOI et al., 2010) and which represents the lowermost part of the Upper 2nd Bani Formation, yielded chitinozoan taxa which already were present in the Lower 2nd Bani Formation, but in addition *S. oulebsiri* was also present indicating the base of the *S. oulebsiri* biozone. Furthermore, they stated that this sequence was succeeded by glacial sandy deposits of the upper member of the Upper 2nd Bani Formation which did not yield any chitinozoans. At the top of this succession the *Hirnantia sagittifera* Fauna occurs.

The above stated facts (BOURAHROUH et al., 2004: 27; VIDET et al., 2010: 369) indicate that there are discrepancies between the stratigraphical and environmental data of the *T. elongat*a biozone and the *S. oulebsiri* biozone in the Bou Ingarf section and of those in other North Gondwana localities. According to LOI et al. (2010: Fig. 12), Unit 2 (i.e. the lowermost part of the Upper 2nd Bani Formation, from which *Spinachitina oulebsiri* has been reported, see above) represents deposition during a short interglacial transgression in the lower Hirnantian which was succeeded by the main glaciation later in the Hirnantian. The whole glacial sequence usually is attributed to the *T. elongata* chitinozoan biozone which occurs in the North Gondwana realm in glacio-marine sediments (see below) and which is correlated with the period from the *Normalograptus extraordinarius* to the lower *Metabolograptus persculptus* graptolite biozones. The exact age determination of the base of the *T. elongat*a biozone by correlation with the *N. extraordinarius* biozone, however, has so far not been possible. The *S. oulebsiri* biozone, in contrast, typically represents the uppermost post-glacial part of the Hirnantian (upper *M. persculptus* graptolite biozone: GRAHN & PARIS, 2011: 230) when on the shelf holomarine pre-glacial conditions had been restored (PARIS et al., 2000a; VANDENBROUCKE et al., 2009; LE HÉRISSÉ et al., 2013; THUSU et al., 2013).

The *Tanuchitina elongata* chitinozoan biozone is widely distributed in the North Gondwana realm:

- It occurs in *Iran* in the Zagros Mountains in the lower Dargaz Diamictites (GHAVIDEL-SYOOKI et al., 2011a), as well as in the Alborz Mountain Range in the upper part of the Gorgan Schists (GHAVIDEL-SYOOKI, 2008), in the upper part of the Ghelli Formation (GHAVIDEL-SYOOKI, 2016, 2017b, c), in the Abarsaj Formation (GHAVIDEL-SYOOKI, 2017a).
- In *southern* and *south-eastern Turkey* (Taurus Range, Border Folds) it has been identified within glacio-marine deposits of the Halevikdere Formation (PARIS et al., 2007), in *Saudi Arabia* in glacial sediments of the subsurface basal disrupted facies of the Sarah Sandstone Member (i.e., the upper part of Assemblage 2) (PARIS et al., 2015b) and in the upper part of the Quwarah Member of the Qasim Formation (AL-SHAWAREB et al., 2017).
- In *north-eastern Libya* the *T. elongata* biozone has been reported by MOLYNEUX & PARIS (1985), PARIS (1988a) and PARIS (1990) from subsurface glacio-marine micro-conglomeratic deposits. In *western Libya* and *Tunesia* it is present in the subsurface Djeffara Formation (PARIS, 1990).
- In the *north-eastern Algerian Sahara* it occurs within glacio-marine diamictites (Argiles Microconglomératiques) of the subsurface Hassi el Hadja Formation and M'Kratta Formation (PARIS, 1990; OULEBSIR & PARIS, 1995; PARIS et al., 2000a; VIDET et al., 2010).
- VIDET et al. (2010) also referred to the frequent occurrences of this biozone within glacio-marine diamictites, e.g. from a borehole in the *south-eastern Algerian Sahara* (lower Tamadjert Formation), in outcrops of the Ougarta Range in the *western Algerian Sahara* (El Kseib Member of the Djebel Seraf Formation) and in a borehole in the *central Algerian Sahara* (El Golea Member).
- In the Djado basin of *Niger* the *T. elongata* biozone was present in the subsurface Faunizone B of BOUCHÉ (1965) (PARIS, 1990).
- Further strata cited by PARIS (1990) and containing chitinozoans of the *T. elongata*-Zone are: the upper part of the Ra'an Shale of the Tabuk Formation of *Saudi Arabia*; the Rio Ceira Group in *Central Portugal* and the subsurface Soubirous Formation of the *Aquitaine basement*.
- According to VIDET et al. (2010) it is also present in the lowermost Cosquer Formation, i.e. glacio-deltaic shallow-water deposits of the Armorican Massif in *western France*, however, with an impoverished fauna.
- The *T. elongata* biozone could not be identified by DUFKA & FATKA (1993) in the uppermost Kosov Formation of the *Prague Basin* since the samples yielded only a few not specifically identifiable representatives of the genus *Conochitina* EISENACK, 1931 and *Lagenochitina* EISENACK, 1931. However, according to THUSU et al. (2013: 114), the *T. elongata* biozone has been proven in the uppermost Kosov Formation of the *Prague Basin* where it co-occurs with *Metabolograptus persculptus*.

The palaeogeographical affinities of the chitinozoans

The late Ordovician palaeogeographical position of the Carnic Alps, which as a part of the Peri-Gondwana Terranes presumably were located along the northern margin of Gondwana, is estimated as being about 50° southern latitude concluded from faunal and lithological data (SCHÖNLAUB & HISTON, 2000; SCHÖNLAUB, 2000; CORRADINI et al., 2015b). According to SCHÖNLAUB (2000) the pre-Hirnantian faunas, notably the brachiopods, exhibit closer relationships to north-European, British and Sardinian warm-water faunas than to communities of North Gondwana such as Morocco, supposedly due to an invasion of northern warm water faunas to the Carnic Alps far in the

Conodont biozones	?				*P. a. angulatus*				*)	*P. a. amorphognathoides*				*K. patula*			*K. o. ortus*		*O. s. sagitta–A. ploeck.*
Global chitinozoan biozones	*Angochitina longicollis*											?							
Species // Samples	**46A**	**46**	**47**	**130**	**48**	**131**	**49**	**50**	**132**	**51**	**133**	**134**	**53**	**135**	**55**	**54**	**136**	**56**	**57–62**
Eisenackitina dolioliformis	23																		
Eisenackitina cf. *inanulifera*	5																		
Eisenackitina sp. 2	6																		
Ancyrochitina gr. *ancyrea*	9																		
Cyathochitina sp.	2																		
Lagenochitina sp.	1																		
Sphaerochitina sp. 1	6																		
Eucono. sp. 2 sensu Nestor 1994?	2																		
Bursachitina conica	7	-	25	-	-	1?													
Eisenackitina causiata	3	-	-	-	-	1													
Lagenochitina sp. 1	2	-	-	-	-	-	-	-	2										
Angochitina longicollis	6	-	-	-	-	-	1	-	-	-	7								
Lagenochitinidae indet.	~130	-	-	-	-	-	-	-	-	-	4								
Sphaerochitina sp. 2	7	-	-	-	-	-	-	-	-	-	1								
Sphaerochitina spp.	1	-	-	-	-	-	-	-	-	-	1								
Ancyrochitininae indet.	~60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1		
Conochitina sp. 2 (reworked?)	-	-	-	11															
Calpichitina? sp.	-	-	-	1	-	1?													
Conochitina cf. *iklaensis*	-	-	-	8	-	-	-	2	20	-	1								
Conochitina leviscapulae	-	-	-	-	-	4													
Eucono. sp. 3 sensu Nestor 1994?	-	-	-	-	-	2													
Conochitina praeproboscifera	-	-	-	-	-	-	-	3	1										
Cono. sp. 1 sensu Mullins & Loydell, 2001	-	-	-	-	-	-	-	-	1										
Conochitina cf. *armillata*	-	-	-	-	-	-	-	-	6										
Conochitina cf. *elongata*	-	-	-	-	-	-	-	-	1										
Conochitina sp. A	-	-	-	-	-	-	-	-	4										
Eisenackitina sp. 1	-	-	-	-	-	-	-	-	3	-	2								
Conochitina sp. B	-	-	-	-	-	-	-	-	-	-	1								
Bursachitina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
	46A	**46**	**47**	**130**	**48**	**131**	**49**	**50**	**132**	**51**	**133**	**134**	**53**	**135**	**55**	**54**	**136**	**56**	**57–62**
Number of species	16	-	1	3	-	5	1	2	8	-	7	-	-	-	-	-	1	1	-
Number of specimens	~270	-	25	20	-	9	1	5	38	-	17	-	-	-	-	-	1	2	-
Undeterminable chitinozoans	54	-	44	4	-	2	5	6	25	-	36	-	-	1	-	8	6	1	-

south. Unfortunately, the Valbertad and Uqua formations, which represent this period, did not yield any chitinozoans for documenting the palaeobiogeographic relationships of this fossil group in pre-Hirnantian times.

The Hirnantian chitinozoans of the Cellon section, however, show distinct affinities to the cold-water realm of the North Gondwana faunal province represented by the *T. elongata* chitinozoan biozone, the latter being distributed there over a vast area (see above). At that time the polar front seems to have moved far to the north into the temperate zone at about 40° S (Vandenbroucke et al., 2010: 1; 2014: 404). This short-term cold-water invasion presumably was also responsible for the appearance of the *Hirnantia* Fauna in the lower part of the Plöcken Formation. Yet, according to Schönlaub (2000), some fossil groups from the Carnic Alps, such as the ostracods, echinoids and nautiloids even in the Hirnantian displayed contacts to the warm-water areas of Baltoscandia.

However, there existed no affinities between the chitinozoan communities of the Plöcken Formation and coeval associations from the palaeocontinents of Baltica and Laurentia, which together with the North Gondwana realm have been the focus for many decades for chitinozoan research (Paris et al., 2004: Fig. 28.1).

In the Ordovician, chitinozoans, like other fossil groups, were affected by provincialism due to the unique palaeogeographic configuration. The continents were mainly located in the southern hemisphere, far apart from each other and lying at different geographical latitudes: North Gondwana in high and Baltica in temperate to low southern latitudes, while Laurentia took an equatorial position. As the chitinozoans were part of the marine plankton and water temperature was a major environmental factor, the main reason for their endemism in the Ordovician was the temperature-related control of their distribution (Paris, 1996) which in turn was dependent on the palaeolatitudes. However, over time the Ordovician provincialism of the chitinozoans became weakened due to palaeocurrents and by the continuous approach of the palaeoplates to each other, processes which allowed moderate intermixture of the faunas from different provinces (Oulebsir & Paris, 1995; Paris et al., 1999b; Achab & Paris, 2007).

In the Ordovician, the latitudinally controlled chitinozoan populations led to different chitinozoan biozonations on different palaeocontinents. Webby et al. (2004: Fig. 2.2) published a stratigraphic chart delineating the precise correlation of the North American, the Baltoscandian and the North Gondwanan chitinozoan biozonations in the Ordovician, which illustrates considerable differences between these three areas.

◀ Tab. 2.
Distribution of the chitinozoans within the Kok Formation. The position of the samples in the Cellon section is illustrated in Text-Figure 2.
*) *P. a. lennarti* + *P. a. lithuanicus* conodont biozones (no samples available in this part of the section).

The chitinozoans of the Kok Formation

The Kok Formation (upper Telychian–lowermost Ludfordian) unconformably covers the Hirnantian Plöcken Formation with a significant hiatus in between and it is characterised by completely different chitinozoan populations (Text-Fig. 2, Tabs. 1, 2).

The distribution of the fossils in the succession

On the whole, 25 samples were palynologically prepared and examined, however, only 10 yield identifiable chitinozoans, mainly from the Telychian part of the Kok Formation.

Besides the chitinozoans, melanosclerites, small cones of different shape, foraminifers? and sphaeromorphs with walls of different thickness are present; moreover – as in the Upper Ordovician succession – also rare lenticular biogenous objects with mica-like areas on their bodies, caused by imprints of crystals, as well as sporadic chitinozoan-like thin crumpled graphitic particles were found.

In the lower part of the Kok Formation, phytoplankton is commonly present, in contrast to the subjacent Upper Ordovician part of the Cellon section where well preserved assemblages are missing (Priewalder, 1987). The state of preservation is fairly good and numerous taxa occur also in samples where the chitinozoans are rare or absent. However, in the upper part of the Kok Formation, i.e., above *Bed 13B*, acritarchs are present, but unidentifiable to any taxon level.

The following samples yield chitinozoans: sample **46A** [basal part of *Bed 9* (c. 270 specimens; 16 taxa)], sample **47** [upper part of *Bed 9* (25 specimens; 1 species)], sample **130** [uppermost part of *Bed 9* (20 specimens; 3 species)], sample **131** [*Bed 10A* (9 specimens; 5 species)], sample **49** [*Bed 10F* (1 specimen; 1 species)], sample **50** [*Bed 10G* (5 specimens; 2 species)], sample **132** [upper part of *Bed 10J* (38 specimens; 8 species)], sample **133** [*Bed 11A* (17 specimens; 7 species)], sample **136** [*Bed 13* (1 specimen; 1 species)] and sample **56** [*Bed 13B* (2 specimens; 1 species)]. This chitinozoan bearing succession (except sample **136** and **56**) belongs to the “Lower Shales and Ferruginous Limestones” (Brett et al., 2009) which comprises *Beds 9–11B* and whose dark grey, partly ferruginous shale provided the studied chitinozoans. The remaining samples from the succeeding “Kok Limestones” (*Beds 11C–19*) usually yield only unidentifiable chitinozoans or they are completely barren.

On the whole, 27 species could be distinguished, due to poor preservation frequently in open nomenclature, belonging to nine genera and two “accumulative taxa”. However, 192 chitinozoans could not be classified, and in several samples they represent the majority of the collected fossil specimens. Due to the poor preservation of the chitinozoans and their occasionally sporadic occurrence, no estimate of concentration in the rock is given hence no amount of chitinozoans per gram of rock is indicated.

The Kok Formation is a strongly condensed succession, showing several gaps in sedimentation and frequent sea-level changes (chapter “Kok Formation”), that was studied in detail by Brett et al. (2009). The degree of condensation becomes obvious when the thicknesses of the sequences are compared: c. 13 m Kok Formation (upper Llandovery–lowermost Ludfordian) in the Cellon section, deposited in the proximal Plöcken Facies, as opposed to a coeval succession of >40 m from the transitional facies towards the basin [Oberbuchach I section; Findenig-Facies (Brett et al., 2009: Fig. 19)].

The "Lower Shales and Ferruginous Limestones" (*Beds 9–11B* = lower part of the Kok Formation) consist of c. 3 m of alternating dark-grey to black shale and thin brownish and dark grey ferruginous limestone, showing several short term oxygenation events (Histon, 1997a; Histon & Schönlaub, 1999; Brett et al., 2009). According to Schönlaub & Histon (1999) this sequence was deposited in a relatively shallow environment, "periodically affected by storm currents, with episodic deepening and intervals of reduced deposition and non-sedimentation". The succeeding c. 10 m thick "Kok Limestones" (*Beds 11C–19*; i.e., the upper part of the Kok Formation, devoid of chitinozoans) mainly consist of red-brown and black-grey nautiloid-bearing strata (bioclastic wackestone-packstone), with a few intercalations of thin dark shale (Histon, 1997a; Histon & Schönlaub, 1999; Brett et al., 2009). Histon (2012) studied in detail this sequence and the included cephalopods and recognised environmental conditions which could be responsible for the mechanical and/or chemical destruction of the chitinozoans or their flushing out of the depositional area. She reported – among others – frequent sea-level lowstands, condensed sequences with low sedimentation rates and mineralized hardgrounds, bioturbation, frequent high energy hydrodynamic regimes, as well as periodic current activities ventilating the sea floor. Such oxygenising and agitating conditions are devastating for the otherwise fairly resistant chitinozoans.

A remarkable phenomenon are the short stratigraphical ranges of numerous taxa, frequently occurring in only one sample. This however, could be due to the too long intervals between the sample points within this strongly condensed succession (see Loydell et al., 2003: 213).

Chitinozoans are much better preserved in the upper part of the Cellon section (Ludlow–lower Lochkovian) which is characterised by a quieter sedimentary environment (see the illustrations in Priewalder, 2000: Pls. 2, 3). Therefore, it is thought for large parts of the Kok Formation that unfavourable environmental conditions existed during or for a short time after deposition and before their burial which could have been responsible for the poor state of preservation of the fossils or their absence. However, it should also be taken into consideration that both the Variscan and Alpine Orogenies (see chapter "Geological setting") definitely had an adverse impact on the preservation of the chitinozoans.

Chitinozoans

The chitinozoan fauna of the Kok Formation predominantly consists of impoverished assemblages, nevertheless containing some diagnostic taxa of the upper Llandovery.

The oldest chitinozoans of the Kok Formation come from the base of *Bed 9* (sample **46A**) in the lowermost part of the formation. Sample **46A** is an unusual and unique sample. It is rich in taxa and in specimens, c. 270 individuals are assigned to 16 taxa, much more than in any other of the succeeding samples. The dark grey shale probably is highly condensed and "time-rich" which may have led to a considerable accumulation of chitinozoans in this sedimentary beds. It is remarkable that the representatives of the Conochitinidae which are usually common in coeval localities are very rare in this sample while the Lagenochitinidae and the Ancyrochitininae occur in large numbers (altogether c. 190 specimens); the Ancyrochitininae may presumably comprise species of the genus *Ancyrochitina* Eisenack, 1955a and also of *Plectochitina* Cramer, 1964, but due to their poor condition (the appendages are partly or completely broken) it was difficult to classify them more precisely. Moreover, it is striking that eight taxa of which some usually have much longer stratigraphical ranges are restricted to this sample. The following taxa are present in sample **46A**:

Desmochitinidae*:* *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964) sensu Mullins & Loydell, 2001 [7 specimens], *Eisenackitina causiata* Verniers, 1999 [3 specimens], *E. dolioliformis* Umnova, 1976 [23 specimens (restricted to sample **46A**)], *E.* cf. *inanulifera* Nestor, 2005 [5 specimens (restricted to **46A**)], *Eisenackitina* sp. 2 [6 specimens (restricted to **46A**)].

Lagenochitinidae: *Ancyrochitina* gr. *ancyrea* Eisenack, 1931 [9 specimens (restricted to **46A**)], Ancyrochitininae indet. [c. 60 specimens], *Angochitina longicollis* Eisenack, 1959 [6 specimens], *Cyathochitina* sp. [2 specimens (restricted to **46A**)], *Lagenochitina* sp. 1 [2 specimens], *Lagenochitina* sp. [1 specimen (restricted to **46A**)], Lagenochitinidae indet. [c. 130 specimens], *Sphaerochitina* sp. 1 [6 specimens (restricted to **46A**)], *Sphaerochitina* sp. 2 [7 specimens], *Sphaerochitina* spp. [1 specimen].

Conochitinidae*:* *Euconochitina* sp. 2 sensu Nestor, 1994? [2 specimens (restricted to **46A**)].

In the upper part of *Bed 9*, sample **47** (dark-grey shale) yields a monospecific chitinozoan community of *B. conica* [25 specimens]. A few cm higher in sample **130**, *Calpichitina*? sp. [1 specimen] and *Conochitina* cf. *iklaensis* Nestor, 1980b [8 specimens] occur, furthermore *Conochitina* sp. 2 [11 specimens, identical with the specimens in the Plöcken Formation], as well as one poorly preserved specimen of *Armoricochitina nigerica* (Bouché, 1965) are present, both most probably reworked from the Hirnantian.

Samples **46A**, **47** and **130** are from the lowermost part of the Kok Formation (*Bed 9*), in which unfortunately no conodonts were recovered (Text-Fig. 2).

In sample **131** (*Bed 10A*; dark grey, partly black ferruginous shale), *Conochitina leviscapulae* Mullins & Loydell, 2001 [4 specimens (restricted to sample **131**)], *Euconochitina* sp. 3 *sensu* Nestor, 1994? [2 specimens (restricted to **131**)] and *E. causiata* [1 specimen] were found, as well as one questionable *B. conica* and a *Calpichitina*? sp., and one fragment of a *Laufeldochitina* Paris, 1981, the latter most probably reworked from the Ordovician.

In sample **49** (dark grey ferruginous shale) from *Bed 10F*, one specimen of *A. longicollis* occurs and a short distance above in *Bed 10G* (sample **50**), *Conochitina praeproboscifera* Nestor, 1994 [3 specimens] and *C.* cf. *iklaensis* [2 specimens] are present.

Samples **131**, **49** and **50** belong to the *P. celloni* conodont superzone/*P. a. angulatus* conodont biozone.

Sample **132** (dark-grey to black, rusty weathering shale) from the upper part of *Bed 10J* is remarkable as *Conochitina* species now are the dominant feature: *C.* cf. *iklaensis* [20 specimens], *C. praeproboscifera* [1 specimen], *C.* cf. *armillata* Taugourdeau & de Jekhowsky, 1960 [6 specimens (restricted to sample **132**)], *C.* cf. *elongata* Taugourdeau, 1963 [1 specimen (restricted to **132**)], *Conochitina* sp. 1 *sensu* Mullins & Loydell, 2001 [1 specimen (restricted to **132**)], *Conochitina* sp. A [4 specimens (restricted to **132**)]; further taxa are: *Lagenochitina* sp. 1 [2 specimens] and *Eisenackitina* sp. 1 [3 specimens].

Sample **133** (dark-grey to black, rusty weathering shale) from *Bed 11* yields *A. longicollis* [7 specimens], *C.* cf. *iklaensis* [1 specimen], *Conochitina* sp. B [1 specimen], *Sphaerochitina* sp. 2 [1 specimen], *Sphaerochitina* spp. [1 specimen], *Eisenackitina* sp. 1 [2 specimens], *Lagenochitinidae* indet. [4 specimens].

Samples **132** and **133** belong to the Lower *P. a. amorphognathoides* conodont biozone.

The succeeding samples from *Beds 11F–19* of the Kok Formation provided only sporadic chitinozoans: in sample **136** (black limestone with shaly layers) from *Bed 13* one Ancyrochitininae indet. was found; in sample **56** from *Bed 13B* (red-brown limestone with layers of black shale) two *Bursachitina* sp. occur. *Bed 12B* and *12D* yield unidentifiable chitinozoans, the remaining samples are devoid of chitinozoans.

Summing up it should be noted that most of the chitinozoans which have been documented in the Kok Formation occur within their known stratigraphical ranges yet their distribution in the section is unusual: many are present in only one sample and/or their first appearance is relatively high in the succession. Taxa occurring exclusively in sample **46A** are: *E. dolioliformis, E.* cf. *inanulifera, Ancyrochitina* gr. *ancyrea, Euconochitina* sp. 2 sensu Nestor, 1994? and two specimens of *Cyathochitina* sp., a genus, whose LAD (last appearance datum) is probably in the uppermost Telychian. Exclusively present in sample **131** are *Euconochitina* sp. 3 sensu Nestor, 1994? and *Conochitina leviscapulae*, and in sample **132** *C.* cf. *armillata, C.* cf. *elongata* und *C.* sp. 1 sensu Mullins & Loydell, 2001. All these taxa have their established FAD (first appearance datum) more or less far below the base of the Kok Formation and many rang into the lower Sheinwoodian. *Angochitina longicollis, Bursachitina conica* und *Eisenackitina causiata* are here represented with short stratigraphical ranges within the lowermost part of the sequence, while *Conochitina praeproboscifera* does not appear until samples **50** and **132**. *C.* cf. *elongata* [lower Aeronian–lower Telychian (Paris, 1996: Fig. 6)] and *Conochitina* cf. *iklaensis* [upper Rhuddanian–lower Telychian (Nestor, 2012: Figs. 2, 3)] occur here above their known stratigraphical ranges. However, Loydell et al. (2007: 228) stated that *C. iklaensis* might range into the basal Sheinwoodian (for the geographical and stratigraphical occurrences of the studied taxa see their descriptions in chapter "Systematic palaeontology").

Many of the typical upper Llandovery species are not present in the Kok Formation. In the lowermost part of the "Lower Shales and Ferruginous Limestones" (*Beds 9–11B*) particularly the Conochitinidae like *Belonechitina cavei* Mullins & Loydell, 2001; *B. meifodensis* Mullins & Loydell, 2001; *B. oeselensis* Nestor, 2005; *Conochitina emmastensis* Nestor, 1982b; *C. leptosoma* Laufeld, 1974; *C. mathrafalensis* Mullins & Loydell, 2001; *C. visbyensis* Laufeld, 1974 are missing. The numerous Ancyrochitininae indet. with broken processes and Lagenochitinidae indet. may contain taxa such as *Ancyrochitina gutnica* Laufeld, 1974; *A. primitiva* Eisenack, 1964; *Plectochitina magna* (Nestor, 1982c); also *Ramochitina angusta* (Nestor, 1982c) is not present, furthermore some representatives of the Desmochitinidae [i.e., *Bursachitina nana* (Nestor, 1994), *B. nestorae* Mullins & Loydell, 2001, *Calpichitina densa* (Eisenack, 1962)] were not recorded. Many of these species range into the Sheinwoodian.

In the upper part of the "Lower Shales and Ferruginous Limestones", the Lagenochitinidae are almost completely absent, such as *Ancyrochitina ansarviensis* Laufeld, 1974; *A. mullinsi* Nestor, 2005; *A. porrectaspina* Nestor, 1994; *A. vikiensis* Nestor, 1994; *Anthochitina primula* Nestor, 1994; *Plectochitina pachyderma* (Laufeld, 1974); *Ramochitina costata* (Umnova, 1981); *R. nestorae* Grahn, 1995 and *R. ruhnuensis* (Nestor, 1982c). In addition important species of the genus *Conochitina* such as *Conochitina acuminata* Eisenack, 1959; *C. flamma* Laufeld, 1974 and *C. proboscifera* Eisenack, 1937 are missing. Only a few individuals of the Desmochitinidae are still present, but important taxa such as *Margachitina banwyensis* Mullins, 2000 and *M. margaritana* (Eisenack, 1937) are lacking.

The above cited species have mainly been documented in Baltic and British localities (Loydell et al., 2003: Fig. 15; Loydell & Nestor, 2005: Fig. 3; Loydell et al., 2010: Fig. 10; Mullins & Loydell, 2001: Fig. 7; Nestor, 1990, 1994, 1999: Fig. 10; 2005: Figs. 2–5; 2012: Fig. 2; Rubel et al., 2007: Fig. 3). The absence of so many taxa from the "Lower Shales and Ferruginous Limestones" (*Beds 9–11B*) most probably is due to an unsuitable habitat for the chitinozoans, but also unfavourable conditions for the preservation of the chitinozoans may have eliminated some of them, as this obviously is the case in the succeeding "Kok Limestones" (*Beds 11C–19*) where chitinozoans are entirely missing.

The chitinozoan biozones

Due to the rapid evolution of many Silurian chitinozoans and their broad palaeogeographical distribution as a result of their planktonic mode of life, Verniers et al. (1995) were able to establish 17 global chitinozoan biozones for the whole Silurian of which three are partly or entirely referable to the Telychian (upper Llandovery): the *Eisenackitina dolioliformis*, the *Angochitina longicollis* and the *Margachitina margaritana* chitinozoan biozones. These Silurian chitinozoan biozones are interval zones, whose bases are defined by the first appearance of the index species and the tops by the first appearance of the index species of the succeeding biozone.

In order to improve the stratigraphical resolution of the chitinozoan biozones, numerous integrated studies on chitinozoans, graptolites and conodonts were carried out on lower Silurian successions during the following decades, mainly at localities from the former Baltica and Avalonia palaeocontinents [Eastern Baltic (numerous drill cores) and UK], but also from Laurentia, with the goal of correlating the biozones of the three fossil groups important for biozonation (DUFKA et al., 1995; GRAHN, 1998; LOYDELL et al., 1998, 2003, 2007, 2010; MULLINS, 2000; MULLINS & LOYDELL, 2001, 2002; VANDENBROUCKE et al., 2003; MULLINS & ALDRIDGE, 2004; LOYDELL & NESTOR, 2005; RUBEL et al., 2007; KIIPLI et al., 2010; MÄNNIK et al., 2015). Further papers illustrating the correlation of the chitinozoan biozones with the graptolite and/or conodont biozones were published by VERNIERS (1999); NESTOR et al. (2002); ASSELIN et al. (2004); NESTOR (2009, 2012); KLEFFNER & BARRICK (2010); KIIPLI et al. (2012).

***Eisenackitina dolioliformis* global Biozone** (VERNIERS et al., 1995: 657):

- *Definition of the base of the biozone*: First occurrence of *E. dolioliformis* UMNOVA, 1976, defined in the Kirikukula borehole (-49.3 m), Rumba Formation, Estonia (NESTOR, 1984, 1990, 1994), referred to the upper part of the Aeronian (KALJO, 1990).
- *Characteristic features of the biozone*: *E. dolioliformis* is generally abundant.
- *Accompanying species*: *Conochitina emmastensis*. Northern Gondwanan diagnostic taxa include *Plectochitina pseudoagglutinans*, *P. saharica*, *Conochitina edjelensis* and *C. vitrea*.
- *Distribution*: Northern Gondwana, Baltica, Avalonia, Laurentia, Southern China?

The top of this global biozone is defined by the first appearance of *Angochitina longicollis*, the index-species of the succeeding biozone. In VERNIERS et al. (1995: Fig. 2), the biozone approximately corresponds to the level of the *S. sedgwickii–S. crispus* graptolite biozones (upper Aeronian–lower Telychian). Furthermore, it is worth mentioning that – according to Figure 4 in the latter paper – the index-species was not present in most Northern Gondwana locations and that the biozone there was represented by diagnostic Northern Gondwana taxa.

Despite numerous detailed biostratigraphic studies during the following years it was not possible to entirely resolve the question concerning the exact age of the base and the top of this biozone. The oldest reported FAD of *E. dolioliformis* was in the upper *S. sedgwickii* graptolite biozone (uppermost Aeronian; VANDENBROUCKE et al., 2003: Fig. 8). MULLINS & ALDRIDGE (2004: Fig. 3) and NESTOR (2009: Fig. 2) correlated it with the *S. guerichi* graptolite biozone (lowermost Telychian). Most frequently, however, there were references to the FAD of *E. dolioliformis* in the upper *S. turriculatus* graptolite biozone (MULLINS & LOYDELL, 2002: Fig. 2; LOYDELL et al., 2003: Figs. 15, 17; 2010: Figs. 10, 16; KLEFFNER & BARRICK, 2010: Fig. 9; KIIPLI et al., 2010: Figs. 4, 5; NESTOR, 2012: Figs. 2, 3) and the *D. staurognathoides* conodont biozone, respectively (LOYDELL et al., 2003: Figs. 15, 17; 2010: Figs. 10, 16; KLEFFNER & BARRICK, 2010: Fig. 9; KIIPLI et al., 2010: Figs. 4, 5); however, in the above mentioned studied sections in the literature frequently a hiatus has been encountered beneath that level.

The top of the *E. dolioliformis* biozone is predominantly correlated with the top of the *M. crenulata* graptolite biozone and the lower *P. a. angulatus* conodont biozone (lower *celloni* biozone), respectively. Only in Wales, does the *E. dolioliformis* biozone range into the *O. spiralis* graptolite biozone (MULLINS & LOYDELL, 2001: Figs. 7, 8; 2002: Figs. 2, 5).

NESTOR (2012: Figs. 2, 3) placed the base of the global *E. dolioliformis* biozone in the uppermost Aeronian while the base of the East Baltic *E. dolioliformis* biozone coincided with the Aeronian/Telychian boundary. However, in the latter case below the base of the biozone there was a gap comprising the sequence from the *S. sedgwickii* to the lower *S. turriculatus* graptolite biozones. The top of the *E. dolioliformis* biozone in both schemes was at the same level and correlated with the top of the *M. crenulata* graptolite biozone.

According to LOYDELL & NESTOR (2005: 374), *E. dolioliformis* appeared in the East Baltic sections in the lowermost Telychian. It was numerously and continuously present in the lower Telychian, while in the upper Telychian and lower Sheinwoodian its occurrence was scarce and patchy.

***Angochitina longicollis* global biozone** (VERNIERS et al., 1995: 657):

- *Definition of the base of the biozone*: First occurrence of *A. longicollis* EISENACK, 1931, defined in the Rosendal borehole (-155 m), in the Lower Visby Beds, Gotland, Sweden, at a level referred to as middle or upper part of the Telychian (LAUFELD, 1974).
- *Characteristic features of the biozone*: *Conochitina acuminata* and *Densichitina densa* appear within the biozone, *Conochitina proboscifera* may occur earlier (VERNIERS et al., 1995: 657).
- *Accompanying species*: Other diagnostic species of the biozone, i.e. *Angochitina macclurei*, occur on northern Gondwana.
- *Distribution*: Northern and western Gondwana, Baltica, Avalonia, Laurentia, Southern China.

The top of this global biozone is defined by the first appearance of *Margachitina margaritana* (EISENACK, 1937), the index-species of the succeeding global biozone. In VERNIERS et al. (1995: Fig. 2), the biozone approximately corresponds to the level of the *M. griestonensis–C. insectus* graptolite biozones (upper Telychian). It should be mentioned that – according to Figure 4 in the latter paper – the index-species was not present in most Northern Gondwana locations and the biozone there was represented by the characteristic or accompanying species.

During the following years, detailed studies of numerous lower Silurian sequences, frequently originating from drill cores and exhibiting graptolite and/or conodont biostratigraphical control, showed that the base of the *A. longicollis* chitinozoan biozone may be diachronous. In most of the investigated successions it was correlated with the base of the *O. spiralis* graptolite biozone and the lower part of the *P. a. angulatus* conodont biozone, respectively (DUFKA et al., 1995: Fig. 4; GRAHN, 1995: Fig. 5; LOYDELL et al., 2003: Figs. 15, 17; VANDENBROUCKE et al., 2003: Fig. 8; MULLINS & ALDRIDGE, 2004: Fig. 3; LOYDELL & NESTOR, 2005: Fig. 3; RUBEL et al., 2007: Figs. 3, 5, 8; NESTOR, 2009: Fig. 2; 2012: Figs. 2, 3; KIIPLI et al., 2010: Figs. 4, 5; LOYDELL et al., 2010: Figs. 10, 16; MÄNNIK et al., 2015: Figs. 3, 4, 9, 11). In Wales, however, the FAD of *A. longicollis* was located in the middle or upper *O. spiralis* biozone (MULLINS & LOYDELL, 2001: Figs. 7, 8; 2002: Figs. 2, 5).

Also the definition of the upper boundary of the global *A. longicollis* biozone was problematical as it was based on the FAD of *Margachitina margaritana*, the index-fossil of the succeeding global chitinozoan biozone whose appearance, however, seemed to be diachronous. The solution of this problem was complicated by the fact that in the drill cores of the East Baltic, which were important for the correlation between the chitinozoan, graptolite and conodont biozonal schemes, the crucial horizons of uppermost Telychian age were missing. Currently the top of the global *A. longicollis* biozone is correlated with the lowermost *C. insectus* graptolite biozone and the Upper *P. a. amorphognathoides* conodont biozone, respectively (uppermost Telychian) (Dufka et al., 1995; Mullins, 2000; Mullins & Loydell, 2001; Mullins & Aldridge, 2004; Nestor, 2005, 2012; Rubel et al., 2007; Kiipli et al., 2010), though *M. margaritana* was found sporadically already in the upper *O. spiralis* graptolite biozone (Grahn, 1995; Loydell & Nestor, 2005; Männik et al., 2015).

A. longicollis ranged into the Sheinwoodian. Most often its LAD has been reported from the *C. murchisoni* graptolite biozone, but at a few localities it was still present in the *M. riccartonensis* biozone (Nestor, 2005).

Margachitina margaritana **global biozone** (Verniers et al., 1995: 657):

- *Definition of the base of the biozone*: First occurrence of *Margachitina margaritana* (Eisenack, 1937), defined 5 cm above the base of the Buildwas Formation, Leasows section, Hughley Brook, Shropshire, Welsh Borderland, England, that is, at the global stratotype for the Llandovery/Wenlock boundary, at the very base of the Sheinwoodian (Mabillard & Aldridge, 1985).
- *Characteristic features of the biozone*: Large typical *Conochitina proboscifera*.
- *Accompanying species: Gotlandochitina corniculata*; in the lower part of the biozone the accompanying species are the same as in the *A. longicollis* Biozone, plus *Salopochitina monterrosae* (Cramer, 1969) (= *Salopochitina bella* Swire, 1990).
- *Distribution*: Northern and western Gondwana, Baltica, Avalonia, Laurentia.

The top of this global biozone is defined by the first appearance of *Cingulochitina cingulata* (Eisenack, 1937), the index-species of the succeeding global biozone. In Verniers et al. (1995: Fig. 2), the biozone approximately correlates with the level of the *C. centrifugus*–*M. belophorus* graptolite biozones (lower Sheinwoodian). According to Figure 4 in the latter paper, *M. margaritana* is widely distributed not only in Baltica, Avalonia and Laurentia but also in Northern and Western Gondwanan localities.

Numerous detailed biostratigraphical studies, mainly carried out in the East Baltic and in Great Britain, pointed over the following years not only to the onset of the *M. margaritana* biozone already in the uppermost Telychian (in contrast to the original assumption that its base is designating the Llandovery/Wenlock boundary), but also to its diachronous occurrence. At present, its base is usually assigned to the lowermost *C. insectus* graptolite biozone and the upper part of the *P. a. amorphognathoides* conodont biozone, respectively (Dufka et al., 1995; Mullins, 2000; Mullins & Loydell, 2001; Mullins & Aldridge, 2004; Nestor, 2005, 2012; Rubel et al., 2007; Kiipli et al., 2010); however, in rare cases, *M. margaritana* has been reported from the upper part of the *O. spiralis* graptolite biozone (Grahn, 1995; Loydell & Nestor, 2005; Männik et al., 2015). The top of the biozone is correlated with the *M. belophorus* graptolite biozone (lower Sheinwoodian) (Nestor, 2009: Fig. 2; 2012: Figs. 2, 3).

According to Mullins (2000), the stratigraphical range of *M. margaritana* is from the uppermost Telychian Stage (Llandovery Series) to the lower Homerian Stage (Wenlock Series).

In localities of the palaeocontinents Baltica and Avalonia which exhibit sequences of an age equivalent to the upper part of the global *A. longicollis* biozone (upper *O. spiralis*–lowermost *C. insectus* graptolite biozone), three further important chitinozoan biozones have been distinguished after the establishment of the global chitinozoan biozonation (Verniers et al., 1995).

The base of the lowermost of these biozones, the ***Conochitina proboscifera*** **biozone**, first identified by Nestor (1990), was defined by the first occurrence of *C. proboscifera* Eisenack, 1937 and it was correlated with the interval from the upper *O. spiralis* to the lowermost *C. lapworthi* graptolite biozone and approximately with the interval from the uppermost *P. a. angulatus* to the lowermost *P. a. amorphognathoides* conodont biozone, respectively. The diachronous nature of the FAD of the eponymous species, observed at several localities (Verniers et al., 1995: 657), has been denied by Loydell et al. (2003: 219) and Kiipli et al. (2010: 38) as they supposed that in past studies *C. proboscifera* might have been confused with the similar taxon *Conochitina praeproboscifera* Nestor, 1994 which, however, appeared much earlier. The *C. proboscifera* biozone has been reported particularly from the East Baltic investigation areas (Nestor, 1990, 1994, 2005, 2012; Loydell et al., 1998, 2003, 2010; Loydell & Nestor, 2005; Rubel et al., 2007; Kleffner & Barrick, 2010; Kiipli et al., 2010; Männik et al., 2015).

The base of the succeeding ***Conochitina acuminata*** **biozone**, identified by Mullins & Loydell (2001) was defined by the FAD of *C. acuminata* Eisenack, 1959, and the biozone was correlated with the lower *C. lapworthi* graptolite biozone and the lower *P. a. amorphognathoides* conodont biozone, respectively. It is well established in the Baltic area and in Great Britain (Mullins & Loydell, 2001, 2002; Vandenbroucke et al., 2003; Loydell et al., 2003, 2010; Mullins & Aldridge, 2004; Nestor, 2005, 2012; Rubel et al., 2007; Kiipli et al., 2010; Männik et al., 2015).

In Wales, the *C. acuminata* biozone is succeeded by the ***Margachitina banwyensis*** **biozone**, identified by Mullins (2000), which was correlated with the interval of the upper *C. lapworthi*–lowermost *C. insectus* graptolite biozone and the upper *P. a. amorphognathoides* conodont biozone, respectively; in the Baltic, this biozone has been identified only very rarely (Mullins, 2000; Mullins & Loydell, 2001; Nestor, 2005, 2012; Loydell & Nestor, 2005; Rubel et al., 2007). The top of the *M. banwyensis* biozone is formed by the base of the succeeding *Margachitina margaritana* chitinozoan biozone (see above).

In the Cellon section, the presence of *Angochitina longicollis* in samples **46A**, **49** and **133** from the lower part of the Kok Formation indicates the presence of the global *A. longicollis* chitinozoan biozone, whose base is correlated with the base of the *O. spiralis* graptolite biozone and with the lower part of the *P. a. angulatus* conodont biozone, respectively. Hence the stratigraphical data in the Cellon section are in good accordance with those in the East Baltic sections (Loydell et al., 2003; Rubel et al., 2007; Kiipli et al., 2010).

The conodont biozonation of the Silurian part of the Cellon section, originally established by Walliser (1964), has been recently revised by Corradini et al. (2014). The lowermost part (*Bed 9*) of the Kok Formation, however, did not yield conodonts. Due to the documentation of the *A. longicollis* biozone from the basal *Bed 9* (sample **46A**) upward, also this part of the succession can be assigned to the *P. a. angulatus* conodont biozone (*P. celloni* superzone) with which the *A. longicollis* chitinozoan biozone is correlated (see above) [according to Corradini et al., 2014, the first *P. a. angulatus* appeared in *Bed 10B*, the first *P. celloni* in *Bed 10*].

Due to its peculiar chitinozoan assemblage, sample **46A** has to be briefly discussed again as it seems to be a particular case (see above). It is characterised not only by large numbers of individuals, but also by uncommonly numerous taxa, more than in all other samples. This may lead to the assumption that the dark-grey shale represents a highly condensed and "time-rich" rock in which an enrichment of chitinozoans took place. Furthermore it is remarkable that the sample yielded six specimens of *A. longicollis*, but 23 individuals of *Eisenackitina dolioliformis*, the index-species of the subjacent chitinozoan biozone [plus 6 specimens of *Eisenackitina* sp. 2 which is very similar to *E. dolioliformis* (both taxa are restricted to sample **46A**)]. It therefore could be possible that sample **46A** also represents at least the upper part of the *E. dolioliformis* chitinozoan biozone (*S. turriculatus*–top *M. crenulata* graptolite biozone = *D. staurognathoides*–lower *P. a. angulatus* conodont biozone), since Loydell & Nestor (2005: 374) stated that *E. dolioliformis* is numerously and continuously present in the lower Telychian, while in the upper Telychian and lower Sheinwoodian its occurrence is scarce and patchy.

Further conspicuous horizons are the samples **50** (*Bed 10G*; uppermost *P. a. angulatus* biozone) and **132** (upper *Bed 10J*; lowermost *P. a. amorphognathoides* conodont biozones) [there are no studied samples from the *P. a. lennarti* and *P. a. lithuanicus* biozones (*Bed 10H* and lower *Bed 10J*)]. These samples are characterised by the appearance of several *Conochitina* taxa (see above) which were missing in the lower part of the succession. In the Baltic area, this interval coincides with the *Conochitina proboscifera* chitinozoan biozone (approximately uppermost *P. a. angulatus* to lowermost *P. a. amorphognathoides* conodont biozone and upper *O. spiralis* to lowermost *C. lapworthi* graptolite biozone, respectively). However, *C. proboscifera* does not occur in the Cellon section, only the similar taxon *C. praeproboscifera*, which has its FAD in the upper Aeronian, is – exclusively – present in samples **50** and **132**. *C. proboscifera* was also missing in upper Telychian sequences of the Girvan area of Scotland (Vandenbroucke et al., 2003), and in the Prague Basin it did not appear below the lower Sheinwoodian *C. murchisoni* biozone (Dufka, 1992). On the other hand, Dufka et al. (1995) reported *C. proboscifera* from other localities in the Prague Basin ranging there from the *O. spiralis* biozone upward. Therefore Loydell & Nestor (2005: 375) assumed that this widespread and common taxon may have a patchy distribution in the lower part of its range, although in the East Baltic it reliably occurs in uppermost Telychian and lowermost Sheinwoodian successions.

The upper part of the *P. a. amorphognathoides* conodont biozone (uppermost Telychian) which is also present in the Cellon section, elsewhere correlates with the *Conochitina acuminata* (lower *C. lapworthi* graptolite biozone), the *Margachitina banwyensis* (upper *C. lapworthi*–lowermost *C. insectus* graptolite biozone) and the lowermost part of the *Margachitina margaritana* chitinozoan biozones (from the lowermost *C. insectus* graptolite biozone upward). These index-fossils, however, could not be proven in the Kok Formation as chitinozoans are missing in this part of the succession.

The chitinozoan bearing lower part of the Kok Formation (samples **46A**–**133**/*Beds 9–11*) is therefore assigned to the global *Angochitina longicollis* chitinozoan biozone whose base is defined by the FAD of *A. longicollis* and the top by the FAD of *M. margaritana*, comprising an interval from the basal *O. spiralis* to the lowermost *C. insectus* graptolite biozone, this is from the lower *P. a. angulatus* to the upper *P. a. amorphognathoides* conodont biozone (upper Telychian).

The palaeogeographical affinities of the chitinozoans

Though many upper Telychian taxa are missing in the Cellon Section, the ones present still show close affinities to localities of the palaeocontinents ***Baltica*** (today represented for example in Estonia, Latvia, Sweden + Gotland, Oslo region/Norway) and ***Avalonia*** (Brabant Massif/Belgium, Wales, England, New Brunswick and Anticosti Island/eastern Canada), less distinctly also to those of ***Laurentia*** (Girvan area/Scotland, North Greenland, New York State and Nevada/USA) (for more detailed information concerning the geographical and stratigraphical occurrences of the studied taxa see their descriptions in chapter "Systematic palaeontology"). Species from the Cellon section such as *Angochitina longicollis*, *Bursachitina conica*, *Conochitina iklaensis*, *C. praeproboscifera*, *Eisenackitina causiata* and *E. dolioliformis* were numerous and wide-spread in the above mentioned palaeocontinents, but also remarkable taxa such as *Conochitina leviscapulae*, *Conochitina* sp. 1 sensu Mullins & Loydell, 2001, Euconochitina sp. 2 sensu Nestor, 1994? and Euconochitina sp. 3 sensu Nestor, 1994?, which were rather rare in Baltica and Avalonia occur in the Kok Formation.

Close relationship to ***Perunica*** (Prague Basin, Bohemia) in the upper Telychian (Dufka, 1992; Dufka et al., 1995) is indicated by the co-occurrence and the distinct resemblance of *A. longicollis, E. causiata* and *E. dolioliformis*, and furthermore by the presence of numerous poorly preserved Lagenochitinidae probably containing the genera *Ancyrochitina*, *Angochitina*, *Lagenochitina*, *Plectochitina, Sphaerochitina* and *Ramochitina* (Dufka, 1992: 120), which is also a conspicuous phenomenon in the Cellon Section (sample **46A**; see above). *C. iklaensis* and *B. conica* (as *Conochitina malleus* and very similar to the studied individuals) occur in the Prague Basin as well: the former species, however, has its LAD there already at the Aeronian/Telychian boundary, the latter in the lower Telychian (Dufka et al., 1995: Fig. 4). *Conochitina emmastensis* and *Margachitina margaritana* (the latter has its FAD in Bohemia at the base of the *C. insectus* graptolite biozone) are not present in the Cellon section, as well as *Conochitina proboscifera*, which according to Dufka et al. (1995: Fig. 4) has its FAD within the *O. spiralis* graptolite biozone, while this species at other localities in the Prague Basin does not appear before the lower Sheinwoodian (Dufka, 1992). The presence of chitinozoans during the interval from the Wenlock–lower Ludlow is also different in both areas: while in the Cellon section in the upper part of the Kok Formation sporadically poorly preserved chitinozoans occur, coeval successions in Bohemia yield rich and diverse chitinozoan assemblages (Kříž et al., 1993; Dufka, 1995).

Nearly no affinities of the upper Llandoverian chitinozoan populations from the Cellon section with those from ***Northern Gondwana*** localities are observed. Only *Conochitina armillata* and *C. elongata* occur there frequently but the latter species have been reported sporadically also from Baltica (Norway, Gotland, Estonia, Latvia) (Taugourdeau & de Jekhowsky, 1964; Nestor, 1999; Loydell et al., 2003, 2010). The chitinozoan assemblages from Northern Gondwana usually show a different composition, where the typical taxa such as *Angochitina longicollis*, *Bursachitina conica*, *Eisenackitina dolioliformis*, *E. causiata*, *Conochitina praeproboscifera* are absent (Hill et al., 1985; Paris, 1988a; Ghavidel-Syooki & Vecoli, 2007; Paris et al., 2015a). Paris et al. (1995: 86) calculated the coefficient of similarity for Aeronian chitinozoan assemblages from Northern Gondwana and Baltica and found that there was only a moderate to low relationship between the two chitinozoan populations. The similarity between the chitinozoans from Perunica and Northern Gondwana was also rather low. Hence, they concluded that the wide extent of the mid-European Rheic Ocean separating the palaeocontinents led to contrasting climatic zones on the northern and on the southern margins of this ocean. This could have affected the occurrence of those chitinozoans, which were less tolerant to temperature variations.

The above diagnosis concerning the close faunistic relationship of the chitinozoans from the Cellon Section particularly to those from Avalonia and Baltica is in accordance with the statement of Schönlaub & Histon (2000: 20, 30), that the Silurian biota (e.g. bivalves, brachiopods, nautiloids, corals, trilobites, conodonts) of the Carnic Alps (which belonged to the Northern Gondwana derived Apulia Terrane) show close affinities to coeval faunas from Baltica, Avalonia and even Siberia. However, they mentioned as well close affinities to the faunas from southern, central and southwestern Europe, but, as stated above, this could not be proved for the chitinozoans (except to central Europe = Prague Basin), in part due to the lack of chitinozoan data from this time interval in the named regions. Schönlaub & Histon (2000: 30, Fig. 13) suggested a palaeogeographical position for the Carnic Alps in the Silurian at 35° S. Also Brett et al. (2009: 26) pointed to the possible vicinity of the Apulia Terrane with Laurentia, Baltica and Avalonia in late Telychian times due to the occurrence of similar environmental conditions in those areas (i.e., the deposition of ironstones). Histon (2012: 242) emphasised the close affinity of Silurian nautiloid faunas from the Carnic Alps with those from Bohemia and Southwest-Sardinia and a Silurian palaeogeographically position of the Carnic Alps closer to Baltica than to Northern Africa. This was supported by data from other fossil groups and palaeomagnetic studies.

Conclusions

In the Cellon section, studies were carried out on the chitinozoan content of the Valbertad Formation (Katian), the Uqua Formation (late Katian–?basal Hirnantian), the Plöcken Formation (Hirnantian) and the Kok Formation (upper Llandovery–lower Ludlow). Only the Plöcken Formation and the lower part of the Kok Formation, which are separated by a large gap (Rhuddanian–lower Telychian), yield taxonomically and stratigraphically useful, but poorly preserved chitinozoans. The shallow-water environment (Plöcken Facies), in which the deposition of the Hirnantian and Silurian successions of the Cellon section took place, seems to have been unfavourable for the preservation of the chitinozoans up until the lower Ludlow. In the upper part of the section (upper Ludlow–lower Lochkovian; not discussed in this paper), however, the environmental conditions obviously improved as the chitinozoans' state of preservation is good to excellent. As written above, the reasons remain unclear for the complete absence of the chitinozoans in the successions below the Plöcken Formation.

The Plöcken Formation was deposited within a storm-dominated shallow-water environment during the melting of the North Gondwana ice-cap, which led to a global sea-level rise and subsequent transgression. In its lower part (*Bed 5*), the index-graptolite of the uppermost Ordovician graptolite biozone, *Metabolograptus persculptus*, occurs, as well as the *Hirnantia* brachiopod fauna, typical of the Kosov Brachiopod Province. The upper part of the succession (*Bed 7* and *8*) yields chitinozoan taxa such as *Tanuchitina elongata*, *Rhabdochitina* cf. *gracilis*, *Armoricochitina nigerica* and *Desmochitina minor*, which are assigned to the Hirnantian *Tanuchitina elongata* chitinozoan biozone. This is one of the rare and remarkable cases that the Hirnantian age of the *T. elongata* biozone could be demonstrated by independent biostratigraphical data. The uppermost Hirnantian *Spinachitina oulebsiri* chitinozoan biozone, however, could not be proven, therefore this time interval may be missing in the Cellon section.

The chitinozoans of the Plöcken Formation show close affinities to those of the cold-water realm of the North Gondwana faunal province, though the palaeogeographical position of the Apulia Terrane, to which the Carnic Alps belonged and which in all likelihood was part of the Peri-Gondwana Terranes, was most probably not higher than 50° southern latitude. A short-term cold-water invasion in the course of the Hirnantian glaciation, which covered large areas of Northern Gondwana and which obviously caused the polar front to move far to the north into the temperate zone (probably as far as 40° S), may have affected the composition of the chitinozoan populations of the Plöcken Formation.

Bourahrouh et al. (2004: 25) studied the chitinozoans of the Upper Ordovician Bou Ingarf section in the Central Anti-Atlas (Morocco), the type section of the *Ancyrochitina merga* and the *Tanuchitina elongata* chitinozoan biozones and they unfortunately based their biozones on incorrect zonal definitions:

> "The ***A. merga*** biozone was defined (Paris, 1990) as the interval-range biozone between the FAD (first appearance datum) of *Ancyrochitina merga* and the FAD of *Tanuchitina elongata*, which is the index species of the succeeding biozone" (*instead of*: "total range zone" of *A. merga* in Paris, 1990: 201).

> "......the ***elongata*** biozone is now restricted to the interval-range biozone between the FAD of *Tanuchitina elongata* and the FAD of S*pinachitina oulebsiri*" [*instead of*: the interval-range zone between the LAD (last appearance datum) of *A. merga* and the FAD of *Spinachitina oulebsiri*].

This led to confusion concerning the base of the Hirnantian in this section, as it thus became located within the preglacial Lower 2nd Bani Shaly Member. However, if the zonal definitions are applied correctly (i.e., total range zone of *A. merga*), the discrepancies between sedimentological and palynological data disappear, as the base of the Hirnantian then coincides with the base of the Lower 2nd Bani Sandstone Member (i.e., Unit 1 of the glaciation related succession in Loi et al., 2010).

After a large gap which comprises most of the Llandovery (Rhuddanian–lower Telychian) the Kok Formation succeeds unconformably the Hirnantian Plöcken Formation. The strongly condensed, transgressive succession, deposited on a shallow to moderately deep, steadily subsiding shelf was frequently affected by sea-level changes creating an unfavourable environment for the preservation of the chitinozoans. The lower part (upper Llandovery) consists of an alternation of thin carbonatic layers and dark shale, from which the chitinozoans originated. The upper part (Wenlock–lower Ludlow) is mainly made up of nautiloid limestone and it is almost completely devoid of chitinozoans.

Chitinozoan taxa such as *Angochitina longicollis*, *Bursachitina conica*, *Eisenackitina dolioliformis*, *E. causiata*, *Conochitina* cf. *iklaensis*, *C. leviscapulae* and *C. praeproboscifera* are present in the succession from *Bed 9* to *Bed 11*, however, several important and wide-spread species are missing here, like *Calpichitina densa*, *Conochitina acuminata*, *C. emmastensis*, *C. proboscifera*, and *Margachitina margaritana*.

The studied chitinozoan assemblage indicates the global *Angochitina longicollis* chitinozoan biozone (upper Telychian), whose base is correlated with the base of the *O. spiralis* graptolite biozone and with the lower part of the *P. a. angulatus* conodont biozone, respectively. The top of this global chitinozoan biozone is defined by the first appearance of *M. margaritana* which correlates with the lowermost *C. insectus* graptolite biozone and the upper *P. a. amorphognathoides* conodont biozone (uppermost Telychian). The succeeding *M. margaritana* chitinozoan biozone, however, could not be proved in the Cellon section as no chitinozoans occur in the corresponding horizons.

Bed 9 from the base of the Kok Formation, from which no conodont data are available, can now be dated by the presence of the *A. longicollis* chitinozoan biozone as *P. a. angulatus* conodont biozone (*P. celloni* superzone).

Sample **46A** from the very base of the Kok Formation has to be mentioned since it is unique and differs from the succeeding samples revealing an unusually large number of taxa and individuals, among others a large number of *E. dolioliformis* (besides a low number of *A. longicollis*). This dark-grey shale seems to be highly condensed and "time-rich" and may possibly mask the upper part of the subjacent *E. dolioliformis* chitinozoan biozone (uppermost Aeronian–lower Telychian).

The chitinozoan populations of the lower part of the Kok Formation reveal close affinities to Baltica, Avalonia and Perunica (Prague Basin) and – less distinct – also to Laurentia, but almost none to Northern Gondwana. This is in accordance with the estimated position of the Apulia Terrane at 35° S in the Silurian, concluded from various macrofossil groups and lithology.

There is a noteworthy phenomenon in the studied lower part of the Cellon section that is of particular interest: *Bed 8*, the uppermost layer of the Plöcken Formation, contains a Hirnantian chitinozoan assemblage with a distinct relationship to the cold-water areas of Northern Gondwana, while the chitinozoans from the immediately succeeding *Bed 9*, i.e. the basal (upper Telychian) bed of the Kok Formation, are completely different and show close affinities to the warm-water environments of Baltica and Avalonia. This could be an indication of the northward drift of the Apulia Terrane from cold-water areas in the Hirnantian (Late Ordovician) towards the warm-water realms in the late Llandovery (early Silurian).

Systematic Palaeontology

General Remarks

The state of preservation of the studied chitinozoans is generally poor. They are frequently flattened, often showing different intensities of flattening on the same specimen, which made the recognition of the original shape of the vesicles and thus their taxonomic attribution difficult. Only very few chitinozoans are completely preserved, but in most a variably long part of the neck and/or the collarette is missing. Appendages are most often broken with only their basal part remaining; small sculptural elements such as granule or spines are frequently abraded and merely traces of their basalmost parts are visible. Sometimes a cover of amorphous organic material hampered the recognition of micro-ornamentation or the basal structures. The identification of the latter is generally difficult as the vesicle bases often are invaginated due to flattening or had been destroyed by internal and/or external imprints of crystals.

Consequently, due to insufficient data for specific characters, numerous taxa have been treated in open nomenclature. No synonymy lists can be given in the description of such taxa, because they are restricted to reliably identifiable species. The generation of the synonymy lists and the application of open nomenclature is based upon the recommendations of Granzow (2000).

The poor condition of the chitinozoans also hampered accurate measurements of the size of the vesicles. As on the one hand almost all of the specimens are missing a variably long portion of their upper parts and as on the other hand it seemed necessary to state the present vesicle sizes, also the lengths of broken specimens are cited, but marked by the symbol ">" ("larger than").

In addition, the measurement of the diameter of many vesicles turned out to be problematic due to the different degrees of flattening, frequently observed in one and the same specimen. Moreover, many individuals are partly infilled with framboids or crystals, others are distorted and/or folded. Thus, the choice of the proper coefficient of correction for the flattening often was rendered difficult as most vesicles are not completely flattened. Normally the correction coefficient for the diameter of completely flattened specimens is x 0.7. This coefficient in our cases is therefore frequently based on an approximation.

The abbreviations used in the list of vesicle dimensions in the descriptions of the taxa are adopted from Paris (1981):

L = total length of the vesicle
Lp = length of the chamber
Dp = diameter of the chamber
lc = length of the neck
dc = diameter of the neck
$d_{apert.}$ = diameter of the aperture
$l_{coll.}$ = length of the collarette

The SEM investigations of the chitinozoans were made under a CAMBRIDGE STEREOSCAN 150, usually at 20 KV and 20 mm WD. The photographs were taken on an AGFAPAN 25 PROFESSIONAL (15 Din) roll film. For the preparation of the plates the film negatives were digitised with the *CanoScan 9000F* of Canon.

The permanent slides (40 in number) containing the illustrated chitinozoans are stored in the collections of the Geological Survey of Austria, Vienna, under the numbers 2020/002/0001–0040. In these slides, the illustrated chitinozoans can be found by Englandfinder data, mentioned in the description of the illustrations on the plates.

List of discovered chitinozoans

Ancyrochitina gr. *ancyrea* Eisenack, 1931....p. 94.
Ancyrochitininae indet..... p. 93.
Angochitina longicollis Eisenack, 1959.... p. 95.
Armoricochitina nigerica (Bouché, 1965) .... p. 77.
Bursachitina conica (Taug. & Jekh., 1964) sensu Mullins & Loydell, 2001.... p. 69.
B. sp..... p. 71.
Calpichitina ? sp..... Pl. 4, Fig. 8 (without description).
Conochitina cf. *armillata* Taug. & Jekh., 1960.... p. 78.
C. cf. *elongata* Taugourdeau, 1963.... p. 79.
C. cf. *iklaensis* Nestor, 1980b.... p. 80.
C. leviscapulae Mullins & Loydell, 2001.... p. 82.
C. praeproboscifera Nestor, 1994.... p. 83.
C. sp. A.... p. 84.
C. sp. B.... p. 84.
C. sp. 1 sensu Mullins & Loydell, 2001.... p. 85.
C. sp. 1.... p. 86.
C. sp. 2.... p. 86.
C. sp. 3.... p. 87.
C. sp. 4.... p. 87.
C. ? sp..... p. 87.
Cyathochitina sp..... p. 97.
Desmochitina minor Eisenack, 1931.... p. 71.
Eisenackitina causiata Verniers, 1999.... p. 72.
E. dolioliformis Umnova, 1976.... p. 73.
E. cf. *inanulifera* Nestor, 2005.... p. 75.
E. sp. 1.... p. 76.
E. sp. 2.... p. 76.
Euconochitina sp. 2 sensu Nestor, 1994 ?.... p. 88.
E. sp. 3 sensu Nestor, 1994?.... p. 88.
E. sp..... p. 89.
E. ? sp.... p. 89.
Lagenochitina sp. 1.... p. 97.
L. sp. (among *L.* sp. 1).... p. 97.
Lagenochitinidae indet..... p. 93.
Rhabdochitina cf. *gracilis* Eisenack, 1962.... p. 90.
Sphaerochitina sp. 1.... p. 98.
S. sp. 2.... p. 98.
S. spp..... p. 99.
Spinachitina sp..... p. 91.
Tanuchitina elongata (Bouché, 1965) .... p. 91.

Incertae sedis group Chitinozoa Eisenack, 1931
Order Operculatifera Eisenack, 1931
Family Desmochitinidae Eisenack, 1931, emend. Paris, 1981
Subfamily DESMOCHITININAE Paris, 1981
Genus Bursachitina Taugourdeau, 1966, restr. Paris, 1981

Bursachitina conica (Taugourdeau & de Jekhowsky, 1964) sensu Mullins & Loydell, 2001

(Pl. 4, Figs. 1–5)

Synonymy

1964 *Conochitina brevis conica* n. ssp. – Taugourdeau & de Jekhowsky, p. 858, Pl. III, Figs. 26–27.
non1967 *Euconochitina brevis conica* (Taug. & Jekh.). – Rauscher & Doubinger, p. 316, Pl. III, Fig. 11.
non1968 *Euconochitina brevis conica* (Taugourdeau & de Jekhowsky). – Rauscher, p. 54, Pl. 3, Fig. 1.
non1976 *Conochitina brevis conica* Taugourdeau & Jekhowsky. – Umnova, Pl. II, Figs. 12, 13; Figs. 5d–f.
?1980 *Eisenackitina conica* (Taugourdeau & Jekhowsky), 1964. – Zaslavskaya, p. 68, Pl. III, Fig. 7.
non1982 *Clavachitina conica* (Taugourdeau & Jekhowsky, 1964). – Tsegelnyuk, p. 29, Pl. 1, Figs. 6, 7.
?1983 *Eisenackitina conica* (Taugourdeau & Jekhowsky), 1964. – Zaslavskaya, p. 67, Pl. VII, Figs. 1–3; Pl. XV, Fig. 6.
2001 *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964) n. stat., n. comb. – Mullins & Loydell, p. 733, Pl. 1, Figs. 1–5; Pl. 2, Figs. 9–11 (***cum syn.***).
2002 *Bursachitina conica* (Taugourdeau & de Jekhowsky). – Mullins & Loydell, Figs. 3b, c, d, g.
2003 *Bursachitina* sp. – Loydell et al., Fig. 16n.
2004 *Bursachitina* sp. – Asselin et al., Pl. 2, Figs. 20, 21.
2004 *Bursachitina conica* (Taugourdeau & de Jekhowsky). – Mullins & Aldridge, Pl. 1, Figs. 5–6.
2010 *Bursachitina conica* (Taugourdeau & de Jekhowsky, sensu Mullins & Loydell, 2001). – Loydell et al., Fig. 13a.
2015 *Bursachitina conica* (Taugourdeau & de Jekhowsky). – Männik et al., Fig. 6Z.

Material

Sample **46A**: Seven flattened specimens of which only one is complete.

Sample **47**: Twenty-five flattened specimens of which fifteen are complete. Moreover, there are numerous antiapertural fragments which resemble *B. conica* but taxonomically are not indicative enough to allow a positive assignment.

Sample **131**: One questionable flattened fragment.

Description

Chambers cono-ovoid with the maximum diameter within the lower half and the lowermost fourth of the chamber length; flanks slightly convex; base slightly convex or flat, frequently invaginated; basal margin usually sharply, occasionally broadly rounded; no unequivocal basal structure is visible due to flattening-related destruction and/or the invagination of the basal part of the chambers. Usually no flexure or shoulder developed, in rare cases a faint flexure on both or only on one side of the vesicle visible but without forming a neck. The aperture is surrounded by a thin, short, crenulate collarette. A disk-like operculum with a low narrow ridge along the outer border and with a short flange in antiapertural direction is located at the base of the collarette. The surface of the vesicle is smooth.

Measurements

Fifteen flattened specimens, many of them missing the collarette. The values of the flattened specimens have been corrected (coefficient of correction for Dp and $d_{apert.}$ = 0.7).

Lp = 106–241 µm
Dp = 52–90 µm
$d_{apert.}$ = 32–67 µm

Discussion

Mullins & Loydell (2001: 733, Pl. 1, Figs. 1–5; Pl. 2, Figs. 9–11) provided a detailed description of *E. conica* which applies precisely to the fossils studied herein. The specimens illustrated in Mullins & Loydell (2002: Figs. 3b, c, d, g) and in Mullins & Aldridge (2004: Pl. 1, Figs. 5, 6) are also very similar.

The occurrence of this species in the Cellon section is peculiar: the species is first recorded by a few specimens in sample **46A** about 80 cm below sample **47** (Text-Fig. 2), which contained a monospecific chitinozoan community of numerous *E. conica*. However, in sample **131**, taken c. 30 cm higher in the section, the species' last presence is documented by only one fragmented vesicle.

A great variety of chamber lengths was observed in the studied specimens, and there is also considerable variation in shape from almost cylindrical to conical outlines both of which in turn vary from wide to quite slender forms.

Regarding the affinities with other species described herein *Eisenackitina causiata* Verniers, 1999 has a similar shape to *E. conica*, but is differentiated from the latter in that the vesicle is covered by granules which can be connected by delicate ridges. *Eisenackitina dolioliformis* Umnova, 1976 differs from *E. conica* by the ornamentation of granules which are best developed in the lower half of the chamber and disappear towards the aperture. Comparison with *Eisenackitina* cf. *inanulifera* Nestor, 2005 highlights in the latter contrasting features such as ornamentation of granules and delicate wrinkles and in addition the vesicles show a short cylindrical neck and more or less pronounced shoulders. Furthermore *Eisenackitina* sp. 1 is distinguished from the present species in that it is covered with tiny broad-based thorn-like sculptural elements and is smaller in dimension. Finally, *Eisenackitina* sp. 2 has a similar shape but in contrast shows an ornamentation of tiny broad-based spines and granules that are often connected by delicate short ridges whose density is very great around the basal margin and becomes reduced towards the aperture.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *B. conica* is recorded within the lowermost Kok Formation, Telychian in age [occurring in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) and in the upper part of *Bed 9* (sample **47** = c. 30 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*); present in *Bed 10A* (sample **131**): lower *P. a. angulatus* conodont biozone; global *A. longicollis* chitinozoan biozone].

The geographical and stratigraphical distribution of *B. conica*, illustrated as transmitted light photomicrographs in Taugourdeau & de Jekhowsky (1960); Taugourdeau (1961); Beju & Dănet (1962) and Taugourdeau & de Jekhowsky (1964) and included within the synonymy list in Mullins & Loydell (2001: 736), is listed in the latter paper (p. 736).

Ocurrences of *B. conica* outside the Cellon section:
*) = included in the synonymy list in Mullins & Loydell (2001: 733).

- *?Siberian Platform* [Zaslavskaya, ***1980*** (questionably as *Eisenackitina conica*)]: Silurian.
- *Belgium* (Mehaigne Area) [Verniers, ***1982*** (as *Eisenackitina* sp. A; Figs. 8, 10)]: middle and/or late Llandoverian [Formation MB 3A]. *)
- *?Siberian Platform* [Zaslavskaya, ***1983*** (questionably as *Eisenackitina conica*; Tab. 1)]: upper Llandovery.
- *Estonia, North Latvia* [Nestor, ***1994*** (as *Conochitina* sp. 5; p. 42; Tab. 1)]: Adavere Stage [Rumba and lowermost Velise Formation, uppermost Dobele Formation and Degole Beds of the Jurmala Formation (Interzone II–*A. longicollis* chitinozoan biozone). *)
- *Bohemia* (Prague Basin) [Dufka et al., ***1995*** (as *Conochitina malleus* nom. nud. van Grootel, Pl. 2, Figs. 3, 4 only; Fig. 4)]: upper Aeronian, lower Telychian [*M. sedgewickii* and *S. turriculatus* graptolite biozones]. *)
- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (p. 736, Text-Figs. 1, 7, 8)]: upper Telychian–lower Sheinwoodian [Tarannon Shales Formation, Nant-ysgollon Shales Formation (*E. dolioliformis*–*S. bella* chitinozoan biozone = *S. crispus*–*C. murchisoni* graptolite biozone; ?*M. riccartonensis* graptolite biozone)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: upper Llandovery [Tarannon Shales Formation (*E. dolioliformis* chitinozoan biozone = *S. turriculatus* (*S. johnsonae* Subzone)–lower *O. spiralis* or possibly *M. crenulata* graptolite biozone)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (as *Bursachitina* sp.; Figs. 15, 17)]: Aeronian–Telychian [Dobele For-

mation–Jurmala Formation (*C. alargada*, *E. dolioliformis*, lower *A. longicollis* chitinozoan biozones)].

- *Eastern Canada* (NW New Brunswick) [ASSELIN et al., ***2004*** (as *Bursachitina* sp.)]: Telychian [Upsalquitch Formation].
- *Shropshire* (Hughley Brook = Leasows section) [MULLINS & ALDRIDGE, ***2004*** (Text-Fig. 2)]: upper Telychian–lower Sheinwoodian [Purple Shales Formation–Buildwas Formation].
- *Latvia* (Kolka-54 core) [LOYDELL et al., ***2010*** (Figs. 10, 16)]: Adavere Stage = Telychian (*E. dolioliformis*, *A. longicollis*, *C. proboscifera, lower C. acuminata* chitinozoan biozones = upper *S. turriculatus*–lower *C. lapworthi* graptolite biozone = *D. staurognathoides*–lower *P. a. amorphognathoides* conodont biozone).
- *Gotland/Sweden* (Grötlingbo-1 core section) [MÄNNIK et al., ***2015*** (Fig. 3)]: Telychian (*A. longicollis* (?) and *C. acuminata* chitinozoan biozones).

Bursachitina sp.

(Pl. 4, Fig. 6)

Material

Sample **56**: Two flattened, poorly preserved, partly broken specimens.

Description

Chamber cono-ovoid with the maximum diameter at about the lowest third of the chamber length; no flexure or shoulder developed; flanks and base slightly convex, basal margin broadly rounded; no basal structure visible due to destruction of the corresponding area on the base. The aperture is surrounded by the remains of a collarette; an operculum is located at the base of the collarette. The surface is covered by a thin layer of amorphous organic material therefore it is not possible to specify the actual ornamentation, most probably it is smooth as no other sculptural elements are visible.

Measurements

One flattened, slightly damaged specimen. The value has been corrected (coefficient of correction for Dp = 0.7).

Lp = 176 µm

Dp = 96 µm

Discussion

The two poorly preserved representatives of *Bursachitina* sp. recorded from sample **56** of late Sheinwoodian age co-occur with a few specimens of Lagenochitinidae indet. described herein. Together these taxa represent the last documentation of chitinozoans within the Kok Formation marking a significant time gap in the Cellon section until their re-appearance in *Bed 20* within the lowermost Cardiola Formation (early Ludfordian).

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Bursachitina* sp. is recorded in the middle part of the Kok Formation, late Sheinwoodian in age [*Bed 13B* (sample **56**): *K. o. ortus* conodont biozone].

Genus Desmochitina EISENACK, 1931

Desmochitina minor EISENACK, 1931

(Pl. 1, Fig. 7)

Synonymy

2000 *Desmochitina minor* EISENACK, 1931. – PRIEWALDER, Pl. 1, Fig. 2.

2008 *Desmochitina minor* EISENACK, 1931. – VANDENBROUCKE, p. 86, Pl. 3, Fig. 14 [see for remarks on synonymy].

Material

Sample **129**: One almost complete three-dimensional specimen.

Sample **45**: One fractured and deformed specimen.

Description

Chamber elongated ovoid, with the greatest diameter near the aperture; thus, shoulder distinctly developed. Flanks and base slightly convex, basal margin broadly rounded. Base devoid of any structure. Operculum in situ. Thin collarette, broken close to the rim of the operculum. Wall glabrous.

Measurements

One three-dimensional specimen almost completely preserved.

L = 86 µm

Dp = 54 µm

$d_{apert.}$ = 25 µm

Discussion

Only two specimens of *Desmochitina minor* were extracted from the strata of the Plöcken Formation: one is almost completely preserved (Pl. 1, Fig. 7), the description above is based on this form. The other specimen is deformed and broken.

According to VANDENBROUCKE (2008: 86), *D. minor* has only minor taxonomic value “due to its wide range in chamber morphology and glabrous surface”. However, PARIS (1981: 123) and ELAOUAD-DEBBAJ (1984: 57) emphasised the need for reviewing EISENACK’s type material of this species under the SEM in order to identify potential morphotypes which most probably are included in the current definition and which seem to be responsible for the actual long stratigraphic range of *D. minor*.

Geographical and stratigraphical distribution

In the Cellon section (Text-Figs. 2, Tab. 1), *D. minor* is recorded in the upper part of the Plöcken Formation, Hirnantian in age [*Bed 8* (samples **129, 45**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

D. minor is a long ranging Ordovician species that has been reported from all palaeocontinents. It disappears at the Ordovician/Silurian boundary.

Subfamily EISENACKITININAE PARIS, 1981

Genus Eisenackitina JANSONIUS, 1964, restr. PARIS, 1981

Eisenackitina causiata VERNIERS, 1999

(Pl. 4, Figs. 10, 11)

Synonymy

1982 *Eisenackitina* sp. C. – VERNIERS, p. 44, Pl. 5, Figs. 103–118, 119?; Pl. 6, Figs. 120–121.

1994 *Eisenackitina* sp. 1. – NESTOR, p. 18, Pl. 25, Figs. 5–6.

1995 *Eisenackitina delioliformis* [sic] UMNOVA. – DUFKA et al., Pl. 2, Figs. 6–8.

1999 *Eisenackitina causiata* sp. nov. – VERNIERS, p. 375, Pl. 1, Fig. 10.

1999 *Eisenackitina dolioliformis* UMNOVA, 1976. – PRIEWALDER, Fig. 7.

2001 *Eisenackitina causiata* VERNIERS, 1999. – MULLINS & LOYDELL, p. 744, Pl. 3, Figs. 10, 12; Pl. 4, Figs. 1-6, 9 (***cum syn.***).

2002 *Eisenackitina causiata* VERNIERS, 1999. – MULLINS & LOYDELL, Figs. 3i–j.

2002 *Eisenackitina causiata* VERNIERS, 1999. – NESTOR et al., Pl. 1, Fig. 3.

2002 *Eisenackitina causiata* VERNIERS, 1999. – NESTOR, H. & NESTOR, V., Pl. 1, Fig. 9.

2002 *Eisenackitina causiata* VERNIERS, 1999. – VERNIERS et al., Pl. 1, Fig. 12.

2003 *Eisenackitina causiata* VERNIERS, 1999. – LOYDELL et al., Fig. 16w.

2004 *Eisenackitina causiata* VERNIERS, 1999. – MULLINS & ALDRIDGE, Pl. 1, Figs. 1–4.

2005 *Eisenackitina causiata* VERNIERS, 1999. – LOYDELL & NESTOR, Fig. 4j.

2005 *Eisenackitina causiata* VERNIERS, 1999. – NESTOR, Pl. 1, Fig. 13.

2010 *Eisenackitina causiata* VERNIERS, 1999. – LOYDELL et al., Fig. 13d.

2015 *Eisenackitina causiata* VERNIERS, 1999. – MÄNNIK et al., Fig. 6l.

Material

Sample **46A**: Three flattened specimens.

Sample **131**: One fragment of the antiapertural part of the vesicle.

Description

Chambers cono-ovoid with the maximum diameter within the lowermost third of the chamber length; flanks and base slightly convex; basal margin broadly rounded; no unequivocal basal structure is visible due to flattening-related destruction or the invagination of the basal part of the chambers. No flexure and shoulder developed; in some specimens slight remains of a thin-walled collarette are present. The ornamentation consists of small granules which are connected to each other by short delicate ridges and are distributed in a consistent pattern over the whole vesicle, also at the base. The size and density of the granules can vary from specimen to specimen and when the size of the granules becomes strongly reduced or when they are eroded, the ridges then become the dominant feature giving the surface a wrinkled appearance (Pl. 4, Fig. 11).

Measurements

Two flattened specimens, probably missing the collarette. The values of the flattened specimens have been corrected (coefficient of correction for Dp and $d_{apert.}$ = 0.7).

Lp = 160–185 µm

Dp = 85–87 µm

$d_{apert.}$ = 49–62 µm

Discussion

The outlines of the studied vesicles coincide with those of the representatives of *Eisenackitina* sp. *C* in VERNIERS (1982: Pl. 5, Figs. 103–118; Pl. 6, Figs. 120–121) which subsequently were included within the synonymy list of the original description of *Eisenackitina causiata* by VERNIERS (1999). However, the maximum chamber length of 185 µm of the specimens from the Kok Formation exceeds the values of the Mehaigne chitinozoans (length 119–173 µm).

The morphological differentiation between *E. causiata* and *Eisenackitina dolioliformis* UMNOVA, 1976 as shown in MULLINS & LOYDELL (2001: 746, Pl. 4) applies perfectly to the chitinozoans studied herein and is underlined by the striking similarity between the taxa from both localities (Pls. 4, 5).

In contrast to Wales (Banwy River section: MULLINS & LOYDELL, 2001: Text-Fig. 7; Buttington Brick Pit: MULLINS & LOYDELL, 2002: Text-Fig. 2), where *E. causiata* did not co-occur with *E. dolioliformis*, these two similar species occur together in the Kok Formation as they do in several localities of the Baltic area [e.g. LOYDELL et al., 2003: Fig. 15; 2010: Fig. 10; LOYDELL & NESTOR, 2005: Fig. 3; NESTOR, 2005: Figs. 2–5; RUBEL et al., 2007: Fig. 3; MÄNNIK et al., 2015: Fig. 3].

In the Cellon section, *E. causiata* differs from *E. dolioliformis* UMNOVA, 1976 in having smaller granules which are typically connected by delicate ridges and distributed all over the vesicle, while in the latter species the ornamentation is best developed in the lower half of the chamber. Moreover, there the vesicles are longer and more slender. *Eisenackitina* cf. *inanulifera* NESTOR, 2005 has a short cylindrical neck and somewhat pronounced shoulders and the ornamentation decreases in size towards the aperture. *Eisenackitina* sp. 1 has a similar shape but it is smaller and lacks the ornamentation of granulae and delicate ridges which is typical for *E. causiata*. *Eisenackitina* sp. 2 is larger than *E. causiata* and more slender, the sculptural elements, also consisting of granules and delicate short ridges, are smaller and very densely distributed around the basal margin showing decreasing density towards the aperture. The vesicles of *Bursachitina conica* (TAUGOURDEAU & DE JEKHOWSKY, 1964) have a similar shape, but are smooth.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *E. causiata* is recorded within the basal part of the Kok Formation, Telychian in age [occurring in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*); questionable in *Bed 10A* (sample **131**): *P. celloni* conodont superzone/*P. a. angulatus* conodont biozone; global *A. longicollis* chitinozoan biozone].

Outside the studied area the species has been reported from many localities, mainly from the palaeocontinents of Baltica and Avalonia [for further quotations of the geographical and stratigraphical distribution of *Eisenackitina causiata* before 2001 see Mullins & Loydell, 2001: 746]:

- *Belgium* (Brabant Massif, Mehaigne area) [Verniers, ***1982*** (as *Eisenackitina* sp. C; Figs. 3, 8)]: middle (or late?) Llandoverian–early Wenlockian [informal formations MB 2A–MB 4].
- *Estonia, North Latvia* [Nestor, ***1994*** (as *Eisenackitina* sp. 1; p. 18, Tab. 1, Tab. 3)]: uppermost Adavere Stage [Velise and Jurmala formations], Jaani Stage [lowermost Trôlla Member] [*A. longicollis* chitinozoan biozone–Interzone IV].
- *Bohemia* (Prague Basin) [Dufka et al., ***1995*** (as *E. delioliformis* [sic]; Fig. 4)]: Telychian [*M. crispus–O. spiralis* graptolite biozone].
- *Wales* (Builth Wells district) [Verniers, ***1999*** (Text-Fig. 3)]: Sheinwoodian [Dolfawr Mudstones Formation–Builth Mudstones Formation (*M. margaritana–C. cingulata* chitinozoan biozone = *C. centrifugus–P. dubius* graptolite biozone)].
- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (p. 746, Text-Figs. 1, 7)]: upper Telychian–lower Sheinwoodian [Tarannon Shales Formation, Nant-ysgollon Shales Formation (possible *M. crenulata*–lower *O. spiralis* to *M. riccartonensis* graptolite biozone)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: upper Llandovery–lower Wenlock [Tarannon Shales Formation, Trewern Brook Mudstone Formation (*A. longicollis–M. margaritana* chitinozoan biozone = middle? *O. spiralis–C. murchisoni* graptolite biozone)].
- *Northwest Gotland* (Ireviken 3 section) [Nestor et al., ***2002*** (Fig. 1)]: uppermost Telychian [upper Lower Visby Formation].
- *Southwestern Estonia* (Ikla core) [Nestor, H. & Nestor, V., ***2002*** (Fig. 3)]: lower Sheinwoodian [Tõlla Member (Interzone IV)].
- *Belgium* (Brabant Massif, Ronquières-Monstreux area) [Verniers et al., ***2002*** (Fig. 3)]: uppermost Telychian–lower Sheinwoodian [Fallais Formation, Corroy Formation (global *M. margaritana* chitinozoan biozone)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: Telychian–lower Sheinwoodian [Jurmala Formation (upper *E. dolioliformis*, *C. proboscifera*, *M. margaritana* chitinozoan biozones, basal Interzone IV)].
- *Shropshire* (Hughley Brook = Leasows section) [Mullins & Aldridge, ***2004*** (p. 749, Text-Fig. 2)]: upper Telychian–lower Sheinwoodian [Purple Shales Formation–Buildwas Formation].
- *Latvia* (Ventspils D-3 core) [Loydell & Nestor, ***2005*** (Fig. 3)]: Telychian [*A. longicollis–C. proboscifera* chitinozoan biozone = lower–upper *O. spiralis* graptolite biozone].
- *West Estonia* (Viki, Kaugatuma, Ohesaare, Ruhnu cores) [Nestor, ***2005*** (Figs. 2–5)]: Adavere Stage, Jaani Stage [Velise Formation, Riga Formation (*C. proboscifera, C. acuminata, M. banwyensis, M. margaritana* chitinozoan biozones and in the succeeding Interzone)].
- *Western Estonia* (Viirelaid core) [Rubel et al., **2007** (Figs. 3, 5)]: Adavere Stage–lower Jaani Stage [Rumba Formation–lower Mustjala Member of the Jaani Formation (*E. dolioliformis*, *A. longicollis*, *C. proboscifera*, *C. acuminata*, *M. banwyensis* chitinozoan biozones and in the succeeding Interzone = lower *P. eopennatus* ssp. n. 1–lower Upper *P. bicornis* conodont biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Adavere Stage–lower Jaani Stage = Telychian–lower Sheinwoodian (*E. dolioliformis*, *A. longicollis*, *C. proboscifera, C. acuminata, M. margaritana* chitinozoan biozones and in the succeeding Interzone = upper *S. turriculatus–M. firmus* graptolite biozone = upper *D. staurognathoides–P. pennatus procerus* conodont biozone).
- *Gotland/Sweden* (Grötlingbo-1 core section) [Männik et al., ***2015*** (Figs. 3, 4, 9, 11)]: Telychian–lowermost Sheinwoodian (*A. longicollis–M. margaritana* chitinozoan biozone = *O. spiralis–C. murchisoni* graptolite biozone = *P. a. angulatus–P. p. procerus* conodont biozone).

Eisenackitina dolioliformis Umnova, 1976

(Pl. 4, Figs. 7, 9; Pl. 5, Figs. 1, 2, 4)

Synonymy

1976	*Eisenackitina dolioliformis* n. sp. – Umnova, p. 405, Pl. 2, Figs. 20, 21.
?1982b	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Pl. 12, Figs. 3, 4.
1984	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Pl. 1, Figs. 6–8.
non1988	*Eisenackitina dolioliformis* Umnova, 1976. – Grahn, Fig. 16.
?1989	*Eisenackitina dolioliformis* Umnova, 1976. – Grahn & Nøhr-Hansen, Fig. 4i.
?1990	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Pl. 14, Fig. 14.
1992	*Eisenackitina brabantium* van Grootel. – Dufka, Pl. 2, Figs. 8–10.
1994	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, p. 17, Pl. 25, Figs. 1–4.
non1995	*Eisenackitina delioliformis* [sic] Umnova. – Dufka et al., Pl. 2, Figs. 6–8.
1995	*Eisenackitina dolioliformis* Umnova, 1976. – Grahn, Fig. 7o.
1995	*Eisenackitina dolioliformis* Umnova, 1976. – Verniers et al., Fig. 5l.
1999	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Pl. 2, Fig. 11
2000b	*Eisenackitina dolioliformis* Umnova, 1976. – Soufiane & Achab, Pl. 4, Fig. 9.
2000	*Eisenackitina dolioliformis* Umnova, 1976. – Priewalder, Pl. 1, Fig. 6.
2001	*Eisenackitina dolioliformis* Umnova, 1976. – Mullins & Loydell, Pl. 4, Figs. 7–8, 10–12.
2002	*Eisenackitina dolioliformis* Umnova. – Mullins & Loydell, Figs. 3e, h.
2002	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor et al., Pl. 1, Fig. 12.
?2002	*Eisenackitina dolioliformis* Umnova, 1976. – Nestor, H. & Nestor, V., Pl. 1, Fig. 8.
2003	*Eisenackitina dolioliformis* Umnova, 1976. – Loydell et al., Fig. 16r.

2003 *Eisenackitina dolioliformis*. – Vandenbroucke et al., Figs. 11m, n.

2004 *Eisenackitina dolioliformis* Umnova. – Asselin et al., Pl. 2, Fig. 26, non Figs. 24, 25.

2005 *Eisenackitina dolioliformis* Umnova, 1976. – Loydell & Nestor, Fig. 4m.

2005 *Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Pl. 1, Fig. 4.

2008 *Eisenackitina dolioliformis*. – Vandenbrouke et al., Figs. 8–10.

2010 *Eisenackitina dolioliformis* Umnova, 1976. – Loydell et al., Fig. 12x.

2012 *Eisenackitina dolioliformis* Umnova, 1976. – Nestor, Fig. 4i.

2013 *Eisenackitina dolioliformis*. – Davies et al., Fig. 16d.

2015 *Eisenackitina dolioliformis* Umnova. – Männik et al., Fig. 6R.

Material

Sample **46A**: Twenty-three flattened specimens, most of them are partially fractured and missing the apertural part.

Description

Chambers cono-ovoid; wall thick, thinning towards the aperture; greatest diameter within the lowermost third of the chamber length; flanks straight or slightly convex; no flexure, no shoulder developed; basal margin broadly rounded; base flat or slightly convex; no conspicuous mucron visible, there is only a small, shallow, minor ornamented depression in the centre. At the aperture, the chamber flares into a short (c. 11 µm), thin walled, crenulate collarette. Occasionally, a thin operculum is present at the base of the collarette. The ornamentation around the basal margin and at the base is usually made up of granules and/or small cones which may vary in size from specimen to specimen, ranging from delicate to coarse and which are occasionally connected by delicate ridges. The ornamentation gradually decreases in size in the apertural direction culminating in delicate granulation and wrinkles within an area of variable extent around the aperture.

Measurements

Seven more or less complete, flattened specimens. Since the collarette frequently is missing, only the chamber-length is given, instead of the total length. The values of the flattened specimens have been corrected (coefficient of correction for Dp and $d_{apert.}$ = 0.7).

Lp = 182–259 µm
Dp = 85–101 µm
$d_{apert.}$ = 49–69 µm

Discussion

Eisenackitina dolioliformis Umnova, 1976 is a conspicuous taxon within the chitinozoan communities of the studied section, however, it has been found in only one sample. The vesicle shapes vary between relatively short and stout and long and slender, respectively, but a few of them are exceptionally slender (Pl. 4, Fig. 9). The latter character distinguishes these specimens from most other published representatives of this species. Vandenbroucke et al. (2008: Figs. 7, 10), however, illustrate a similar long and slender form from the Cwm-yr-Aethnen Formation in Wales.

Mullins & Loydell (2001: 744) pointed out that in the past *E. dolioliformis* has been repeatedly confused with the similar taxon *Eisenackitina causiata* Verniers, 1999. Their morphological differentiation (Mullins & Loydell, 2001: Pl. 4, Figs. 1–12) can be very well observed also in the studied chitinozoan community herein where both *E. dolioliformis* and *E. causiata* show remarkable similarities with their counterparts from Wales (Pls. 4, 5).

In contrast to Wales (Banwy River section: Mullins & Loydell, 2001: Text-Fig. 7; Buttington Brick Pit: Mullins & Loydell, 2002: Text-Fig. 2), where *E. dolioliformis* and *E. causiata* have successive stratigraphical ranges the two taxa occur together in the Cellon section which has also been proved in several localities of the Baltic region (e.g. Loydell et al., 2003: Fig. 15; 2010: Fig. 10; Loydell & Nestor, 2005: Fig. 3; Nestor, 2005: Figs. 2–5; Rubel et al., 2007: Fig. 3; Männik et al., 2015: Fig. 3).

In the Cellon section, *E. dolioliformis* is distinguished from *E. causiata* by the ornamentation which in the latter species consists of small granules connected by short, delicate ridges forming thus an irregular pattern which is distributed invariably over the whole vesicle; moreover, the vesicles are shorter and less slender. *Eisenackitina* cf. *inanulifera* Nestor, 2005 has a short cylindrical neck and somewhat pronounced shoulders, the ornamentation is different and is, beside granules, made up of delicate wrinkles, and the vesicles are generally shorter and less slender. *Eisenackitina* sp. 1 is smaller and is covered with tiny broad-based thorn-like sculptural elements. The shape and size of the vesicles of *Eisenackitina* sp. 2 are similar to *E. dolioliformis*, as is also the distribution of the ornamentation but it differs in the much finer and denser sculptural elements. *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964) has a smooth vesicle.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *E. dolioliformis* is recorded within the basal part of the Kok Formation, Telychian in age, within only one sample [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Outside the studied area, *E. dolioliformis* has been identified mainly at locations belonging to the palaeocontinents of Baltica and Avalonia:

- *Baltic region* (Virtsu core: 38.6–41.0 m) [Umnova, ***1976*** (p. 406)]: Lower Silurian, Wenlockian Stage.
- *Bohemia* (Prague Basin) [Dufka, ***1992*** (Tab. 1)]: Telychian (*M. crispus*–*M. spiralis* graptolite biozone.
- *Estonia, North Latvia* [Nestor, ***1994*** (Tab. 1, Tab. 3)]: Late Raikülla Stage–Jaani Stage (Interzone II–*Conochitina* cf. *mamilla* Biozone).
- *Global chitinozoan biozonation* [Verniers et al., ***1995*** (Fig. 3)]: Uppermost Aeronian–lower Sheinwoodian (*E. dolioliformis*–upper *M. margaritana* chitinozoan biozone).
- *Subsurface Gotland* (Sweden) [Grahn, ***1995*** (Fig. 5)]: uppermost Aeronian–Sheinwoodian (*M. sedgwickii*–*C. rigidus*

graptolite biozone) (see the remarks in Mullins & Loydell, 2001: 770).

- *Belgium* (Brabant Massif; Saint-Antonius, Brewery Lust, Steenkerke boreholes) [van Grootel et al., ***1998*** (p. 135, 136)]: lower Telychian [*M. turriculatus* graptolite biozone].
- *Oslo region* [Nestor, ***1999*** (Text-Fig. 10)]: upper Aeronian–uppermost Telychian [Rytteråker Formation, Vik Formation, Skinnerbukta/Bluflat Formation (*E. dolioliformis*–lower *M. margaritana* chitinozoan biozone)].
- *Central Nevada/USA* (Monitor Range) [Soufiane & Achab, ***2000b*** (Fig. 2)]: Lower Silurian [uppermost Hanson Creek Formation (uppermost *A. hansonica* chitinozoan biozone)].
- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (Text-Fig. 7)]: Telychian [Tarannon Shales Formation (*S. crispus*–*S. sartorius* graptolite biozone)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: Llandovery [Tarannon Shales Formation (*S. turriculatus*/*S. johnsonae* Subzone–*S. crispus* or *S. sartorius* graptolite biozone)].
- *Northwest Gotland* (Ireviken 3 section) [Nestor et al., ***2002*** (Fig. 1)]: uppermost Telychian–lowermost Sheinwoodian [upper Lower and lower Upper Visby formations].
- *Southwestern Estonia* (Ikla core), *northernmost Latvia* (Staicele core) [Nestor, H. & Nestor, V., ***2002*** (Figs. 2, 3)]: Telychian–lower Sheinwoodian [Rumba Formation, Velise Formation, Tõlla Member (*E. dolioliformis* chitinozoan biozone–Interzone IV)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: Telychian–lower Sheinwoodian [Jurmala Formation (*E. dolioliformis* chitinozoan biozone–basal Interzone IV = upper *S. turriculatus*–*M. firmus* graptolite biozone = uppermost *D. staurognathoides*–lower Upper *P. p. procerus* conodont biozone)].
- *Scotland* (Girvan area) [Vandenbroucke et al., ***2003*** (Tab. 2, Fig. 8)]: uppermost Aeronian–lower Telychian [Wood Burn Formation, Penkill Formation, Protovirgularia Grits, Lauchlan Formation, Drumyork Flags (upper *S. sedgwickii*–lower *O. spiralis* graptolite biozone)].
- *Latvia* (Ventspils D-3 core) [Loydell & Nestor, ***2005*** (Fig. 3)]: Telychian [*A. longicollis*–*C. proboscifera* chitinozoan biozone = lower–upper *O. spiralis* graptolite biozone].
- *West Estonia* (Viki, Kaugatuma, Ohesaare, Ruhnu cores) [Nestor, ***2005*** (Figs. 2–5)]: Adavere Stage [Velise Formation], Jaani Stage [Riga Formation] [*C. proboscifera*, *C. acuminata*, *M. banwyensis*, *M. margaritana* chitinozoan biozones, Interzone].
- *Western Estonia* (Viirelaid core) [Rubel et al., ***2007*** (Figs. 3, 5)]: Adavere Stage–lower Jaani Stage [Rumba Formation–lower Mustjala Member of the Jaani Formation (*E. dolioliformis*, *A. longicollis*, *C. proboscifera*, *C. acuminata*, *M. banwyensis*, *M. margaritana* chitinozoan biozones = lower *P. eopennatus* ssp. n. 1–lower Lower *P. bicornis* conodont biozone)].
- *Wales* [Vandenbroucke et al., ***2008*** (p. 401, 403)]: Aeronian–Telychian [Cwm-yr-Aethnen Formation (*E. dolioliformis* chitinozoan biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Adavere Stage = Telychian (*E. dolioliformis* chitinozoan biozone = upper *S. turriculatus*–top *M. crenulata* graptolite biozone = upper *D. staurognathoides*–lower *P. a. angulatus* conodont biozone).
- *East Baltic* [Nestor, ***2012*** (Figs. 2, 3)]: Telychian–lower Sheinwoodian [upper Rumba Formation, Velise Formation, lower Riga Formation (*E. dolioliformis*, *A. longicollis*, *C. proboscifera*, *C. acuminata*, *M. margaritana* chitinozoan biozones, Interzone = upper *S. turriculatus*–lower *M. riccartonensis* graptolite biozone)].
- *Gotland/Sweden* (Grötlingbo-1 core section) [Männik et al., ***2015*** (Fig. 3)]: Telychian (*C. proboscifera*–*M. margaritana* chitinozoan biozone).

Eisenackitina cf. *inanulifera* Nestor, 2005

(Pl. 5, Figs. 3, 6)

Material

Sample **46A**: Five flattened specimens, of which the aperturalmost part is damaged.

Description

Vesicles with an ovoid chamber and a short wide cylindrical neck. Flanks and base slightly convex, basal margin broadly rounded. Due to unfavourable preservation no mucron visible. Flexure and shoulder somewhat pronounced. The vesicle wall is covered by small granules which vary in shape, size and density, and/or short delicate wrinkles. The ornamentation tends to decrease in size towards the aperture.

Measurements

Two flattened specimens with damaged apertural parts. The values of the flattened specimens have been corrected (coefficient of correction for Dp and $d_{apert.}$ = 0.7).

Lp = 164–212 µm

Dp = 85–99 µm

$d_{apert.}$ = 74 µm

Discussion

The shape of *Eisenackitina* cf. *inanulifera* is quite similar to the specimens in Nestor (2005: Pl. 1, Figs. 10–12), however, the development of the ornamentation is different: while in the latter it is most pronounced at the aboral part and the shoulders, the ornamentation of *Eisenackitina* cf. *inanulifera* shows a more or less distinct decrease in size from the basal margin towards the aperture. Furthermore, the maximum vesicle dimension of *E.* cf. *inanulifera* is a little larger than that in the original description (i.e. 190 µm).

In the Cellon section, *Eisenackitina dolioliformis* Umnova, 1976 differs from *E.* cf. *inanulifera* in the absence of neck and shoulders, the predominantly granulate ornamentation and the longer and more slender vesicles. *Eisenackitina causiata* Verniers, 1999 has no neck or shoulders and the ornamentation which is distributed invariably over the whole vesicle consists of small granules typically connected by delicate ridges. *Eisenackitina* sp. 2 has longer and more slender vesicles without neck and shoulders, and the granules and connecting ridges are smaller and denser giving the vesicle wall a rough appearance. *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964) is smooth and lacks necks and shoulders.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *E.* cf. *inanulifera* is recorded within the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Ocurrences of *E. inanulifera* outside the Cellon section:

- *West Estonia* (Viki, Kaugatuma, Ohesaare, Ruhnu cores) [NESTOR, ***2005*** (Figs. 2–5)]: Adavere Stage, Jaani Stage = Upper Llandovery and Lower Wenlock [Velise, Riga and Jaani formations (*C. proboscifera*, *C. acuminata*, *M. banwyensis* and *M. margaritana* chitinozoan biozones and in the succeeding Interzone)].
- *Latvia* (Kolka-54 core) [LOYDELL et al., ***2010*** (Fig. 10)]: Adavere–lower Jaani Stage [*E. dolioliformis*, *A. longicollis*, *C. proboscifera*, *C. acuminata* and *M. margaritana* chitinozoan biozones and in the succeeding Interzone].
- *Gotland/Sweden* (Grötlingbo-1 core section) [MÄNNIK et al., ***2015*** (Figs. 3, 4, 9, 11)]: Telychian–lowermost Sheinwoodian (*A. longicollis*–*M. margaritana* chitinozoan biozone = *O. spiralis*–*C. murchisoni* graptolite biozone = *P. a. angulatus*–*P. p. procerus* conodont biozone).

Eisenackitina sp. 1

(Pl. 5, Figs. 5, 9)

Material

Sample **132**: Three three-dimensionally preserved, broken and abraded vesicles, apertural part partly destroyed.

Sample **133**: Two three-dimensionally preserved, broken and abraded vesicles, apertural part partly destroyed.

Description

Chamber cono-ovoid with the maximum diameter within the lowermost third of the chamber length; thin-walled; flanks slightly convex; base slightly convex or flat; basal margin broadly rounded; no basal structure visible due to damage of the central part of the base or coverage of this region with amorphous organic material; a faint flexure may be developed. Aperture wide and surrounded by a short, thin collarette; thin operculum at the base of the collarette. Formerly dense occurrence of tiny broad-based thorn-like sculptural elements of which only few have been preserved, most of them have been abraded to short delicate ridges which are distributed over the whole chamber including the base and the collarette.

Measurements

Four three-dimensionally preserved specimens, whose apertural areas are partly damaged.

Lp = 126–162 µm

Dp = 77–92 µm

$d_{apert.}$ = 56–61 µm *)

*) values from only two specimens.

Discussion

Eisenackitina sp. 1 is similar in shape and size to some representatives of *Eisenackitina* sp. 1 in MULLINS & LOYDELL (2001: 748, Pl. 5, Figs. 3, 4; not Figs. 1, 2, which are more slender and cylindrical) from the Banwy River section where the species ranges from the upper *C. centrifugus* to the ?*M. riccartonensis* graptolite biozone (uppermost Llandovery–lower Sheinwoodian), that means that they are a little younger than the fossils from the Kok Formation. However, the latter do not resemble *Eisenackitina* sp. 1 sensu MULLINS & LOYDELL in MULLINS & ALDRIDGE (2004: Pl. 2, Figs. 3, 4; Pl. 3, Fig. 6) from the Llandovery/Wenlock boundary beds in the Hughley Brook section as the illustrated specimens there are more slender and cylindrical. *Eisenackitina* sp. 1 sensu MULLINS & LOYDELL, 2001 in NESTOR (2005: Pl. 3, Fig. 5) from the Llandovery/Wenlock boundary beds in West Estonian drill cores has a wider aperture and is thus also more cylindrical.

In the Cellon section, the shape of *Eisenackitina* sp. 1 is similar to *Eisenackitina causiata* VERNIERS, 1999 but the latter is larger and shows a particular ornamentation of granulae connected by delicate ridges. *Bursachitina conica* (TAUGOURDEAU & DE JEKHOWSKY, 1964) is larger and smooth.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Eisenackitina* sp. 1 is recorded within the lower part of the Kok Formation, Telychian in age [*Bed 10J* (sample **132**) and *Bed 11A* (sample **133**): lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Eisenackitina sp. 2

(Pl. 5, Figs. 7, 8, 10; Pl. 6, Figs. 1–3)

Material

Sample **46A**: Six flattened specimens, three of them are missing the apertural part and/or the collarette.

Description

Chamber elongated ovoid, with the maximum diameter within the lowermost third of the vesicle length; walls thick, thinning towards the aperture; flanks slightly convex; no flexure and shoulder developed; basal margin broadly rounded; the base is more or less convex and frequently invaginated; no unequivocal basal structure is visible due to the flattening-related destruction and/or the invagination of the basal parts of the chambers. In any case, this structure most probably is not conspicuous, it may be only a small depression in the centre of the base. When preserved, a short flaring collarette (L ~11 µm) surrounding the aperture is thin-walled and crenulated (Pl. 6, Fig. 3). In one specimen an operculum was found in situ, which was protruding and cap-shaped (Pl. 5, Figs. 7, 10). The ornamentation consists of tiny broad-based spines and granules often connected by delicate short ridges. The density of the sculptural elements is very great around the basal margin and becomes reduced towards the aperture (Pl. 5, Fig. 8; Pl. 6, Fig. 2). The ornamentation is present also on the base and the collarette and gives the vesicle walls a rough appearance at minor magnifications.

Measurements

Four more or less complete, flattened specimens. The values of the flattened specimens have been corrected (coefficient of correction for Dp and $d_{apert.}$ = 0.7).

Lp = 191–248 µm

Dp = 82–98 µm

$d_{apert.}$ = 63–64 µm (values of two specimens)

$l_{coll.}$: 11 µm.

Discussion

Eisenackitina causiata Verniers, 1999 differs from *Eisenackitina* sp. 2 in having smaller and broader ovoid vesicles and in the greater size and lesser density of the sculptural elements which, moreover, are consistent over the whole vesicle.

The shape and size of the vesicles of *Eisenackitina dolioliformis* Umnova, 1976 from the Kok Formation is similar to that of *Eisenackitina* sp. 2, but it differs in the coarser and less dense ornamentation. The vesicles of *Eisenackitina* cf. *inanulifera* Nestor, 2005 are shorter and less slender compared to *E.* sp. 2 and have a short cylindrical neck and a somewhat pronounced shoulder, and the ornamentation is a little coarser and less dense. *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964) has similar but smooth vesicles.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Eisenackitina* sp. 2 is recorded within the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Subfamily PTEROCHITININAE Paris, 1981

Genus Armoricochitina Paris, 1981

Armoricochitina nigerica (Bouché, 1965)

(Pl. 1, Figs. 1–6)

Synonymy

1965 *Cyathochitina hymenophora nigerica* n. subsp. – Bouché, p. 157, Pl. 2, Figs. 8, 12, 13.

non1971a *Cyathochitina hymenophora nigerica* Bouché, 1965. – Da Costa, p. 83, Pl. XVII, Figs. 5–6.

non1971b *Cyathochitina hymenophora nigerica* Bouché, 1965. – Da Costa, p. 241, Fig. 47.

1984 *Armoricochitina* aff. *armoricana* (Rauscher & Doubinger, 1967). – Elaouad-Debbaj, p. 52, Pl. 1, Fig. 7; Pl. 2, Fig. 23; Pl. 3, Figs. 4, 13, 22, 24; Text-Figs. 4a–c.

1985 *Armoricochitina nigerica* (Bouché, 1965). – Molyneux & Paris, Pl. 6, Figs. 9, 10; Pl. 7, Figs. 1–3.

1986 *Armoricochitina nigerica* (Bouché, 1965). – Elaouad-Debbaj, p. 38, Pl. 1, Figs. 6, 13–16; Pl. 3, Fig. 9; Text-Figs. 6, 7.

1988 *Armoricochitina nigerica* (Bouché, 1965). – Grahn, Fig. 4; Text-Fig. 1.

1988a *Armoricochitina nigerica* (Bouché, 1965). – Paris, p. 65, Text-Fig. 9.

1990 *Armoricochitina nigerica* (Bouché, 1965). – Paris, p. 200–203, Text-Fig. 4.

?1992 *Armoricochitina nigerica* ? (Bouché, 1965). – Grahn, p. 709, Fig. 7:1.

1992 *Armoricochitina nigerica* (Bouché, 1965). – Paris, Text-Fig. 3.

1993 A*rmoricochitina nigerica* (Bouché, 1965). – Soufiane & Achab, Pl. 4, Fig. 1.

1995 *Armoricochitina nigerica* (Bouché, 1965). – Al-Hajri, Pl. VII, Fig. 6.

1995 *Armoricochitina nigerica* (Bouché, 1965). – Oulebsir & Paris, Text-Figs. 5, 6.

1996 *Armoricochitina nigerica* (Bouché, 1965). – Paris, Pl. 1, Fig. 2; Text-Fig. 2.

1996 *Armoricochitina nigerica* (Bouché, 1965). – Steemans et al., Pl. VII, Figs. 3, 4.

1999 *Armoricochitina nigerica* (Bouché, 1965). – Priewalder, Fig. 6.

2000 *Armoricochitina nigerica* (Bouché, 1965). – Priewalder, Pl. 1, Fig. 3.

2000a *Armoricochitina nigerica* (Bouché, 1965). – Paris et al., Text-Fig. 5.

2000b *Armoricochitina nigerica* (Bouché, 1965). – Paris et al., Pl. 1 Fig. i; Text-Fig. 2.

2001 *Armoricochitina* sp. cf. *A. nigerica* (Bouché, 1965). – Ottone et al., p. 101, Pl. 2, Fig. 10.

2001 *Armoricochitina nigerica* (Bouché, 1965). – Samuelsson et al., Fig. 3:1.

pars2002 *Armoricochitina* cf. *nigerica* (Bouché, 1965). – Ghavidel-Syooki & Winchester-Seeto, p. 82, Pl. II, Fig. 10.

2004 *Armoricochitina nigerica* (Bouché, 1965). – Bourahrouh et al., Pl. II, Fig. 2; Pl. III, Fig. 11; Text-Fig. 4.

2007 *Armoricochitina nigerica* (Bouché, 1965). – Paris et al., Pl. 2, Figs. 5, 9; Text-Figs. 7, 8.

2008 *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki, Pl. 7, Fig. 9.

2011a *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki et al., Fig. 3K.

2011b *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki et al., Pl. VIII, Figs. 2, 3.

2015b *Armoricochitina nigerica* (Bouché, 1965). – Paris et al., p. 81, Pl. I, Fig. 9; Pl. II, Fig. 1; Pl. III, Figs. 1, 4; Pl. V, Fig. 1; Text-Fig. 5.

2016 *Armoricochitina nigerica*. – Ghavidel-Syooki, Pl. 9, Figs. 6, 7, 12, 13.

2017 *Armoricochitina nigerica* (Bouché, 1965). – Al-Shawareb et al., p. 342, Pl. 2, Fig. 5.

2017a *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki, Pl. III, Fig. 2.

2017b *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki, Figs. 9A, E, J, R, S, T.

2017c *Armoricochitina nigerica* (Bouché, 1965). – Ghavidel-Syooki, Pl. IX, Figs. 6, 7, 12, 13.

2018 *Armoricochitina nigerica*. – Ghavidel-Syooki & Borji, Pl. VI, Figs. 1, 2.

2019 *Armoricochitina nigerica* Bouché, 1965. – Oktay & Wellman, Pl. IX, Fig. 1.

Material

All of the studied vesicles are badly preserved, frequently compressed and fractured.

Sample **128**: Six specimens.

Sample **45**: Five specimens.

Description

Chamber ovoid, with the greatest diameter within the lower third of the chamber length. Flexure weakly developed, separating a very short cylindrical neck from the chamber. Neck provided with a short, thin, slightly flaring collarette. Shoulder inconspicuous. Basal margin broadly rounded. Below the greatest diameter, where the margin merges with the slightly convex base, a short carina arises. One three-dimensionally preserved specimen shows a shallow apical pit on the base and the fragment of an operculum with a thin flange in aboral direction, situated at the base of the collarette. Wall micro-granulated.

Measurements

Four fractured specimens, of which three are flattened and one is three-dimensionally preserved. The values of the flattened specimens have been corrected (coefficient of correction for Dp and dc = 0.7–0.9). The lengths of the carina and the collarette have not been measured as only fragments are present.

Lp = 119–151 µm

Dp = 74–99 µm

dc = 50–76 µm

Discussion

Most representatives of *Armoricochitina nigerica* in the Plöcken Formation are flattened and partly broken. Invariably, the carina is present only in fragments, but it is always easily recognisable. The collarette has also usually been removed. The typical microgranulation of the vesicle wall is well developed in some specimens, but due to erosion often only a few traces remained. The structure of the base is only visible on the single three-dimensionally preserved specimen, but because of imprints of crystals and adherent amorphous organic material merely an apical pit could be identified.

The shape and size of the studied specimens of *A. nigerica* vary considerably: short and stout specimens occur together with longer and more slender vesicles. This is in accordance with the results of biometric studies on numerous *A. nigerica* from a rock sample from the upper part of the Quwarah Member of the Quasim Formation (late Katian) in the Qusaiba core hole (north central Saudi Arabia) in Paris et al. (2015b: 81, Fig. 12), which show remarkable variations in the vesicle lengths. There, beside the classical vesicles known to date also numerous very long morphotypes were observed. The lengths of the chambers vary between 125 µm and 336 µm, and the cross plots show that the measured specimens all belong to the same species. In contrast, *A. nigerica* from the Plöcken Formation represents the original, that is the smaller morphotype.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *A. nigerica* is recorded within the upper part of the Plöcken Formation, Hirnantian in age [*Bed 7* (sample **128**); *Bed 8* (sample **45**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

According to Paris et al. (2015b), *A. nigerica* has been reported from late Katian and Hirnantian sequences at numerous locations in northern Africa, the middle East, in Iran, Turkey and southern and central Europe (for detailed information see Paris et al., 2015b: 81). Moreover, the authors emphasise the significance of this species for the reconstruction of a Northern Gondwana Palaeobiogeographic Province in the Late Ordovician, as *A. nigerica* does not occur on the northern margin of the Rheic Ocean. It is thus considered to be a "Polar" taxon.

Order Prosomatifera Eisenack, 1972

Family Conochitinidae Eisenack, 1931, emend. Paris, 1981

Subfamily CONOCHITININAE Paris, 1981

Genus Conochitina Eisenack, 1931, emend. Paris et al., 1999a

Conochitina cf. *armillata* Taugourdeau & Jekhowsky, 1960

(Pl. 6, Figs. 4–7, 11)

Material

Sample **132**: Six flattened specimens (one is questionable); all are missing variable parts of the vesicle.

Description

Vesicle thin-walled, slender, conical; in all specimens the apertural part is missing [for the characterisation of the questionable specimen (Pl. 6, Fig. 6) see under "Discussion"]. Flanks straight or slightly convex, slowly tapering towards the aperture; flexure and shoulder not developed. Basal margin broadly rounded, base distinctly convex and provided with a delicate mucron: a low membranous rim surrounds a relatively wide (~25 % of the vesicle diameter) flat central pit. The vesicle wall is smooth.

Measurements

The specimens are flattened and missing the distal part of their vesicles. As the degree of flattening is different in different vesicles, a coefficient between 0.7 and 0.95 for the correction of Dp has been applied; thus the vesicle diameters vary between 58 and 70 µm [except for the questionable example (Pl. 6, Fig. 6), see under "Discussion"].

The dimensions of the most characteristic specimen (Pl. 6, Fig. 5) are:

L = >288 µm

Dp = 60 µm

Discussion

One of the studied specimens (Pl. 6, Fig. 6) differs morphologically from the others: it shows a vesicle which has a significantly larger diameter (L = 253 µm, Dp = 90 µm) and is slightly inflated in the lower part resulting in a gentle flexure; it possesses a mucron like those in *C.* cf. *armillata*. This form resembles an illustration of *C. armillata* in Taugourdeau & Jekhowsky (1960: Pl. III, Fig. 45).

The remaining representatives of *C.* cf. *armillata* are more slender and slowly tapering towards the aperture. They show a certain similarity to the holotype of *C. armillata* (Taugourdeau & Jekhowsky, 1960: Pl. III, Fig. 44) but are lacking the typical inflation of the lower part of the vesicle. However, the latter feature may possibly be obscured by the different degrees of flattening in one and the same vesicle.

On the other hand, the studied vesicles also resemble an individual from the Wenlock of Gotland in Taugourdeau & Jekhowsky (1964), named *Conochitina* cf. *armillata* (857; Pl. 4, Fig. 34), which lacks the distinct inflation and whose attributes were described as being intermediate.

C. cf. *armillata* has a similar outline to *Conchitina praeproboscifera* Nestor, 1994, however, in the latter the base is only slightly convex and provided with a thickened ridge around a small central pit. *Conochitina* sp. A has a flat base and the mucron is a thickened ridge around a broad central pit. In *C.* cf. *iklaensis* Nestor, 1980b the vesicle is sub-cylindrical and lacks the mucron. *Conochitina* cf. *elongata* Taugourdeau, 1963 has a gentle constriction at about half-way along the vesicle length separating the sub-conical chamber from a long, broad, slightly widening neck, moreover the flat base lacks a mucron.

Paris (1988a: 68) mentioned that "the total range of *C. armillata* is still unknown in terms of the British Llandoverian stages or of standard graptolite zones". This is still true. Moreover, the stratigraphical ranges of the individuals from the palaeocontinent of Baltica (Taugourdeau & Jekhowsky, 1964; Loydell et al., 2010) differ considerably from those from North Gondwana locations (Wenlock vs. Llandovery; see below). Maybe they belong to different taxa because *C. armillata* seems not to be very well defined, as the species characteristics are based on light microscope investigations carried out in the early sixties.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *C.* cf. *armillata* is recorded within the lower part of the Kok Formation, Telychian in age [*Bed 10J* (sample **132**): lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Below, the geographical and stratigraphical data of selected and unquestionably identified representatives of *C. armillata* are quoted. This species has been reported from both North Gondwana and Baltica, however, it seems to occur there at different times.

- *Algerian Sahara* [Taugourdeau & Jekhowsky, ***1960*** (Fig. 2)]: Gothlandien (zone 5) [= "Middle-Upper" Llandovery according to Paris (1988a: 68)].
- *Gotland* [Taugourdeau & Jekhowsky, ***1964*** (Tab. 3)]: uppermost Llandovery–Wenlock [Upper Visby, Slite, Mulde beds].
- *Libya* (wells E1-81, D1-31, A1-81, A1-46) [Hill et al., ***1985*** (p. 27–28)]: middle-late Llandovery.
- *Northeast Libya* (central and southern Cyrenaica) [Paris, ***1988a*** (Figs. 6, 7, 9)]: upper Aeronian–lower Telychian [*C. armillata*–*Cyathochitina* sp. B concurrent range chitinozoan biozone = *L. convolutus*–*S. turriculatus* graptolite biozone; *M. margaritana*–*Pt. deichaii* concurrent range chitinozoan biozone = *M. griestonensis* graptolite biozone].
- *Global level* [Paris, ***1989*** (Fig. 174)]: lower Aeronian–lower Telychian [*M. argentus*–*M. griestonensis* graptolite biozone].
- *Northern Gondwana* [Paris, ***1996*** (Text-Fig. 6)]: upper Aeronian–lower Telychian.
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 11, 16)]: upper Sheinwoodian–lower Homerian [upper *C. tuba*–upper *C. cingulata* and uppermost *C. cribrosa* chitinozoan biozones].
- *North Central Saudi Arabia* (Qusaiba type area) [Paris et al., ***2015a*** (Figs. 6, 8, 9; as *C.* gr. *armillata*)]: upper Aeronian [Qusaiba Member of the Qalibah Formation (*A. hemeri* chitinozoan biozone = *L. convolutus*–*S. halli* graptolite biozone)].

Conochitina cf. *elongata* Taugourdeau, 1963

(Pl. 7, Figs. 2, 3)

Material

Sample **132**: One flattened specimen, missing the apertural part of the neck.

Description

Flattened vesicle with a subcylindrical chamber and a long broad slightly flaring neck of which the apertural part is missing. Flanks slightly convex (probably due to preservation); basal margin rounded, base almost flat, deformed by crystal imprints therefore no basal structure visible. The greatest diameter is just above the basal margin but due to the stronger flattening of the chamber above this area it has been apparently shifted toward the middle of the chamber length. The flexure is gentle, no shoulder developed. The neck widens slightly towards the aperture (Ø at its base = 58 µm; Ø at its uppermost part = 62 µm), it is long (45 % of the vesicle length) and broad with the value of its maximum diameter close to that of the maximum chamber diameter (66 µm). The vesicle wall is smooth.

Measurements

The flattened specimen is missing the apertural part of the vesicle. The flattening has been corrected (coefficient of correction for Dp = 0.8).

L = >261 µm

Dp = 66 µm

Discussion

Though the single representative of *Conochitina* cf. *elongata* is somewhat deformed by the infill of framboids and the different degree of vesicle flattening, its overall shape is similar to the holotype of *Conochitina edjelensis elongata* in Taugourdeau (1963: 138, Pl. 3, Fig. 60) where the neck displays the mirror-inverted outline of the chamber. However, the present specimen is much longer than the value given in the original description of the subspecies (205 µm). Hence it is retained herein in open nomenclature.

Conochitina cf. *elongata* bears also a clear resemblance to an individual of *Conochitina edjelensis elongata* illustrated in Hill et al. (1985: Pl. 13, Fig. 11) and in Paris (1996: Pl. 2, Fig. 11), respectively, as well as to an example of *Conochitina elongata* in Paris et al. (2015a: Pl. 1, Fig. 9).

Conochitina cf. *armillata* Taugourdeau & Jekhowsky, 1960, *C.* cf. *iklaensis* Nestor, 1980b, *C.praeproboscifera* Nestor, 1994 and *Conochitina* sp. A mainly differ from *C.* cf. *elongata* in the absence of a gentle constriction at about the half-way point of the vesicle length. Moreover, *C.* cf. *armillata, C. praeproboscifera* and *C.* sp. A possess a distinct mucron.

C. cf. *elongata* is a little younger than the stratigraphical range of most of the unquestionably identified *C. elongata* (Aeronian–lower Telychian; see below). However, in the Amazonas Basin this species also occurs in the upper Aeronian to lower Sheinwoodian sequence of the Lower Pitinga Formation (Grahn, 2005: Fig.12). For further information concerning the stratigraphical range of *C. elongata* see Butcher (2013: 85).

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *C.* cf. *elongata* is recorded within the lower part of the Kok Formation, Telychian in age [*Bed 10J* (sample **132**): lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

C. elongata has mainly been reported from the palaeocontinents of Gondwana and Baltica. Below, the geographical and stratigraphical data of selected and unquestionably identified representatives of this species are quoted.

- *Algerian Sahara* (Edjelé-Tiguentourine region) [Taugourdeau, ***1963*** (p. 138; as *Conochitina edjelensis elongata*)]: middle–upper Llandovery.
- *Libya* (wells E1-81, D1-31, A1-81, A1-46) [Hill et al., ***1985*** (p. 27; as *Conochitina edjelensis elongata*)]: middle–late Llandovery.
- *Bohemia* (Prague Basin) [Dufka et al., ***1995*** (p. 8, 9; as *Conochitina edjelensis elongata*)]: upper Aeronian–lower Telychian (*L. convolutus*, *S. sedgwickii* and *S. turriculatus* graptolite biozones).
- *Central Saudi Arabia* [Paris et al., ***1995*** (Figs. 2, 4)]: Aeronian–lower Telychian [Qaliba Formation (*C. alargada/P. paraguayensis–S. solitudina/A. hemeri* concurrent range chitinozoan biozone)].
- *Northern Gondwana* [Paris, ***1996*** (Text-Fig. 6; as *Conochitina edjelensis elongata*)]: lower Aeronian–lower Telychian.
- *Oslo region* [Nestor, ***1999*** (Text-Fig. 10)]: Aeronian [Solvik, Rytteråker formations (upper *S. maennili*, *C. alargada*, *E. dolioliformis* chitinozoan biozones)].
- *Brazil, Paraguay* (Paraná Basin) [Grahn et al., ***2000*** (Text.-Fig. 9)]: Aeronian (*C. elongata* total range chitinozoan biozone)].
- *Southwestern Estonia, northernmost Latvia* (Ikla, Staicele drill cores) [Nestor, H. & Nestor, V., ***2002*** (Figs. 2, 3, 4)]: upper Llandovery [Saarde (?), Rumba formations (*C. alargada* chitinozoan biozone)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: middle Aeronian [Dobele Formation (*C. alargada* chitinozoan biozone = upper *P. leptotheca*–lower *L. convolutus* graptolite biozone = *A. fluegeli* conodont biozone)].
- *Northern Brazil* (Amazonas Basin) [Grahn, ***2005*** (Fig. 12)]: latest Aeronian–early Sheinwoodian [Lower Pitinga Formation (chitinozoan assemblage 2, 3)].
- *Northern Brazil* (Parnaíba Basin) [Grahn et al., ***2005*** (Tabs. 1, 2)]: late Aeronian–early Telychian [Tianguá Formation (*P. tianguaense* chitinozoan biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Raikküla Stage/Aeronian [*C. elongata*, *C. alargada* chitinozoan biozones = *D. triangulatus–L. convolutus* graptolite biozone = *A.? expansa–D. staurognathoides* conodont biozone].
- *North Central Saudi Arabia* (Qusaiba type area) [Paris et al., ***2015a*** (Figs. 6, 8, 9)]: Aeronian–lower Telychian [Qusaiba Member of the Qalibah Formation (*A. qusaibaensis*, *A. macclurei*, *T. obtusa* chitinozoan biozones = *M. triangulatus–M. crenulata* graptolite biozone)].
- *Bohemia* (Prague Basin) [Tonarová et al. ***2019*** (Text-Fig. 3)]: upper Aeronian [Želkovice Formation (*C. alargada* chitinozoan biozone)].

Conochitina cf. *iklaensis* Nestor, 1980b

(Pl. 6, Figs. 8–10; Pl. 7, Fig. 1)

Material

A total of thirty-one specimens have been identified. All of them are poorly preserved, predominantly flattened and partly filled with framboids, some are three-dimensionally preserved and all are missing variable amount of the upper part of the vesicle.

Sample **130**: Eight specimens.

Sample **50**: Two specimens.

Sample **132**: Twenty specimens.

Sample **133**: One specimen.

Description

Vesicle sub-cylindrical, slender; apertural part missing. Flanks straight or slightly convex, no flexure or shoulder developed; basal margin broadly rounded; base flat or slightly convex, no mucron present, and as the base is frequently deformed by crystal imprints or invaginated due to flattening, no basal scar was observed. The vesicle wall is smooth.

Measurements

All specimens are poorly preserved and missing the upper part of their vesicles; most of them are flattened and many are filled with framboids. The flattening has been corrected and as its degree was different in different vesicles, a coefficient of correction for Dp between 0.7 and 0.9 has been applied. The vesicle diameter thus varies between 52 and 70 µm; the dimensions of the two largest specimens (Pl. 6, Figs. 8, 9) are:

L = >311 µm

Dp = 61–65 µm

Discussion

Conochitina cf. *iklaensis* is the most frequent *Conochitina*-species occurring in the Kok Formation but due to the poor preservation of the material studied, it is left in open nomenclature.

According to Nestor (1994: 31) the specific features of *Conochitina iklaensis* are inexpressive and are easily modified by less favourable preservational conditions; as one such characteristic the large size of the species was mentioned (L = 220–580 µm, average length = 400 µm), as well as a L/D ratio of 4:1 to 6:1. Although the examined vesicles are badly preserved and broken (only very few were longer than 200 µm) and their actual sizes and L/D ratios cannot be indicated, their outlines closely resemble the illustrated examples given in the original description of *Conochitina iklaensis* in Nestor (1980b: 139, 142, Pl. III, Figs. 3–5); close similarity has also been observed with illustrations e.g. in Nestor (1998: Pl. I, Figs. 4–5) and Nestor (1999: Pl. I, Figs. 4–5). Moreover, the vesicle diameters of the studied material (52–70 µm) match the range of the values given in Nestor (1994: 32: 45–70 µm) which is also the case regarding the value of the length of the most complete specimens here available (Pl. 6, Figs. 8, 9). Compared to examples of *C. iklaensis* in Loydell et al. (2007: Figs. 3a, e, f, h, i, k) from the lower Williamson Shale (New York State, USA; Llandovery), the vesicles from the Kok Formation are more slender and have a definite sub-cylindrical shape.

Conochitina cf. *armillata* Taugourdeau & Jekhowsky, 1960 differs from *C.* cf. *iklaensis* in having an elongated-conical vesicle and a distinctly convex base provided with a mucron. *Conchitina* cf. *elongata* Taugourdeau, 1963 has a slight constriction at about half-way along the vesicle length separating the sub-conical chamber from a long, broad, slightly widening neck. In Loydell et al. (2007: 228), the only distinctive feature between *Conchitina praeproboscifera* Nestor, 1994 and *C. iklaensis* was the absence of a basal mucron in the latter species. However, in the material from the Kok Formation the outline of the two taxa is also different: *C. praeproboscifera* is a little more conical. *Conochitina* sp. A has a similar outline but a distinct broad mucron.

C. cf. *iklaensis* seems to be younger than the fossils from the Baltic region as (according to Nestor, 2012: Fig. 2) *C. iklaensis* ranges there from the upper *B. postrobusta*–lower *E. dolioliformis* global chitinozoan biozone (upper Rhuddanian–lower Telychian). However, Loydell et al. (2007: 228) stated that identical morphotypes of this species have been recovered from the basal Wenlock Series at Hughley Brook, England (as *C. praeproboscifera* in Mullins & Aldridge, 2004) and that *C. iklaensis* therefore may be a long-ranging taxon.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *C.* cf. *iklaensis* is recorded in the lower part of the Kok Formation, Telychian in age [uppermost part of *Bed 9* (sample **130** = c. 25 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*); *Bed 10G* (sample **50**); *Bed 10J* (sample **132**); *Bed 11A* (sample **133**): *P. a. angulatus*–Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Below only the geographical and stratigraphical data of unquestionably identified representatives of this species are quoted (except the form from Anticosti Island mentioned in the synonymy list of Nestor, 1994: 31).

- *Southwestern Estonia* [Nestor, ***1980b*** (p. 142)]: upper part of the Raikküla Stage = Middle Llandovery [Ikla, Lemme, Staitsele Members of the Saarde Formation].
- *Canada* (Anticosti Island) [Achab, ***1981*** (p. 146, 147; as *Conochitina* cf. *C. iklaensis*)]: middle Llandovery [upper part of the Gun River Formation].
- *China* (Yangzi Region) [Geng & Cai, ***1988*** (Fig. 1)]: upper Aeronian [top of the Lojoping Formation–middle part of the Shamao Formation (*C. iklaensis*–*C. emmastensis* chitinozoan biozone = *S. sedgwickii* graptolite biozone)].
- *North Greenland* [Grahn & Nøhr-Hansen, ***1989*** (p. 37; Fig. 2)]: middle Llandovery [Cape Schuchert Formation (chitinozoan assemblage 2 = *M. argentus*–*S. turriculatus* graptolite biozone)].
- *Global level* [Paris, ***1989*** (Fig. 174)]: upper Rhuddanian–upper Aeronian [*C. cyphus*–*S. sedgwickii* graptolite biozone].
- *Estonia* [Nestor, ***1990*** (Tab. 2; Fig. 15)]: upper Rhuddanian–top Aeronian [*B. postrobusta*–*C. emmastensis* chitinozoan biozone = *H. acinaces*–*S. sedgwickii* graptolite biozone].
- *Bohemia* (Prague Basin) [Dufka, ***1992*** (Tab. 1)]: Aeronian [chitinozoan assemblages C, D = *M. triangulatus*–*M. sedgwickii* graptolite biozone].
- *Bohemia* (Prague Basin) [Dufka & Fatka, ***1993*** (Text-Fig. 1)]: upper Aeronian [Želkovice Formation (*M. triangulatus* graptolite biozone)].
- *Estonia, North Latvia* [Nestor, ***1994*** (Tab. 1; Fig. 24]: uppermost part of the Juuru, Raikküla Stage = uppermost Rhuddanian–top Aerionian [*B. postrobusta*, *C. electa*, *A. convexa*, *C.* cf. *protracta*, Interzone II, *C. emmastensis* chitinozoan biozones = *C. cyphus*–*S. sedgwickii* graptolite biozone].
- *Bohemia* (Prague Basin) [Dufka et al., ***1995*** (Fig. 4)]: upper Rhuddanian–top Aeronian [*C. cyphus*–*S. sedgwickii* graptolite biozone].
- *Subsurface Gotland* [Grahn, ***1995*** (Fig. 5)]: upper Rhuddanian–upper Aeronian [*M. cyphus*–*M. sedgwickii* graptolite biozone].
- *Global chitinozoan biozonation* [Verniers et al., ***1995*** (Fig. 3)]: upper Rhuddanian–top Aeronian [*C. electa*, *S. maennili*, *C. alargada*, lower *E. dolioliformis* chitinozoan biozones].
- *Global occurrence* [Paris, ***1996*** (Text-Fig. 6)]: upper Rhuddanian - uppermost Aeronian.
- *Belgium* (Brabant Massif) [van Grootel et al., ***1998*** (p. 135, 136)]: late Rhuddanian (Lichtervelde borehole); late Aeronian (Brewery Lust borehole; lower *E.dolioliformis* chitinozoan biozone).
- *East Baltic* (Viki, Ohesaare, Ventspils cores) [Nestor, ***1998*** (Fig. 2)]: Late early Llandovery [*C. cyphus* graptolite biozone].
- *Sweden* (Skåne; Lovisefred drilling 1) [Grahn, ***1998*** (Figs. 4, 15)]: upper Rhuddanian–upper Aeronian [*B. postrobusta*–*S. maennili* & *C. alargada* chitinozoan biozone = *C. cyphus* (*M. revolutus*)–*M. convolutus* graptolite biozone].
- *Oslo region* [Nestor, ***1999*** (Text-Fig. 10)]: upper Rhuddanian–lower Telychian [Solvik, Rytteråker formations (*C. electa*, *C. maennili*, *C. alargada*, *E. dolioliformis*, lowermost *A. longicollis* chitinozoan biozones)].
- *Canada* (Anticosti Island; Jupiter River section) [Soufiane & Achab, ***2000a*** (Figs. 6, 7)]: upper Rhuddanian [Gun River Formation (upper *C. electa* chitinozoan biozone)].
- *Central Nevada/USA* (Monitor Range) [Soufiane & Achab, ***2000b*** (Fig. 2)]: Lower Silurian [uppermost Han-

son Creek Formation (uppermost *A. hansonica* chitinozoan biozone)].

- *Southwestern Estonia, northernmost Latvia* (Ikla, Staicele drill cores) [Nestor, H. & Nestor, V., ***2002*** (Figs. 2, 3, 4)]: upper Llandovery [Saarde (?), Rumba formations (*C. alargada*, lower *E. dolioliformis* chitinozoan biozones)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: upper Rhuddanian–lower Telychian [upper Remte, Dobele, lower Jūrmala formations (*C. postrobusta*, *A. convexa*, *C. alargada*, lower *E. dolioliformis* chitinozoan biozones = *C. cyphus*–lower *S. crispus* graptolite biozone = upper *D. kentuckyensis*–lower *P. eopennatus* ssp. n. 1 conodont biozone)].
- *Northern Brazil* (Amazonas Basin) [Grahn, ***2005*** (Fig. 12; as *Euconochitina iklaensis*)]: upper Rhuddanian–upper Aeronian [Lower Pitinga Formation (chitinozoan assemblage 1)].
- *Northern Brazil* (Amazonas Basin) [Cuevas De Azevedo-Soares, ***2007*** (Fig. 2; as *Euconochitina iklaensis*)]: upper Rhuddanian–upper Aeronian [Lower Pitinga Formation (chitinozoan assemblage 1)].
- *Western Gondwana* [Grahn, ***2006*** (Figs. 6, 9; as *Euconochitina iklaensis*)]: upper Rhuddanian–upper Aeronian [*B. postrobusta*, *S. herringtoni* chitinozoan biozones].
- *New York State/USA* [Loydell et al., ***2007*** (p. 228, 230; Fig. 10)]: middle or late Telychian [lower Williamson Shale (*M. banwyensis* chitinozoan biozone)].
- *Western Estonia* (Viirelaid core) [Rubel et al., ***2007*** (Fig. 3)]: Lower Adavere Stage [uppermost Rumba Formation (*E. dolioliformis* chitinozoan biozone = *P. eopennatus* ssp. n. 2 conodont biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Raikküla Stage/Aeronian [*E. electa*, *S. maennili*, *C. elongata*, *C. alargada* chitinozoan biozones = ~20 m below the *D. triangulatus*–*L. convolutus* graptolite biozone = *A.? expansa*–*D. staurognathoides* conodont biozone].
- *East Baltic* [Nestor, ***2012*** (Figs. 2, 3)]: upper Rhuddanian–lower Telychian [upper *B. postrobusta*, *E. electa*, *S. maennili*, *C. alargada*, lower *E. dolioliformis* chitinozoan biozones = *C. cyphus*/*M. revolutus*–*S. crispus* graptolite biozone].
- *Gotland/Sweden* (Grötlingbo-1 core section) [Männik et al., ***2015*** (Fig. 3)]: Aeronian (*S. maennili* chitinozoan biozone).

Conochitina leviscapulae **Mullins & Loydell, 2001**

(Pl. 8, Figs. 7, 8, 10)

Synonymy

2001 *Conochitina leviscapulae* sp. nov. – Mullins & Loydell, p. 754, Pl. 8, Figs. 2–6.

2002 *Conochitina leviscapulae* Mullins & Loydell. – Mullins & Loydell, Figs. 3f, 3k.

?2005 *Conochitina* cf. *leviscapulae* Mullins & Loydell 2001. – Nestor, Pl. 2, Fig. 7.

?2010 *Conochitina* cf. *leviscapulae* Mullins & Loydell. – Loydell et al., Pl. 2, Fig. 7.

2015 *Conochitina leviscapulae* Mullins & Loydell. – Männik et al., Fig. 6U.

Material

Sample **131**: Four flattened and fractured specimens, part of the necks missing.

Description

Completely flattened, fractured and deformed vesicles with a conical to ovoid chamber and a relatively short broad cylindrical neck of varying length. The apertural part of the necks is missing. Flanks slightly convex; basal margin sharp; base flat (invaginated), no basal structure visible. The greatest diameter is between a point near the base and the lower half of the chamber length. Shoulder and flexure are gentle but may be secondarily accentuated by the deformation of the vesicles. The vesicle wall is smooth.

Measurements

Two of the flattened and broken specimens seem to be missing only a short part of the neck. The flattening has been corrected (coefficient of correction for Dp and dc = 0.7).

L = >122–>124 µm
Dp = 81–94 µm (corr.: 57–66 µm)
dc = 45 µm (corr.: 32 µm)
lc = ~1/3 of vesicle length

Discussion

Though the preservation of the studied representatives of *Conochitina leviscapulae* is poor their taxonomic assignment is clear due to the distinct morphologic features of these fossils. However, they are small and belong to the lowermost segment of the range of the vesicle lengths in Mullins & Loydell (2001: 754: L = 130.1–276 µm). *Conochitina* sp. 1 sensu Mullins & Loydell, 2001 has a roughly similar outline but is much larger and in relation to the vesicle length much more slender; the flexure is less distinct. In addition, *Euconochitina* sp. 2 sensu Nestor, 1994? is larger and in relation to the chamber the neck is much longer. *Euconochitina* sp. 3 sensu Nestor, 1994? differs from *C. leviscapulae* by its greater vesicle length, its more slender conical chamber, the longer neck and the inconspicuous flexure.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *C. leviscapulae* is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 10A* (sample **131**): Lower *P. a. angulatus* conodont biozone; global *A. longicollis* chitinozoan biozone].

Occurrences of *Conochitina leviscapulae* outside the Cellon section:

- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (p. 754, Text-Figs. 1, 7, 8)]: upper Telychian [Tarannon Shales Formation, Nant-ysgollon Shales Formation (*S. crispus*–*C. insectus* graptolite biozones = *E. dolioliformis*–lower *M. margaritana* chitinozoan biozones)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: upper Llandovery [Tarannon Shales Formation (*S. crispus* or *S. sartorius*–middle or probably upper *O. spiralis* graptolite biozone = *E. dolioliformis*–*A. longicollis* chitinozoan biozone)].
- *West Estonia* (Viki, Kaugatuma, Ohesaare cores) [Nestor, ***2005*** (Figs. 2–5)]: Adavere Stage [Velise Formation (*C. proboscifera*, *C. acuminata*, *M. banwyensis*, lower *M. margaritana* chitinozoan biozones)].

- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Adavere Stage/Telychian [*E. dolioliformis*–lower *A. longicollis* chitinozoan biozone = upper *S. turriculatus*–lower *O. spiralis* graptolite biozone = upper *D. staurognathoides*–upper *P. a. angulatus* conodont biozone].
- *Gotland/Sweden* (Grötlingbo-1 core section) [Männik et al., ***2015*** (Figs. 3, 11)]: Telychian (upper *C. proboscifera* chitinozoan biozone, Lower *P. a. amorphognathoides* conodont biozone).

Conochitina praeproboscifera Nestor, 1994

(Pl. 7, Figs. 4–8, 10, 11)

Synonymy

1994 *Conochitina praeproboscifera* n. sp. – Nestor, p. 35, Pl. 18, Figs. 4–8 (***cum syn.***).

1999 *Conochitina praeproboscifera* Nestor, 1994. – Nestor, Pl. 1, Fig. 14.

2001 *Conochitina praeproboscifera* Nestor, 1994. – Mullins & Loydell, Pl. 7, Figs. 1, 2, 6; Pl. 8, Figs. 11–14.

2002 *Conochitina praeproboscifera* Nestor. – Mullins & Loydell, Figs. 3m, 3t.

2002 *Conochitina praeproboscifera* Nestor 1994. – Nestor, H. & Nestor, V., Pl. 1, Fig. 5.

2003 *Conochitina praeproboscifera* Nestor. – Loydell et al., Fig. 16y.

2004 *Conochitina praeproboscifera* Nestor. – Mullins & Aldridge, Pl. 6, Figs. 1, 2; Pl. 8, Figs. 3, 4, 10, 11, 13.

2007 *Conochitina praeproboscifera* Nestor. – Loydell et al., Figs. 3b–d, g, j.

2010 *Conochitina praeproboscifera* Nestor. – Loydell et al., Fig. 12w.

2015 *Conochitina praeproboscifera* Nestor. – Männik et al., Fig. 6J.

Material

Each of the four recovered specimens is missing a variably long piece of the distal part of the vesicle.

Sample **50**: Three flattened specimens.

Sample **132**: One three-dimensional specimen.

Description

Vesicle relatively thin-walled, elongated-conical, with the greatest diameter at the basal margin; apertural part missing. Flanks straight or slightly convex, slowly tapering towards the aperture; in rare cases, a slight constriction may be present directly above the basal margin; no flexure or shoulder developed. Basal margin broadly rounded, base flat or slightly convex, provided with a distinct conical mucron: a thickened ridge with tapering sides (c. 5.4 µm high) surrounds a small central pit. The vesicle wall is smooth.

Measurements

All four specimens (three flattened and one three-dimensionally preserved) are missing the distal part of their vesicles. The vesicle diameters vary between 58 and 71 µm (coefficient of correction for Dp: 0.85 and 0.9).

The dimensions of the two largest specimens (Pl. 7, Figs. 5, 6) are:
L: >284–>307 µm
Dp: 68–71 µm

Discussion

Though the studied examples of *C. praeproboscifera* are poorly preserved, they clearly correspond to the original description of the species in Nestor (1994: 35).

The outline of the vesicles in this taxon is quite variable and it is fairly similar to that of the younger and stratigraphically important species *Conochitina proboscifera* Eisenack, 1937, a fact which in the past, i.e. before the publication of the new species *C. praeproboscifera* in 1994, frequently led to erroneous specific attributions of the fossils concerned. However, *C. proboscifera* is easy to identify by its considerably thicker vesicle wall and shiny surface (Nestor, 1994: 35). In addition, Mullins & Aldridge (2004: 762) distinguish *C. praeproboscifera* from *C. proboscifera* by the occurrence of a narrower vesicle with straight flanks tapering to the aperture, a thickened ridge along the basal margin and a central indentation instead of the prominent, membranous mucron of *C. proboscifera*. This characterisation also applies to the studied material except with regard to the basal structure: in the Kok chitinozoans the protruding conical mucron is a thickened ridge with tapering sides around a small central pit (Pl. 7, Fig. 4).

C. cf. *iklaensis* Nestor, 1980b differs from *C. praeproboscifera* in having a sub-cylindrical vesicle and the absence of a mucron. *Conochitina* cf. *armillata* Taugourdeau & Jekhowsky, 1960 has a similar outline but the base is more convex and the mucron is a low membranous rim around a flat central pit. *Conochitina* cf. *elongata* Taugourdeau, 1963 lacks a prominent mucron and the vesicle shows a gentle constriction at a point about half-way along the vesicle length, separating the sub-conical chamber from a slightly widening neck. In *Conochitina* sp. A, the vesicle is sub-cylindrical and the basal structure is a thickened rim surrounding a wide and fairly deep central depression.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *C. praeproboscifera* is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 10G* (sample **50**); *Bed 10J* (sample **132**): *P. a. angulatus*–lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Outside the studied area the species has been identified mainly at localities belonging to the palaeocontinents Baltica, Avalonia and Laurentia:

- *Estonia, North Latvia* [Nestor, ***1994*** (Tab. 1]: uppermost part of the Raikküla Stage - Adavere Stage [Rumba, Velise, Jurmala and Dobele formations (*C.* cf.*protracta*, *C. emmastensis*, *A. longicollis*, *C. proboscifera* chitinozoan biozones)].
- *Sweden* (Skåne) [Grahn, ***1998*** (Figs. 2, 9, 13, 15)]: upper Aeronian–upper Telychian [*S. maennili*, *C. emmastensis*, lower *A. longicollis* chitinozoan biozones = *L. convolutus*–*O. spiralis* graptolite biozone].
- *Oslo region* [Nestor, ***1999*** (Text-Fig. 10)]: upper Aeronian–uppermost Telychian [Rytteråker, Vik, Skinnerbukta

formations (*E. dolioliformis*, *A. longicollis*, *C. proboscifera*, lowermost *M. margaritana* chitinozoan biozones)].

- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (Text-Figs. 1, 7)]: upper Telychian [Tarannon Shales Formation, basal Nant-ysgollon Shales Formation (upper *E. dolioliformis*, *A. longicollis, lower C. acuminata* chitinozoan biozones = possible *M. crenulata* or lower *O. spiralis–C. lapworthi* graptolite biozone)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: upper Telychian [Tarannon Shales Formation (upper *E. dolioliformis*, *A. longicollis* chitinozoan biozones = possible *M. crenulata* or lower *O. spiralis*–middle or probably upper *O. spiralis* graptolite biozone)].
- *Southwestern Estonia* (Ikla core), *northernmost Latvia* (Staicele core) [Nestor, H. & Nestor, V., ***2002*** (Figs. 2, 3)]: Adavere Stage [Rumba Formation (upper *C. alargada*, *E. dolioliformis* chitinozoan biozones)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: upper Telychian [Jurmala Formation (*A. longicollis* chitinozoan biozone = *O. spiralis* graptolite biozone = upper *P. a. angulatus*–lower *P. a. lithuanicus* + *P. a. lennarti* conodont biozones)].
- *Shropshire* (Hughley Brook = Leasows section) [Mullins & Aldridge, ***2004*** (Text-Figs. 2, 3)]: lower Sheinwoodian [Buildwas Formation (upper *C. bouniensis*, lower *S. bella* chitinozoan biozones = ?*M. firmus* graptolite biozone)].
- *Latvia* (Ventspils D-3 core) [Loydell & Nestor, ***2005*** (Fig. 3): Telychian [lower *A. longicollis* chitinozoan biozone = lower *O. spiralis* graptolite biozone].
- *New York* [Loydell et al., ***2007*** (p. 228, 230; Fig. 10)]: middle or late Telychian [lower Williamson Shale (*M. banwyensis* chitinozoan biozone)].
- *Western Estonia* (Viirelaid core) [Rubel et al., ***2007*** (Fig. 3)]: Adavere Stage [Velise Formation (*A. longicollis*, lower *C. proboscifera* chitinozoan biozones = Lower *P. a. angulatus*–lower *P. a. lennarti* conodont biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Adavere Stage/Telychian [*E. dolioliformis*, *A. longicollis* chitinozoan biozones = *S. turriculatus*–lower *O. spiralis* graptolite biozone = *D. staurognathoides*–*P. a. angulatus* conodont biozone].

Conochitina sp. A

(Pl. 8, Figs. 1, 2, 4, 5)

Material

Sample **132**: Four three-dimensionally preserved specimens, all missing the apertural parts of the vesicles.

Description

Poorly preserved thin-walled sub-cylindrical to slightly conical vesicles of which all have lost their apertural parts; flanks straight, basal margin rounded; base flat, provided with a broad basal structure (comprising c. 50 % of the diameter of the base): a thickened (now almost completely abraded) rim surrounds a wide and fairly deep central depression; one example (Pl. 8, Fig. 2) seems to show the remains of a second circular ridge around a small central pit within this central depression. The vesicle wall is smooth.

Measurements

Each of the four three-dimensionally preserved specimens is missing the apertural part of the vesicle: the lengths of the fragments vary from 136–164 µm, their maximal diameters are 56–65 µm.

Discussion

The representatives of *Conochitina* sp. A are poorly preserved and obviously missing a considerable part of their vesicles therefore they are retained in open nomenclature. However, they exhibit a particular morphological feature which has not been observed in any other taxon of the studied chitinozoans: a large apical structure.

Mullins & Loydell (2001) described in their new species *Belonechitina meifodensis* three morphological types of basal structure of which two (Pl. 10, Fig. 8: “broad central pit surrounded by a smooth ridge”; Pl. 10, Fig. 11: “double circular basal structure”) strongly resemble the two types described herein under *Conochitina* sp. A (Pl. 8, Figs. 2, 5). However, the studied fossils have a smooth wall surface and a much smaller vesicle diameter.

Furthermore the “double circular basal structure” of *Conochitina* aff. *tuba* Eisenack, 1932, in Mullins & Aldridge (2004: Pl. 1, Fig. 14; Pl. 8, Fig. 14) and also the apical structure of *Conochitina tuba* in Laufeld (1974: Fig. 36A) show a certain similarity to the basal structure in one specimen of *Conochitina* sp. A (Pl. 8, Fig. 2; unfortunately, the majority of the inner ridge is covered by amorphous organic material). The vesicle shapes and sizes, however, are different.

Conochitina sp. A differs from *Conochitina* cf. *armillata* Taugourdeau & Jekhowsky, 1960 and from *C. praeproboscifera* Nestor, 1994 by the distinct broad mucron. *C.* cf. *iklaensis* Nestor, 1980b lacks a mucron as well as *C.* cf. *elongata* Taugourdeau, 1963, which moreover is characterised by a gentle constriction at a point about half-way along the vesicle length.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Conochitina* sp. A is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 10J* (sample **132**): lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Conochitina sp. B

(Pl. 7, Fig. 9)

Material

Sample **133**: One flattened specimen, of which part of the apertural area is missing.

Description

Flattened, thick-walled, subcylindrical (sack-like) vesicle of which the apertural part is missing; flanks slightly convex, basal margin is thickened and broadly rounded; base flat, no prominent basal structure visible; the vesicle wall is smooth.

Measurements

The flattened specimen is missing the apertural part. The flattening has been corrected (measurement at the basal margin; coefficient of correction for Dp = 0.9).

L = >207 µm

Dp = 97 µm

Discussion

The only available specimen of *Conochitina* sp. B shows different degrees of flattening along the vesicle axis thus its definite original shape is not unequivocally estimable (i.e., cylindrical vs. slightly conical).

Conochitina sp. B differs clearly from all other *Conochitina* taxa from the Kok Formation by its wider vesicle und thus its sack-like appearance, and its thick vesicle wall.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Conochitina* sp. B is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 11A* (sample **133**): Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Conochitina sp. 1 sensu MULLINS & LOYDELL, 2001

(Pl. 8, Fig. 6)

Synonymy

1967 *Conochitina edjelensis alargada* n. var. – CRAMER, Pl. 2, Fig. 50 (according to MULLINS & LOYDELL, 2001: 757).

2001 *Conochitina* sp. 1. – MULLINS & LOYDELL, p. 757, Pl. 9, Figs. 1–4; Text-Figs. 3H–I.

2005 *Conochitina* sp. 1 (of MULLINS & LOYDELL, 2001). – LOYDELL & NESTOR, Fig. 4b.

Material

Sample **132**: One flattened but otherwise complete specimen.

Description

Slender, sub-conical chamber with slightly convex flanks that slowly taper towards a sub-cylindrical neck with straight aperture; length of the neck about one third of the vesicle length; flexure very gentle, no shoulder. The greatest diameter is at the lowermost fourth of the vesicle length; basal margin sharp, the base is invaginated and covered with amorphous organic material, therefore no statement concerning the basal structure is possible. The wall surface is smooth.

Measurements

One specimen measured. The vesicle is not completely flattened as it is partly filled with framboids. No correction of the flattening has been carried out.

L = 266 µm

Dp = 84 µm

dc = 47 µm

Discussion

This single specimen is unique and very easy to distinguish by its shape from all other *Conochitina* taxa recorded from the Kok Formation.

It is smaller than the taxon in MULLINS & LOYDELL (2001: 757: 342–445 µm), but the description therein coincides with the morphology of the studied example from the Kok Formation which resembles Figure 3 on Plate 9 in MULLINS & LOYDELL (2001) but is different from Figures 1 and 2.

LOYDELL & NESTOR (2005: Fig. 5b) illustrate the taxon *Conochitina* sp. 1 (of MULLINS & LOYDELL, 2001) which is very similar to the form from the Kok Formation but it is obviously smaller. In Text-Figure 3 the authors state that the identification is problematic: possibly because also this specimen shows similarity only to Figure 3 on Plate 9 in MULLINS & LOYDELL (2001).

Conochitina leviscapulae MULLINS & LOYDELL, 2001 has a roughly similar outline but is smaller and broader with a shorter neck and a more distinct flexure. *Euconochitina* sp. 2 sensu NESTOR, 1994? is also smaller with a shorter and a little broader conical chamber and a much more distinct flexure. *Euconochitina* sp. 3 sensu NESTOR, 1994? differs from *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 by the smaller vesicle length and the more distinct flexure.

The representatives of *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 from both Wales and Latvia are a little older than those from the Kok Formation (global *A. longicollis* chitinozoan biozone) as they are there restricted to the upper part of the *E. dolioliformis* chitinozoan biozone.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 10J* (sample **132**): lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Ocurrences of *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 outside the Cellon-section:

- *Spain* (Aralla, La Vid and El Tueiro sections) [CRAMER, ***1967*** (as *Conochitina edjelensis*-long forms; Figs. 1–4)]: upper Llandovery–lower Wenlock [Formigoso–lower San Pedro Formation].
- *Wales* (Banwy River section) [MULLINS & LOYDELL, ***2001*** (p. 757, Text-Figs. 1, 7)]: upper Telychian [Tarannon Shales Formation (*E. dolioliformis* chitinozoan biozone = possible *S. Sartorius*–lower *M. griestonensis* to *O. spiralis* graptolite biozones)].
- *Latvia* (Ventspils D-3 core) [LOYDELL & NESTOR, ***2005*** (p. 370; Fig. 3)]: Telychian [upper Degole Beds of the upper Jũrmala Formation (upper part of the *E. dolioliformis* chitinozoan biozone)].

Conochitina sp. 1

(Pl. 2, Figs. 3, 4, 6, 7)

Material

All vesicles are missing the apertural part; they are somewhat flattened, but at least their basal areas are three-dimensionally preserved.

Sample **126**: One specimen.

Sample **128**: Five specimens.

Sample **129**: Seven specimens.

Description

Long, slender, conical vesicle, apertural part missing. Flanks straight, slightly tapering towards the aperture, no flexure, no shoulder; basal margin broadly rounded, merging into the hemispherical base. The base has an apical pit (~20 % of the diameter) which is surrounded by a low, narrow (abraded?) rim. Surface smooth.

Measurements

Six broken specimens, apertural parts missing.

L = >223–>286 µm

Dp = 52–61 µm

Discussion

The species is found in all of the fertile samples of the Plöcken Formation. Unfortunately, its preservation is rather poor. The antiapertural area is always three-dimensionally preserved, however, in many cases the remaining vesicle is flattened, with the flattening starting at any point from directly above the base. Moreover, the base frequently is damaged by imprints of crystals which have destroyed the basal structure.

Conochitina sp. 1 shows some similarities to *Conochitina rotundata* PARIS et al., 2015b from late Katian–Hirnantian sequences in North Central Saudi Arabia. The features noted in common are the long slender vesicle and the hemispherical base, however, the specimens from the Plöcken Formation show slightly tapering flanks and a relatively small apical pit surrounded by an almost invisible rim instead of the large annular callus described in *C. rotundata*.

Conochitina sp. 2, which is also long and slender, is distinguished from *Conochitina* sp. 1 by its flat or slightly concave base.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Conochitina* sp. 1 is recorded in the Plöcken Formation, Hirnantian in age [*Bed 5* (sample **126**), *Bed 7* (sample **128**) and base of *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Conochitina sp. 2

(Pl. 2, Figs. 8, 11, 12; Pl. 3, Figs. 1–4)

Material

All specimens are poorly preserved and missing a variable amount of the upper part of the vesicles; the zone around the basal margins shows no or only slight flattening while the remaining parts are more or less compressed; moreover, in many cases the vesicle walls have been deformed by internal growth of framboids.

Sample **128**: Nine specimens.

Sample **129**: Eight specimens.

Sample **130**: Eleven (reworked ?) specimens.

Description

Long, slender, subcylindrical to slightly conical vesicle with straight flanks, apertural parts missing. Basal margin rounded; base flat or slightly concave. The base shows a distinct apical pit (diameter about 10 µm), which is possibly surrounded by a low, narrow, now almost completely abraded rim. Wall smooth.

Measurements

Nine specimens, in which at least the basal area is three-dimensionally preserved; in all specimens variably long parts of the apertural area are missing.

L = up to 266 µm and above

Dp = 56–68 µm

Discussion

Due to the different types of preservation observed in one and the same specimen (three-dimensionally close to the base, flattened towards the aperture) it is difficult to estimate whether the vesicles are cylindrical or slightly conical. In a taxon devoid of other morphological characteristics this deficiency creates uncertainties in its assignment to an appropriate species or even genus.

The silhouette of the vesicles of *Conochitina* sp. 2 shows some similarities to *Tanuchitina elongata*, however, they differ by the absence of a carina. Also *Rhabdochitina* cf. *gracilis* is closely similar to *Conochitia* sp. 2 and they are not readily distinguished from each other: the basal margin of the former has a more rectangular appearance.

A relatively high number (eleven) of almost identical individuals of *Conochitina* sp. 2 is observed within sample **130** from the Telychian part of the Kok Formation (Pl. 3, Figs. 1–4). They show the same outline and dimension and also the typical apical pit. Due to the fact that a specimen of *Armoricochitina nigerica* (BOUCHÉ, 1965) is also documented in the same sample, it is possible that their presence is due to reworking from the Hirnantian strata.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tabs. 1, 2), *Conochitia* sp. 2 is recorded in the upper part of the Plöcken Formation, Hirnantian in age [*Bed 7* (sample **128**); base of *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone] and – most probably reworked – in the lower part of the Kok Formation, Telychian in age [in the upper part of *Bed 9* (sample

130 = c. 25 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Conochitina sp. 3

(Pl. 2, Fig. 9)

Material

Three-dimensional vesicles, apertural parts missing.

Sample **128**: One specimen.

Sample **129**: Two specimens.

Description

Relatively broad conical vesicles, apertural parts missing. Flanks slightly tapering towards the aperture, straight to slightly sigmoidal, showing a gentle constriction in the lowermost part, just above the broadly rounded basal margin. Base flat, having a shallow apical pit. Surface smooth.

Measurements

Three broken three-dimensional specimens, variably long pieces of the apertural area are missing.
L = >144–>158 µm
Dp = 73–92 µm

Discussion

The vesicles are three-dimensionally preserved and broken, the length of the missing apertural parts and the morphology of the apertures are therefore unknown. The bases of the vesicles are partly covered with some organic matter and are deformed by imprints of crystals, however, one vaguely shows a shallow depression at its centre. The relatively broad-conical vesicles and the slight constrictions just above the broadly rounded basal margins distinguish this species from the remaining representatives of *Conochitina* documented in the Plöcken Formation.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Conochitina* sp. 3 is recorded in the upper part of the Plöcken Formation, Hirnantian in age [*Bed 7* (sample **128**); base of *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Conochitina sp. 4

(Pl. 3, Figs. 7, 8)

Material

Sample **129**: One three-dimensional, broken vesicle.

Description

Relatively broad conical vesicle, apertural part missing. Flanks straight, slightly tapering towards the aperture, basal margin broadly rounded. Base slightly convex with a large low mucron (Ø c. 20 µm), giving the basal area in lateral view the appearance of a truncated cone. Surface smooth.

Measurements

One three-dimensional vesicle, apertural part broken.
L = >142 µm
Dp = 71 µm

Discussion

The vesicle is three-dimensionally preserved and broken, the length of the missing apertural part and the morphology of the aperture are thus unknown. The characteristic feature of this species is the slightly convex base with a low broad rim around a flat apical pit, by which it is distinguished from the remaining *Conochitina* species of the Plöcken Formation.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Conochitina* sp. 4 is recorded in the upper part of the Plöcken Formation, Hirnantian in age [base of *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Conochitina ? sp.

(Pl. 3, Figs. 5, 6)

Material

Sample **129**: One three-dimensional, broken vesicle.

Description

Relatively broad conical vesicle, slightly tapering towards the aperture; apertural part missing. Flanks straight, no flexure, no shoulder. In the lowermost fifth, the vesicle shows a slight widening. Basal margin acute-angled, but rounded, devoid of any structure. Base flat with a small shallow apical pit. Surface smooth.

Measurements

One three-dimensional specimen, apertural part missing.
L = >176 µm
Dp = 79 µm

Discussion

The overall shape of this species strongly resembles the outline of representatives of the genus *Spinachitina* SCHALLREUTER, 1963, emend. PARIS et al., 1999a, but the basal margin is lacking the spines. An explanation could be that the outer vesicle layer has been removed along with the spines, which is suggested by remnants of this layer still present on the base of the vesicle (Pl. 3, Fig. 6).

The outline of *Conochitina* ? sp. shows a vague similarity to *Cyathochitina kourneidaensis* in BOUCHÉ (1965: Pl. 2, Figs. 16–19) from the two “faunizones” A and B of late Ordovician age from a well in the Djado basin (Niger), as well as to *Spinachitina* cf. *kourneidaensis* (BOUCHÉ 1965) in PARIS et al. (2015b: Pl. 1, Fig. 15) from upper Ordovician sequences, also in the Djado basin. However, the basal widening of *S. kourneidaensis* is obviously more pronounced.

Beside the conical shape and the smooth vesicle wall, the shallow apical pit on the base is the reason for the assignment herein of *Conochitina* ? sp. to the genus *Conochitina*

EISENACK, 1931, emend. PARIS et al., 1999a, and not to *Euconochitina* TAUGOURDEAU, 1966, emend. PARIS et al., 1999a, which according to the latter authors lacks such a structure.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Conochitina*? sp. is recorded in the upper part of the Plöcken Formation, Hirnantian in age [base of *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Genus Euconochitina TAUGOURDEAU, 1966, emend. PARIS et al., 1999a

Euconochitina sp. 2 sensu NESTOR, 1994 ?

(Pl. 8, Fig. 11)

Synonymy

1994 *Vitreachitina* sp. 2. – NESTOR, p. 50, Pl. 30, Figs. 5–6.

2003 "*Vitreachitina*" sp. 2 (of NESTOR, 1994). – LOYDELL et al., Fig. 16s.

Material

Sample **46A**: Two flattened and slightly folded specimens (one doubtful); part of the necks missing.

Description

Flattened and slightly folded, thin-walled vesicle with a subconical chamber and a broad, long neck of which the apertural part is missing. Flanks slightly convex; basal margin sharp; antiapertural edge of the chamber straight (base slightly invaginated), no basal structure visible; the greatest diameter is at about the lowermost third of the chamber length; both flexure and shoulder are gentle. The vesicle wall is smooth.

Measurements

Measurements are given from the better-preserved specimen only. The flattening has been corrected (coefficient of correction for Dp and dc = 0.7).

L = >148 µm

Dp = 81 µm (corr.: 57 µm)

Dc = 38 µm (corr.: 27 µm) = 47 % of the chamber diameter

lc = >55 % of the total length

Discussion

The taxon originally has been described as *Vitreachitina* sp. 2 by NESTOR, 1994, however, according to PARIS et al. (1999a: 570) this genus is a junior synonym of *Euconochitina* TAUGOURDEAU, 1962.

Only one unquestionable specimen of *Euconochitina* sp. 2 sensu NESTOR, 1994? is available. One of the main characteristics of this taxon in NESTOR (1994: 50) is its thin and semi-transparent wall. The shape of the studied vesicle is very similar to Figure 6 on Plate 30 in NESTOR (1994) and it is also thin-walled. However, it is opaque probably as a consequence of the epizonal overprint of the depositional area during the Variscan Orogeny (see chapter "Geological setting/The Carnic Alps"). Therefore, the identification of the taxon is provided herein with a question mark.

Euconochitina sp. 2 sensu NESTOR, 1994? differs from *Euconochitina* sp. 3 sensu NESTOR, 1994? in having a smaller vesicle length, a shorter and broader conical chamber and a distinct flexure. The shape of *Conochitina leviscapulae* MULLINS & LOYDELL, 2001 is similar, however, it is smaller and in relation to the chamber the neck is much shorter. *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 is much larger and in relation to its length more slender and its flexure is less distinctive. *Sphaerochitina* sp. 1 looks slightly similar but is larger and has a spherical chamber.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Euconochitina* sp. 2 sensu NESTOR, 1994? is recorded in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Ocurrences of *Euconochitina* sp. 2 sensu NESTOR, 1994 outside the Cellon section:

- *Estonia, North Latvia* (Viki and Nagli cores) [NESTOR, ***1994*** (as *Vitreachitina* sp. 2; p. 50; Tab. 1)]: Adavere Stage [Dobele, Jūrmala and Velise formations (Biozone 7, 9 = Interzone II, *A. longicollis* chitinozoan biozone)].
- *Latvia* (Aizpute-41 core) [LOYDELL et al., ***2003*** (as "*Vitreachitina"* sp. 2; Figs. 15, 17)]: lower Telychian [Jūrmala Formation (basal *E. dolioliformis* chitinozoan biozone = upper *S. turriculatus* graptolite biozone = upper *D. staurognathoides* conodont biozone)].

Euconochitina sp. 3 sensu NESTOR, 1994 ?

(Pl. 8, Fig. 3)

Synonymy

1994 *Vitreachitina* sp. 3. – NESTOR, p. 51, Pl. 30, Figs. 7–8.

Material

Sample **131**: Two flattened and fractured specimens (one doubtful); part of the necks missing.

Description

Completely flattened and partly broken vesicle with a slender conical chamber and a long broad cylindrical neck, the apertural part is missing. Flanks slightly convex (almost straight); basal margin at the lower left and right side of the chamber damaged; antiapertural edge of the chamber straight, no basal structure visible; shoulder inconspicuous, flexure gentle. The vesicle wall is smooth.

Measurements

Only the measurements of the better-preserved specimen are given. The flattening has been corrected (coefficient of correction for Dp and dc = 0.7).

L = >181 µm

Dp = 87 µm (corr.: 61 µm)

dc = 49 µm (corr.: 34 µm) = 56 % of the chamber diameter

lc = >39 % of the total length

Discussion

The taxon originally has been described as *Vitreachitina* sp. 3 by NESTOR, 1994, however, according to PARIS et al. (1999a: 570) this genus is a junior synonym of *Euconochitina* TAUGOURDEAU, 1962.

Only one unequivocal specimen of *Euconochitina* sp. 3 sensu NESTOR, 1994? is found. It is poorly preserved, nevertheless it strongly resembles the specimen in Figure 8 on Plate 30 in NESTOR (1994). Though its vesicle wall is thin, it is opaque instead of semi-transparent, which is a main characteristic of this species. However, this could very well be a secondary feature as the depositional area underwent an epizonal overprint during the Variscan Orogeny (see chapter “Geological setting/The Carnic Alps”). Due to this deficiency only an identification with a question mark is used.

Euconochitina sp. 3 sensu NESTOR, 1994? differs from *Euconochitina* sp. 2 sensu NESTOR, 1994? by the greater vesicle length, the longer and more slender conical chamber and the less distinct flexure. *Conochitina leviscapulae* MULLINS & LOYDELL, 2001 is smaller and broader and has a much shorter neck. *Conochitina* sp. 1 sensu MULLINS & LOYDELL, 2001 is larger and the flexure is much less distinct.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Euconochitina* sp. 3 sensu NESTOR, 1994? is recorded in the lower part of the Kok Formation, Telychian in age [*Bed 10A* (sample **131**): Lower *P. a. angulatus* conodont biozone; global *A. longicollis* chitinozoan biozone].

Ocurrence of *Euconochitina* sp. 3 sensu NESTOR, 1994? outside the Cellon section:

- *Latvia* (Nagli and Ventspils cores) [NESTOR, ***1994*** (as *Vitreachitina* sp. 3; p. 51; Tab. 1)]: Adavere Stage [lowermost part of the Degole Beds of the Jũrmala Formation (Biozone 9 = *A. longicollis* chitinozoan biozone)].

Euconochitina sp.

(Pl. 3, Figs. 10, 11)

Synonymy

2000 *Conochitina* sp. – PRIEWALDER, Pl. 1, Fig. 1.

Material

Sample **128**: One three-dimensional vesicle, apertural part missing.

Description

Slender conical vesicle with slightly tapering flanks, apertural part destroyed. The flanks show a sigmoidal outline caused by a gentle constriction in the lower part of the vesicle, just above the basal margin. Neck short and cylindrical, flexure and shoulder inconspicuous, basal margin acute-angled, but rounded. Base flat, without any apical structure. Vesicle wall microgranulated, best visible on the lowermost fourth of the vesicle.

Measurements

One almost complete three-dimensional vesicle.

L = >216 µm

Dp = 70 µm

dc = 45 µm

Discussion

Euconochitina sp. is a conspicuous species. Characteristic features are the slender conical vesicle, the sigmoidal flanks and the rounded angular basal margin. The precise vesicle length, however, is unknown as the apertural area is destroyed. The only ornamentation is the microgranulation of the vesicle wall and the small holes on the basal margin (Pl. 3, Fig. 11) are not scars of broken spines but the imprints of crystals such as those higher up on the vesicle surface.

The outline of *Euconochitina* sp. resembles *Euconochitina moussegoudaensis* PARIS in LE HÉRISSÉ et al. (2013) from the basal Tanezzuft Formation of latest Hirnantian or basal Rhuddanian age from the Moussegouda borehole in the Erdi Basin, northern Chad. This species also has a slender conical vesicle with sigmoidal flanks, however, it is smaller (L = 114–195 µm) and the basal margin seems to be more rounded. THUSU et al. (2013) presented *Euconochitina* cf. *moussegoudaensis* from the basal Tenezzuft Formation, occurring in two wells from the Kufra Basin, southeastern Libya. This taxon differs from *E. moussegoudaensis* in having a greater length (more than 200 µm and up to 230 µm). This indeed coincides well with the length of *Euconochitina* sp. described herein, however, concluding from the illustrations, the sigmoidal shape of the flanks in *Euconochitina* cf. *moussegoudaensis* seems to be less pronounced and only one specimen (Pl. X, Fig. 2) in THUSU et al. (2013) is roughly comparable with the studied individual.

The outline of *Euconochitina* sp. also resembles some representatives of the genus *Spinachitina* SCHALLREUTER, 1963, emend. PARIS et al., 1999a, such as *S. oulebsiri* PARIS et al. (2000a) or *S. verniersi* VANDENBROUCKE in VANDENBROUCKE et al. (2009), which are late Hirnantian taxa, predominantly found in strata from Northern Gondwana. However, there are no traces of spines on the basal margin of *Euconochitina* sp.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Euconochitina* sp. is recorded in the upper part of the Plöcken Formation, Hirnantian in age [*Bed 7* (sample **128**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Euconochitina? sp.

(Pl. 2, Fig. 10)

Synonymy

2000 *Conochitina* sp. – PRIEWALDER, Pl. 1, Fig. 5.

Material

Sample **126**: One flattened vesicle.

Description

Cylindro-conical vesicle with gentle flexure and without shoulder. The cylindrical neck gradually merges into the slender conical chamber with straight flanks. Basal margin broadly rounded. The base of the chamber is invaginated, so its structure is invisible. The apertural area is partly damaged, therefore only small remnants of a thin collarette are present around the aperture. Surface sparsely covered with tiny granulae, with the greatest density observed around the basal margin.

Measurements

One flattened, otherwise almost complete specimen (coefficient of correction for Dp, dc = 0.7).

L = 239 µm

Dp = 69 µm

dc = 50 µm

Discussion

According to Paris et al. (1999a), an *Euconochitina* species is distinguished from a conical *Conochitina* species by the absence of a mucron. As the conical chamber of *Euconochitina*? sp. is flattened and the base is invaginated, it is impossible to see whether there is a basal structure. Therefore, the species is assigned herein with reservation to the genus *Euconochitina*.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Euconochitina*? sp. is recorded in the lower part of the Plöcken Formation, Hirnantian in age [*Bed 5* (sample **126**): *M. persculptus* graptolite biozone (?); *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Genus Rhabdochitina Eisenack, 1931

Rhabdochitina cf. *gracilis* Eisenack, 1962

(Pl. 2, Figs. 1, 2, 5)

Material

Broken vesicles, three-dimensionally preserved around the basal margin and somewhat compressed in apertural direction.

Sample **128**: Three specimens;

Sample **129**: Six specimens.

Description

Vesicles long, slender, cylindrical; flanks straight. Apertural parts broken. Base flat or slightly concave or convex, basal margins slightly rounded with a rather rectangular appearence in lateral view. A small apical pit is sometimes present in the centre of the base. Wall smooth.

Measurements

Seven specimens, of which at least the antiapertural part is three-dimensionally preserved; in all specimens variably long pieces of the apertural area are missing.

L = up to 356 µm and above

Dp = 56–67 µm

Discussion

The preservation of the specimens of *R.* cf. *gracilis* is poor, all are missing variably long parts of the apertural vesicle area. Some are entirely three-dimensionally preserved, others are somewhat flattened with the exception of the zone around the basal margin.

According to the original description of *Rhabdochitina gracilis* in Eisenack (1962: 307), this species is distinguished from the similar *R. magna* Eisenack, 1931 by its reduced length and diameter (Ø = 42–67 µm in *R. gracilis*, >80 µm in *R. magna*). In addition, Elaouad-Debbaj (1984: 60) and Vandenbroucke (2008: 26) consider that the diameter is the main and only distinguishing feature: less than 80 µm in *R. gracilis*, more than 80 µm in *R. magna*. Due to the diameter being smaller than 80 µm, the specimens from the Plöcken Formation are attributed herein to *R. gracilis*, however, because of their poor preservation they are retained in open nomenclature.

Conochitina sp. 2 closely resembles *R.* cf. *gracilis*, its basal margin, however, is more rounded without the rectangular appearance of the basal margin area.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *R.* cf. *gracilis* is recorded in the upper part of the Plöcken Formation, Hirnantian in age [*Bed 7* (sample **128**) and basal *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

R. gracilis has a wide geographical and stratigraphical distribution. A selection of the numerous records of this species is given below [for further information concerning its distribution refer to Grahn (1980: 36) and Elaouad-Debbaj (1984: 60)]:

- *Normandy* (Rauscher & Doubinger, ***1967***, ***1970***; Rauscher, ***1973***): Llanvirn (Schistes à Calymène).
- *Montagne Noire* (Rauscher, ***1968***): Arenig.
- *Morocco* (Elaouad-Debbaj, ***1984***): Ashgill (Upper Ktaoua–Lower 2nd Bani Formation).
- *Morocco* (Elaouad-Debbaj, ***1986***): uppermopst Caradoc–early Ashgill (Agadir-Tissinnt Member of the Lower Ktaoua Formation).
- *Morocco* (Soufiane & Achab, ***1993***): late Ashgill (Assemblage E).
- *Algerian Sahara* (Oulebsir & Paris, ***1995***): Llanvirn (Membres des Argilles d’Azzel of the Formation Argilo-Gréseuse de Hassi Touareg).
- *Central Saudi Arabia* (Paris et al., ***2000b***): Llanvirn (Assemblage 4, i.e. the Hanadir Member of the Qasim Formation).
- *Morocco* (Bourahrouh et al., ***2004***): Caradoc to late Ashgill (Lower Ktaoua–Lower 2nd Bani Formation).
- *Northern England* (Vandenbroucke et al., ***2005***): Onnian (Dufton Shale Formation).
- *Baltoscandia* (Hints & Nõlvak, ***2006***): Hunneberg to Porkuni Stages.
- *Belgium* (Condroz Inlier) (Vanmeirhaeghe, ***2007***): late Sandbian–early Katian (Sart Bernard Formation).
- *Iran* (Ghavidel-Syooki, ***2008***): late Katian–late Hirnantian (Goran Schists, Unit I, II).

- *Gotland/Sweden* (Grötlingbo-1 core section) [MÄNNIK et al., ***2015*** (Fig. 2)]: Upper Ordovician/Kukruse Stage (*L. stentor* chitinozoan biozone), Porkuni Stage (?).
- *Northwest Saudi Arabia* (wells 180-3, 180-4) [AL-SHAWAREB et al., ***2017*** (Figs. 8, 9)]: Upper Ordovician (Katian) [upper part of the Quwarah Member of the Qasim Formation (*A. merga–T. elongata* chitinozoan biozone = *T. ontariensis* Assemblage–*T. elongata* Partial Range Subzone)].
- *Iran* (Alborz Mountains) [GHAVIDEL-SYOOKI, ***2017a*** (Fig. 2)]: Ashgillian [Abarsaj Formation (*A. merga–T. elongata* chitinozoan biozone)].

Subfamily SPINACHITININAE PARIS, 1981

Genus Spinachitina SCHALLREUTER, 1963, emend. PARIS et al., 1999a

Spinachitina sp.

(Pl. 3, Figs. 9, 12)

Material

Sample **129**: One three-dimensional, broken vesicle.

Description

Cylindro-conical vesicle, the aperturalmost part is missing. Slender cylindrical neck, gradually merging into the conical chamber. Flexure inconspicuous, no shoulder. In the lowermost third of the chamber there is a slight constriction below which the chamber widens considerably. Basal margin sharp-angled, but rounded, showing the relics of spines (Ø at the base: c. 3 µm) or circular holes in the wall where the former spines were inserted. Base slightly convex, but due to a cover of other organic matter its stucture is unobservable. Surface – apart from the spines on the basal margin – smooth.

Measurements

One three-dimensional specimen, apertural part missing.

L = >126 µm

Dp = 79 µm

dc = 34 µm

Discussion

Due to its poor preservation, the specimen described herein is retained in open nomenclature. However, its outline resembles *Spinachitina multiradiata* (EISENACK, 1959), notably the holotype from the Ostseekalk in EISENACK (1959: Pl. 1, Fig. 2). LAUFELD (1967) described the overall shape of his representatives of *S. multiradiata* from the “Skagen” Formation (Dalarna/Central Sweden) as “superficial similar to a chanterelle”, which also applies to *Spinachitina* sp.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *Spinachitina* sp. is recorded in the upper part of the Plöcken Formation, Hirnantian in age [basal *Bed 8* (sample **129**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

Subfamily TANUCHITININAE PARIS, 1981

Genus Tanuchitina JANSONIUS, 1964, emend. PARIS et al., 1999a

Tanuchitina elongata (BOUCHÉ, 1965)

(Pl. 1, Figs. 8–11)

Synonymy

1965	*Cyathochitina elongata* n. sp. – BOUCHÉ, p. 157, Pl. 3, Fig. 6.
1965	*Cyathochitin* sp. 1. – BOUCHÉ, p. 158, Pl. 3, Figs. 12, 16.
1965	*Rhabdochitina magna* EIS. 1931. – BOUCHÉ, p. 157, Pl. 3, Figs. 9, 10.
1985	*Tanuchitina bergstroemi* LAUFELD, 1967. – MOLYNEUX & PARIS, Pl. 5, Fig. 7; Pl. 7, Fig. 6.
1990	*Tanuchitina elongata*. – PARIS, p. 202.
1995	*Tanuchitina elongata* (BOUCHÉ, 1965). – AL-HAJRI, Pl. 7, Fig. 4.
non1995	*Tanuchitina elongata* (BOUCHÉ, 1965). – ACHAB & ASSELIN, Pl. 4, Fig. 5.
1996	*Tanuchitina elongata* BOUCHÉ, 1965. – STEEMANS et al., Pl. 7, Fig. 1.
1999	*Tanuchitina* sp. – PRIEWALDER, Fig. 10.
2000	*Tanuchitina elongata* (BOUCHÉ 1965). – PRIEWALDER, Pl. 1, Fig. 4.
2004	*Tanuchitina elongata* (BOUCHÉ, 1965). – BOURAHROUH et al., Pl. 3, Figs. 5, 6; Pl. 4, Fig. 4.
2008	*Tanuchitina elongata* (BOUCHÉ, 1965). – GHAVIDEL-SYOOKI, Pl. 6, Fig. 7; Pl. 7, Figs. 1, 4.
2016	*Tanuchitina elongata*. – GHAVIDEL-SYOOKI, Pl. 9, Fig. 20.
2017a	*Tanuchitina elongata* (BOUCHÉ, 1965). – GHAVIDEL-SYOOKI, Pl. 4, Fig. 16.
2017c	*Tanuchitina elongata* (BOUCHÉ, 1965). – GHAVIDEL-SYOOKI, Pl. 9, Fig. 20.

Material

All vesicles are missing the apertural part; at least around the basal area they are three-dimensionally preserved.

Sample **128**: Ten specimens.

Sample **129**: Seven specimens.

Sample **45**: One specimen.

Description

Long, slender, cylindrical vesicles with straight flanks, apertural parts broken at different points of the vesicle length. Basal margin broadly rounded; base flat or slightly concave, having a distinct apical pit with an average diameter of 10 µm. On the base, a carina is developed at a short distance from the basal margin towards the centre. Due to poor preservation, the carina is only observed in fragmentarily form. Wall smooth.

Measurements

Eleven specimens, of which at least the antiapertural part is three-dimensionally preserved; in all specimens a piece of undefined length of the apertural area is missing.

L = >131–>365 µm

Dp = 52–68 µm

Discussion

Bouché (1965) described *Cyathochitina elongata* based on transmitted light microscope observations. In many studies over the years, this species has proved to be a highly valuable taxon in age determination of North Gondwanan Upper Ordovician strata. Nevertheless, to date, a detailed SEM-illustration, description and evaluation of this important species on the basis of well-preserved assemblages is still missing.

The specimens of *T. elongata* recorded in the Cellon section are poorly preserved (like most of the Hirnantian chitinozoans at the locality): the carina is always fragmented and the vesicle bases are often deformed by crystal imprints. The apertural parts have been removed and many vesicles show a flattening that starts just above the basal margin. However, the area around the basal margin is always three-dimensionally preserved. Despite all these constraints, the main morphological features of *T. elongata* are recognisable.

The shape of the vesicle of *Conochitina* sp. 2 is similar, but it is missing a carina.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 1), *T. elongata* is recorded in the upper part of the Plöcken Formation, Hirnantian in age [(*Bed 5*: it has to be pointed out that due to misinterpretation, the occurrence of *T. elongata* in *Bed 5* in Schönlaub et al., 2011: Text-Fig. 3 has to be revoked); *Bed 7* (sample **128**); *Bed 8* (sample **129**, **45**): *M. persculptus* graptolite biozone; *A. ordovicicus* conodont biozone; *T. elongata* chitinozoan biozone].

In the lower part of the Plöcken Formation, the index fossil *M. persculptus* and also the *Hirnantia brachiopod fauna* have been collected (see chapter “The Plöcken Formation”).

T. elongata is a typical North Gondwana species and ranges from the upper part of the *A. merga* chitinozoan biozone to the lower part of the *S. oulebsiri* chitinozoan biozone [latest Katian–late (not latest) Hirnantian]. It has a wide geographical distribution.

- *Niger* (Djado basin) [Bouché, ***1965*** (Tab.A)]: Upper Ordovician [Faunizone A].
- *Northeastern Libya* (wells E1-81, J1-81A) [Molyneux & Paris, ***1985*** (p. 24; as *T. bergstroemi*)]: latest Caradoc–Ashgill.
- *Northeastern Libya* (wells J1-81A, E1-81) [Paris, ***1988a*** (Fig. 9; as *T. bergstroemi*)]: Rawtheyan, Hirnantian [*P. sylvanica*–*S. debbajae*, *A. nigerica* chitinozoan biozone].
- *Northern Gondwana* [Paris, ***1990*** (Fig. 4)]: Ashgill [lower *A. merga*–top *T. elongata* chitinozoan biozone].
- *Northern Gondwana* [Paris, ***1992*** (Fig. 3)]: upper Cautleyan–top Hirnantian.
- *NW Saudi Arabia* [Al-Hajri, ***1995*** (Fig. 4)]: late Cautleyan–early Hirnantian [Quwarah Member of the Qasim Formation, Sarah Formation (upper part of the *A. merga* chitinozoan biozone)].
- *Algerian Sahara* (boreholes GD.1 bis NI.2) [Oulebsir & Paris, ***1995*** (Figs. 2, 3, 5, 6)]: late Ashgill [Formation de Hassi El Hadjar/Argiles microconglomératiques (*T. elongata* chitinozoan biozone)].
- *Northern Gondwana* [Paris, ***1996*** (Fig. 2)]: upper Cautleyan–top Hirnantian.
- *SE Turkey* (Border Folds) [Steemans et al., ***1996*** (p. 38–40)]: middle Ashgillian–Hirnantian [upper part of the Bedinan Formation (upper *A. merga*–*T. elongata* chitinozoan biozone)].
- *NE Algerian Sahara* (borehole NI.2) [Paris et al., ***2000a*** (Fig. 5)]: late Hirnantian [M’Kratta Formation (upper *T. elongata*, *S. oulebsiri* chitinozoan biozone)].
- *Morocco* (Bou Ingarf section, Anti Atlas) [Bourahrouh et al., ***2004*** (Fig. 4)]: upper Ashgill [Lower Second Bani Formation (upper *A. merga* chitinozoan biozone; see discussion in chapter “The chitinozoans of the Plöcken Formation”)].
- *Turkey* (Taurus Range, Border Folds) [Paris et al., ***2007*** (p. 93, 95)]: Hirnantian [Halevikdere Formation (*T. elongata* chitinozoan biozone)].
- *Iran* (Eastern Alborz Mountain Ranges) [Ghavidel-Syooki, ***2008*** (Fig. 2)]: lower Hirnantian [Gorgan Schists (*T. elongata* chitinozoan biozone)].
- *Iran* (Zagros Mountains) [Ghavidel-Syooki et al., ***2011a*** (Tab. 1)]: Hirnantian [lower and upper Dargaz diamictites (*T. elongata*, *S. oulebsiri* chitinozoan biozone)].
- *Bohemia* (Prague basin) [Thusu et al., ***2013*** (p. 114)]: total range of *T. elongata* = latest Katian–late Hirnantian [Kosov Formation].
- *North central Saudi Arabia* (Qusaiba-1 core hole) [Paris et al., ***2015b*** (p. 80; Fig. 5)]: late Katian–Hirnantian [Quwarah Member of the Qasim Formation; basal disrupted facies of the Sarah Sandstone Member of the Sarah Formation (*A. merga*, *T. elongata* chitinozoan biozones)].
- *Iran* (Alborz Mountain Range) [Ghavidel-Syooki, ***2016*** (Fig. 2)]: Hirnantian [upper Ghelli Formation (*T. elongata*–*S. oulebsiri* chitinozoan biozone)].
- *Northwest Saudi Arabia* (wells 180-3, 180-4) [Al-Shawareb et al., ***2017*** (Figs. 8, 9, 10)]: Upper Ordovician (Katian) [upper part of the Quwarah Member of the Qasim Formation (upper *A. merga*–*T. elongata* chitinozoan biozone = *T. contracta*–*T. elongata* Partial Range Subzone)].
- *Iran* (Alborz Mountains) [Ghavidel-Syooki, ***2017a*** (Fig. 2)]: Ashgillian (Abarsaj Formation).
- *Iran* (Alborz Mountain Range) [Ghavidel-Syooki, ***2017b*** (Fig. 2)]: Hirnantian [Glacial Member of the Ghelli Formation (*T. elongata*–*S. oulebsiri* chitinozoan biozone)].
- *Iran* (Alborz Mountain Range) [Ghavidel-Syooki, ***2017c*** (Fig. 2)]: Hirnantian [upper Ghelli Formation (upper *T. elongata*–*S. oulebsiri* chitinozoan biozone)].

For the discussion of the stratigraphical range of the *T. elongata* chitinozoan biozone in the Bou Ingarf section (Anti Atlas, Morocco), the type section of this biozone, and for further references to the geographical distribution of the *T. elongata* chitinozoan biozone, see above in chapter “The chitinozoans of the Plöcken Formation”.

Family Lagenochitinidae Eisenack, 1931, emend. Paris, 1981

Lagenochitinidae indet.

(Pl. 11, Figs. 2–6)

Material

Sample **46A**: About one hundred and thirty flattened, folded, fractured specimens.

Sample **133**: Four flattened, folded, fractured specimens.

Measurements

The fossils are poorly preserved and of no taxonomic value, therefore, only the vesicle lengths of some selected specimens illustrated on the plates are given for comparison purposes (see the plate descriptions).

Description and Discussion

Several individuals of the Ancyrochitininae indet. (see below) exhibiting only one remaining process show that formerly present appendages had been removed from the vesicles without leaving any trace. The chitinozoan assemblage of sample **46A** in turn yields numerous vesicles without appendages but with the same conical, spherical and ovoid chambers as in the "accumulative taxon" Ancyrochitininae indet. It may therefore be possible that they originally were members of this subfamily. On the other hand, some of these fossils, mainly those with spherical chambers, correspond also to the definition of *Sphaerochitina* Eisenack, 1955a, emend. Paris et al., 1999a. However, the micro-ornamentation of the vesicles (characteristic of many *Sphaerochitina* taxa) is often hardly visible as the fossils seem to have been exposed to erosional processes. The ovoid chambers in this assemblage again resemble those in *Lagenochitina* Eisenack, 1931, and some conical chambers with a damaged basal area are similar to *Cyathochitina* Eisenack, 1955b. Consequently, the poor preservation of the vesicles (broken necks; flattened, folded and broken chambers; removed/missing appendages; abraded wall surfaces) prevents reliable attribution of these chitinozoans to established species and/or genera or even subfamilies. Therefore, all these forms are united herein within the broad group Lagenochitinidae indet.

Lagenochitinidae with destroyed ornamentation has also been reported by Dufka (1992: 120) from the Prague Basin which he grouped as Lagenochitinidae indet.

The studied individuals are classified into three groups based on the shape of their chambers, comparable as to the groups A, B and C within the Ancyrochitininae indet. (see below). However, the overall shape of the vesicles varies considerably within the different groups as they probably originally belonged to different species.

> *Group A*
>
> Conical chamber with rounded basal margin; flat to slightly convex base; cylindrical neck; glabrous surface (smooth to finely granulated, rarely with tiny spines) (Pl. 11, Fig. 2). This group comprises 38 individuals.
>
> *Group B*
>
> Ovoid chamber with broadly rounded basal margin; convex base; cylindrical neck; glabrous surface (smooth to finely granulated or with tiny spines) (Pl. 11, Fig. 3). 18 individuals belong to this group.
>
> *Group C*
>
> Spherical chamber; cylindrical neck; wall surface finely granulated or with minute spines (Pl. 11, Fig. 4–6). 16 specimens are attributed to this group.

A further 61 specimens are too poorly preserved (fractured and/or folded) to attribute them to one of the above groups.

The shape of some of the members of Group C with spherical chambers and a relatively short cylindrical, slightly flaring neck (Pl. 11, Figs. 4, 6; sample **46A**) and also one specimen of Group B having a broadly ovoid chamber (Pl. 11, Fig. 3; sample **133**) resembles that of *Sphaerochitina solutidina* Paris, 1988b, originally described from a Late Aeronian–Early Telychian sequence from a well in northeastern Libya (Paris, 1988b: 78). The specimen from sample **133** (a single form with broken neck) moreover shows a dense coverage of tiny spines, while obviously abrasion affected the surfaces of the specimens from sample **46A**, leaving only scattered minute tubercles. This poor state of preservation prohibits a positive specific assignment of the cited fossils.

Like the Ancyrochitininae indet. (about 60 specimens; see below), members of the Lagenochitinidae indet. occur very frequently within sample **46A** (about 130 specimens) but are rare or absent within the other samples from the Kok Formation. Unfortunately, they all show poor preservation which makes them useless for taxonomical and stratigraphical purposes.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), representatives of the Lagenochitinidae indet. are recorded in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A**) = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*) and in *Bed 11A* (sample **133**): Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Subfamily ANCYROCHITININAE Paris, 1981

Ancyrochitininae indet.

(Pl. 10, Figs. 7–12; Pl. 11, Fig. 1)

Material

Sample **46A**: About sixty flattened, folded, fragmented specimens.

Sample **136**: One flattened, fragmented specimen.

Measurements

The fossils are poorly preserved and missing diagnostic features, and cannot be identified taxonomically. Therefore, only the vesicle lengths of some selected specimens which are illustrated on the plates are given for the purpose of comparison (see the descriptions of the plates).

Description and Discussion

A reliable taxonomic attribution of process-bearing chitinozoans requires – beside several other criteria – undamaged appendages. In the studied chitinozoan assemblages herein, however, most of the processes have been removed and only their basal parts or the traces of their insertion in the vesicle walls are preserved. Since they – due to their incomplete appendages – are comparable with several genera (*Ancyrochitina* EISENACK, 1955a, *Clathrochitina* EISENACK, 1959, *Plectochitina* CRAMER, 1964), individuals with only rudimentary processes are herein united within the "accumulative taxon" Ancyrochitininae indet., to which subfamily the above mentioned genera belong. In addition, a single specimen showing one complete simple process is also included. As a result of the poor preservation, the structure of the wall surface is generally difficult to describe.

Based on the shape of the chamber and the diameter of the remaining parts of the appendages, respectively, five different morphological groups have been distinguished (however, the overall shape of the vesicles varies considerably within the different groups, which probably originally represent different species):

> ***Group A***
> Conical chamber with broadly rounded basal margin; flat to slightly convex base; cylindrical, slightly flaring neck of variable length; smooth wall surface; proximal parts of the processes thin (Ø ~3.6 µm) (Pl. 10, Fig. 7). 31 individuals belong to this group.
>
> ***Group B***
> Ovoid chamber with broadly rounded basal margin; convex base; cylindrical neck; smooth wall surface; proximal parts of the processes thin (Ø ~4.5–6.8 µm) (Pl. 10, Figs. 8, 9). Moreover, the specimen on Plate 10, Figure 9 shows a short relic of an irregular nodular process such as in some *Plectochitina* taxa. This group comprises 13 individuals.
>
> ***Group C***
> Spherical chamber; cylindrical neck; smooth or granulate wall surface; proximal part of the process thin (Ø ~3.6 µm) (Pl. 11, Fig. 1). Six specimens have been found.
>
> ***Group D***
> Asymmetric conical chamber; slightly tapering neck; smooth wall surface; short unbranched conical processes (Pl. 10, Fig. 12). Only a single specimen available.
>
> ***Group E***
> Ovoid chamber with broadly rounded basal margin; slightly flaring neck; smooth wall surface; proximal part of the processes thick (Ø ~11–14 µm) (Pl. 10, Figs. 10, 11). Only two individuals available: one almost complete vesicle with a short relic of a thick process and one chamber fragment with a thick and relatively long remnant of an appendage. This type of process is similar to those observed in some taxa of *Plectochitina*.

12 specimens of the studied Ancyrochitininae indet. are too poorly preserved (fragmented and/or folded) to be attributed to one of the above morphogroups.

The members of the group Ancyrochitininae indet. occur in only two samples of the Kok Formation (**46A** and **136**; for the precise age see below). While in sample **136** only one specimen is present, they represent the second largest chitinozoan group in sample **46A**, with Lagenochitinidae indet., c. 130 specimens, being the most numerous chitinozoan group.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), representatives of Ancyrochitininae indet. are mainly present in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *Angochitina longicollis* chitinozoan biozone]; one individual is recorded in the middle part of the Kok Formation, Sheinwoodian in age [in *Bed 13* (sample **136**): *K. o. ortus* conodont biozone].

Genus Ancyrochitina EISENACK, 1955a

Ancyrochitina gr. *ancyrea* EISENACK, 1931

(Pl. 9, Figs. 5–7)

Material

Sample **46A**: Nine folded and flattened specimens; variably long part of the necks missing; on each specimen only very few processes preserved, of which the distal parts are usually broken off.

Description

Flattened and/or folded vesicles with a conical chamber and a cylindrical neck of which the aperturalmost part is generally missing. Basal margin broadly rounded, base (due to folding and flattening) convex to concave (invaginated); no basal structure visible. Flanks straight to convex, shoulder distinct or inconspicuous, flexure distinct. The basal margin is ornamented with tapering processes of varying length and width, showing only few branchings (three at the most, estimated from the thin distal parts of the processes which are usually broken off). The branchings may start at any point along the process length from relatively close to the process base outwards. Frequently only a single process is preserved, not allowing to count the number of the processes per vesicle. The vesicle wall is commonly smooth but in rare cases some small granulae are present on the chamber.

Measurements

None of the nine recovered specimens, which are flattened and/or folded, is completely preserved; in four of them, a relatively long part of the neck is still present. Their vesicle lengths have been measured to give an impression of their dimensions: L = >90–>135 µm. The length of the few remaining processes of which the outermost parts are missing vary between 17 and 31 µm.

Discussion

The studied vesicles are poorly preserved, particularly the processes have been severely damaged: the majority of them had been removed and the ones still present are in poor condition as they are all missing their outermost parts. Their vesicles are comparable to those of *A. ancyrea*. Also the branching of their processes up to the 2nd order (or 3rd order at the most, as in LAUFELD, 1974: Figs. 5C, E) is similar to that in *A. ancyrea*, however, the shape of the processes is different. Therefore these specimens are attributed herein to the *Ancyrochitina* group *ancyrea* sensu PARIS, 1981: 275, who stated that this group consists of individuals which differ in their outline, in the dimensions of their processes or in the potential ornamentation of their neck, and that on none of these individuals is the whole set of typical morphological features of *A. ancyrea* (as emended by Laufeld, 1974: 39) developed.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Ancyrochitina* gr. *ancyrea* is recorded in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

A.ancyrea is a geographically widespread taxon and – due to the broad emendation of the species by Eisenack (1955a: 163) – ranges in age from the Ordovician to the Devonian. However, under the restriction of Laufeld (1974: 39: branching only up to 2nd order) it became a species that is typical for and abundant throughout the Silurian [see remarks on the stratigraphical distribution of *A. ancyrea* in Paris (1981: 274); Nestor (1994: 60) and Butcher (2013: 86)].

Subfamily ANGOCHITININAE Paris, 1981

Genus Angochitina Eisenack, 1931

Angochitina longicollis Eisenack, 1959

(Pl. 9, Figs. 1–4)

Synonymy

2000 *Angochitina* sp. cf. *A. longicollis* Eisenack 1959. – Priewalder, Pl. 1, Fig. 9.

2001 *Angochitina longicollis* Eisenack, 1959. – Mullins & Loydell, p. 763, Pl. 2, Figs. 1–8, 12, 13 (***cum syn.***).

2002 *Angochitina longicollis* Eisenack. – Mullins & Loydell, Figs. 3r, 4a, e(?).

2002 *Angochitina longicollis* Eisenack, 1959. – Nestor et al., Pl. 1, Fig. 6.

2003 *Angochitina longicollis* Eisenack. – Loydell et al., Fig. 16x.

2003 *Angochitina longicollis*. – Vandenbroucke et al., Figs. 12h–j.

2004 *Angochitina longicollis* (Eisenack). – Mullins & Aldridge, Pl. 3, Figs. 3, 5.

?2005 *Angochitina longicollis* Eisenack 1959. – Grahn, Pl. 2, Fig. 11.

2005 *Angochitina longicollis* (Eisenack 1959). – Grahn et al., Pl. 2, Fig. 2.

2005 *Angochitina longicollis* Eisenack. – Loydell & Nestor, p. 374, Fig. 4d.

2005 *Angochitina longicollis* Eisenack 1959. – Nestor, Pl. 1, Fig. 7.

2010 *Angochitina longicollis* Eisenack. – Loydell et al., Fig. 13h.

2012 *Angochitina longicollis* Eisenack. – Nestor, Fig. 4K.

2013 *Angochitina longicollis*. – Vandenbroucke et al., Fig. 5F.

2015 *Angochitina longicollis* Eisenack. – Männik et al., Fig. 6H.

2015 *Angochitina longicollis* Eisenack. – Peng Tang et al., Figs. 3C–I.

Material

Sample **46A**: Six poorly preserved, flattened and folded specimens; in general, a part of the neck is missing with only one specimen showing almost complete preservation. Only traces of the ornamentation are usually observed, and one specimen shows clearly visible spines.

Sample **49**: One flattened specimen; part of the neck missing, bases of spines present.

Sample 133: Seven fragmented specimens: three-dimensionally preserved, slightly compressed or completely flattened; if at all, only the lowermost part of the neck is present; most of the ornamentation is abraded.

Description

Vesicle with a slender ovoid chamber and a long subcylindrical neck, which in only one specimen seems to be almost complete, showing a slight curvature; the position of the greatest diameter varies between the middle and the lower third of the chamber length; flanks convex, basal margin and base broadly rounded; distinct flexure, no shoulder. Generally, the ornamentation seems to be worn off, only single short spines or the bases of spines are visible; in one specimen, however, a few complete and flexible spines are preserved, some of them are birooted or have bifurcate endings; in several cases, the bases of the spines are connected by delicate ridges. Due to the poor preservation it is impossible to state whether the distribution of the spines was regular, i.e. in rows, or rather random.

Measurements

Only one almost complete, but flattened and folded vesicle available for measurement (Pl. 9, Fig. 1). The values of the flattened specimen have been corrected (as the intensity of flattening is different, the coefficient of correction is for Dp 0.85, for dc 0.7).

L = 205 µm

Lp = 108 µm [Lp of the 13 remaining chambers: 88–133 µm]

Dp = 63 µm [Dp of the 13 remaining chambers (without correction): 61–95 µm]

dc = 20 µm

Discussion

The representatives of *Angochitina longicollis* are poorly preserved: in samples **46A** and **49** they are flattened and folded, in sample **133** most of the specimens are 3-dimensionally preserved but considerably damaged. All are missing a variably long part of the neck and most of the ornamentation has been destroyed. Nevertheless, sufficient morphologic features are present to allow the vesicles to be attributed to the index species of the upper Telychian *Angochitina longicollis* chitinozoan biozone.

The characteristic outline of *A. longicollis*, i.e. the typical slender ovoid chamber and the long neck, which may be slightly curved (Mullins & Loydell, 2001: 763) (Pl. 9, Figs. 1, 2) is recognised in the studied fossils.

Furthermore, some of the preserved spines on the otherwise rather abraded surface of one vesicle (Pl. 9, Figs. 3, 4) show the λ-bases mentioned in Eisenack (1959: 13) and Nestor (1994: 51), bifurcate endings (Laufeld, 1974: 56; Nestor, 1994: 51) and delicate ridges connecting the spines (Laufeld, 1974: 56; Mullins & Loydell, 2001: 764). However, it is impossible to indicate whether the spines were regularly arranged in rows which is typical in *A. longicollis*, or randomly which also has been reported in this taxon (Mullins & Loydell, 2001: 764).

In addition, the dimensions of the fossils studied herein are comparable with the values reported by several authors (Eisenack, 1959: 13; Mullins & Loydell, 2001: 764).

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Angochitina longicollis* is recorded in the lower part of the Kok Formation, Telychian in age [i.e., in the basalmost part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*); in *Bed 10F* (sample **49**) and in *Bed 11A* (sample **133**): *P. celloni* conodont superzone/*P. a. angulatus* conodont biozone–Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Occurrences of *A. longicollis* outside the Cellon section (for the geographical and stratigraphical distribution of *A. longicollis* in publications issued before the year 2000 see in Mullins & Loydell, 2001: 764):

- *Wales* (Banwy River section) [Mullins & Loydell, ***2001*** (p. 764, Text-Figs. 1, 7)]: upper Telychian–lower Sheinwoodian [Tarannon Shales Formation, Nant-ysgollon Shales Formation (*A. longicollis, C. acuminata, M. banwyensis, M. margaritana, C. bouniensis, S. bella* chitinozoan biozones = upper *O. spiralis*–*M. riccartonensis* graptolite biozone)].
- *Wales* (Buttington Brick Pit) [Mullins & Loydell, ***2002*** (Fig. 2)]: upper Llandovery–lower Wenlock [Tarannon Shales Formation, Trewern Brook Mudstone Formation (*A. longicollis*–*M. margaritana* chitinozoan biozone = middle or probably upper *O. spiralis*–*C. murchisoni* graptolite biozone)].
- *Northwest Gotland* (Ireviken 3 section) [Nestor et al., ***2002*** (Fig. 1)]: uppermost Telychian–lowermost Sheinwoodian [Lower Visby–lower Upper Visby formations].
- *Belgium* (Brabant Massif, Ronquières-Monstreux area) [Verniers et al., ***2002*** (p. 299; Fig. 3)]: lower Sheinwoodian [Top Corry Formation–base Petit Roeul Formation (global *M. margaritana* chitinozoan biozone)].
- *Latvia* (Aizpute-41 core) [Loydell et al., ***2003*** (Figs. 15, 17)]: upper Telychian–lower Sheinwoodian [Jurmala Formation (base *A. longicollis*–top *M. margaritana* chitinozoan biozone = base *O. spiralis*–top *C. murchisoni* graptolite biozone = upper *P. a. angulatus*–lower Upper *P. p. procerus* conodont biozone)].
- *Scotland* (Girvan area) [Vandenbroucke et al., ***2003*** (Tab. 2; Fig. 8)]: Telychian [Lauchlan Formation, Drumyork Flags (*A. longicollis* chitinozoan biozone = lower *O. spiralis* graptolite biozone)].
- *Shropshire* (Hughley Brook = Leasows section) [Mullins & Aldridge, ***2004*** (p. 749; Text-Fig. 2)]: upper Telychian–lower Sheinwoodian [upper Purple Shales Formation–Buildwas Formation (upper *M. margaritana*–top *S. bella* chitinozoan biozone)].
- *Northern Brazil* (Amazonas Basin) [Grahn, ***2005*** (Fig. 12)]: latest Aeronian–Early Sheinwoodian [upper Lower Pitinga Formation].
- *Northeast Brazil* (Parnaíba Basin) [Grahn et al., ***2005*** (Figs. 1–3)]: late Aeronian-early Telychian [Tianguá Formation].
- *Latvia* (Ventspils D-3 core) [Loydell & Nestor, ***2005*** (Fig. 3)]: Telychian [*A. longicollis*–*C. proboscifera* chitinozoan biozone = lower *O. spiralis*–*C. lapworthi* graptolite biozone].
- *West Estonia* (Viki, Kaugatuma, Ohesaare, Ruhnu cores) [Nestor, ***2005*** (Figs. 2–5)]: Adavere Stage, Jaani Stage [Velise Formation, Jaani Formation, Riga Formation (*C. proboscifera, C. acuminata, M. banwyensis, M. margaritana* chitinozoan biozones and in the succeeding Interzone)].
- *Western Gondwana* (Amazon Basin, Parnaíba Basin) [Grahn, ***2006*** (Figs. 6, 9)]: upper Aeronian–lower Sheinwoodian [Lower Pitinga Formation, Tianguá Formation (*P. djalmai*–*M. margaritana*–*S. monterrosae* chitinozoan biozone)].
- *Western Estonia* (Viirelaid core) [Rubel et al., ***2007*** (Figs. 3, 5)]: Adavere Stage–lower Jaani Stage [Velise Formation–lower Mustjala Member of the Jaani Formation (*A. longicollis*, *C. proboscifera*, *C. acuminata*, *M. banwyensis*, *M. margaritana* chitinozoan biozones = Lower *P. a. angulatus*–Upper *P. a. amorphognathoides* conodont biozone)].
- *Estonia, Latvia* (Aizpute, Ohesaare, Ruhnu, Viki cores) [Kiipli et al., ***2010*** (Figs. 4, 5)]: upper Telychian–lower Sheinwoodian [Velise Formation, Jaani Formation (basal *A. longicollis*–top *M. margaritana* chitinozoan biozone = basal *O. spiralis*–*C. murchisoni* graptolite biozone = upper *P. a. angulatus*–*P. procerus* conodont biozone)].
- *Latvia* (Kolka-54 core) [Loydell et al., ***2010*** (Figs. 10, 16)]: Adavere Stage–basal Jaani Stage = Telychian–lower Sheinwoodian [*A. longicollis*, *C. proboscifera, C. acuminata, M. margaritana* chitinozoan biozones = basal *O. spiralis*–*C. murchisoni* graptolite biozone = upper *P. a. angulatus*–?basal *P. p. procerus* conodont biozone].
- *Gotland/Sweden* (När drill core), *Latvia* (Ventspils-D3 and Aizpute-41 drill cores) [Kiipli et al., ***2012*** (Fig. 2)]: FAD of *A. longicollis* and *O. spiralis* are at approximately the same level in the upper Telychian.
- *East Baltic* [Nestor, ***2012*** (Figs. 2, 3)]: upper Adavere–lower Jaani Stage = upper Telychian–lower Sheinwoodian [upper Jurmala–lower Riga Formation = upper Velise–lower Riga Formation (base *A. longicollis*, *C. proboscifera*, *C. acuminata* to top *M. margaritana* East Baltic chitinozoan biozones = base *A. longicollis*–lower *M. margaritana* global chitinozoan biozone = *O. spiralis*–*C. murchisoni* graptolite biozone)].
- *Gotland/Sweden* (Grötlingbo-1 core section) [Männik et al., ***2015*** (Figs. 3, 4, 9, 11)]: Telychian–lowermost Sheinwoodian (*A. longicollis*–*M. margaritana* chitinozoan biozone = *O. spiralis*–*C. murchisoni* graptolite biozone = *P. a. angulatus*–*P. p. procerus* conodont biozone).
- *Shaanxi Province, NW China* (Bajiaokou A, B sections) [Peng Tang et al., ***2015*** (Figs. 2, 7)]: late Llandovery–early Sheinwoodian [Wuxiahe Formation (upper *O. spiralis*–lower *C. murchisoni* graptolite biozone = upper *P. celloni*–lower *P. p. procerus* conodont biozone)].

Subfamily CYATHOCHITININAE Paris, 1981

Genus Cyathochitina Eisenack, 1955b, emend. Paris et al., 1999a

Cyathochitina sp.

(Pl. 8, Figs. 9, 12)

Synonymy

1999 *Cyathochitina caputoi* Da Costa 1971a. – Priewalder, Fig. 5.

Material

Sample **46A**: Two flattened, partly broken specimens, part of the necks absent.

Description

Small *Cyathochitina*-vesicle with a conical to slightly bell-shaped chamber and a cylindrical neck. Flanks slightly convex to slightly concave, tapering rapidly towards the base of the neck; basal margin provided with a relatively wide (13–14 µm) rigid carina; structure of the base not visible as the specimens are either completely compressed with partly destroyed basal margin, or resting on the basal plane. Flexure distinct, shoulder not or faintly developed; apertural part not preserved. At low magnification the vesicles appear to be smooth, however, in places there are delicate remains of irregular granules on the chamber and on the neck.

Measurements

Only two flattened, distorted specimens are available for measurement (Pl. 8, Figs. 9, 12), of which an undefined part of the neck is missing: the actual vesicle length therefore cannot be determined. No coefficient of correction has been applied to the values below.

L = >128–>146 µm

Lp = 83–95 µm

Dp = 90–99 µm

dc = 38 µm

Discussion

The two representatives of *Cyathochitina* sp. are poorly preserved: flattened, broken and distorted, therefore they are retained in open nomenclature. Their outline and especially their relatively wide carina (13–14 µm), however, resemble *Cyathochitina kuckersiana* (Eisenack, 1934), a mainly Ordovician species but which also has been reported from the lower Silurian, e.g., ranging up into the *C. lapworthi* graptolite biozone (late Telychian) of the Banwy River section in Wales (Mullins & Loydell, 2001: Fig. 7). In contrast to *C. kuckersiana*, the specimens described herein are rather small and do not show the conspicuous ornamentation (longitudinal and/or concentric ribbing) on the neck and chamber, frequently reported in *C. kuckersiana*. However, the intraspecific variation within the latter species concerning its dimensions, outline and ornamentation is considerable as has been emphasised by several authors (e.g., Wrona et al., 2001: 324; Butcher, 2009: 612; 2013: 79). A similar and also highly variable species that also ranges from the Middle Ordovician into the lower Silurian is *Cyathochitina campanulaeformis* (Eisenack, 1931) (see Butcher, 2009: 611). The latter is characterised by a narrow carina that thus distinguishes it from *Cyathochitina* sp.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Cyathochitina* sp. is recorded in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Subfamily LAGENOCHITININAE Paris, 1981

Genus Lagenochitina Eisenack, 1931, emend. Paris et al., 1999a

Lagenochitina sp. 1

(Pl. 10, Figs. 4, 5)

Material

Sample **46A**: Two flattened, folded and fractured specimens.

Sample **132**: Two three-dimensionally preserved specimens, part of the necks absent.

Description

Tear-shaped vesicles with an ovoid chamber, gradually merging into the neck which tapers towards the aperture; fragments of a thin-walled slightly flaring collarette present. Flexure and shoulder are slightly developed, the flanks are convex and extend into a broadly rounded basal margin; the base is convex, no basal structure visible; the greatest diameter lies between the middle and the lower third of the chamber length. The wall surface is glabrous.

Measurements

Only one (three-dimensional) specimen is almost completely preserved and suitable for measurement; the apertural area, however, was destroyed.

L = >143 µm

Dp = 69 µm

Lp = 90 µm

dc = 43 µm (proximal part)

dc = 27 µm (distal part)

Discussion

The few specimens of *Lagenochitina* sp. 1 are poorly preserved, particularly those from sample **46A**: they are flattened and broken and missing part of the chamber and/or the neck. They show some similarities to a remarkable, but also poorly preserved single specimen studied herein, *Lagenochitina* sp. (Pl. 10, Fig. 6), which, however, is characterised by a long asymmetrical chamber (possibly caused by deforming processes during lithification), a short cylindrical neck and a relatively long flaring collarette.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Lagenochitina* sp. 1 is recorded in the lower part of the Kok Formation, Telychian in age [i.e., in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*) and just above *Bed 10J* (sample **132**): lowermost *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Genus Sphaerochitina EISENACK, 1955a, emend. PARIS et al., 1999a

Sphaerochitina sp. 1

(Pl. 9, Figs. 8–10)

Material

Sample **46A**: Six specimens with folded and flattened chambers and flattened necks; part of the necks absent.

Description

Flattened and folded vesicles with an approximately spherical chamber and a long, wide, cylindrical, slightly flaring neck of which the distal part is missing; the neck is rather long and exceeds the chamber length by far; its diameter is a little more than 50 % of the chamber diameter. The flanks and base of the chamber are convex, the basal margin is broadly rounded; no basal structure visible; the greatest diameter is located at a point about half-way along the chamber length; the flexure is distinct, the shoulder absent or inconspicuous. The wall surfaces seem to be abraded but here and there the original ornamentation of tiny spines is still visible.

Measurements

Three specimens with folded and flattened chambers and flattened necks, of which the uppermost parts are missing. Due to the complex folding of the chambers, no correction of the values of the flattened specimens has been carried out.

L = >158–>176 µm
Lp = 59–81 µm
Dp = 72–81 µm
dc = 40–42 µm

Discussion

Sphaerochitina sp. 1 is characterised by a wide and long neck and – in relation to the latter feature – a small sub-spherical chamber. Presumably it represents a new species, however, the low number of individuals and their poor preservation do not support the creation of a new taxon herein.

A roughly similar taxon is *Euconochitina* sp. 2 sensu NESTOR, 1994?, but it is smaller in dimension and has a subconical chamber.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Sphaerochitina* sp. 1 is recorded in the basal part of the Kok Formation, Telychian in age [in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*): global *A. longicollis* chitinozoan biozone].

Sphaerochitina sp. 2

(Pl. 10, Figs. 1–3)

Material

Sample **46A**: Seven flattened and partly folded vesicles of which part of the chambers and necks are absent.

Sample **133**: One flattened vesicle, apertural part of the neck absent.

Description

Flattened vesicles with pear-shaped chamber and cylindrical neck that flares slightly towards the aperture, which has not been preserved in any of the fossils studied herein. Flanks straight or slightly concave, merging into the broadly rounded basal margin; greatest diameter at about the lowermost third of the chamber length; base slightly convex, no basal structure visible; flexure slightly developed as the chamber tapers gradually towards the neck; no shoulder present. Wall surface glabrous: it becomes apparent only at higher magnification that the vesicle is densely covered with minute tubercles showing decreasing density towards the aperture; at the transition from the chamber to the neck the basal parts of a few larger spines are visible.

Measurements

Only one specimen (Pl. 10, Fig. 1) is almost completely preserved, however, in the latter the distal part of the neck was also missing. The values of the flattened vesicle have been corrected (coefficient of correction for Dp and dc = 0.7).

L = >168 µm
Lp = 104 µm
Dp = 54 µm
dc = 22 µm

Discussion

Except for the single specimen from sample **133**, the members of *Sphaerochitina* sp. 2, all from sample **46A**, are poorly preserved: flattened and/or folded and fractured; most of their minute tubercles have been abraded, as well as the larger spines at the transition from the chamber to the neck. However, the typical shape of the vesicle is still present.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Sphaerochitina* sp. 2 is recorded in the lower part of the Kok Formation, Telychian in age [i.e., in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*) and in *Bed 11A* (sample ***133***): Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

Sphaerochitina spp.

(Pl. 9, Figs. 11, 12)

Material

Sample **46A**: One single specimen, flattened and deformed.

Sample **133**: One single specimen, flattened and fractured.

Description and discussion

The two single specimens available for study are both related to *Sphaerochitina* Eisenack, 1955a, but are different from all other studied members of this genus; each of the specimens is characterised by a remarkable morphology. However, as their preservation is poor and as only one specimen per taxon is available, only a short description is given below.

Sphaerochitina sp. A (Pl. 9, Fig. 11):

Small flattened vesicle with a deformed conical chamber and a broad cylindrical neck which is terminated by a crenulate aperture. The wall surface is covered by minute spines (L <1 µm), most of them, however, seem to have been abraded.
Measurements (flattening not corrected): L = 106 µm; Dp = 80 µm; lc = 52 µm; dc = 41 µm.

Sphaerochitina sp. B (Pl. 9, Fig. 12):

Flattened vesicle with a pear-shaped chamber: broadly rounded basal margin merging into a semi-circular base; straight flanks rapidly tapering towards the neck which, however, is broken off; the wall surface is densely covered with minute tubercles (L ~1 µm).
Measurements: L = 122 µm.

Geographical and stratigraphical distribution

In the Cellon section (Text-Fig. 2, Tab. 2), *Sphaerochitina* spp. are recorded in the lower part of the Kok Formation, Telychian in age [i.e., in the basal part of *Bed 9* (sample **46A** = c. 95 cm below the first documented occurrence of *P. celloni*) (no conodont data available for *Bed 9*) and in *Bed 11A* (sample **133**): Lower *P. a. amorphognathoides* conodont biozone; global *A. longicollis* chitinozoan biozone].

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Plate 1

Chitinozoans from the Plöcken Formation (Hirnantian, Upper Ordovician).
Samples **128**, **129**: *M. persculptus* graptolite biozone.

Figs. 1–6: *Armoricochitina nigerica* (Bouché, 1965)

Fig. 1: Flattened specimen with short carina; L = 135 µm (x 400); slide 2020/002/0020; Englandfinder (EF): O69-1; sample **128**.

Fig. 2: Close-up of the lower part of the vesicle in Figure 1, showing the short carina and the granulation of the vesicle wall (x 500).

Fig. 3: Three-dimensional vesicle with almost completely removed carina; L = 125 µm (x 400); slide 2020/002/0022; EF: R61-1; sample **128**.

Fig. 4: Oblique view of the base of the vesicle in Figure 3 showing the remains of the carina and a shallow apical pit (x 700).

Fig. 5: Flattened specimen missing the collarette; carina partially fractured; L = 119 µm (x 450); slide 2020/002/0024; EF: N60-1; sample **128**.

Fig. 6: Close-up of the fragments of the carina in Figure 5 (x 500).

Fig. 7: *Desmochitina minor* Eisenack, 1931

Three-dimensional vesicle with partly removed collarette; L = 86 µm (x 500); slide 2020/002/0027; EF: O58; sample **129**.

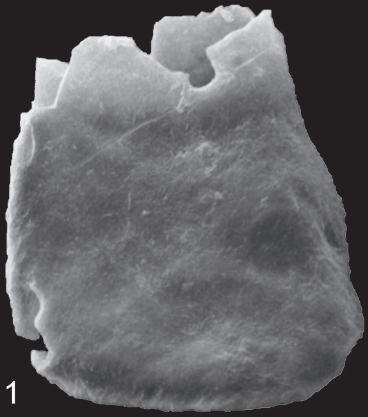
Figs. 8–11: *Tanuchitina elongata* (Bouché, 1965)

Fig. 8: Broken vesicle, showing the remains of a short carina; L = 207 µm (x 300); slide 2020/002/0020; EF: P63-2; sample **128**.

Fig. 9: Close-up of the partly removed carina in Figure 8; base showing crystal imprints (x 800).

Fig. 10: Broken vesicle, showing the rudiment of a carina beneath the basal margin; L = 216 µm (x 300); slide 2020/002/0025; EF: L64-2; sample **129**.

Fig. 11: Vesicle with short carina beneath the basal margin; L = 329 µm (x 300); slide 2020/002/0022; EF: S64-3; sample **128**.



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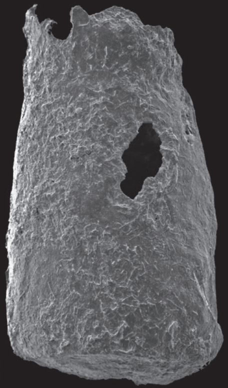

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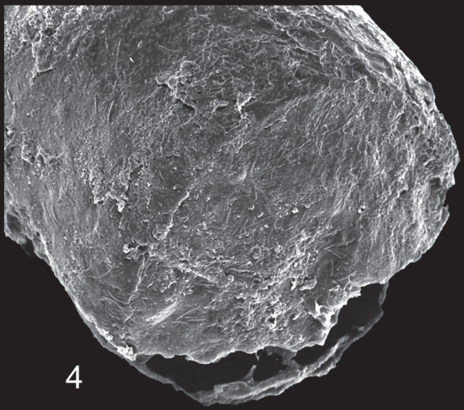

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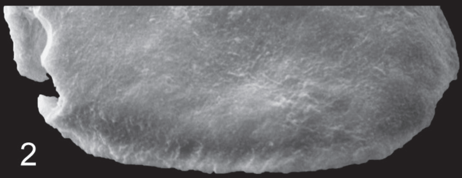

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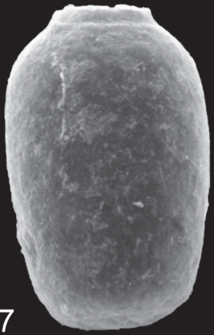

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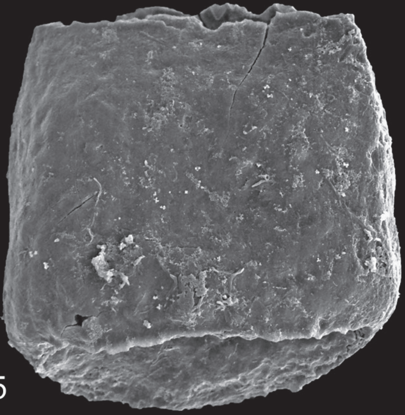

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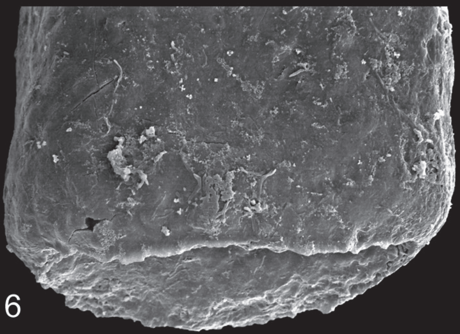

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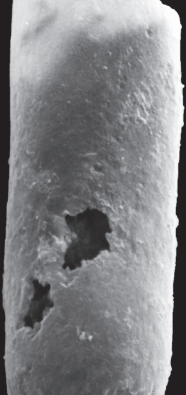

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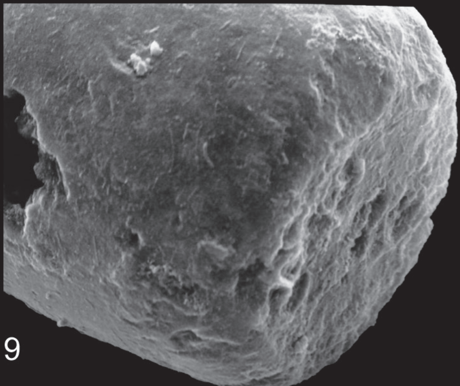

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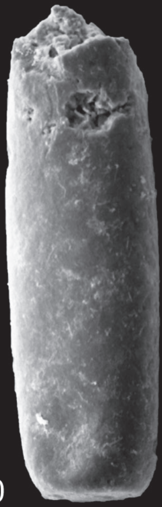

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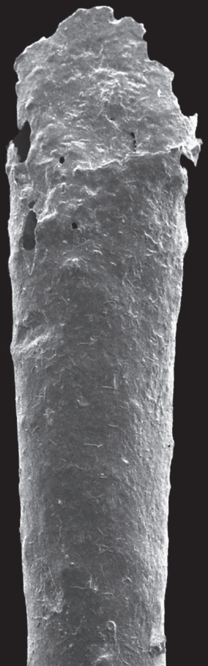


11

Plate 2

Chitinozoans from the Plöcken Formation (Hirnantian, Upper Ordovician).
Samples **126**, **128**, **129**: *M. persculptus* graptolite biozone.

Figs. 1, 2, 5: *Rhabdochitina* cf. *gracilis* Eisenack, 1962

Fig. 1: Specimen missing the upper part of the vesicle; L = 356 µm (x 300); slide 2020/002/0020; Englandfinder (EF): N61; sample **128**.
Fig. 2: Specimen missing the upper part of the vesicle; L = 293 µm (x 300); slide 2020/002/0021; EF: O61; sample **128**.
Fig. 5: View of the base of the vesicle in Figure 1 with small apical pit (x 670).

Figs. 3, 4, 6, 7: *Conochitina* sp. 1

Fig. 3: Broken specimen, missing most of the vesicle; L = 153 µm (x 350); slide 2020/002/0021; EF: M63; sample **128**.
Fig. 4: View of the vesicle base of Figure 3: a low narrow rim surrounds the apical pit (x 570).
Fig. 6: Close-up of the antiapertural part of the vesicle in Figure 7 (x 580).
Fig. 7: Broken specimen, missing the distal part of the vesicle; L = 286 µm (x 300); slide 2020/002/0026; EF: P61-1; sample **129**.

Figs. 8, 11, 12: *Conochitina* sp. 2

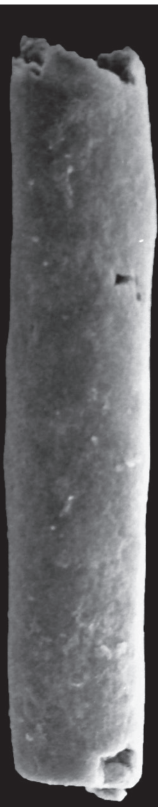
Fig. 8: Broken specimen, missing the distal part of the vesicle; L = 240 µm (x 300); slide 2020/002/0020; EF: O61-4; sample **128**.
Fig. 11: Broken and partly flattened vesicle; L = 214 µm (x 300); slide 2020/002/0025; EF: L64-4; sample **129**.
Fig. 12: View of the base of Figure 8 with distinct apical pit; showing inside framboidal pyrite (x 770).

Fig. 9: *Conochitina* sp. 3

Partly broken specimen, showing a gentle constriction above the basal margin; L = 168 µm (x 300); slide 2020/002/0023; EF: Q65-1; sample **128**.

Fig. 10: *Euconochitina*? sp.

Almost complete flattened vesicle; L = 239 µm (x 300); slide 2020/002/0019; EF: M61-1; sample **126**.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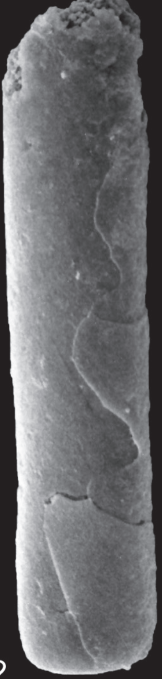
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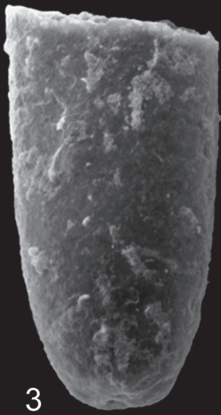
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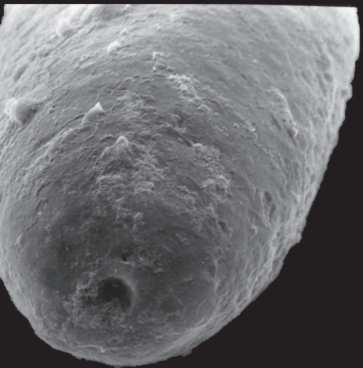
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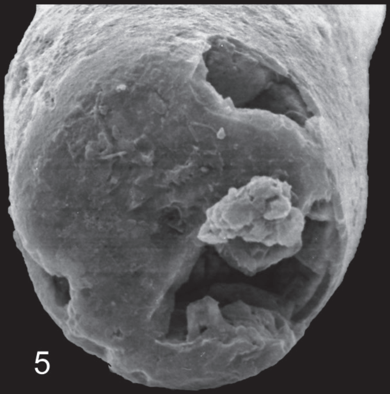
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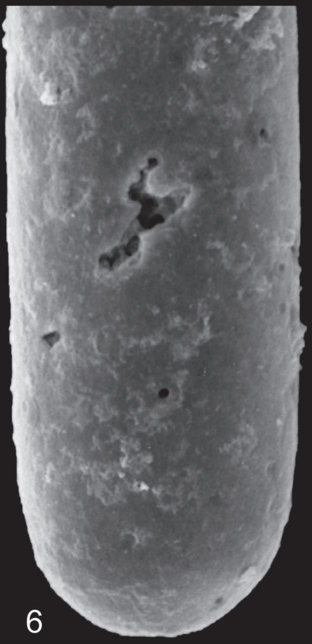
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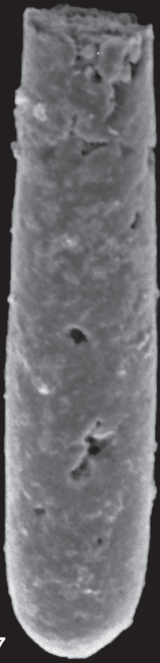
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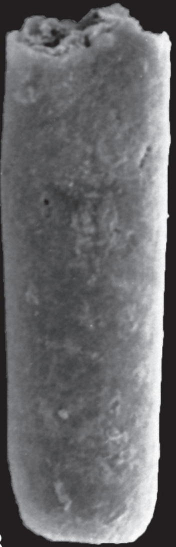
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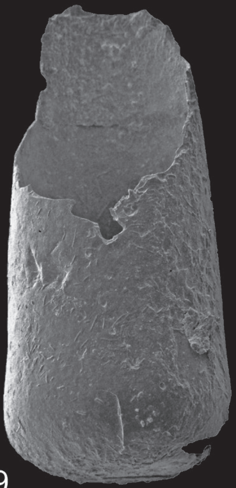
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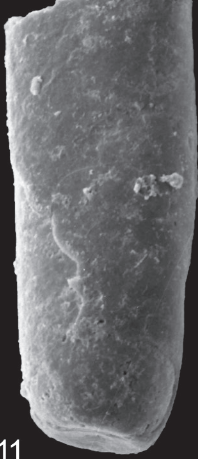
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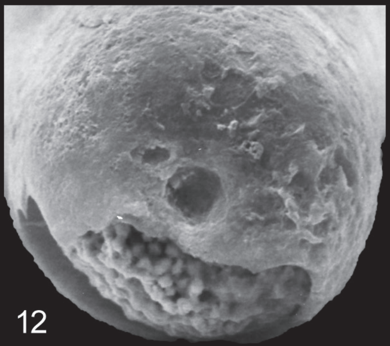
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Plate 3

Chitinozoans from the Plöcken Formation (Hirnantian, Upper Ordovician) (Figs. 5–12) and the lower part of the Kok Formation (Telychian, Llandovery) (Figs. 1–4).

Samples **128**, **129**: *M. persculptus* graptolite biozone; sample **130**: c. 25 cm below the first documented occurrence of *P. celloni*.

Figs. 1–4: *Conochitina* sp. 2

Fig. 1: Possibly reworked specimen missing the apertural part of the vesicle; L = 170 µm (x 300); slide 2020/002/0030; Englandfinder (EF): O61-3; sample **130**.

Fig. 2: View of the vesicle base with distinct apical pit of Figure 1 (x 410).

Fig. 3: View of the vesicle base of Figure 4 with distinct apical pit (x 560).

Fig. 4: Possibly reworked specimen missing the apertural part of the vesicle; L = 173 µm (x 300); slide 2020/002/0030; EF: Q61; sample **130**.

Figs. 5, 6: *Conochitina* ? sp.

Fig. 5: Broken specimen showing a gentle widening in the lowermost part of the vesicle and a shallow apical pit on the base; L = 176 µm (x 300); slide 2020/002/0025; EF: K64-4; sample **129**.

Fig. 6: Close-up of the base of Figure 5 with relics of a thin wall layer (x 570).

Figs. 7, 8: *Conochitina* sp. 4

Fig. 7: Broken vesicle showing convex base with low mucron; L = 142 µm (x 350); slide 2020/002/0028; EF: K65; sample **129**.

Fig. 8: Oblique view of the base of Figure 7 with distinct mucron (x 630).

Figs. 9, 12: *Spinachitina* sp.

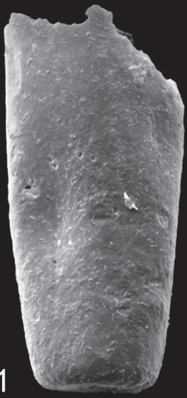
Fig. 9: Almost complete vesicle with scars and basal parts of detached processes; L = 126 µm (x 400); slide 2020/002/0026; EF: L62-3; sample **129**.

Fig. 12: Close-up of the basal margin of Figure 9 with the scars and basal parts of the former processes (x 730).

Figs. 10, 11: *Euconochitina* sp.

Fig. 10: Almost complete vesicle; the small holes on the basal margin are imprints of crystals; L = 216 µm (x 300); slide 2020/002/0020; EF: O66; sample **128**.

Fig. 11: Close-up of the basal margin of Figure 10 showing the imprints of crystals (x 620).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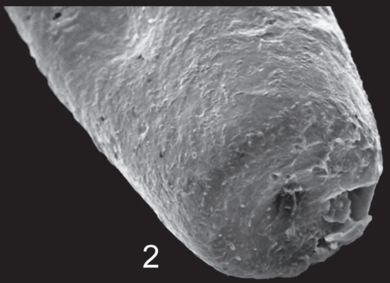
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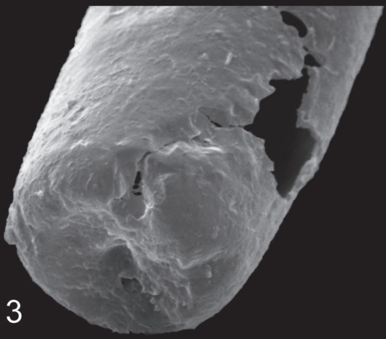
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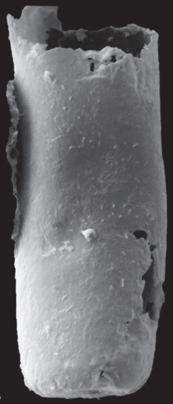
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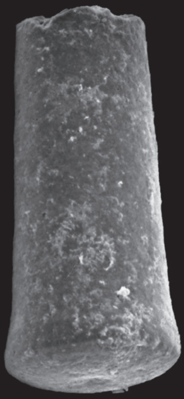
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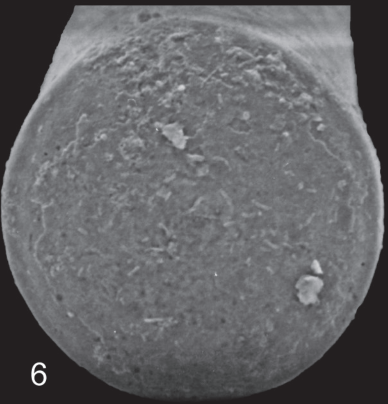
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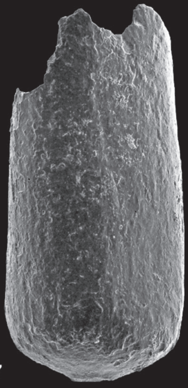
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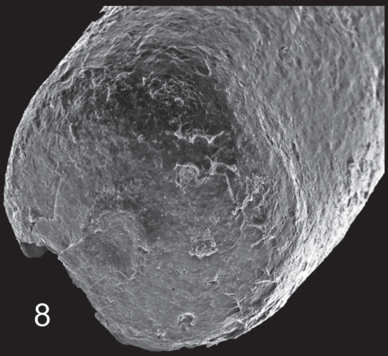
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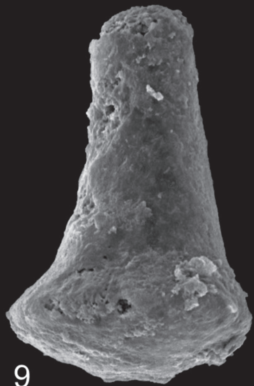
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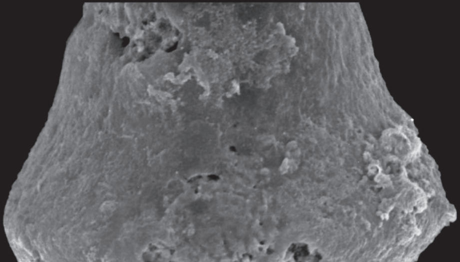
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Plate 4

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **47**: c. 30 cm below the first documented occurrence of *P. celloni*; sample **130**: c. 25 cm below the first documented occurrence of *P. celloni*; sample **56**: *K. o. ortus* conodont biozone.

Figs. 1–5: *Bursachitina conica* (Taugourdeau & de Jekhowsky, 1964)

Fig. 1: Sub-cylindrical vesicle; L = 189 µm (x 300); slide 2020/002/0005; Englandfinder (EF): N58-4; sample **46A**.

Fig. 2: Short conical vesicle; L = 122 µm (x 400); slide 2020/002/0012; EF: M60; sample **47**.

Fig. 3: Long sub-cylindrical vesicle; L = 241 µm (x 300); slide 2020/002/0014; EF: K59-2; sample **47**.

Fig. 4: Deformed conical vesicle; L = 155 µm (x 350); slide 2020/002/0013; EF: J62; sample **47**.

Fig. 5: Close-up of the operculum in Figure 4 (x 690).

Fig. 6: *Bursachitina* sp.

Flattened conical vesicle; L = 176 µm (x 300); slide 2020/002/0018 (vesicle lost); sample **56**.

Figs. 7, 9: *Eisenackitina dolioliformis* Umnova, 1976

Fig. 7: Stout conical vesicle with less pronounced granulation; L = 182 µm (x 300); slide 2020/002/0005; EF: G60-3; sample **46A**.

Fig. 9: Long slim vesicle exhibiting the typical ornamentation; L = 270 µm (x 300); slide 2020/002/0005; EF: N64; sample **46A**.

Fig. 8: *Calpichitina* ? sp.

Antiapertural pole of a lenticular smooth specimen; no basal structure visible; Ø = 88 µm (x 500); slide 2020/002/0030; EF: P60-1; sample **130**.

Figs. 10, 11: *Eisenackitina causiata* Verniers, 1999

Fig. 10: Flattened specimen with typical ornamentation; L = 185 µm (x 300); slide 2020/002/0005; EF: L60-3; sample **46A**.

Fig. 11: Specimen with wrinkled appearance of the vesicle surface; L = 160 µm (x 300); slide 2020/002/0008; EF: K67; sample **46A**.

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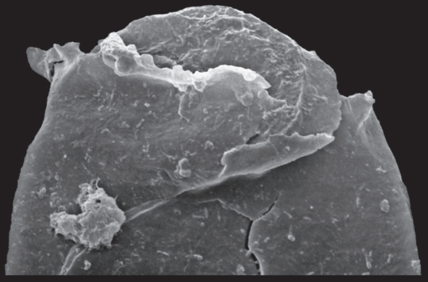

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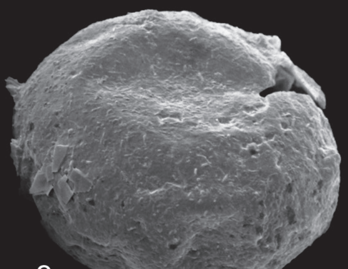

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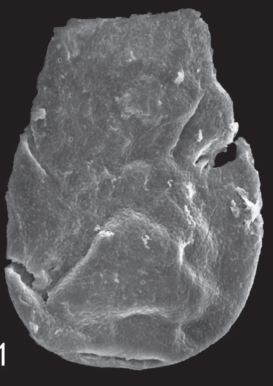

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Plate 5

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **132**: lowermost *P. a. amorphognathoides* conodont biozone; sample **133**: Lower *P. a. amorphognathoides* conodont biozone.

Figs. 1, 2, 4: *Eisenackitina dolioliformis* Umnova, 1976

Fig. 1: Completely preserved slender-conical specimen; L = 223 µm (x 300); slide 2020/002/0008; Englandfinder (EF): R63; sample **46A**.

Fig. 2: Close-up of Figure 1, showing the antiapertural part of the vesicle covered with coarse granulae (x 600).

Fig. 4: Close-up of Figure 1, showing the apertural part of the vesicle with considerably finer granulation and crenulate collarette (x 680).

Figs. 3, 6: *Eisenackitina* cf. *inanulifera* Nestor, 2005

Fig. 3: Flattened vesicle with damaged apertural part; L = 212 µm (x 300); slide 2020/002/0005; EF: J57-4; sample **46A**.

Fig. 6: Almost complete flattened vesicle; L = 164 µm (x 300); slide 2020/002/0010; EF: L60-4; sample **46A**.

Figs. 5, 9: *Eisenackitina* sp. 1

Fig. 5: Deformed vesicle; L = 162 µm (= x 300); slide 2020/002/0039; EF: O64-3; sample **133**.

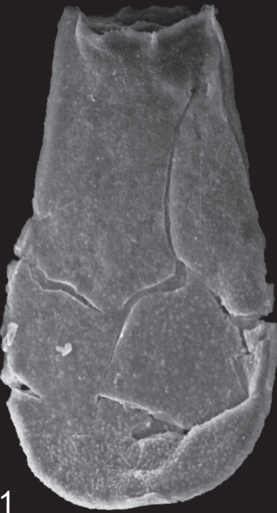
Fig. 9: Almost complete vesicle; L = 140 µm (x 350); slide 2020/002/0033; EF: P62-1; sample **132**.

Figs. 7, 8, 10: *Eisenackitina* sp. 2

Fig. 7: Almost complete flattened vesicle; L = 225 µm (x 300); slide 2020/002/0009; EF: L69; sample **46A**.

Fig. 8: Close-up of Figure 7, showing the antiapertural part of the vesicle with dense ornamentation around the basal margin (x 460).

Fig. 10: Oblique view of the aperture of Figure 7, showing the protruding operculum (x 650).



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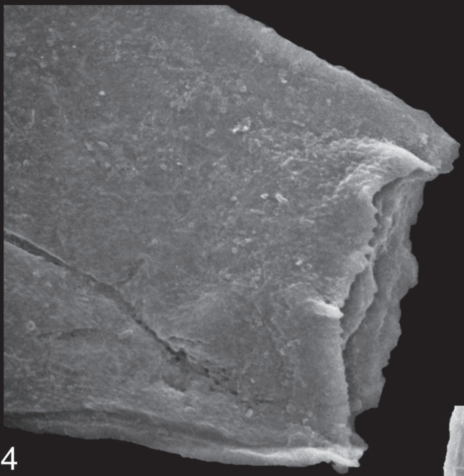

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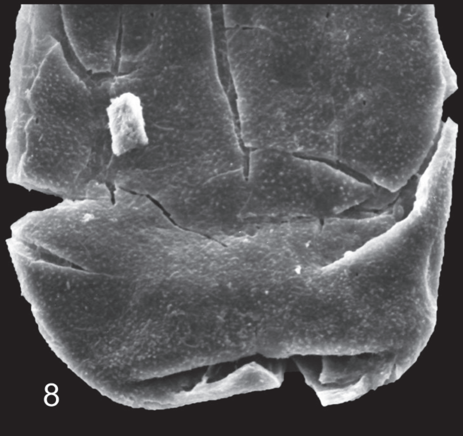

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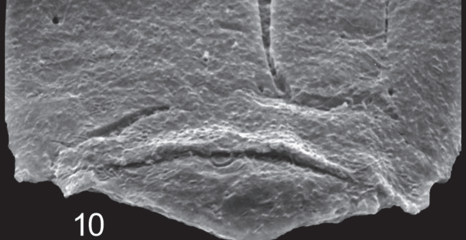

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Plate 6

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **50**: Upper (?) *P. a. angulatus* conodont biozone; sample **132**: lowermost *P. a. amorphognathoides* conodont biozone.

Figs. 1–3: *Eisenackitina* sp. 2

Fig. 1: Complete flattened vesicle; L = 202 µm (x 300); slide 2020/002/0006; Englandfinder (EF): K62-3; sample **46A**.

Fig. 2: Close-up of Figure 1: antiapertural part of the vesicle showing the great density of tiny granulae around the basal margin (x 520).

Fig. 3: Close-up of Figure 1: apertural part of the vesicle where the ornamentation is less dense (x 620).

Figs. 4–7, 11: *Conochitina* cf. *armillata* TAUGOURDEAU & JEKHOWSKY, 1960

Fig. 4: Oblique view of the specimen in Figure 5 showing the different degree of vesicle flattening and the membranous mucron (x 720).

Fig. 5: Slender flattened specimen showing a low and delicate mucron; L = 288 µm (x 300); slide 2020/002/0033; EF: O62-1; sample **132**.

Fig. 6: Questionable specimen with larger diameter and invaginated base; L = 253 µm (x 300); slide 2020/002/0036; EF: P64; sample **132**.

Fig. 7: Close up of the mucron in Figure 6 (x 480).

Fig. 11: Slender slightly flattened specimen; L = 213 µm (x 300); slide 2020/002/0034; EF: L64-2; sample **132**.

Figs. 8–10: *Conochitina* cf. *iklaensis* NESTOR, 1980b

Fig. 8: Specimen missing the apertural part; L = 311 µm (x 300); slide 2020/002/0032; EF: N59-3; sample **132**.

Fig. 9: Specimen missing the apertural part; L = 311 µm (x 300); slide 2020/002/0016; EF: N62-2; sample **50**.

Fig. 10: Oblique view of the base of Figure 9, lacking a mucron (x 600).

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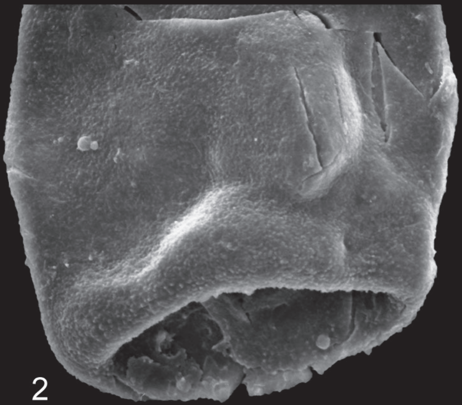

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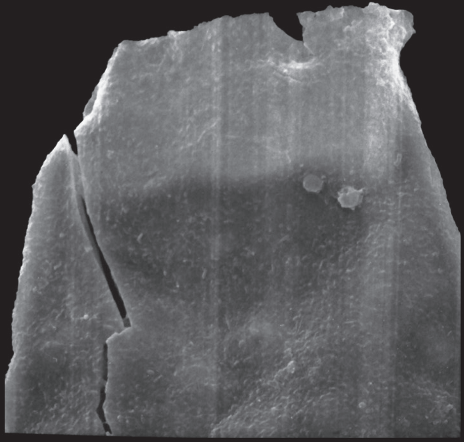

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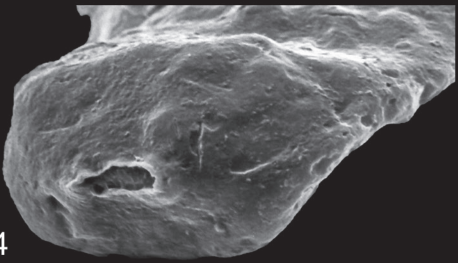

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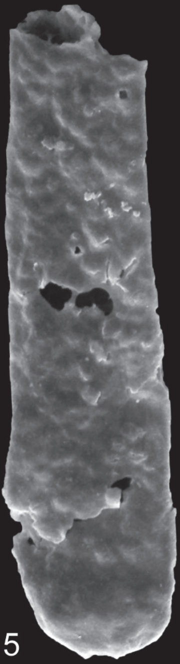

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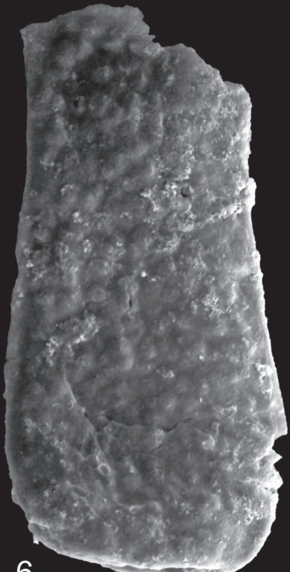

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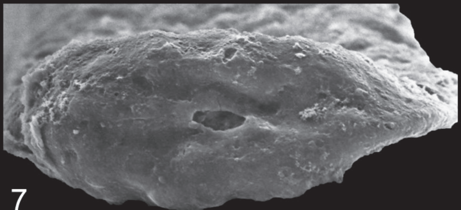

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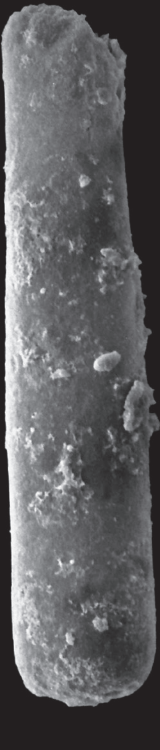

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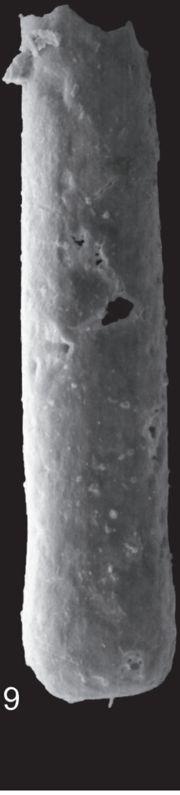

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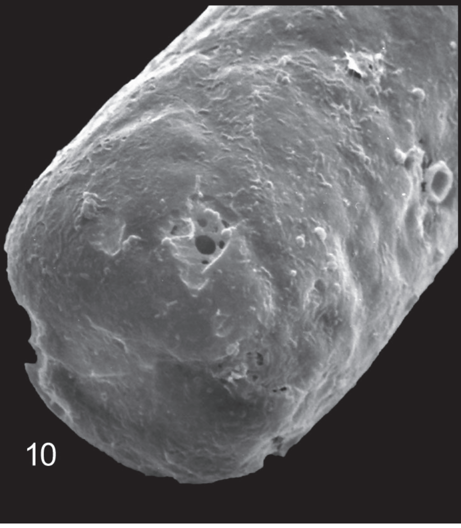

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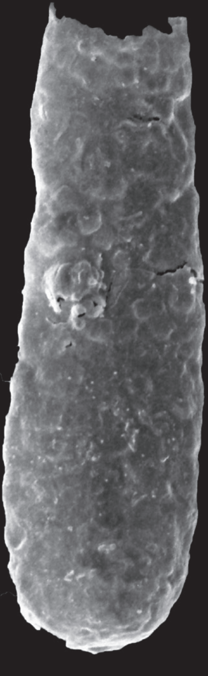

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Plate 7

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **130**: c. 25 cm below the first documented occurrence of *P. celloni*; sample **50**: Upper (?) *P. a. angulatus* conodont biozone; sample **132**: lowermost *P. a. amorphognathoides* conodont biozone; sample **133**: Lower *P. a. amorphognathoides* conodont biozone.

Fig. 1: ***Conochitina* cf. *iklaensis* NESTOR, 1980b**

Flattened damaged specimen missing the apertural part; L = 252 µm (x 300); slide 2020/002/0029; Englandfinder (EF): M59-1; sample **130**.

Figs. 2, 3: *Conochitina* cf. *elongata* TAUGOURDEAU, 1963

Fig. 2: Flattened specimen with a constriction at about the middle of the vesicle length; L = 261 µm (x 300); slide 2020/002/0033; EF: P61; sample **132**.

Fig. 3: Oblique view of the base of Figure 2 which has been damaged by crystal imprints (x 530).

Figs. 4–8, 10, 11: *Conochitina praeproboscifera* NESTOR, 1994

Fig. 4: Oblique view of the base of Figure 5 showing the mucron which is a thick 5,4 µm high rim surrounding a small apical pit (x 560).

Fig. 5: Flattened specimen missing the apertural part; L = 284 µm (x 300); slide 2020/002/0017; EF: N64-3; sample **50**.

Fig. 6: Three-dimensional vesicle with a gentle constriction just above the basal margin; L = 307 µm (x 300); slide 2020/002/0033; EF: L59-1; sample **132**.

Fig. 7: Flattened specimen with invaginated base; L = 223 µm (x 300); slide 2020/002/0017; EF: L61-1; sample **50**.

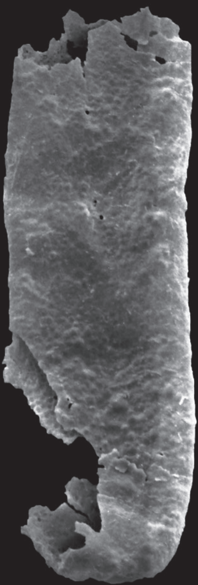
Fig. 8: Slim flattened specimen missing the apertural part; L = 272 µm (x 300); slide 2020/002/0016; EF: O61; sample **50**.

Fig. 10: Oblique view of the base of Figure 6 showing the almost completely abraded circular rim and the apical pit of the mucron (x 620).

Fig. 11: Oblique view of the base of Figure 8 showing the partly destroyed mucron (x 810).

Fig. 9: ***Conochitina* sp. B**

Thick-walled, sack-like specimen; L = 207 µm (= x 300); slide 2020/002/0037; EF: N65-3; sample **133**.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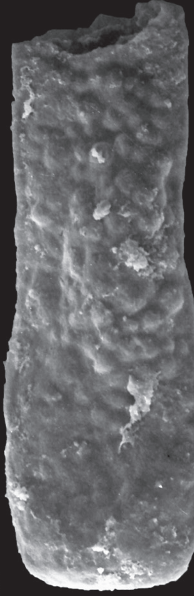
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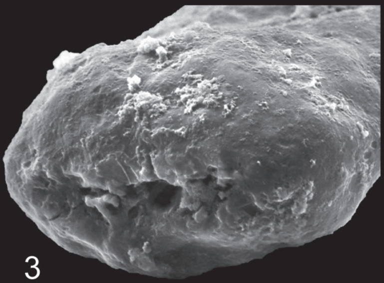
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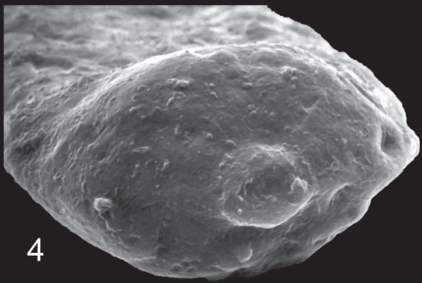
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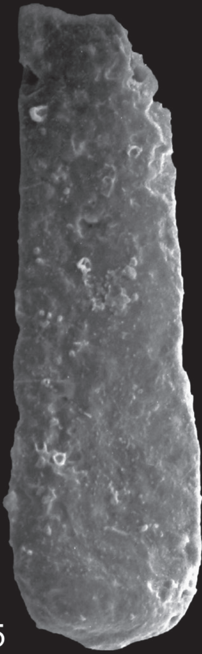
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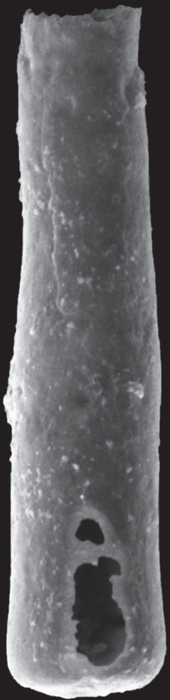
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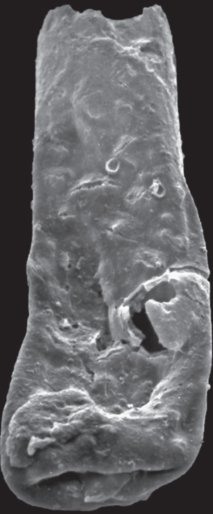
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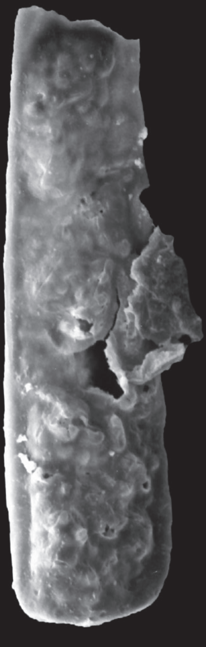
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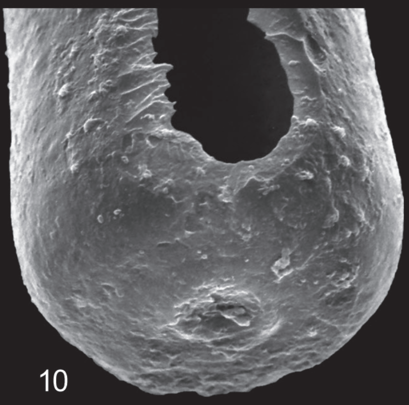
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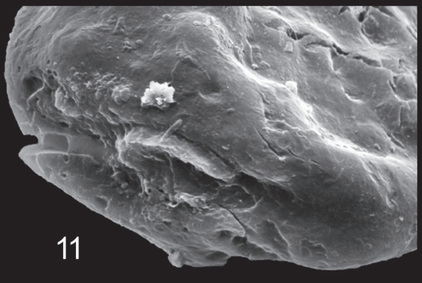
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Plate 8

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **131**: *P. celloni* conodont superzone/Lower *P. a. angulatus* conodont biozone; sample **132**: lowermost *P. a. amorphognathoides* conodont biozone.

Figs. 1, 2, 4, 5: *Conochitina* sp. A

Fig. 1: Vesicle fragment missing the apertural part; L = 160 µm (x 300); slide 2020/002/0034; Englandfinder (EF): L59-4; sample **132**.

Fig. 2: Oblique view of the base of Figure 1 showing a large apical structure of two concentric rims; most of the inner ridge is covered with amorphous organic material (x 630).

Fig. 4: Vesicle fragment damaged by internal crystal growth; L = 162 µm (x 300); slide 2020/002/0035; EF: O60-3; sample **132**.

Fig. 5: Oblique view of the base of Figure 4 showing a large apical pit surrounded by an almost completely abraded mucron (x 620).

Fig. 3: *Euconochitina* sp. 3 sensu Nestor, 1994?

Flattened and fractured specimen; L = 181 µm (x 300); slide 2020/002/0031; EF: N57-1; sample **131**.

Fig. 6: *Conochitina* sp. 1 sensu Mullins & Loydell, 2001

Flattened specimen, partly filled with framboids; L = 266 µm (x 300); slide 2020/002/0032; EF: K60-2; sample **132**.

Figs. 7, 8, 10: *Conochitina leviscapulae* Mullins & Loydell, 2001

Fig. 7: Flattened and fractured specimen, neck missing; L = 100 µm (x 450); slide 2020/002/0031; EF: O61-3; sample **131**.

Fig. 8: Flattened and fractured specimen, part of the neck missing; L = 122 µm (x 400); slide 2020/002/0031; EF: O66-3; sample **131**.

Fig. 10: Flattened and fractured specimen, part of the neck missing; L = 124 µm (x 400); slide 2020/002/0031; EF: P64; sample **131**.

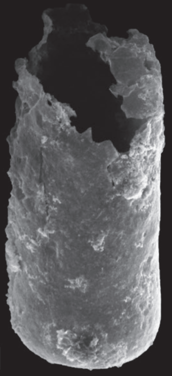
Figs. 9, 12: *Cyathochitina* sp.

Fig. 9: Flattened smooth vesicle with a relatively wide, rigid carina; L = 146 µm (x 350); slide 2020/002/0006; EF: Q62-3; sample **46A**.

Fig. 12: Flattened smooth vesicle with a relatively wide, rigid carina; L = 128 µm (x 400); slide 2020/002/0009; EF: R68; sample **46A**.

Fig. 11: *Euconochitina* sp. 2 sensu Nestor, 1994?

Flattened, thin-walled specimen; L = 148 µm (x 350); slide 2020/002/0010; EF: N63-2; sample **46A**.



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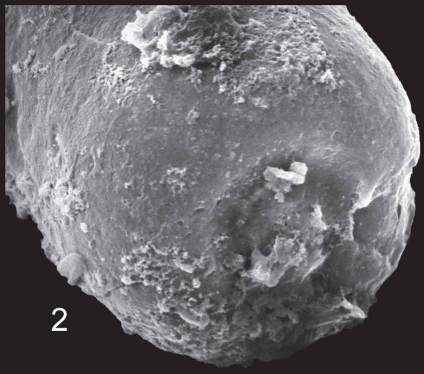

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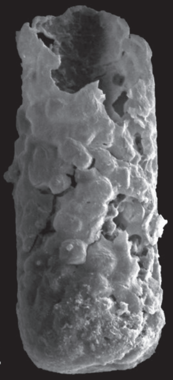

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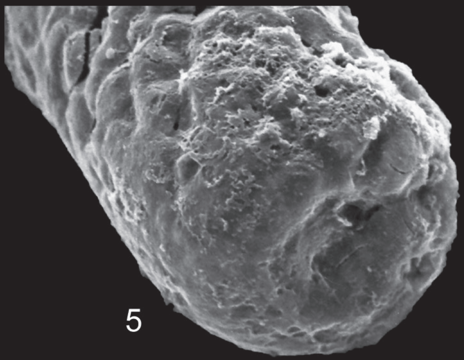

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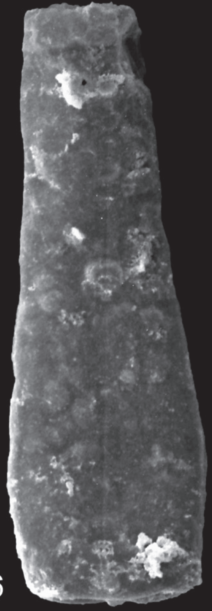

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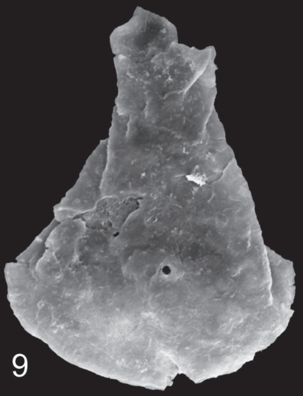

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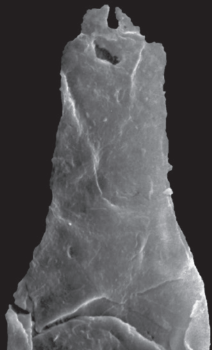

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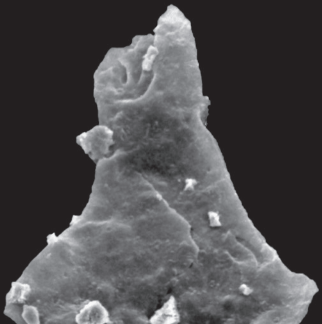

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Plate 9

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **49**: *P. celloni* conodont superzone/Lower *P. a. angulatus* conodont biozone; sample **133**: Lower *P. a. amorphognathoides* conodont biozone.

Figs. 1–4: *Angochitina longicollis* Eisenack, 1959

Fig. 1: Flattened and folded vesicle; spines almost completely eroded, only a few of their bases are visible on the flanks on the right side as slightly serrated section; L = 205 µm (x 300); slide 2020/002/0005; Englandfinder (EF): K59-2; sample **46A**.

Fig. 2: Flattened vesicle missing part of the neck and covered with a few short, broad-based remnants of spines; L = 133 µm (x 400); slide 2020/002/0015; EF: M61-4; sample **49**.

Fig. 3: Oblique view of an ornamented vesicle missing a considerable part of the neck; L = 122 µm (x 400); slide 2020/002/0011; EF: M62-4; sample **46A**.

Fig. 4: Close-up of the ornamentation in Figure 3, of which only a few complete spines have been preserved; they vary from simple to bifurcated and birooted (x 900).

Figs. 5–7: *Ancyrochitina* gr. *ancyrea* Eisenack, 1931

Fig. 5: Flattened and folded vesicle with two remaining, damaged processes; L = 99 µm (x 450); slide 2020/002/0010; EF: P64-1; sample **46A**.

Fig. 6: Flattened and folded vesicle with only one remaining, damaged process; L = 90 µm (x 500); slide 2020/002/0005; EF: O60-3; sample **46A**.

Fig. 7: Flattened and folded vesicle with only one remaining, damaged process; L = 135 µm (= x 400); slide 2020/002/0010; EF: Q61; sample **46A**.

Figs. 8–10: *Sphaerochitina* sp. 1

Fig. 8: Flattened specimen with folded subspherical chamber and large cylindrical neck; L = 158 µm (x 350); slide 2020/002/0004; EF: Q59-3; sample **46A**.

Fig. 9: Flattened specimen with folded subspherical chamber and large cylindrical neck; L = 167 µm (x 300); slide 2020/002/0004; EF: R58; sample **46A**.

Fig. 10: Flattened specimen with folded subspherical chamber and large cylindrical neck; L = 176 µm (= x 300); slide 2020/002/0010; EF: R62-1; sample **46A**.

Figs. 11, 12: *Sphaerochitina* spp.

Fig. 11: Small vesicle (form A) with a broad neck and crenulate aperture (discussion under "*Sphaerochitina* spp."); L = 106 µm (x 450); slide 2020/002/0009; EF: M65-2; sample **46A**.

Fig. 12: Vesicle (form B) with a pear-shaped chamber and dense granulation on the wall surface (discussion under "*Sphaerochitina* spp."); L = 122 µm (x 400); slide 2020/002/0038; EF: M63; sample **133**.

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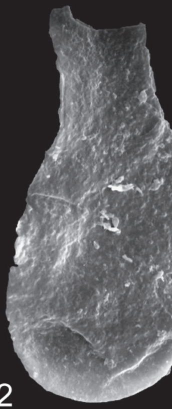

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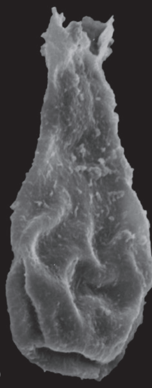

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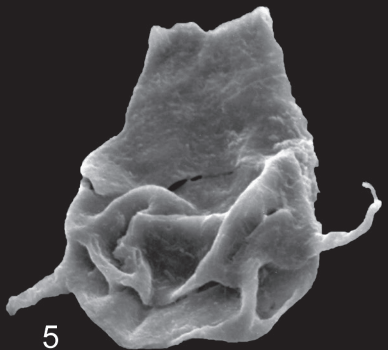

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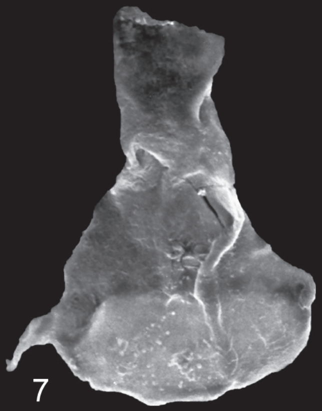

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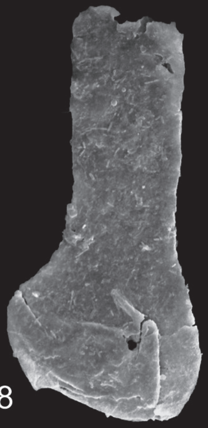

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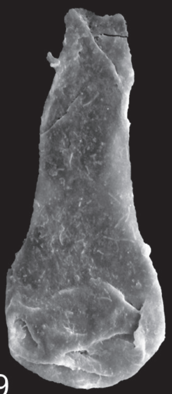

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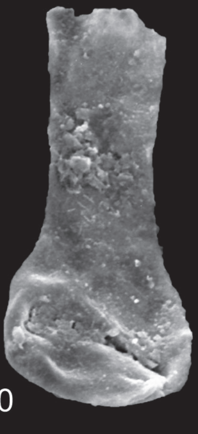

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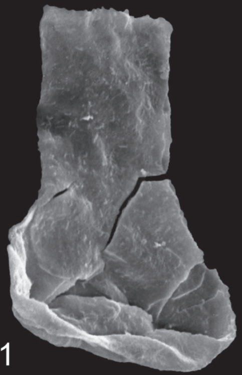

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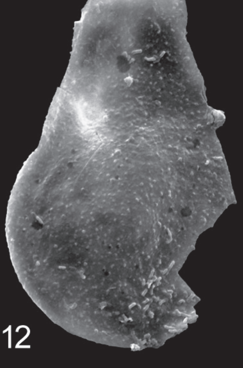

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Plate 10

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery).

Sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **132**: lowermost *P. a. amorphognathoides* conodont biozone; sample **133**: Lower *P. a. amorphognathoides* conodont biozone.

Figs. 1–3: *Sphaerochitina* sp. 2

Fig. 1: Flattened specimen with basal parts of a few spines at the transition from the chamber to the neck; L = 168 µm (= x 300); slide 2020/002/0037; Englandfinder (EF): Q65; sample **133**.

Fig. 2: Flattened and fractured specimen; L = 162 µm (x 300); slide 2020/002/0006; EF: J60-3; sample **46A**.

Fig. 3: Flattened and fractured specimen; L = 144 µm (= x 350); slide 2020/002/0007; EF: N60-2; sample **46A**.

Figs. 4, 5: *Lagenochitina* sp. 1

Fig. 4: Flattened vesicle with broken chamber and collarette; neck partly filled with crystals; L = 150 µm (x 350); slide 2020/002/0006; EF: L61-3; sample **46A**.

Fig. 5: Three-dimensional tear-shaped vesicle with destroyed apertural area; L = 143 µm (x 350); slide 2020/002/0036; EF: L68-2; sample **132**.

Fig. 6: *Lagenochitina* sp.

Single specimen, flattened and fractured, with asymmetrical pear-shaped chamber, a short (11 µm) cylindrical neck and a relatively long (25 µm), flaring collarette; L = 171 µm (= x 300); slide 2020/002/0008; EF: M59-3; sample **46A**.

Figs. 7–12: Ancyrochitininae indet.

Fig. 7: Specimen with a conical chamber and short relic of a thin process (Group A); L = 171 µm (x 300); slide 2020/002/0008; EF: L68-3; sample **46A**.

Fig. 8: Specimen with an ovoid chamber and a short relic of a thin process (Group B); L = 135 µm (x 400); slide 2020/002/0008; EF: R62-1; sample **46A**.

Fig. 9: Specimen with an ovoid chamber and a short relic of an irregular nodular process such as in some *Plectochitina* taxa (Group B); L = 135 µm (x 400); slide 2020/002/0007; EF: H63-4; sample **46A**.

Fig. 10: Single specimen with a short relic of a very thick process such as in some *Plectochitina* taxa (Group E); L = 153 µm (x 350); slide 2020/002/0005; EF: L65-2; sample **46A**.

Fig. 11: Single chamber fragment with a very thick process such as in some *Plectochitina* taxa (Group E); D = 72 µm; slide 2020/002/0004; EF: O55-4; sample **46A**.

Fig. 12: Single specimen with a short, conical, non-branching process (Group D); L = 124 µm (x 400); slide 2020/002/0006; EF: K60-1; sample **46A**.

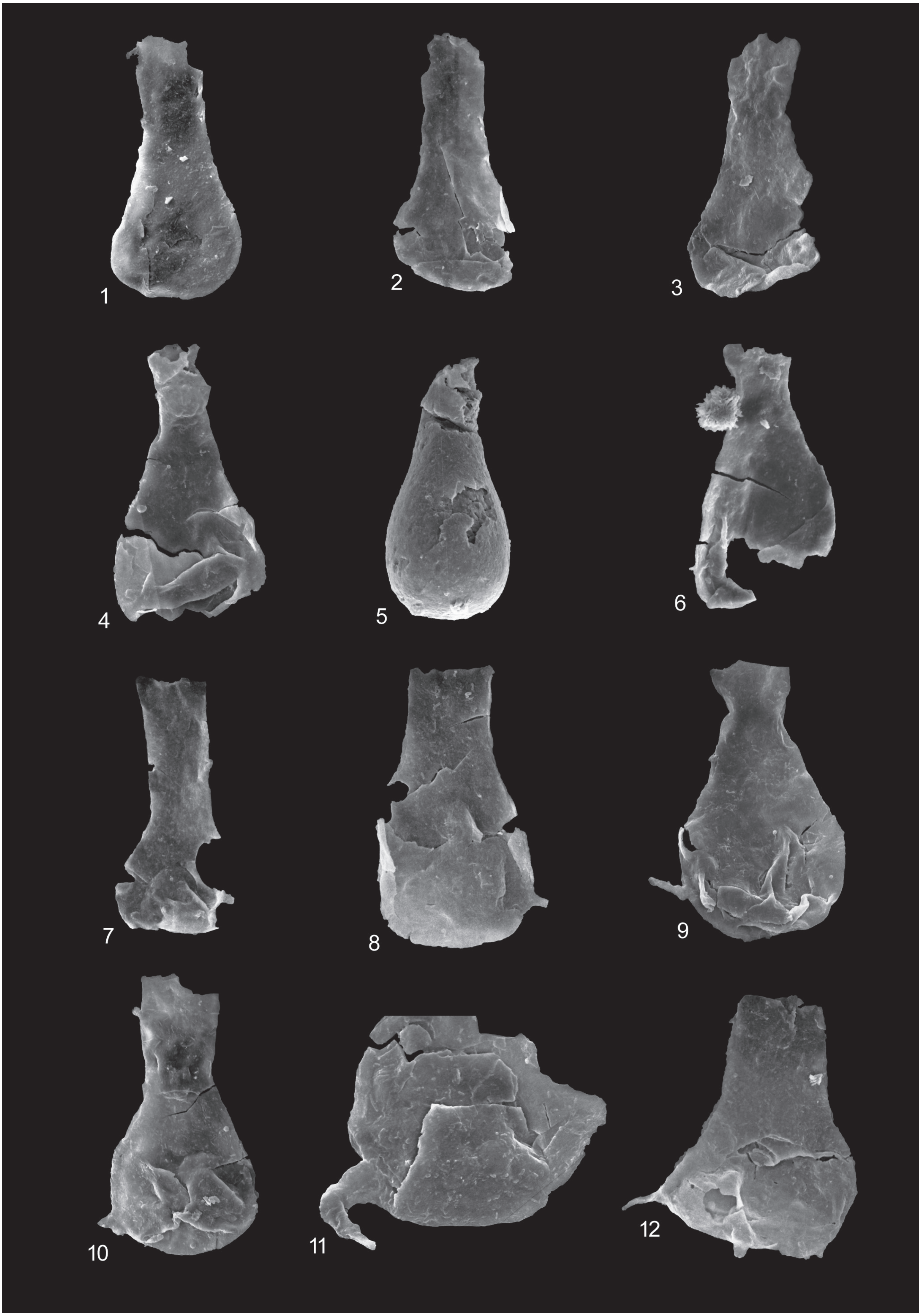
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Plate 11

Chitinozoans from the lower part of the Kok Formation (Telychian, Llandovery) (Figs. 1–6) and graphitic particles from the Plöcken Formation (Hirnantian, Upper Ordovician) (Figs. 7–11).

Sample **45**: *M. persculptus* graptolite biozone; sample **46A**: c. 95 cm below the first documented occurrence of *P. celloni*; sample **133**: Lower *P. a. amorphognathoides* conodont biozone; sample **136**: *K. o. ortus* conodont biozone.

Fig. 1: Ancyrochitininae indet.

Specimen with a spherical chamber, a short relic of a thin process and a granulated surface (Group C); L = 122 µm (= x 400); slide 2020/002/0040; Englandfinder (EF): M60-2; sample **136**.

Figs. 2–6: Lagenochitinidae indet.

Fig. 2: Specimen with a conical chamber (Group A); L = 149 µm (x 350); slide 2020/002/0009; EF: N69-2; sample **46A**.

Fig. 3: Specimen with a granulated ovoid chamber (Group B); it resembles *Sphaerochitina solutidina* PARIS, 1988b; L = 126 µm (x 400); slide 2020/002/0039; EF: O62-3; sample **133**.

Fig. 4: Specimen with a spherical chamber and a relatively short, slightly flaring neck (Group C); it resembles *Sphaerochitina solutidina* PARIS, 1988b; L = 122 µm (x 400); slide 2020/002/0008; EF: P62-4; sample **46A**.

Fig. 5: Specimen with a spherical chamber and a long slender cylindrical neck (Group C); L = 159 µm (x 350); slide 2020/002/0006; EF: N63; sample **46A**.

Fig. 6: Specimen with a spherical chamber and a relatively short, slightly flaring neck (Group C); it resembles *Sphaerochitina solutidina* PARIS, 1988b; L = 137 µm (x 400); slide 2020/002/0005; EF: N58-2; sample **46A**.

Figs. 7–11: Graphitic particles

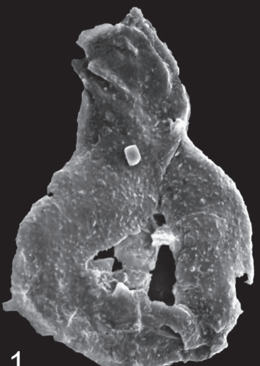
Fig. 7: Thin crumpled graphitic particle with chitinozoan-like appearance; L = 208 µm (x 300); slide 2020/002/0002; EF: N64-2; sample **45**.

Fig. 8: Thin crumpled graphitic particle with chitinozoan-like appearance; L = 200 µm (x 300); slide 2020/002/0001; EF: P59-2; sample **45**.

Fig. 9: Flattened circular object of biological origin (sphaeromorph?, foraminifer?): its central part shows a crumpled mica-like appearance; Ø = 120 µm (x 350); slide 2020/002/0002; EF: M64-1; sample **45**.

Fig. 10: Thin crumpled graphitic particle resembling a poorly preserved scolecodont; L = 440 µm (x 150); slide 2020/002/0003; sample **45**.

Fig. 11: Flattened circular object of biological origin (sphaeromorph?, foraminifer?): its central part shows a crumpled mica-like appearance; Ø = 180 µm (x 350); slide 2020/002/0002; EF: R64-2; sample **45**.



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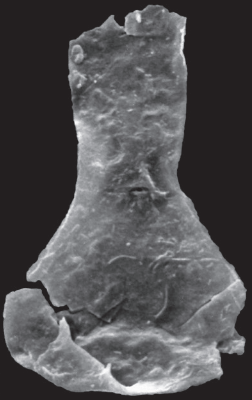

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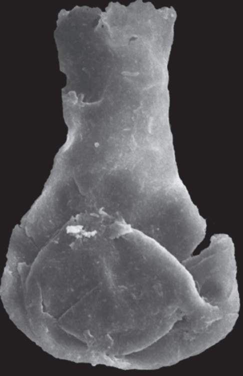

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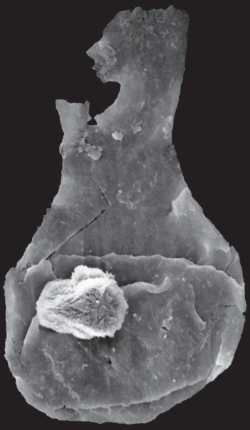

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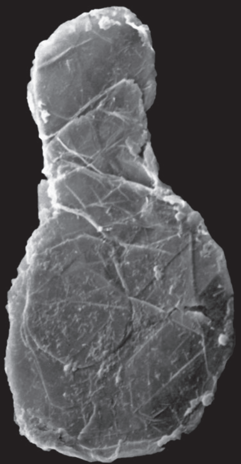

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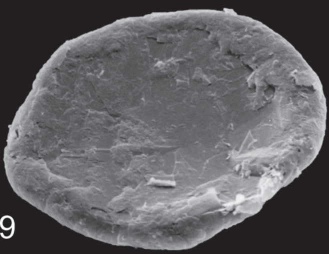

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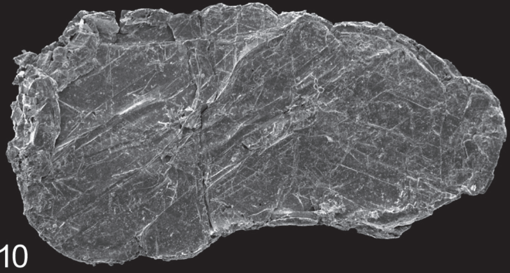

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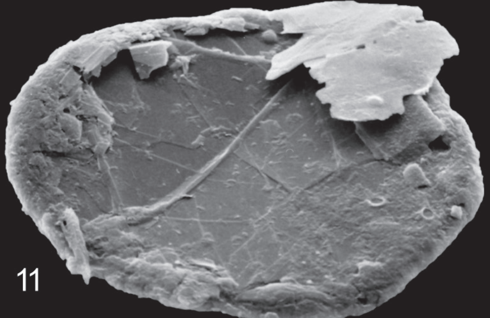

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