In the SW Poland, especially in the Fore-Sudetic Block (Mokrzeszów Quarry, Świebodzice outcrop), many glacial erratic boulders, Cambrian to Neogene in age, occur in Pleistocene sands and tills (Fig. 1). They originated in Baltoscandia (Salamon et al., 2013 and references therein) and probably were transported and deposited during the Middle Polish Glaciation (Saalian Glaciation, see Marks, 2004; Marks et al., 2016). The most interesting are glacial erratic boulders of sedimentary rocks, because of their rich body and trace fossil content.

The erratic boulders studied contain diverse trace fossils, in some cases new for the source areas. The most interesting discovery is Arachnostega in the pygidium of the trilobites ?Megistaspis sp. (probably from Sweden) and Asaphus sp. (from the St. Petersburg region of Russia, or from Estonia).

So far, Mikuláš and Dronov (2010, p. 63) described this trace fossil from Baltoscandia on the mould of an unidentified trilobite (Asaphus raniceps – Asaphus striatus Zone, Tab. 1), Kunda Regional Stage (St. Petersburg region), but this ichnotaxon was unknown on arthropods in Estonia and Sweden. Arachnostega found in hyolithids (this study), might come from the St. Petersburg region (Russia), where it was reported only in cephalopods and trilobites. The next interesting and rare Palaeozoic boring is Osprioneides kampoto, encountered both in ?Ordovician Orthoceratite Limestone, which is exposed mainly in southern and central Sweden, western Russia and Estonia, and also in Norway (Oslo Region). The most interesting discovery in these deposits is the occurrence of Arachnostega gastrochaenae in the Ordovician trilobites (?Megistaspis sp. and Asaphus sp.), cephalopods and hyolithids. This is the first report of Arachnostega on a trilobite (?Megistaspis) from Sweden. So far, this ichnotaxon was described on trilobites from Baltoscandia only from the St. Petersburg region (Russia). Arachnostega on a trilobite (Asaphus), a cephalopod and hyolithids is from Russia or Estonia. Another interesting ichnotaxon is Balanoglossites, which also was encountered in the erratic boulders from the Ordovician Orthoceratite Limestone of Sweden. So far, this ichnotaxon was known only from Russia (St. Petersburg region). Some rare borings (e.g., Osprioneides kampto, ?Palaeosabella isp.) also were found in glacial erratics of Silurian stromatoporoids, excellent outcrops of which are located in Gotland (Sweden) and Saaremaa (Estonia). In addition, stromatoporoid/coral, coral/coral and some new fossil associations are reported. The material studied probably was transported from the N, the NE, and less commonly from the NW.

**Key words:** Pleistocene deposits, Fore-Sudetic Block, Roztoka-Mokrzeszów Graben, ichnology, Arachnostega, Osprioneides, Balanoglossites.

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**INTRODUCTION**

In the SW Poland, especially in the Fore-Sudetic Block (Mokrzeszów Quarry, Świebodzice outcrop), many glacial erratic boulders, Cambrian to Neogene in age, occur in Pleistocene sands and tills (Fig. 1). They originated in Baltoscandia (Salamon et al., 2013 and references therein) and probably were transported and deposited during the Middle Polish Glaciation (Saalian Glaciation, see Marks, 2004; Marks et al., 2016). The most interesting are glacial erratic boulders of sedimentary rocks, because of their rich body and trace fossil content.

The erratic boulders studied contain diverse trace fossils, in some cases new for the source areas. The most interesting discovery is Arachnostega in the pygidium of the trilobites ?Megistaspis sp. (probably from Sweden) and Asaphus sp. (from the St. Petersburg region of Russia, or from Estonia). So far, Mikuláš and Dronov (2010, p. 63) described this trace fossil from Baltoscandia on the mould of an unidentified trilobite in the Obukhov Formation (the trilobite Asaphus raniceps – Asaphus striatus Zone, Tab. 1), Kunda Regional Stage (St. Petersburg region), but this ichnogenus was unknown on arthropods in Estonia and Sweden. Arachnostega found in hyolithids (this study), might come from the St. Petersburg region (Russia), where it was reported only in cephalopods and trilobites. The next interesting and rare Palaeozoic boring is Osprioneides kampto, encountered both in ?Ordovician Orthoceratite Limestone, which is exposed mainly in southern and central Sweden, western Russia and Estonia, and also in Norway (Oslo Region). The most interesting discovery in these deposits is the occurrence of Arachnostega gastrochaenae in the Ordovician trilobites (?Megistaspis sp. and Asaphus sp.), cephalopods and hyolithids. This is the first report of Arachnostega on a trilobite (?Megistaspis) from Sweden. So far, this ichnotaxon was described on trilobites from Baltoscandia only from the St. Petersburg region (Russia). Arachnostega on a trilobite (Asaphus), a cephalopod and hyolithids is from Russia or Estonia. Another interesting ichnotaxon is Balanoglossites, which also was encountered in the erratic boulders from the Ordovician Orthoceratite Limestone of Sweden. So far, this ichnotaxon was known only from Russia (St. Petersburg region). Some rare borings (e.g., Osprioneides kampto, ?Palaeosabella isp.) also were found in glacial erratics of Silurian stromatoporoids, excellent outcrops of which are located in Gotland (Sweden) and Saaremaa (Estonia). In addition, stromatoporoid/coral, coral/coral and some new fossil associations are reported. The material studied probably was transported from the N, the NE, and less commonly from the NW.
Fig. 1. Location of the Roztoka Mokrzeszów Graben in the Sudetes Mountains (A) and the Świebodzice outcrop and the Mokrzeszów Quarry (B).
Interesting discoveries in the glacial erratic boulders of North Germany and Lower Silesia already were studied by German geologists in the nineteenth century (e.g., Emmrich, 1839, 1844; Roemer, 1861, 1885). Some trace fossils were reported first from erratic boulders, e.g. the early Cambrian *Tubichnus angulatus* in NE Germany (Rügen Island, Western Pomerania) and S Sweden (Öland Island) by Hoffmann *et al.* (2016 and references therein).

In addition, some coral/coral and stromatoporoid/coral intergrowths as well as rare or new fossil associations, such as crinoid/stromatoporoid, brachiopod/bryozoan, brachiopod/coral and coral/microconchid, also were noted in the glacial erratic blocks studied in SW Poland. Some of them were bored by *Trypanites*.

Most of the trace fossils were found in the Mokrzeszów Quarry. This is partly due to the poor exposure of the Pleistocene deposits at Świebodzice, now completely flooded, by comparison with the very well exposed deposits in the Mokrzeszów Quarry.

The newly collected trace fossils are now in the Geological Museum of the University of Wrocław (samples MGUWr-6593s–MGUWr-6622s). Some specimens are in the private collection of Józef Kawalko at Świebodzice.

The aim of this paper is to report on and describe all of the ichnotaxa found in the erratic boulders at the study sites. The probable source areas of the boulders were indicated on the basis of the trace fossils, the associated body fossils and the lithology. A large number of the trace fossils are from the Ordovician Orthoceratite Limestone. The colour of the limestones, reddish or grey, and their skeletal fossil content (e.g., the trilobites *Asaphus* sp., *Megistaspis* sp., or the cephalopod *Anthoceras vaginatum* Schlotheim, 1820) allow recognition of the possible source areas, i.e., Sweden, Estonia or Russia. However, it is important to note that the distribution of their outcrops at present and during the glaciation period might have been slightly different. For instance, some exposures might have been eroded or become covered with post-glacial sediments, while others...
appeared at the surface only recently. The determination of the source area of the glacial erratic boulders also indicates the direction of ice-sheet movement.

**GEOLOGICAL SETTING OF THE AREA**

The Mokrzeszów Quarry and the Świedbodzice outcrop are situated in the Fore-Sudetic Block of the Roztoka-Mokrzeszów Graben (Zelaźniewicz et al., 2011). This geological unit is bounded by the Strzegom-Sobótka Granite Pluton, Sowie Mountains Gneiss Massif, Świedbodzice Unit and the Kaczawa Greenstone-and-Slate Fold Belt (Fig. 1). The Roztoka-Mokrzeszów Graben, situated along the Sudetic Marginal Fault, started to subside during the latest Oligocene to Early Miocene (Jarosiński et al., 2009 and references therein).

The Mokrzeszów Quarry is situated in the southern part of the Roztoka-Mokrzeszów Graben, 1.5 km from the Sudetic Marginal Fault, whereas the Świedbodzice outcrop is 1.5 km to the north of Świedbodzice (Fig. 1). The Roztoka-Mokrzeszów Graben is filled with Neogene and Pleistocene deposits, which are 200–400 m and 30–50 m thick, respectively (Krzyszowski and Bowman, 1997; Niedzielski and Migoń, 2005).

In the Mokrzeszów Quarry, sands predominate in the lower part, while gravel intercalations are common in the middle and upper parts. These deposits are subdivided into five units showing differences in lithology (Salamon et al., 2013). Krzyszowski (2013) reported erratic blocks from several centimetres to 1.0–1.5 m in diameter, in some cases larger, 35–45% of which are “Baltic limestone”, and 23–39% are Scandinavian crystalline rocks. Less common are Mesozoic sandstones and limestones, as well as local granites.

The Mokrzeszów Quarry (Fig. 1) dates back to 1920, but discoveries of fossils there (known as Nieder Kunzendorf bei Freiburg in the older literature) were reported much earlier (Emmrich, 1839; Salamon et al., 2013 and references therein). It is still a very rich palaeontological site (Pluta, 2013). The quarry yields well preserved macrofossils (e.g., sponges, trilobites, corals, stromatoporoids, bryozoans, molluscs, brachiopods, echinoderms, graptolites, and vertebrate remains) and trace fossils (Pluta, 2013). The holotypes of the trilobites Odontopleura ovata Emmrich, 1839 and Leonaspis mutica Emmrich, 1844 are from erratic blocks at this site (see also Bruton, 1967). Only recently, Calmet et al. (2006) reported the first Odontopleura ovata in Scandinavia (Sweden, Gotland). As well, Silurian graptolites from the quarry were mentioned by Urbanek (1966) and studied by Radzievičius et al. (2010).

The Pleistocene deposits, exposed in the SW Poland, were assigned to the Middle Polish Glaciation (Saalian, see Marks, 2004; Marks et al., 2016) by Dyjor and Kuszell (1977), Jahn (1981) and Badura et al. (1992). However, Czubla (2013) suggested that they are referable to the South Polish Glaciation (Elsterian).

The sequence studied is interpreted as coarse-grained delta deposits (Salamon et al., 2013 and references therein). Czubla (2013) also analyzed the transport directions of the erratic material, mostly the Scandinavian crystalline boulders. This author suggested that the Öland region, Sweden, is the source area for the “red Baltic limestone” (Ordovician Orthoceratite Limestone). Earlier, Jahn (1981) noted the N and NE directions of movement of the ice sheet in Lower Silesia. Gór ska-Zabielska (2008) reported that sedimentary, especially Palaeozoic erratics, come mainly from the bottom of the Baltic Sea area, as well as Götaland, Öland and the Baltic countries, whereas the Cretaceous blocks were derived from the SW Baltic region.

A large part of the glacial erratic boulders in SW Poland (Mokrzeszów Quarry, Świedbodzice outcrop) come from the Ordovician Orthoceratite Limestone, outcrops of which are located mainly in northern, central and southern Sweden (e.g., Öland), Norway (Oslo Region), East Baltic (e.g., Estonia) and in the St. Petersburg region of western Russia. These deposits are known also from deep boreholes in N Poland and from the Pleistocene erratics in northern Germany and northern Poland (Kröger, 2004 and references therein; Eriksson, 2010). Numerous erratic blocks studied are composed of Silurian stromatoporoids, which are known from excellent outcrops in Saaremaa (Estonia) and Gotland (Sweden) or neighbouring areas (see Sandström and Kershaw, 2002, 2008).

The Ordovician Orthoceratite Limestone, which consists of mainly bioclastic limestones or calcareous shales, slightly dolomitized and containing glauconite grains (Mikulás and Dronov, 2005, 2010; Meidla et al., 2008; Eriksson, 2010), belongs mainly to the Volkhov and Kunda regional stages, which are Floian to Dariwilian in age (Tab. 1). These limestones are grey, brownish or red in colour, depending on the rising oxygenation of the sediment (Kröger, 2004; Histon, 2012). The reddish limestones occur mainly in Sweden, whereas light-grey or yellowish-grey limestones are in Estonia and Russia. These deposits are known also as the Endoceras Limestone (Oslo area), Vaginatenvalk in the eastern Baltic and the Vaginatum Limestone in Sweden (see Kröger, 2012; Kröger and Rasmussen, 2014). Their name is reference to the abundance of large, orthoceracocn cephalopods, including orthocerids, endocerids and actinoceratids (see Kröger, 2004). Trilobites (asaphids), echinoderms (especially cystoids) and molluscs (e.g., hyolithids) also occur in abundance, in addition to the very common nautiloids (Benner et al., 2004; Eriksson et al., 2013).

**SYNOPSIS OF TRACE FOSSILS**

Seventeen ichnogenera, nine referable to burrows and eight to borings, were found in the glacial erratic boulders studied. They occur mainly in the Ordovician Orthoceratite Limestone (Arachnostegite, Balanoglossitites, Planolitites) and in the Silurian stromatoporoids (Osprioneides, ?Palaeosabella, Trypanites). Chondrites, Diplocraterion, Phycodes, ?Rosselia, Skolithos and Thalassinoides were found in boulders made up of Palaeozoic rocks, whereas ?Gastrochaenolites, Maeandropolydora, Oichnus, Talpina, Teredolites occurred in boulders of Mesozoic-Cenozoic rocks.
**Burrows**

_Arachnostega_ Bertling, 1992  
_Arachnostega gastrochaenae_ Bertling, 1992

**Material:** Six specimens: two on the pygidium of the trilobites: ?_Megistaspis_ (10–13 cm long; Fig. 2A–E; MGUWr-6593s), one on a pygidium of _Asaphus_ sp. (4 cm long; Fig. 2F; MGUWr-6594s), one specimen on a cephalopod (16 cm long; Fig. 3A; MGUWr-6595s) and two on hyolithid conchs (45–72 mm long; Fig. 3B; private collection of J. Kawalko) found in Ordovician Orthoceratite Limestone erratic boulders: reddish (Fig. 2A–E) and grey (Figs 2F, 3A, B) in the Mokrzeszów Quarry. The sixth specimen was noticed on the pygidium of the trilobite _Asaphus expansus_ (5.5 cm ong; Fig. 2G, H), from the collection of the Geological Museum of the Wrocław University (MGUWr-129s), found in the glacial erratic boulders near Olesnica (Sadowice, formerly Sadewitz), probably by Roemer (1861).

**Description:** Net-like structure, composed of straight or slightly curved, ramified tunnels at the surfaces of pygidia of the Ordovician trilobites _Megistaspis_ sp. and _Asaphus_, and on cephalopod and hyolithid moulds. In some cases, the tunnels are widened slightly at junctions, typical for this ichnogenus. The tunnels are oval or elliptical in cross-section, 0.1–1.5 mm, mainly 1.0 mm wide.

**Remarks:** _Arachnostega_ usually is interpreted as a feeding structure of the category fodinicchia, produced by detritus- or deposit-feeding polychaetes (Bertling, 1992). However, Fatka et al. (2011) considered it also as a domicichnion. This ichnogenus was recognized in Baltoscandia, in the Middle–Upper Ordovician (Darrwilian–Katian) deposits of Russia (Mikuláš and Dronov, 2005, 2010) and Estonia (Vinn et al., 2014b; Chrząstek and Pluta, 2017 and references therein). In Russia, it was found on a cephalopod and a trilobite, whereas in Estonia it occurred on bivalves, gastropods, cephalopods, hyolithids and cystoids. On the basis of the associated lithology, the specimens found in the trilobite _Megistaspis_ probably are from Sweden, while those in _Asaphus_, the cephalopod and hyoliths are from Russia (St. Petersburg region) or Estonia. The range of _Arachnostega_ is from the Cambrian (Fatka and Kozak, 2014) to Recent (Bertling, 1992). It is common in the Mesozoic and Cenozoic. Paleozoic _Arachnostega_ was reported mainly from the Cambrian and Ordovician of the Czech Republic (Bruthansová and Kraft, 2003; Fatka et al., 2011, 2015), Spain and Portugal (Gil Cid and Lebron Moreno, 2010) and Argentina (Aceñolaza et al., 2003).

_Balanoglossites_ Mägdefrau, 1932  
_Balanoglossites_ isp.

**Material:** Five blocks with several specimens in erratic boulders, composed of the reddish Ordovician Orthoceratite Limestone from the Mokrzeszów Quarry, which contain trilobites and large endocerids (up to 24.5 cm long; Figs 3C–F; MGUWr-6596s–6598s). Two specimens, determined as _Balanoglossites_ isp. (MGUWr-6599s, MGUWr-6600s; Fig. 3G, H), are probably from Devonian limestones with brachiopods (Spiriferida).

**Description:** Branched, unlined tunnels with circular or elliptical cross-sections, 2–12 mm in diameter, which display blind-ending side branches and terminations. They plunge into the rock at least up to 20–40 mm and show openings, which are 5–10 mm wide. Some of the tunnels are U-shaped.

In the possibly Devonian limestone, _Balanoglossites_ appears as irregular, branched tunnels, 3–5 mm in diameter, visible in cross-section (Fig. 3G, H), segments of which are 25–40 mm long between branches.

**Remarks:** _Balanoglossites_ is regarded as a combined feeding and dwelling structure (fodinichnion/domicichnion) of worm-like animals (Knaust and Costamagna, 2012). The tracemaker of _Balanoglossites_ was probably an eunicid polychaete, which had the ability to bioerode and burrow the sediment (see Knaust, 2008; Knaust and Dronov, 2013).

_Balanoglossites_ was described from the Ordovician Orthoceratite Limestone of western Russia (St. Petersburg region) by Knaust and Dronov (2013). The lithology of the boulders, in which _Balanoglossites_ occurs, indicates Sweden as an area of origin. According to A. Dronov (pers. comm., 2014), this ichnogenus occurs there. It ranges from the ?Middle Cambrian (Ekdale et al., 2012) to the Neogene (Schäfer et al., 1996), but it is most common in the Ordovician, even more than in the Triassic (see Knaust and Dronov, 2013).

_Chondrites_ Sternberg, 1833  
?_Chondrites_ isp.

**Material:** One specimen on a parting surface (Fig. 4A, B; housed in the private collection of J. Kawalko) and one in cross-section (Fig. 4C; MGUWr-6601s), both in probably Lower Palaeozoic limestones.

**Description:** A complex, root-like burrow system of mostly vertical or inclined, regularly branching, unlined tunnels, which are open to the surface. The tunnels are circular and elliptical in cross-section, 2–3 mm in diameter and 20–50 mm long, without crossings. Their fill is darker than the host rock.

**Remarks:** The specimen studied (Fig. 4A, B) shows some similarities to _Chondrites affinis_ Sternberg, 1833, described by Uchman et al. (2012) as having straight to slightly curved tunnels (which never cross) and rounded terminations of these tunnels. By comparison with _Chondrites affinis_, the tunnels of the specimen described are narrower (2–3 mm instead of 4–5 mm in width) and they do not show the characteristic twigs in the branched tunnels, which run outward from the centre (compare Uchman et al., 2012). The specimen studied does not consist of ramified tunnels that form a dendritic network, characteristic of this ichnogenus but has a number of main shafts open to the surface (cf. Bhattacharaya and Banerjee, 2014). For these reasons, it should be assigned only tentatively to the ichnogenus _Chondrites_.

**Remarks:** Balanoglossites isp.
Fig. 2. *Arachnostega gastrochaenae* on pygidium of the trilobite *Megistaspis* and *Asaphus*, erratic blocks built of the Ordovician Orthoceratite Limestone. A–C. On the trilobite *Megistaspis*, Mokrzewsów Quarry (private collection of J. Kawalko). D, E. On the trilobite *Megistaspis* (a), cephalopod *Anthoceras vaginatum* (b), Mokrzewsów Quarry; MGUWr-6593s. F. On pygidium of *Asaphus* sp., Mokrzewsów Quarry; MGUWr-6594s. G, H. *A. gastrochaenae* (a) on pygidium of the trilobite *Asaphus expansus* (MGUWr-129s, specimen found by Roemer in 1861 in erratic boulders; Sadowice, near Oleśnica (formerly Sadewitz by Oels), the same specimen. Arrows indicate *Arachnostega*, on the pygidium of *Megistaspis* sp.
Fig. 3.  

**A.** *Arachnostega* on other fossils and *Balanoglossites*. *A. gastrochaenae* (a) on a cephalopod, Mokrzeszów Quarry; MGUWr-6595s; arrow is pointing *Arachnostega*. **B.** *A. gastrochaena* (a) on hyolithids, Mokrzeszów Quarry (private collection of J. Kawałko). **C, D.** *Balanoglossites* isp. in the Ordovician Orthoceratite Limestone, Mokrzeszów Quarry; MGUWr-6596s. **E.** *Balanoglossites* (a) and the cephalopod *Anthoceras vaginatum* (b) in the Orthoceratite Limestone; MGUWr-6597s. **F.** Openings of the *Balanoglossites* isp. (a) seen on the surface of an erratic boulder composed of Orthoceratite Limestone, Mokrzeszów Quarry; MGUWr-6598s. **G, H.** *Balanoglossites* isp. (a) and a spiriferid brachiopod (b) in the Devonian limestone erratic boulders (MGUWr-6599s-MGUWr-6600s).
Fig. 4. Burrows in Lower Palaeozoic erratic boulders. A, B. ?Chondrites isp. in Lower Palaeozoic limestone erratic boulder, Mokrzeszów Quarry. C. ?Chondrites isp. in the cross-section, limestone erratic boulder, Mokrzeszów Quarry, MGUWr-6601s. D. Diplocraterion isp., the pair of the openings; ?Cambrian sandstone block, Mokrzeszów Quarry. E, F. Phycodes isp. in a ?Cambrian sandstone erratic boulder; Mokrzeszów Quarry. G. Planolites isp. (a) in a glacial erratic boulder of the Ordovician Orthoceratite Limestone; Mokrzeszów Quarry. H. ?Rosselia isp. (a) in a Lower Palaeozoic (?Cambrian) sandstone erratic boulder; Mokrzeszów Quarry. Specimens A, B, D–H housed in the private collection of J. Kawalko. Arrows indicate the burrows Diplocraterion (D) and Phycodes (E, F).
Chondrites was regarded as a feeding structure belonging to the category fodinichnia (Häntzschel, 1975; Frey and Howard, 1990). More recently, it is considered to be a chemichnion (see Rindsberg, 2012). Candidates for trace-maker are among the deposit-feeding sipunculids, polychaetes, anthoptiloid sea pens, arthropods (e.g., Osgood, 1970; Pickerill et al., 1984).

In Baltoscandia, Chondrites is known from the Ordovician of the St. Petersburgh region, Russia (Dronov, 2011; Dronov et al., 2002), the Upper Ordovician of the Oslo region, Norway (Hanken et al., 2016), and from the Upper Triassic of Bornholm, Denmark (Nielsen et al., 2015). It ranges from the Eodiogenous (McCann and Pickerill, 1988; Buatois and Mángano, 2011), through the Cambrian to Recent (Häntzschel, 1975; Seilacher, 2007).

Diplocraterion Torell, 1870

Diplocraterion isp.

Fig. 4D

Material: Several specimens, visible in the same sandstone sample (probably Cambrian), housed in the private collection of J. Kawałko.

Description: Endichnial, U-shaped structures, mostly visible as paired circular or dumbbell-like openings. They are 12–27 mm, mostly 15 mm wide. One vertical U-shaped spreiten structure is visible. It shows parallel limbs, perpendicular to the bedding plane, 60 mm long. Only protrusive spreiten have been recognized. The marginal tunnel is 5 mm wide.

Remarks: The study specimen is very similar to the Diplocraterion reported by Prothero (2004, fig. 19.4F) from southern Sweden. This ichnogenus is interpreted as a dwelling or equilibrium structure (Häntzschel, 1975; Bromley, 1996; Pemberton et al., 2001), produced by suspension- detritus- or filter-feeding organisms, mainly polychaetes or amphipod crustaceans (Fürsich, 1974; Cornish, 1986; Gradziński and Uchman, 1994; Pemberton et al., 2001; Hanken et al., 2016).

Diplocraterion was described from the lower Cambrian of south-central Sweden by Torell (1870), Westergård, (1931) and Jensen (1997) and from southern Sweden (Scania) and Denmark (Bornholm) by Nielsen and Schovbso (2011). Bromley and Hanken (2003) and Hanken et al. (2016) reported this ichnogenus from the lower Cambrian and Upper Ordovician of Norway. It is known from Cambrian to Recent (Cornish, 1986; Gradziński and Uchman, 1994).

Phycodes Richter, 1850

Phycodes isp.

Fig. 4E, F

Material: The specimens studied are preserved in a full relief in the Lower Palaeozoic sandstone erratic boulder (private collection of J. Kawałko).

Description: Broom-like bundle of four-seven horizontal tubes, showing two-three branches. The tubes originate from nearly the same point of a thick, single stem. The tubes are about 5 mm in diameter and up to 30 mm long.


In Baltoscandia, this ichnogenus was reported from the lower Cambrian of Sweden by Jensen (1997) and Jensen and Grant (1998) and from the Ordovician of the St. Petersburgh region, Russia by Dronov (2011). Knaust (2004) described this burrow from the Cambrian-Ordovician deposits of SW Norway. Generally, Phycodes is known from the lower Cambrian to the Miocene (Han and Pickerill, 1994) and is common in the Lower Palaeozoic. Recently, this ichnogenus was described also from the Pliocene (Belusteguï and Muñiz, 2016).

Planolites Nicholson, 1873

Planolites isp.

Fig. 4G

Material: Several specimens occur in erratic blocks of the Ordovician Orthoceratite Limestone (private collection of J. Kawałko).

Description: A straight or slightly undulating, smooth, unlined, cylindrical burrow, elliptical or circular in cross-section, 3 mm in diameter, at least 70 mm long. Lithology of the fill differs from the host rock.

Remarks: Planolites is interpreted as a pascichnion of deposit feeders produced by various organisms, mostly polychaetes (Pemberton and Frey, 1982; Keighley and Pickerill, 1995).

In Baltoscandia, this ichnogenus was reported from the Ordovician of the St. Petersburgh region, Russia (Dronov et al., 2002; Dronov, 2011). It is known from the late Proterozoic to Holocene (Häntzschel, 1975; McCann and Pickerill, 1988).

Rosselia Dahmer, 1937

?Rosselia isp.

Fig. 4H

Material: One specimen, collected from a Lower Palaeozoic sandstone erratic boulder (private collection of J. Kawałko).

Description: The specimen studied is visible in a transverse cross-section as an oval structure, about 20 mm wide, and continues into the rock as partly visible on the side. It shows a central shaft and alternating, concentric, sandy and muddy laminae. The shaft is 5 mm in diameter. The concentric, sandy and muddy laminae are 2 mm and 0.5–1.0 mm thick, respectively.

Remarks: The specimen studied resembles the upper part of Rosselia, which is characterized by a funnel or spindle shape and concentric, internal lamination. It is regarded as a fodinichnial-domicnichial (Nara, 1995) and equilibrichnial structure (Nara, 2002).

Rosselia was produced by suspension or detritus feeders, most probably terebellid polychaetes (Nara, 1995, 2002). Sea anemones also have been considered as the possible
producers (Uchman and Krenmayr, 1995). Rosselia has been reported from the lower Cambrian of south-central Sweden by Jensen (1997) and from the Upper Ordovician of Estonia (Vinn and Toom, 2016 and references therein). It ranges from the Cambrian to the Holocene (Nara and Haga, 2007).

Skolithos Haldeman, 1840
Skolithos linearis Haldeman, 1840

**Material:** Several specimens (MGUWr-6606s-MGUWr-6607s), preserved in the Lower Palaeozoic sandstone erratic boulders (probably Cambrian).

**Description:** Straight, smooth, vertical and unbranched cylindrical burrow, perpendicular to the bedding planes, circular or elliptical in cross-section, at least 65 mm long and 2–2.5 mm in diameter. The fill is structureless.

Marine *Skolithos* is a dwelling burrow (domichnion) of suspension-feeding annelids or phoronids (Alpert, 1974; Buckman, 1996).

In Baltica, *Skolithos* was reported from the lower Cambrian of southern-central Sweden by Jensen (1997; and references therein). Nielsen and Schovbos (2011) described this ichnogenus from the lower Cambrian of Bornholm, Denmark, while Vinn and Wilson (2013) from the Silurian of Saaremaa, Estonia. This ichnogenus is common in the Lower Palaeozoic, mostly Cambrian, where it forms piperold (Knaust, 2015). It ranges from the late Precambrian to Recent (Häntzschel, 1975; Fillion and Pickerill, 1990).

Thalassinoides Ehrenberg, 1944
*Thalassinoides* isp.

**Material:** One specimen in a Palaeozoic sandstone block (private collection of J. Kawalko).

**Description:** *Thalassinoides* appears as cylindrical, flattened tunnels, 2.0 cm wide, elliptical in cross-section. This burrow exhibits Y-shaped branching and crossings of the tunnels.

**Remarks:** *Thalassinoides* is regarded as a domicichnion/fo-dinichnion or even an agrichnion produced mostly by thalassinidean shrimps (Myrow, 1995; Bromley, 1996; Ekdale and Bromley, 2003). Frey et al. (1984), Neto de Carvalho et al. (2007) and Neto de Carvalho (2016) proposed also crabs and lobsters.

From Baltoscandia, *Thalassinoides* was described by Cherns et al. (2006), together with *Asaphus* sp. (its possible tracemaker), and by Ekdale and Bromley (2003) from the Ordovician of Sweden. It is known from the Cambrian (Myrow, 1995) to Recent (Ekdale and Bromley, 2003).

Root traces (rhizoliths)

**Material:** A few blocks (20 x 30 cm) of dark brown sandstones (probably Mesozoic-Cenozoic in age), containing fossil wood, some plant or root traces, Mokrzesów Quarry (MGUWr-6615s).

**Description:** Straight or slightly curving, smooth, occasionally branched tunnels, resembling roots. They are 5–50 mm long and 1–6 mm wide. Some of them show a delicate ornamentation in the form of horizontal wrinkles. Additionally, *Trypanites* (1 mm wide, 15–20 mm long) occurs in the same blocks.

**Remarks:** Similar root traces were described from Upper Triassic continental sandstones in Baltoscandia (Bornholm, Denmark) by Knaust (2015).

**Borings**

Gastrochaenolites Leymerie, 1842

**Material:** One specimen in a bivalve shell, Mokrzesów Quarry (private collection of J. Kawalko).

**Description:** Broad, unornamented, drop-like cavity, which is circular in transverse section, 15 mm deep and up to 2 mm wide. The upper neck-like part is eroded.

**Remarks:** *Gastrochaenolites* is regarded as a dwelling structure (domichnion), produced by suspension-feeding gastrochaenid, lithophagid, pholadid and mytilid bivalves (Warne, 1975; Kelly and Bromley, 1984). Recent coralophillid gastropods (closely related to Muricidae, see Oliverio and Mariottini, 2001) and some sipunculan worms also have been suggested as the potential tracemakers of *Gastrochaenolites* (Bromley, 2004). It may occur also as a burrow (Mikuláš et al., 2003).

*Gastrochaenolites* was described from the Lower–Middle Ordovician of Baltoscandia (Sweden, Norway, Estonia, Russia) by Ekdale and Bromley (2001), Ekdale et al. (2002), Dronov et al. (2006) and Vinn and Wilson (2010c). The specimen studied was found in a probably Jurassic *Gryphaea* shell. *Gastrochaenolites* ranges from the Early Ordovician to Recent (Kelly and Bromley, 1984), more commonly in the Jurassic (Wilson and Palmer, 2006).

Maerandropolydora Bromley and D’Alessandro, 1983

**Material:** Borings preserved in two valves of the *Gryphaea* shells, Mokrzesów Quarry (private collection of J. Kawalko).

**Description:** Long, straight or sinuous, shallow, cylindrical borings, usually unbranched, 0.5–1.5 mm in diameter. One shell is almost completely bioeroded, especially the right valve (Fig. 5G).

**Remarks:** *Maerandropolydora* is interpreted as the domicichnion of suspension-feeding organisms, probably polychaetes (Bromley and D’Alessandro, 1983; Taylor and Wilson, 2002).

This ichnogenus is commonly preserved on the shell surfaces, usually bivalves, especially oysters (Parras and...
Fig. 5. Burrows in Palaeozoic rocks and borings in Mesozoic-Cenozoic shells and root traces. A, B. Skolithos linearis, ?Cambrian sandstone block; Mokrzeszów Quarry; MGUWr-6606s-6607s; arrows are pointing vertical burrows ascribed to Skolithos. C. Thalassinooides isp. in Palaeozoic sandstone erratic boulder; Mokrzeszów Quarry. D. Root traces bored by Trypanites; root traces (a), Trypanites (b) in the ?Mesozoic-Cenozoic sandstone erratic boulders; Mokrzeszów Quarry; MGUWr-6615s. E. Gastrochaenolites isp. (a) in the Gryphaea shell; Mokrzeszów Quarry. F, G. Maeandropolydora isp. in the Gryphaea shells; Mokrzeszów Quarry. H. Oichnus isp. (a) in a Mesozoic bivalve shell; Mokrzeszów Quarry, MGUWr-6602s. Specimens C, E–G housed in the private collection of J. Kawałko.
Bromley, 2004). The specimen studied was found on *Gryphaea* shells (probably Jurassic). *Macandropolydora* ranges from the ?Silurian/Devonian to Recent, commonly in the Mesozoic and Cenozoic, mainly in the Jurassic and Cretaceous (Taylor and Wilson, 2003; Bromley, 2004).

*Oichnus* Bromley, 1981  
*iisc*  
Figs 5H, 6A, B

**Material:** One specimen in a Mesozoic bivalve (MGUWr-6602s; Fig. 5H; Mokrzeszów Quarry) and three specimens in Miocene gastropod shells (MGUWr-6603s-6604s; Fig. 6A, B; Świebodzice outcrop).

**Description:** Small, circular or subcircular holes, perpendicu lar to the shell surface, 3–4 mm in diameter. They do not pass through the shells, but terminate within the shell as a flat-bottom depression.

**Remarks:** The specimens studied were found in a bivalve shell (Mesozoic) and gastropods (probably Miocene) in the Mokrzeszów Quarry and the Świebodzice outcrop, respectively. *Oichnus* was reported from Upper Cretaceous corals in Sweden (Sørensen and Surlyk, 2011).

Wisshak et al. (2015) noted that *Oichnus* is not a junior synonym of *Sedilichnus*, as presented by Zonneveld and Gingras (2014). *Oichnus* is interpreted as a paedichnion (Bromley, 1981), which was produced in the Cretaceous and Cenozoic by predatory gastropods of the families Naticidae and Muricidae (Taylor et al., 1983; Mallick et al., 2014 and references therein) in shells belonging to different taxa (Bromley, 1981; Klompmaker et al., 2016). According to Bromley (1993, 2004) and Todd and Harper (2010), octopods can make drill-holes closely similar to those of muricaceans.

*Oichnus* is known from the Cambrian to Recent (Wilson, 2007) and is common in the Cenozoic (Kowalewski et al., 1998; Harper, 2003). According to Bromley (2004) and Buatois et al. (2016), it also occurs in the Ediacaran.

*Osprioneides* Beuck and Wisshak, 2008  
in Beuck et al., 2008  
*Osprioneides kampto* Beuck and Wisshak  
in Beuck et al., 2008  
Figs 6C–F

**Material:** Borings in two stromatoporoid blocks (Fig. 6C, D; MGUWr-6605s) and in a large (8 x 8.5 cm) bryozoan (Fig. 6E, F; private collection of J. Kawalko); Mokrzeszów Quarry.

**Description:** Numerous, large, unbranched, single-entrance, straight or slightly undulating in course, deep cavates with oval cross-sections, up to 22–24 mm long, 10–18 mm deep, and 3–6 mm in diameter. The borings studied are vertical or subparallel to the external surface of the stromatoporoids and the bryozoan. They lack any scratch traces. In some cases, the borings cross each other and usually show a tapered to hemispherical terminus.

**Remarks:** *Osprioneides* is regarded as a domicinion of a suspension-feeder, most likely polychaetes (Beuck et al., 2008).

It was found in the Lower Silurian (Sheinwoodian) stromatoporoids and tabulate corals of Saaremaa (Estonia) by Vinn and Wilson (2010a) and in the Silurian (lower Wenlock) of Gotland (Sweden) by Beuck et al. (2008). Vinn et al. (2014a) found this ichnogenus for the first time in the Late Ordovician (Sandbian) bryozaons of Estonia. Chrząstek and Pluta (2017) also have reported these borings from the Upper Ordovician bryozaons of Estonia. The specimens studied come from Silurian stromatoporoids (Sweden or Estonia) and an ? Upper Ordovician bryozaon (?)Estonia. *Osprioneides kampto* occurs only in the Ordovician (Vinn et al., 2014a) and Silurian, from the Llandovery to the Ludlovian (Beuck et al., 2008).

*Palaeosabella prisca* McCoy, 1855  
*iisc*  
**Material:** A few specimens (MGUWr-6605s) in two stromatoporoid blocks, preserved in glacial erratic boulders; Mokrzeszów Quarry.

**Description:** Straight, vertical drill-holes, circular in a cross-section in the upper part of stromatoporoids, 3–7, mainly 5 mm in diameter. The terminus, which is slightly enlarged distally, is partially visible.

**Remarks:** *Palaeosabella* is regarded as a “worm” boring (Cameron, 1969; Bromley, 2004). Furlong and McRoberts (2014) proposed the name *Clionoides* Fenton and Fenton, 1932 instead *Palaeosabella* McCoy, 1855. The ichnotaxon studied is similar to *Trypanites*, but differs from it by having a terminus, which is enlarged distally (see Bromley, 2004; Wilson and Palmer, 2006; Tapanila and Hutchings, 2012).

*Palaeosabella* was mainly described from Silurian stromatoporoids and corals of Sweden (Gotland) and Estonia (Saaremaa) by Beuck et al. (2008) and Vinn and Wilson (2010a, 2012a). This ichnotaxon also was reported by Wyse Jackson and Key (2007) from Ordovician bryozaons in Estonia. The specimen described was found in the glacial erratic boulders, in stromatoporoids, probably Silurian in age and originating in Sweden (Gotland) or Estonia (Saaremaa). *Palaeosabella* is distributed mainly in the Palaeozoic, but its stratigraphical range is from the Late Ordovician (Taylor and Wilson, 2003) until Recent (Bromley, 2004).

*Talpina* Hagenow, 1840  
*iisc*  
**Material:** One specimen in the rostrum of a belemnite, Mokrzeszów Quarry (private collection of J. Kawalko).

**Description:** Network of straight or gently undulating tunnels on the surface or very shallowly below surface of a belemnite, rarely branching, circular to semi-circular in cross-section, 3–4 mm in diameter.
Fig. 6. Borings in Palaeozoic, Mesozoic and Cenozoic fossils and wood. A, B. *Oichnus* isp. (a) in Miocene gastropod shells; Świebodzice outcrop, MGUWr-6603s-6604s. C. *Osprioneides kampto* (a) in a Silurian stromatoporoid; Mokrzeszów Quarry (MGUWr-6605s). D. *Osprioneides kampto* (a), ?*Palaeosabella* isp. (b) and *Trypanites* isp. (c) in a Silurian stromatoporoid; Mokrzeszów Quarry; MGUWr-6605s. E, F. *Osprioneides kampto* in an ?Upper Ordovician bryozoan; Mokrzeszów Quarry. G. *Talpina* isp. (a) in the rostrum of a belemnite (Cretaceous); Mokrzeszów Quarry. H. *Teredolites* isp. in a piece of wood (Jurassic–Miocene?); Mokrzeszów Quarry. Specimens E–H housed in the private collection of J. Kawałko. Arrows indicate the borings *Osprioneides* (E) and *Teredolites* (H).
Remarks: Owing to the poor state of preservation of the boring, the branching pattern is not clearly visible, but it seems that lateral branches occur on one side, which is typical of *Talpina* (see Uchman *et al.*, 2016). According to some authors (e.g. Bromley, 2004), *Conchostrongylus teichertii*, 1945 is a junior synonym of *Talpina* von Hagenow, 1840. Uchman *et al.* (2016) distinguished and described both ichnotaxa *Talpina* and *Conchostrongylus*, whereas Wisshak *et al.* (2017) rediscovered the type material of *Talpina* (from the Hagenow, 1840 collection). From an ethological point of view, *Talpina* is a domiclinch produced by suspension-feeding phoronid worms (Bromley, 2005; Tapanila and Hutchings, 2012; Zonneveld and Briston, 2013).

From Baltoscandia, *Talpina* was described by Neumann *et al.* (2008) from echinoderm spines in Denmark. The belemnite bearing the specimen studied is probably Cretaceous in age. *Talpina* is known from the Devonian to Recent (Taylor and Wilson, 2003) and is abundant in the Jurassic (Bromley, 2004).

### Teredolites

*Teredolites Leymerie, 1842*

*Teredolites* isp.

Figs 6H, 7A

**Material:** Eight specimens in a piece of fossil wood (Mesozoic–Cenozoic), which is 13 cm long and 6 cm wide; Mokrzeszów Quarry (private collection of J. Kawalko).

**Description:** Clavate borings, in which the neck region passes gradually into the chamber part. They are circular or elliptical in cross-section, 22 mm long and 4–6 mm in diameter. Their surface may show faint bioglyphs in the form of parallel rings and grooves, which encircling the individual tubes (see Kelly and Bromley, 1984; Kumar *et al.*, 2011).

**Remarks:** *Teredolites* is a domiclinch (Savrda and Smith, 1996) or a fodinichnion, produced by wood-boring bivalves (Bromley *et al.*, 1984; Kelly, 1988), mostly in the families Teredenidae and Pholadidae (Evans, 1999). *Teredolites* is known from the Pliensbachian (Jurassic) to Recent (Buatois *et al.*, 2016 and references therein).

**Trypanites Mägdefrau, 1932**

*Trypanites weisei* Mägdefrau, 1932

Figs 5D, 7B–H, 8, 9E

**Material:** Many specimens in Palaeozoic corals (MGUWr-6611s–6612s; Figs 8A, B, D and H), Mesozoic coral (?)*Thamnasteria* sp. (MGUWr-6614s; Fig. 8E), bryozoans (MGUWr-6699s–6610s; Figs 7D–H, 9E), belemnites (Fig. 8F), ammonites (Fig. 8G), bones of the lizard (?) *Platecarpus* sp. (MGUWr-6608s; Fig. 7C) as well as in the Silurian/Devonian (?) erratic limestone blocks (Fig. 7B) and Mesozoic-Cenozoic sandstones (MGUWr-6615s; Fig. 5D). The specimens studied were found in the Mokrzeszów Quarry, with the exception of the Mesozoic corals (Swiebodzice outcrop). Specimens visible in Figs 7B, 8F and G are housed in the private collection of J. Kawalko.

**Description:** A straight or slightly curved, unlined, unbranched, vertical, cylindrical boring with a single, circular aperture (opening to the surface) and a circular cross-section. The base of the boring is blind, and has a tapered to rounded terminus. The boring is up to 10 mm long. It is 0.5–1.0 mm in diameter in stromatoporoids, 2.0–2.5 mm in corals and 6 mm in the bone. Some questionable specimens, mainly preserved in corals (Figs 8A, B, D) and belemnites (Fig. 8F) or ammonites (Fig. 8G), due to their poor preservation were recognized as *Trypanites* isp., whereas this one in the bone (Fig. 7C), owing to its large dimensions, as *?Trypanites* isp.

**Remarks:** *Trypanites* is a domiclinch (Pemberton *et al.*, 2001), produced possibly by polychaetes, sipunculids, phoronids or cirripeds (Pickerill *et al.*, 1984; Pemberton *et al.*, 1988). It was described from Baltoscandia from Ordovician-Silurian hardgrounds and tabulate corals, bryozoans and stromatoporoids of Estonia, Russia, Sweden (Dronov *et al.*, 2002); Wyse Jackson and Key, 2007; Beuck *et al.*, 2008; Mikulás and Dronov, 2010; Vinn and Wilson, 2010a, 2012a, b). *Trypanites* is known from the Cambrian to Recent (Pemberton *et al.*, 1988; Taylor and Wilson, 2003). It is common in Palaeozoic, especially from the Late Ordovician to Silurian and is also abundant in the Mesozoic and Cenozoic (Tapanila *et al.*, 2004a; Wilson and Palmer, 2006; Wilson, 2007).

**Polychaete borings**

Figs 8H

**Material:** One specimen in a Palaeozoic coral (*Heliolites* sp.), Mokrzeszów Quarry (private collection of J. Kawalko).

**Description:** Straight, slightly curving line, 15 mm long, with two clavate cavities, drop-like in shape at both ends. The diameter of swellings (cavities) is about 3 mm, whereas diameter of a cylindrical tunnel about 0.2 mm. The shape of this boring resembles the microboring *Flagrichnus*, interpreted as the work of fungi, in having a sack-shaped cavity (compare Wisshak and Porter, 2006; figs 2–4). It differs from this in the lack of thin galleries, extending deep into the substrate. In the specimen studied, a connecting line is almost horizontal, parallel to the surface of *Heliolites*. On the other hand, this boring might has been slightly inclined, owing to preservation in cross-section. Additionally, the dimensions of the boring studied is much larger than *Flagrichnus* (M. Wisshak, pers. comm., 2014). Other microborings produced by algae and fungi, such as *Rhopalia* and *Saccomorpha* (see Molinu *et al.*, 2015), respectively, also show a net of cavities (knobs or club-shaped sacks), connected by cylindrical tunnels or narrow necks. As in the case of *Flagrichnus*, the macroboring studied differs from these microborings in its pattern of morphology, lack of galleries and much larger dimensions. Most probably, the specimen studied was produced by polychaete worms, which may form circular holes 0.5–2 mm in diameter that penetrate up to several centimetres into a coral skeleton (Glynn and Manzello, 2015). The specimen studied differs from other polychaetes borings (*Talpina, Trypanites*) in having cavities, a lack of branches, and a different shape. It co-occurs with *Trypanites*. 
Fig. 7. Borings in rocks, bone, wood and stromatoporoids. A. *Teredolites* isp. in a piece of wood (Jurassic–Miocene?); Mokrzeszów Quarry. B. *Trypanites weisei* in the ?Silurian-Devonian limestone erratic boulder; Mokrzeszów Quarry. C. ?*Trypanites* isp. (a) in the Mesozoic reptile (lizard) bone of ?*Platecarpus* sp.; Mokrzeszów Quarry; MGUWr-6608s. D–H. *Trypanites* isp. (a) in Silurian stromatoporoids; b – astrorhizae; Mokrzeszów Quarry; MGUWr-6609s-6610s. Specimens A, B housed in the private collection of J. Kawalko. Arrows indicate the borings *Teredolites* (A) and *Trypanites* (D).
Fig. 8. *Trypanites* in corals, bryozoans, belemnites, ammonites. A. *Trypanites* isp. (a) in a Lower Palaeozoic coral; Świebodzice outcrop; MGUWr-6612s. B. *Trypanites* isp. in Palaeozoic rugose coral (a); Mokrzeszów Quarry. C. *Trypanites* isp. in Palaeozoic bryozoan (a); Mokrzeszów quarry; MGUWR-6613s. D. *Trypanites* isp. in Palaeozoic rugose coral (a); microconchid (b); Mokrzeszów Quarry. E. *Trypanites* isp. in Jurassic coral (?*Thamnasteria* sp.); Świebodzice outcrop; MGUWr-6614s. F. *Trypanites* isp. (a) and *Talpina* isp. (b) in the rostrum of a Cretaceous belemnites (a); Mokrzeszów Quarry. G. *Trypanites* isp. in the internal mould of the Mesozoic ammonite (a), Mokrzeszów Quarry. H. Coral intergrowths *Halysites* sp. (a) and *Heliolites* sp. (b) with polychaete boring (c); Mokrzeszów Quarry; arrow indicates the polychaete boring in *Heliolites* sp. Specimens B, D, F–H housed in the private collection of J. Kawalko.
Fig. 9. Fossil associations. A. *Aulopora/Heliolites/stromatoporoid* intergrowth on a rugose coral; a – *Aulopora*; b – *Heliolites*; c – stromatoporoid; Świebodzice outcrop, MGUWr-6616s. B, C. Corals (*Favosites/stromatoporoid* intergrowth; a – stromatoporoid, b – *Favosites*; Mokrzeszów Quarry, MGUWr-6617s-6618s. D. Coral (*Halysites/stromatoporoid* intergrowth; a) – stromatoporoid, b – *Halysites*; Mokrzeszów Quarry, MGUWr-6619s. E. Rugosa/stromatoporoid association (symbiosis); a – Rugosa; b – stromatoporoid; c – the boring *Trypanites*; Mokrzeszów Quarry, MGUWr-6620s. F. Crinoid/stromatoporoid association; a – crinoid, b – stromatoporoid; Mokrzeszów Quarry, MGUWr-6621s. G. Bryozoan/brachiopod association; a – brachiopod, b – bryozoan; Mokrzeszów Quarry, MGUWr-6622s. H. Coral/brachiopod association; a – brachiopod, b – coral; Mokrzeszów Quarry (private collection of J. Kawalko).
ASSOCIATED SKELETAL FOSSILS

Numerous coral/coral (Halysites/Heliolites; Fig. 8H) and stromatoporoid/coral intergrowths (Favosites, Halysites) (MGUWr-6617s-6619s; Fig. 9B–D) or stromatoporoid/Rugosa coral symbioses (MGUWR-6620s; Fig. 9E) were also found in the Mokrzeszów Quarry and the Świebodzice outcrop. Some fossils, such as rugose and tabulate corals and bryozoans (in some cases bored by Trypanites) also were found in the study area (Fig. 8A–D). These organisms usually encrusted Silurian stromatoporoid or Ordovician-Silurian hardgrounds (Kershaw, 1987, 1990; Lebold, 2000). Additionally, rugose coral encrusted by a stromatoporoid and corals association (Aulopora, Heliolites) also was noted (MGUWr-6616s; Fig. 9A). On one specimen of coral, bored with Trypanites, the microconchid was found (coral/microconchid association, Fig. 8D). Many examples of different fossil associations were described from the Silurian stromatoporoid outcrops of Sweden (Gotland) and Saaremaa (Estonia) by Kershaw (1987), Kershaw and Mõtus (2016) and Vinn and Wilson (2016 and references therein). Stromatoporoid/Rugosa symbioses were reported from the Silurian of Baltoscandia (Estonia) by Vinn et al. (2015b), Vinn and Mõtus (2014) and Vinn and Toom (2017). Some new associations, such as crinoid/stromatoporoid (MGUWr-6621s; Fig. 9F) and brachiopod/bryozoan (MGUWr-6622s; Fig. 9G) and brachiopod/coral (Fig. 9H), which have not been reported so far from Baltoscandia, also were found in the Mokrzeszów Quarry. Recently, Zatoń et al. (2016) described the first microconchid-encrusted corals (Estonia, Saaremaa) and brachiopods (Sweden, Gotland). Earlier, microconchids were reported from Baltoscandia by Vinn and Wilson (2010b, 2012b, 2016) and Zatoń and Vinn (2011) from Silurian stromatoporoids and bryozoans of Estonia and Sweden.

DISCUSSION

Ordovician Orthoceratite Limestone

Most of the erratics studied originate in the Ordovician Orthoceratite Limestone, which crops out from Norway, across Sweden, Estonia to Russia (St. Petersburg region). These limestones differ in colour. They are red in Sweden, but grey or yellow-grey in Estonia or Russia (Kröger, 2004; Mikuláš and Dronov, 2010; Histon, 2012). They contain very well preserved, large fossils of cephalopods (mostly endocerids), trilobites and molluscs, especially hyolithids (Eriksson et al., 2013; Lindskog et al., 2015).

Fig. 10. Map of the Baltoscandian Con facies Belts and distribution of maximum occurrences of trilobites (Asaphus, Megistaspis) and cephalopod (Anthoceras vaginatum) during the Middle Ordovician in Baltoscandia. Con facies belts after Jaanusson (1982), chronostratigraphy after Bergström et al. (2009).
The Orthoceratite Limestone was formed in the Baltoscandian Basin, a shallow, epicontinental sea that covered the Scandinavia and Baltic region and is regarded as one of the largest Early Palaeozoic basins (Hints, 2000; Ainsaar et al., 2007; Eriksson, 2010). This basin extended from Norway (Oslo Graben) across southern Sweden (Öland) and Denmark (Bornholm) to the eastern Baltic countries and to the Moscow Basin, in western Russia (Bennet et al., 2004; Dronov et al., 2011). The Baltoscandian platform, on which this basin was developed, is subdivided into SE-NW-oriented facies belts: the Scanian Confinacies Belt (outer ramp or basinal facies), the Central Baltoscandian Confinacies Belt (intermediate facies) and the Estonian Confinacies Belt (middle to inner ramp settings) (see Tinn et al., 2006; Eriksson, 2010; Kröger and Rasmussen, 2014; Fig. 10). These belts show differences in water depth, lithology and facies assemblages.

The Ordovician Orthoceratite Limestone is interpreted mainly as a shallow marine deposit, containing tempestites (Dronov, 2005). However, according to some other views, its environment was slightly deeper, even as much as 200–300 m (see Lindskog et al., 2014 and references therein). This view concerns mainly the western part of the Baltoscandian Basin. The limestones were deposited in cool waters, because these deposits do not contain coral-stromatoporoid reefs, typical of tropical conditions.

The Orthoceratite Limestone represents a stratigraphically condensed sequence, several metres thick (see Eriksson, 2010; Eriksson et al., 2012 and references therein). Numerous hardgrounds are described from these deposits, which contain numerous trace fossils, for example Balanoglossites, Gastrochaenolites and Trypanites? (Ekdale and Bromley, 2001; Dronov et al., 2002; Knaust and Dronov, 2013). The occurrence of the hardgrounds (Dapingian–Katian; see Vinn et al., 2015a) was connected with an extremely low, average rate of sedimentation during the Ordovician (see Dronov, 2005).

The occurrence of Arachnostega gastrochaenae

In boulders from the Mokrzeszów Quarry, numerous large endocerid cephalopods occur (Anthoceras vaginatum Schlotheim, 1820), as well as trilobites (Megistaspis, Asaphus, Illaenus). Some of them contain Arachnostega. The trilobites Asaphus and Megistaspis were very common during Early–Middle Ordovician in Baltoscandia (Pärnaste et al., 2013) and achieved large sizes (see Klug et al., 2015; Dronov et al., 2016). The Baltica was regarded as the Asaphus Province, especially during the Floian and Dapingian (Early–Middle Ordovician; see Pärnaste and Bergström, 2013). The asaphids are endemic to Baltica, owing to the dispersal of palaeocontinents in the Early Ordovician (see Fortey and Owens, 1997; Cocks, 2000). During this time, Baltica was separated from the other continents by wide oceans, i.e. the Tornquist Sea and the Iapetus Ocean; this caused endemism of fauna (Cocks and Fortey, 1982; Torsvik and Trench, 1991; Cocks and Torsvik, 2005).

According to Pärnaste and Bergström (2013), the abundance peak of Megistaspis took place in the late Dapingian (M. limbata Zone), but a number of the megistaspine species remained almost at the same level until the middle Darriwilian (Asaphus raniceps Zone), when it started to disappear by the Sandbian (the boundary between the Kunda and Asari regional stages; see Tab. 1). In the latest Dapingian – early Darriwilian time, Megistaspis occurred on both sides of Baltica (Estonia and Sweden), indicating an exchange of fauna (Cocks, 2001; Pärnaste and Bergström, 2013; Fig. 10). Megistaspis is particularly abundant in southern Sweden, Öland, common in Estonia, rare in central Sweden and almost absent in deeper water settings of the Oslo region (Hoel and Hoyberget, 2002; Fig. 10). This taxon predominates in the Central Baltoscandian Confinacies Belt (Bergström et al., 2013). The second family, Asaphinae (Asaphus expansus Wahlenberg, 1821), is most common in north-west Estonia, common in the St. Petersburg region (Russia) and in Sweden (Öland), and it is less common in central Sweden (see also Cherns et al., 2006) and the Oslo region (Pärnaste and Bergström, 2013; Fig. 10). It is particularly abundant in the North Estonian Confinacies Belt (Fig. 10). The abundance peaks were at the beginning of the Kunda Regional Stage and the Aseri Regional Stage (Tab. 1).

In the same erratic blocks, besides Megistaspis, the cephalopod Anthoceras vaginatum Schlotheim, 1820 occurs (Figs 2D, E), the species that gave rise to the name of the Orthoceratite Limestone in Sweden and Estonia (Vaginatum Limestone or Vaginatennkalk, see Kröger, 2004, 2012). Anthoceras mainly characterizes the Anthoceras Biofacies, distinguished in Baltoscandia (see Kröger and Rasmussen, 2014), which occurs mostly in Sweden, Öland (Central Baltoscandian Confinacies Belt) and in northwestern Estonia, Tallinn (Fig. 10).

The oldest occurrence of Anthoceras vaginatum was noted in the lowermost Darriwilian from the Megistaspis limbata trilobite Zone (Kröger and Rasmussen, 2014). This taxon started to be the dominant cephalopod species near the base of A. raniceps Zone and above in the middle Darriwilian of the Kunda Regional Stage (see Kröger, 2012, 2013; Tab. 1).

In summary, Arachnostega in the reddish glacial erratic boulders on ?Megistaspis comes from Sweden, probably Öland (Fig. 2A–E). This is confirmed by the most common occurrence of the trilobite Megistaspis, as well as the associated fossil Anthoceras vaginatum in this area (Fig. 10). Arachnostega on the trilobites Asaphus sp. and Asaphus expansus in the grey limestone blocks might have its origin in Russia or Estonia (Fig. 2F–H). This is evidenced by the grey colour of the limestones, as well as by the occurrence of Asaphus, which is typical for these areas (Fig. 10). The limestones in erratic boulders with Arachnostega are probably Middle Ordovician (Kunda Regional Stage, Asaphus raniceps trilobite Zone) in age, owing to the abundance peak of the trilobites Megistaspis and Asaphus, and the endocerid Anthoceras.

In the Kunda Stage, other molluscs (gastropods, bivalves and hyoliths) also started to appear in abundance (Kröger and Rasmussen, 2014; Lindskog et al., 2015 and references therein). Besides Arachnostega on the pygidium of trilobites (?Megistaspis, Asaphus), this ichnifax was also
Fig. 11. Geological map of Baltoscandia with possible directions of movement of source material (ice-sheet movement), after Schulz (2003), modified by the authors.
recognized on a cephalopod (Fig. 3A) and on hyolithids (Fig. 3B) in the Mokrzeszów Quarry. Hyolithids are also abundant in the A. raniceps Zone (Kunda Regional Stage; Lindskog et al., 2015; Tab. 1). Limestones of the glacial erratic boulders studied, grey in colour, which contain Arachnostega on a cephalopod and especially on hyolithids, come from Russia and less probably from Estonia (middle Darriwilian, ?Kunda Regional Stage).

Arachnostega was described from Baltoscandia only from the Middle and Upper Ordovician. This trace fossil was most abundant in the Darriwilian, less common in the Sandbian and rare in the Katian (Vinn et al., 2014b). The authors cited suggested that the Arachnostega trace-maker preferred colder (temperate) rather than tropical climates. They connected the common appearance of this ichnogenus in the Darriwilian with the Ordovician drift of Baltica to the north towards the lower latitudes/palaeoequator (Cocks and Torsvik, 2005). These authors also reported that Arachnostega preferentially occurs on bi-valves compared to gastropods and for unknown reasons it does not appear on echinoderms and trilobites in Estonia. The occurrences of Arachnostega on the pygidia of the trilobites ?Megistaspis and Asaphus (from Sweden?) in the glacial erratic boulders in SW Poland, at the Mokrzeszów Quarry, and on the cystoids in Estonia (Chrzastek and Pluta, 2017) show that this ichnogenus also might occur on other groups of invertebrates in Baltoscandia, not only on molluscs.

Balanoglossites

Balanoglossites occurs in the reddish Orthoceratite Limestone in the erratic blocks, which derive from Sweden. It is common in the Mokrzeszów Quarry. This trace fossil was described by Knaust and Dronov (2013) from the Orthoceratite Limestone in Russia (St. Petersburg region). According to these authors, Balanoglossites is very abundant in the Ordovician. So abundant occurrence of Balanoglossites in Baltoscandia in the Ordovician Orthoceratite Limestone might be connected with the abundance of the sclerocodont-bearing polychaetes at that time (Knaust and Dronov, 2013), the possible producers of this trace fossil (see Knaust, 2008). During the Middle Ordovician, the majority of polychaete taxa appeared for the first time and started to diversify very fast (Hints, 2000; Eriksson et al., 2013). A rapid increase in the number of genera was recorded in the Middle Ordovician (Darriwilian) and early Late Ordovician. Sclerocodont-bearing polychaetes were very abundant from the Middle Ordovician (Darriwilian) in Estonia, Sweden, northwestern Russia (Hints, 2000; Hints and Eriksson, 2007, 2010; Eriksson et al., 2016) and in Poland, in glacial erratic boulders (Kielan-Jaworowska, 1962, 1964). The source areas for glacial erratic boulders with Balanoglossites (Fig. 3C–F) were probably in Sweden, as suggested by the red colour of the limestones. Additionally, Balanoglossites co-occurs with Anthoceras vaginatum, which is most common in Sweden (Öland) in the Kunda Regional Stage (near the base of the A. raniceps Zone, middle Darriwilian, Tab. 1).

Osprioneides kampto, ?Palaeosabella, Trypanites

Another interesting and rare trace fossil is Osprioneides kampto, recognized in the ?Ordovician bryozoan and the Silurian stromatoporoid in the erratic blocks of the Mokrzeszów Quarry. The most famous Palaeozoic stromatoporoid outcrops are known from Saaremaa, Estonia, and Gotland, Sweden (Sandström and Kershaw, 2002, 2008). The only report concerning Osprioneides in bryozoans comes from the Upper Ordovician of Estonia (Vinn et al., 2014b). Earlier, it was regarded as a Silurian trace fossil (Beuck et al., 2008; Vinn and Wilson, 2010a). According to Brood (1981), in the Late Ordovician in Baltoscandia (Sweden, Estonia, Norway) bryozaons were especially common and rich in species by comparison with the Early Silurian. The reefs with bryozaons were abundant and commonly bored at that time (Kröger et al., 2014).

In the Mokrzeszów Quarry, Trypanites and Palaeosabella were also encountered in the Silurian stromatoporoids. ?Palaeosabella was reported from the Scandinavia and Baltic region, from the Silurian corals and stromatoporoids (Gotland in Sweden, Saaremaa in Estonia) by Beuck et al. (2008) and Vinn and Wilson (2010a). Trypanites, the most common Palaeozoic boring, was described from the Ordovician-Silurian hardgrounds, tabulate corals, stromatoporoids, bryozaons from Estonia, Sweden and Russia by Dronov et al. (2002), Beuck et al. (2008), Mikuláš and Dronov (2010), and Vinn and Wilson (2010a).

Other common trace fossils and associated fossil associations

Other trace fossils studied (e.g., Chondrites, Phycodes, Skolithos, Diplocraterion, Thalassinaeid) have a wide distribution and are common as well as in Palaeozoic and Mesozoic rocks. Though they occur in Baltoscandia (Russia, Denmark, Sweden, Estonia and Norway), especially in the Lower Palaeozoic, it is very difficult to speculate about source areas of the rocks bearing them (see Synopsis of trace fossils). Jurassic corals (?Thamnasteria; Fig. 8E) with Trypanites might have their origin in the south-western Baltic coast, which are the source areas for erratics containing this trace fossil, described by Roniewicz (1984). It is difficult to speculate about source areas of the Jurassic and Cretaceous shells with the borings ?Gastrochaenolites, Meeandropolydora, Talpina or the bone of ?Platecarpus with Trypanites. The outcrops of these deposits are located from Denmark, through the southern Baltic Sea area to Lithuania (Fig. 11). Vertebrate remains of Mesosauridae (Platecarpus) were described from Sweden by Lindgren (1998). The source areas for Cenozoic (Miocene) gastropods with Oichnus might be located in northern Denmark and Germany (see Rohde, 2008).

The accompanying skeletal fossils, such as coral/coral (Halysites/Heliolites, Aulopora/Heliolites; Figs 8H, 9A) or coral/stromatoporoid (Favosites/stromatoporoid, Halysites/stromatoporoid; Fig. 9B–D) intergrowths or stromatoporoid/Rugosa coral symbioses (Fig. 9E), which were encountered in the Mokrzeszów Quarry and the Świebodzice outcrop,
were probably derived from Silurian stromatoporoids. The excellent, very well preserved stromatoporoid outcrops are situated in Sweden (Gotland) and Saaremaa (Estonia). Isolated fossils of corals (bored with Trypanites and encrusted by microconchid) and bryozaons, which were also found in the study area (Fig. 8A–D), might have encrusted both the Baltoscandian Ordovician-Silurian stromatoporoids and hardgrounds (Kershaw, 1987, 1990; Lebold, 2000). Lower Palaeozoic hardgrounds were encrusted mainly by rugose and tabulate corals, bryozaons, crinoids and microconchids (Vinn and Wilson, 2012a, b, Taylor and Wilson, 2003; Vinn et al., 2015a). Different fossil associations were reported from outcrops in Baltoscandia and the Baltic region by several authors (see Vinn and Wilson, 2016 and references therein), as well as coral/stromatoporoid symbiosis (e.g., Vinn and Mõtus, 2014). Just recently, Zatoń et al. (2016) described the first microconchid-encrusted corals (e.g., Sweden, ?Estonia), demonstrates that this ichnotaxon also occurs on other groups of fauna, not only on molluscs.

The rare boring Ospionoides kampto from the Mokrzeszów Quarry is the second report of this ichnotaxon in a bryozaon (?Ordovician). It occurs also in Silurian stromatoporoids, together with ?Palaeosabella isp. and Trypanites isp., possibly from Sweden (Gotland) and Estonia (Saaremaa) or adjacent areas where stromatoporoid biostromes are well developed.

The Lower Palaeozoic erratic boulders with common trace fossils (e.g., Chondrites, Diplocraterion, Phycodes, Rosselia, Skolithos, Thalassinoides) probably came from Sweden, Denmark (Bornholm), Russia, Norway, where they previously were described.

Mesozoic and Cenozoic shells and wood with the borings Macrandropylopora, Oichnus, Talpina, Teredolitites, Trypanites might have their origin in the south-east Baltic region (from Denmark, S Sweden to Lithuania), where relevant outcrops occur.

The glacial erratic boulders probably were transported mainly from the north and north-east (Scandinavia: Sweden, Öland, Gotland and the Baltic area, i.e., Saaremaa, Estonia, and the St. Petersburg region, Russia) and less commonly from the north-west, especially in the case of younger Mesozoic/Cenozoic blocks (see Fig. 11).

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