A new Wenlock retiolitid (Graptolithina) *Virgellograptus* from the East European Platform, Poland

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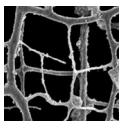

A new retiolitid genus *Virgellograptus*, with a single species *V. perrarus* from the upper Wenlock, *Cyrtograptus ellesi* Biozone from Poland is described. Unlike all other retiolitids, the new form has the virgella, an axis of the sicula, connected into lateral wall of the ancora sleeve. Virgella attaches the mid-lateral list of the ancora sleeve, from which the horizontal lists are going to pleural lists and lateral apertural rods. The connection is on the obverse side of tubarium. *Virgellograptus* gen. nov. has a free nema, which is not preserved, at the same time it has well developed genicular lists of thecae, regarded as advanced feature. The new form is the most similar to *Sokolovograptus*; the key difference is a development of the proximal end – the connection of the sicula to the lateral wall of the ancora sleeve. • Key words: Graptolithina, retiolitids, *Virgellograptus*, *Sokolovograptus*, proximal end, virgella, Silurian.

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The retiolitids are unlike all other graptolites in that most possess double lateral walls: an inner one being the homologue of the "normal" diplograptoid thecal walls, and an outer wall derived entirely from the distal extension of the ancora named ancora sleeve wall (*e.g*. Bates & Kirk 1984, Bates 1990, Bates *et al*. 2005). These walls, built from very thin and incrementally deposited fusellar layers supported by strong lists formed exclusively from bandages, are only very rarely completely preserved. Normally, therefore, only the cable-like, bandaged lists of the retiolitid rhabdosome (tubarium) are preserved.

Early investigations of retiolitids began with flattened material on rock surface (*e.g*. Barrande 1850, Lapworth 1879, Bouček & Münch 1952); later turned to isolated material (*e.g*. Holm 1890; Münch 1931; Eisenack 1951; Obut & Zaslavskaya 1976; Lenz & Melchin 1987; Bates & Kirk 1984, 1992, 1997; Lenz 1993; Kozłowska-Dawidziuk 1995, 1997; Lenz & Kozłowska 2006).

Scanning electron microscopy provided an opportunity to better understand the construction of the tubaria and the details of the retiolitid morphology. Three-dimensional retiolitids have come mostly from the Arctic Canada (Lenz 1993, 1994a, b; Lenz & Kozłowska-Dawidziuk 2001, 2002, 2004; Lenz *et al*. 2012), Poland (Kozłowska-Dawidziuk 1990, 1995, 2001; Kozłowska *et al*. 2009), Germany (Maletz 2008, 2010), and from Lithuania (Kozłowska & Radzevičius 2013). The new form described herein comes from the East European Platform of Poland, from where the numerous well-preserved retiolitids have already been described. Through these more recent studies, the recognized taxonomic diversity among the retiolitids has increased tremendously.

The purpose of this paper is to describe a new Wenlock retiolitid, *Virgellograptus* gen. nov., with a unique feature among retiolitids in that the virgella is incorporated into the lateral wall of ancora sleeve.

Unlike in all previously known retiolitids, the sicula in the new material is connected to the lateral wall of the tubarium and the nema is free within the center of the colony. Other retiolitids exhibit a free sicula and a nema that is either incorporated into lateral wall or is also free. Thus the unusual proximal end structure created a unique retiolitid tubarium, herein observed for the first time.

Systematic palaeontology

Morphological terminology after Bates *et al*. (2005). The new terms "proximal mid-lateral list" and "horizontal lists" for ancora sleeve lists are introduced. The proximal mid-lateral list (proximal m-l list) attaches the virgella and is the main list of the proximal part of the obverse side of

the ancora sleeve. This list is attached to the virgella. Horizontal lists link the proximal m-l list directly with the pleural lists and the lateral apertural rods. The classification of the retiolitines follows Melchin *et al*. (2011).

Superfamily Retiolitoidea Lapworth, 1873
Family Retiolitidae Lapworth, 1873
Subfamily Retiolitinae Lapworth, 1873

Genus *Virgellograptus* gen. nov.

Type and only species. – *Virgellograptus perrarus* gen. et sp. nov.

Etymology. – *Virgello-* after virgella, to point out its unusual connection to lateral wall of tubarium, the ancora sleeve, a feature unknown in any other retiolitids.

Diagnosis. – Ancora umbrella small with four meshes, usually complete rim. Virgella connected to proximal mid-lateral list, main list on proximal part of obverse side of ancora sleeve. Horizontal lists going from mid-lateral list to pleural lists and lateral apertural rods. Sicula long, nema free throughout. Proximal lateral and ventral orifices are overgrown by reticulum in mature colony. Lateral wall on reverse side of tubarium built of stronger oblique lists. Ventral walls composed of distinctive lips, genicular lists, pleural lists. Reticulum well developed in mature specimens.

Remarks. – Early astogenetic patterns are regarded as important for the classification of graptolites (Mitchell 1987). The connection of the virgella to the lateral wall of ancora sleeve in *Virgellograptus* gen. nov. becomes the new feature in the primordial evolutionary development in retiolitids.

***Virgellograptus perrarus* gen. et sp. nov.**
Figures 1, 2, 3A, C

2013 *Sokolovograptus* sp. 1; Dobrowolska, pp. 170–172, pl. 4, fig. 21.

Type material. – Holotype ZPAL G.52/1, mature specimen with three pairs of thecae (Fig. 1E).

Type locality. – Bartoszyce IG-1 borehole, 1726.5 m, geographic coordinates 54°14´ N, 20°57´ S, Poland, East European Platform.

Material. – The investigated material comes from laminated marls, Bartoszyce IG-1 core, eastern part of the Baltica, Peribaltic Syncline of the EEP, Poland, from depths: 1725.0 m, 1726.5 m, and 1727.9 m. According to Tomczyk (1974) the investigated level belongs to the Wenlock, upper Sheinwoodian, *Cyrtograptus ellesi* Biozone, determined from 1723.5 to 1730.0 m. This biozone is correlated with the upper part of *C. perneri* Biozone according to Loydell (2012).

Specimens are well preserved, slightly flattened and slightly squashed in different directions. Ten almost complete specimens with three pairs of thecae, one specimen with four pairs, and 20 fragments come from 1727.9 m; eleven specimens from 1726.5 m, mostly young and fragmentary; three specimens from 1725.0 m. The material that Dobrowolska (2013) described as *Sokolovograptus* sp. 1 from Gołdap IG-1 core, also appears to belong *to V. perrarus* gen. et sp. nov. This collection contains dozens of fragments of specimens; the longest have three pairs of thecae. The specimens from both localities represent similar preservation and the same characters and measurements. Specimens from Gołdap IG-1 core occur in the *Cyrtograptus lundgreni* Biozone whereas those from the Bartoszyce IG-1, occur in the older, *Cyrtograptus ellesi* Biozone.

Material was isolated from rock following slow dissolution in 1–10% HCl (see Kozłowska & Urbanek 2013). The specimens are stored in glycerine in plastic containers, and on SEM stubs in the Institute of Paleobiology, Polish Academy of Sciences in Warsaw.

Etymology. – The Latin *perrarus* means very rare, exceptional.

Diagnosis. – As for the genus.

Description. – Tubarium parallel sided, width about 1.2 mm (Figs 1–3). The largest specimen contains five pairs of thecae (Fig. 2C, D). Length of the tubarium from the ancora to the lip of $th1^1$ is about 0.9 mm, to the lip of 1^2 about 1.5 mm. The distances between thecal lips are about 750 μm.

In the proximal part of the lateral wall of the reverse side the distance between the pleural lists is about 560 μm. The obverse side is wider and has about 1 mm. Seams inside the lists (Fig. 1A, 2E), pustules on bandages (Fig. 1A, C). Above the last horizontal lists of both lateral walls of the ancora sleeve have the similar width, about 530 μm.

Ancora umbrella small with four meshes (Figs 1D, G, 2B), usually not complete rim. Mesh of ancora umbrella placed on the $th1^2$ side of the tubarium is smaller than on $th1^1$ side. Pleural lists connected to the ancora umbrella located asymmetrically, what makes the obverse side of the tubarium wider (Fig. 2B).

Proximal part of lateral wall of obverse side of ancora sleeve is composed of reticulum, vertical m-l list and the horizontal lists, which go from m-l list directly to pleural

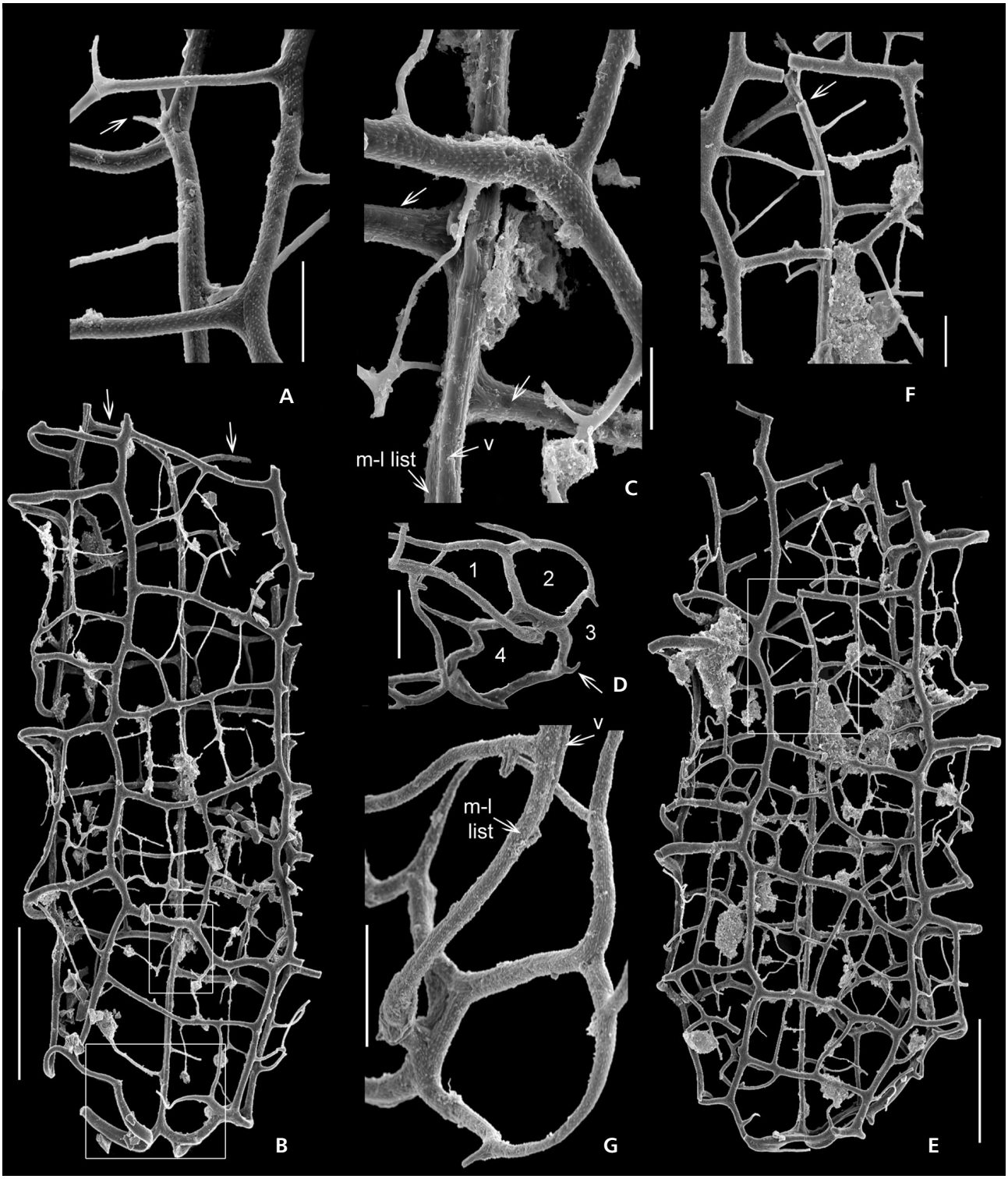

Figure 1. SEM pictures of mature specimens of *Virgellograptus perrarus* gen. et sp. nov., 1726.5 m, Bartoszyce IG-1 drill core, Poland. • A – enlargement of specimen ZPAL G.52/3 showing fragment of prosicular rim (arrow). • B–D – fragment of tubarium with three pairs of thecae, reverse view, latero-ventral side, ZPAL G.52/2, B – whole specimen, C – details of B showing mid-lateral list, virgella and virgellar lists, arrows. • E, F – fragment of tubarium with three pairs of thecae, reverse view, lateral side, ZPAL G.52/1, holotype; E – whole specimen, genicular list of $th3^1$ arrowed, F – details of E showing broken virgella, distal end (arrow). • D, G – ancora umbrella, view from inside, specimen ZPAL G.52/6; D – whole ancora, arrow shows unfinished edge of the mesh, numbers indicate ancora umbrella meshes, G – enlargement. Abbreviations: m-l list – mid-lateral list, v – virgella. Scale bars 100 μm for A, C, D, F, G and 500 μm for B, E.

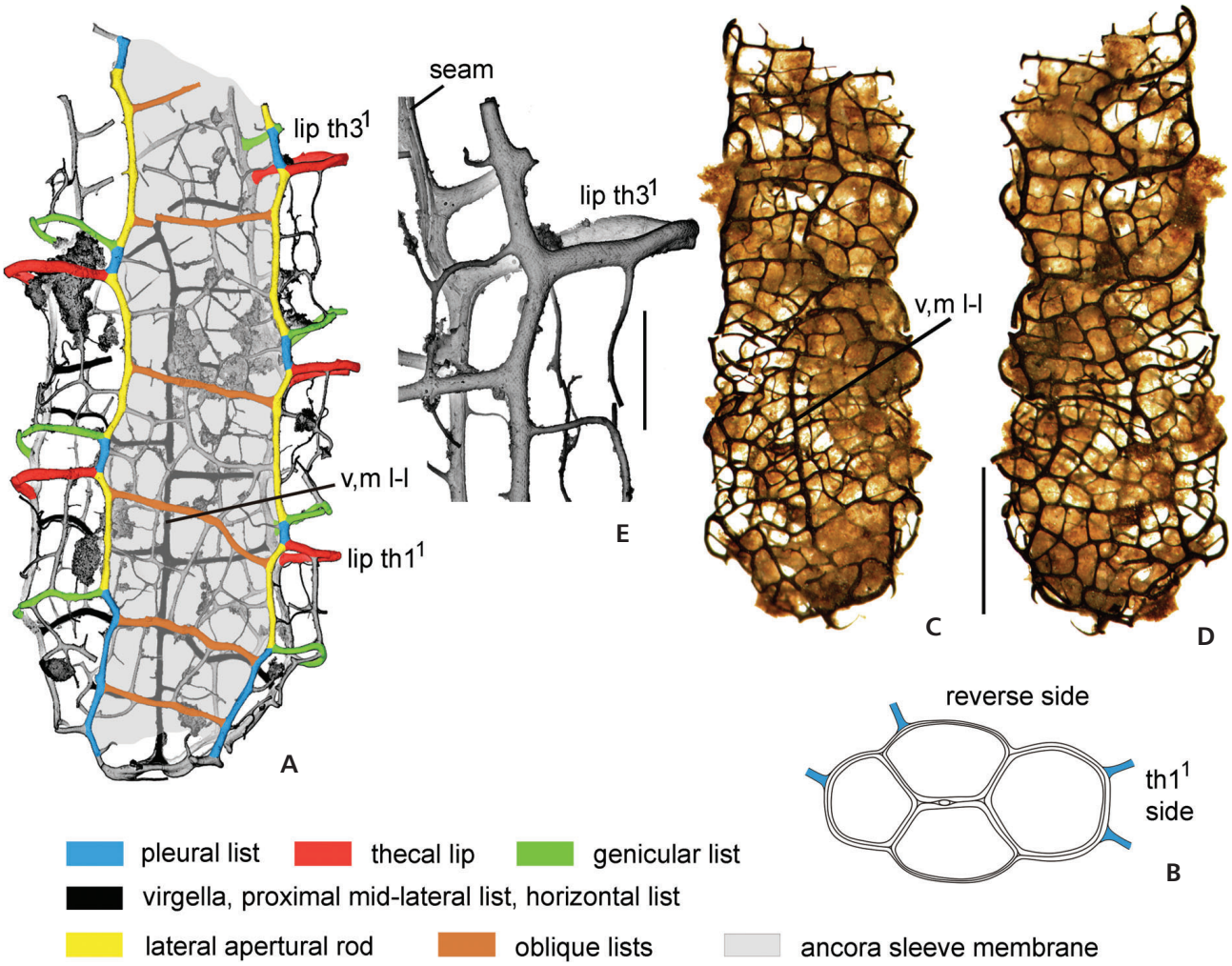

Figure 2. A, E – tubarium of *Virgellograptus perrarus* gen. et sp. nov., ZPAL G.52/1, 1726.5 m, Bartoszyce IG-1 drill core, Poland, reverse view with some broken horizontal lists reconstructed; A – whole specimen; E – enlargement of th3[1]. • B – sketch of idealized ancora umbrella with four meshes of *Virgellograptus perrarus* gen. et sp. nov. • C, D – light photos of mature *Virgellograptus perrarus* gen. et sp. nov. from Bartoszyce IG-1 drill core, 1727.9 m, *Cyrtograptus ellesi* Biozone, ZPAL G.52/6, slightly squashed specimen with five pairs of thecae, C – obverse view showing virgella connected to lateral wall, D – reverse view. Abbreviations: m-l l – mid-lateral list, v – virgella. Scale bars 500 μm for A, C, D and 200 μm for E.

lists and lateral apertural rods. They are located regularly below thecal lists and genicular lists (Figs 1B, E, 2A, 3B). The seams on the inside of the horizontal lists are largely hidden (Fig. 1C). Reverse side of ancora sleeve is composed of oblique lists (Figs 1B, E, 2A, 3D).

The seams on virgella indicate the sicula is approximately 2.5 mm long. Fragment of prosicular apertural rim preserved in one specimen (Fig. 1A) indicates the beginning of metasicula. Prosicular rim is located above genicular list of th2[2], approximately 2.0 mm from ancora, above this point the horizontal list is bending and attaches pleural list above genicular list of th2[2] (Figs 1B, E, F, 2A).

The preservation of material does not demonstrate clearly the connection of the virga to the lateral wall. The virgella attaches the mid-lateral list of the ancora sleeve (Fig. 1C, G, F). It is broken at the level of the geniculum of the th2[2]. Above this point there are last horizontal lists (Fig. 1B, E, F), what may indicates that the virga as well as nema are free. There are no traces of a nema connection to the lateral wall of the ancora sleeve. The specimen of the *Virgellograptus perrarus* gen. et sp. nov. illustrated on Fig. 2C, D has the distal part of the tubarium preserved. It does not have any traces of a nema incorporated into lateral wall.

From the level of th2[2] both lateral walls of ancora sleeve become similar, having oblique main lists and reticulum (Fig. 2C, D).

The ventral walls of the tubarium are built on pleural lists, thecal lips, and genicular lists. It is difficult to trace the development of the proximal orifices because of the poor preservation of seams. The proximal orifices are possibly present in early stages of astogeny when the reticulum

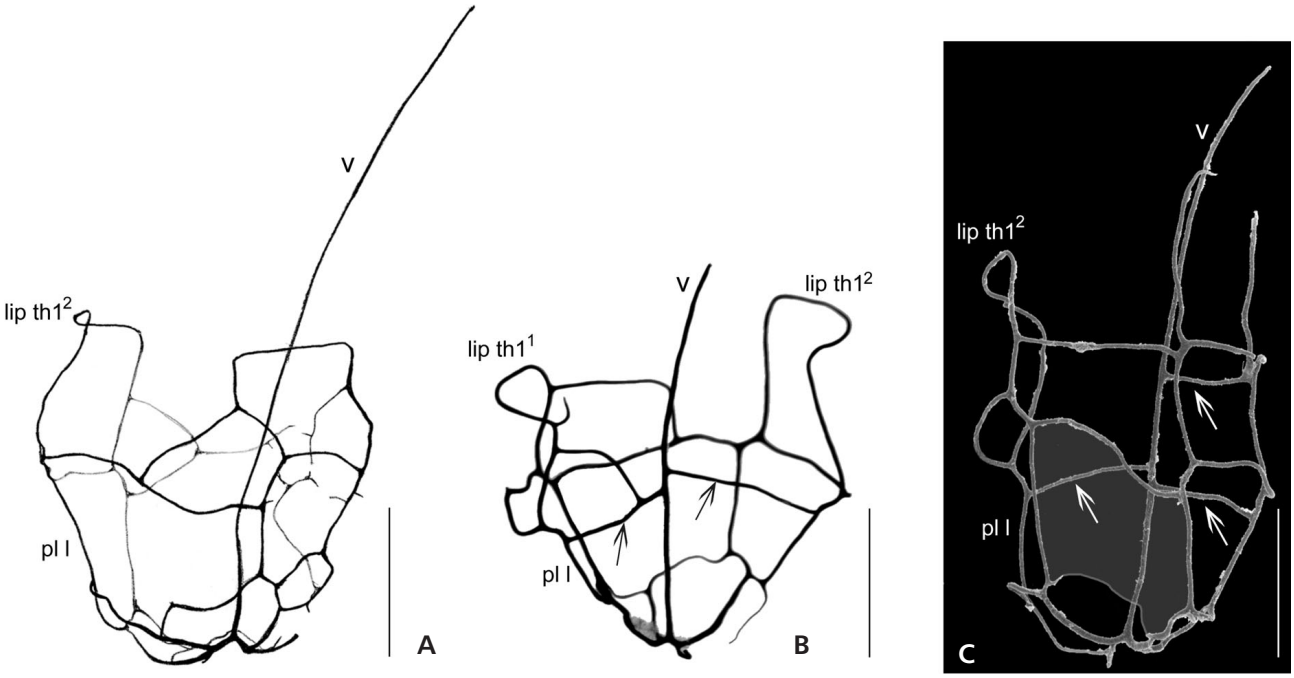

Figure 3. Comparison of young tubaria with the first pair of thecae of *Sokolovograptus* Obut & Zaslavskaya, 1976 and *Virgellograptus perrarus* gen. et sp. nov. • A – *Sokolovograptus* sp. with free virgella, line drawing, 1597.7–1603.1 m, Zawada 1 drill core, Poland, *Cyrtograptus perneri* Biozone. • B – *Virgellograptus perrarus* gen. et sp. nov., 1726.5 m, Bartoszyce IG-1 drill core, *Cyrtograptus ellesi* Biozone, ZPAL G.52/4, light photo, obverse view. • C – *Virgellograptus perrarus* gen. et sp. nov., 1726.5 m, Bartoszyce IG-1 drill core, *Cyrtograptus ellesi* Biozone, ZPAL G.52/5, SEM picture, reverse view, probable proximal lateral orifice on reverse side is coloured grey. Arrows show horizontal lists. Abbreviations: pl l – pleural list, v – virgella. A – after Kozłowska-Dawidziuk 1995, fig. 19. Scale bars 500 μm.

is not developed (Fig. 3C), whereas in mature specimens they are overgrown by reticulum (Figs 1B, E, 2C, D). The reticulum of mature specimens is moderately dense, some secondary lists are very thin (Fig. 1B, C, E, F).

Remarks. – In the majority of isolated retiolitids *e.g*. *Sokolovograptus* and *Plectograptus* Moberg & Törnquist, 1909, there are no traces of a free nema, such as found in the new form. In those cases it is regarded that the nema is completely free.

Stratigraphic occurrence. – *Cyrtograptus ellesi* Biozone, Sheinwoodian, mid Wenlock.

Discussion. – *Virgellograptus* gen. nov. is a unique retiolitid having its virgella connected to the lateral wall of the ancora sleeve. The virgella attaches the vertical list named herein the proximal mid-lateral list, going along the virgella. This kind of proximal end is recognized for the first time.

Similar to the virgella connection to the ancora sleeve, the nema in *Gothograptus* Frech, 1897 is attached to the obverse lateral wall of the ancora sleeve (see Eisenack 1951, pl. 25; Kozłowska-Dawidziuk 1990, pls 23, 24).

The virgella is linked to the thecal wall of the tubarium by a connecting rod in *e.g*. *Retiolites* Barrande, 1850 or *Stomatograptus* Tullberg, 1883 (see Bates & Kirk 1997, figs 1, 5, 6), and *Paraplectograptus* Přibyl, 1948, which are older and also occur in the same stratigraphic interval as *Virgellograptus* gen. nov. They belong to the older groups of retiolitids characterized by *e.g*. the ancora sleeve secreted from the inside of the tubarium and a short sicula, in contrast to the younger forms. In these forms, however, the virgella is not incorporated into the lateral wall. It has a central position and a short connecting rod, which is linked to a transverse rod. This is not developed in the new form and thus, the connecting rods of the older forms do not appear to be homologous to the horizontal lists of the *Virgellograptus* gen. nov.

Virgellograptus gen. nov. is very similar to *Sokolovograptus* Obut & Zaslavskaya, 1976, but the key difference is the free virgella in *Sokolovograptus*. *Sokolovograptus* forms a separate group of retiolitids, one of the most diverse, having eight species. It is the oldest retiolitid having a free nema, long sicula, and ancora sleeve secreted from the outside; this is regarded as an advanced character (Bates *et al*. 2005). *Sokolovograptus* is known from the *Cyrtograptus rigidus* Biozone of Czech Republic (Bouček & Münch 1952), the *C. perneri* Biozone of the Baltic region of Russia (Obut & Zaslavskaya 1976), the *Spirograptus turriculatus/Streptograptus crispus* Biozone up to the *C. lundgreni* Biozone of Arctic Canada (Lenz &

Melchin 1987, Lenz *et al*. 2012), and from the *C. perneri* (Kozłowska-Dawidziuk 1995) to *C. lundgreni* biozones (Dobrowolska 2013) of Poland.

Similarities between *Virgellograptus* gen. nov. and *Sokolovograptus* are expressed in the construction of the simple ancora umbrella with four meshes (Figs 1B, D, 2B), lateral walls in the medial and distal parts of tubaria having main oblique lists, a free nema, and long sicula. There is a similarity in the shape and ventral wall construction in young growth stages (Fig. 3). The new form is the most similar to *S. parens* Obut & Zaslavskaya, 1976; *S. textor* Obut & Zaslavskaya, 1976, and *S. canadensis* Lenz, Senior, Kozłowska & Melchin, 2012 (Lenz *et al*. 2012). They share a similar proximal end shape, and ventral walls with a reticulum.

Despite the similarities there are several essential differences between the genera. The main differences are the position of virgella connected to the lateral wall of the ancora sleeve, and the presence of well-developed genicular lists in the *Virgellograptus* gen. nov. *Sokolovograptus* has well-developed proximal lateral orifices in mature specimens, the opposite of the *Virgellograptus* gen. nov. where the orifices are overgrown.

Well-developed genicular lists were previously recognized in retiolitid history in *Gothograptus*, known from the *Cyrtograptus perneri–C. rigidus* Biozone (Kozłowska-Dawidziuk 1995), and now in the *V. perrarus* gen. et sp. nov. from *C. ellesi* Biozone. Genicular lists are an advanced feature, characteristic for younger, post-*lundgreni* retiolitids (Kozłowska-Dawidziuk 2004). In some species of *Sokolovograptus*, *e.g*. *S. textor*, there are some, mostly irregular looping lists on the ventral walls of tubarium, some of them suggestive of genicular lists (Lenz *et al*. 2012, pl. 4, fig. 1). In some species of *Sokolovograptus*, *e.g*. *S. polonicus* Kozłowska-Dawidziuk, 1995 and *S. telleri* Kozłowska-Dawidziuk, 1995, only the thecal lips are developed in the ventral walls. Thus the development of the ventral wall of the *Sokolovograptus* requires further investigation.

Concluding, the outstanding proximal end of the tubarium with the virgella connected to the lateral wall of the ancora sleeve is observed in *Virgellograptus perrarus* gen. et sp. nov. for the first time in the evolutionary history of retiolitids. This type of the tubarium appeared suddenly, and most probably evolved from a *Sokolovograptus* species.

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