Rosarichnoides sudeticus igen. et isp. nov. and associated fossils from the Coniacian of the North Sudetic Synclinorium (SW Poland)

Alina CHRZĄSTEK1, *, Jolanta MUSZER1, Andrzej SOLECKI1 and Alfred Marian SROKA2

1 Wrocław University, Institute of Geological Sciences, pl. M. Borna 9, 50-204 Wrocław, Poland
2 Kopalnie Piaskowca Sp. z o.o., Modłowa 1, 59-700 Bolesławiec, Poland

INTRODUCTION

Ichnological studies of ophiomorphs from the Cretaceous deposits of Silesia, Saxony and Bohemia have a very long history, probably since the 18th century (Schulze, 1760) and certainly from the first half of the 19th century (Geinitz, 1842; Göppert, 1842). Incompleteness and different states of preservation, besides the historical uncertainty of what a trace fossil is, led to these trace fossils being classified in different taxonomic groups (as crinoid remains, sponges, algae, foraminifers, trace fossils).

The Ophiomorpha–Thalassinoides–Spongeliomorpha group (Bromley, 1996) or informally named “ophiomorphids group” (Uchman, 1995; Seilacher, 2007) includes crustacean burrows of various architectures, the most typical forming branching tunnel networks, which commonly have swellings. Fürsich (1973) and Schlirf (2000) proposed synonymizing these ichnogenera, but this was not accepted (see Bromley and Frey, 1974; Bromley, 1996; Schlirf, 2005). According to Gibert (1996), Sinusichnus should also be included to this group (see Belaústegui et al., 2014). Gyrolithes Saporta, 1884, Ardelia (Chamberlain and Baer, 1973) and Parmaichnus Perversel and Uchman, 2009 are also proposed to represent ophiomorphs (Bromley and Frey, 1974; Netto et al., 2007; Seilacher, 2007; Perversel and Uchman, 2009). Ophiomorpha (Lundgren, 1891) has a characteristic pelleted wall, Spongeliomorpha (Saporta, 1887) shows a criss-cross ornament of sublongitudinal ridges and grooves, which represented abundant wall scratchings, whereas Thalassinoides (Ehrenberg, 1944) refers to a three-dimensional system of burrows, usually unlined or thinly walled. A diagnostic feature of the last ichnogenus is T- or Y-shaped branches. Recently, Hýžný et al. (2015) included the new ichnogenus Egbeilichnus to the group of trace fossils made by decapod crustaceans, while Belaústegui et al. (2016) first reported Lepeichnus, which is interpreted as probably produced by crustaceans.

A new type of ophiomorphid specimen has been found in the Upper Cretaceous Quadersandstein (Coniacian) of the North Sudetic Synclinorium. It is the first such large and finely preserved crustacean burrow from the North Sudetic Synclinorium (Fig. 1A) and the Sudetes. It was prepared from a block of sandstone during mining work in the Czaple Quarry B (Fig. 1B) in 1996 by A.M. Sroka and is housed at the Geological Museum of the University of Wrocław (MGUWr 6650s).

Designation of the specimen was made complicated by similarities with some specimens assigned to Thalassinoides saxonicus (Geinitz, 1842), especially those found by German geologists in the 19th century. However, these trace fossils as well as the specimen in question are unbranched. For this reason they should be excluded from Thalassinoides Ehrenberg, 1944 and the proposal of a new ichnogenus seems necessary.

* Corresponding author, e-mail: alina.chrzastek@uwr.edu.pl

Received: March 20, 2017; accepted: November 8, 2017; first published online: February 1, 2018
Thalassinoides saxonicus (originally Spongites saxonicus Geinitz, 1842), an exceptionally rare crustacean burrow, was reported mainly from the Upper Cretaceous (Cenomanian, Turonian, Coniacian) of Saxony, Bohemia and Lower Silesia (Geinitz, 1842; Otto, 1852; Frič, 1883; Dettmer, 1912; Andert, 1934). All these authors interpreted T. saxonicus as a sponge. The very similar structure of Cylindrites spongioides Göppert, 1842, assigned to algae (fucoids), was also reported from these regions (Göppert, 1842, 1847; Dunker, 1856). Some of these specimens are undoubtedly trace fossils. Häntzschel (1962, 1975) and Kennedy (1967) assigned Spongites saxonicus to the trace fossil Thalassinoides and gave a list of its synonyms.

This paper gives a formal description of a new trace fossil, Rosarichnoides sudeticus, on the basis of the significant differences in shape from other ophiomorphids. We compared this specimen with other similar forms illustrated in the published literature and with a part of the Göppert’s collection from Saxony, Bohemia, Harz and the Sudetes, which were re-discovered in the Geological Museum of the University of Wrocław. In our opinion some unbranched specimens formerly assigned to T. saxonicus should also be included in this new ichnospecies. In this paper other associated trace fossils and body fossils of starfish and inoceramids from the Coniacian of the North Sudetic Synclinorium (Czaple, Żerkowice quarries) are also de-
scribed. On the basis of the fossils collected, some interpretation of the depositional environment is made.

**GEOLOGICAL SETTING**

The sites studied are located in the central part of the North Sudetic Synclinorium (NSS) south of the WNW–ESE trending Jerzmanice Fault (Fig. 1A). The study was conducted in two quarries in the Coniacian sandstones near Czaple and Nowa Wieś villages (Fig. 1B).

The North Sudetic Basin (NSB) is a post-Variscan basin located within the northern Sudetic Foreland above the low-grade Kaczawa Metamorphic Unit (Baranowski et al., 1990). It forms the southeastern prolongation of the East Brandenburg Basin (Musstow, 1968). After the Cretaceous, tectonic inversion of the NSB took place and the North Sudetic Synclinorium was formed (Solecki, 1994).

The Pennsylvanian–Triassic part of the NSB infill includes detrital continental deposits of Rotliegend facies with abundant Early Permian bimodal volcanic rocks (Baranowski et al., 1990). These are overlain by Upper Permian marine marls, carbonates and evaporites (Zečstein facies), followed by Lower Triassic continental Buntsandstein sandstones. The Triassic marine transgression resulted in sedimentation of marls, carbonates and evaporites followed by the Middle Triassic Muschelkalk sequence of marls and limestones (Fig. 2). Locally, in the NW part of the basin the Upper Triassic Keuper evaporites are preserved (Milewicz, 1985; Chrzastek, 2002).

The transgressive Upper Cretaceous marine sedimentary sequence overlies the older basement with slight angular unconformity and a significant hiatus (Fig. 2). In the southern part of the NSS, the Upper Cretaceous marine sedimentary sequence overlies mainly Lower Triassic (Buntsandstein) strata, locally the Rotliegend and rocks of the Kaczawa Metamorphic Unit, while north of the Jerzmanice Fault the Middle Triassic deposits of the Muschelkalk form its basement (Scupin, 1912–1913; Beyer, 1933, 1934; Milewicz, 1997).

The Upper Cretaceous sequence (Rakowice Wielkie Formation sensu Milewicz, 1985, 1997) consists of marine Cenomanian to upper Coniacian (lower Santonian according to Walaszczyk, 2008) marls that locally pass into limestones intercalated by sandstones and mudstones, covered in the eastern part of the study area by the limnic and deltaic deposits of the Czerna Formation (Fig. 2), which are composed of white kaolinitic sandstones intercalated with calcareous kaolinitic clays with lignite. In the more western part of the NSS, shallow marine mudstones of the Węgliniec Formation form the cover of the Rakowice Wielkie Formation (Fig. 2).

According to Walaszczyk (2008), the Cretaceous deposits of the NSB represent a single, major T-R cycle consisting of several minor, unspecified cycles. This is in line with Milewicz’s (1997) opinion that the Coniacian–Santonian deposits of the NSB form the top of a regressive phase of a transgressive-regressive cycle. According to Leszczyński (2010), the Czerna and Węgliniec formations represent the final, complex regressive phase of the minor transgressive-regressive cycles.

Sandstones of the Rakowice Wielkie Formation interpreted by Milewicz (1985) as sandy wedges within predominantly marly or even calcareous deposits have been formally divided into the Wilków, Chmielno, Dobra and Żerkowice members. The lowermost Wilków Member and the uppermost Żerkowice

### Table: Lithostratigraphic Units

| Age      | West (W) | East (E) | Traditional Units |
|----------|----------|----------|-------------------|
| Santonian| Węgliniec Formation | Czerna Formation | Überquader |
| ?        | Rakowice Wielkie Formation | Żerkowice M. | Oberquader |
| Coniacian| Przewóz M. | Dobra M. | Mittelquader |
| Turonian | Wilków M. | Chmielno M. | Unterquader |
| Cenomanian | Raciborów Formation | | |
| Ladinian | | | |
| Anisian | | | |
| Olenian | | | |
| Induan | | | |

![Fig. 2. Stratigraphic position of the site under investigation, marked by a star](image_url)
Coniacian/Santonian boundary within the Czerna and the middle/upper Coniacian transition and put the Rakowice Wielkie Formation and the overlying formations with the NSS.

The Careous Przewóz Member occurs in the more western part of the Nowogrodziec Member of the Czerna Formation is present. A significant hiatus between the Rakowice Wielkie Formation and the Nowogrodziec Member of the Czerna Formation is present (Milewicz, 1956, 1965, 1979, 1997; Walaszczyk, 2008; Leszczyński, 2010). The deposits studied are well-sorted but poorly-rounded (see Milewicz, 1997). Sedimentary structures within them are not easily visible. Parallel lamination, ripple marks and large-scale cross-stratification occur locally. The laminae dip mainly to the south and south-east, towards the north-western outlet of a narrow, shallow marine strait (Scupin, 1910, 1936) being influenced by both the Boreal and Tethyan realms (Fig. 4). The northeastern and southwestern boundaries of this strait are marked by non-depositional areas of the so-called Eastern and Western Sudetic islands, ESI and WSI respectively (Biernacka, 2012). From the palaeogeographic point of view, the sites under investigation were located at the northwestern outlet of a shallow connection where deltaic to shallow marine clastic sedimentation prevailed (Wilmsen et al., 2014).

Fig. 3. Coniacian sandstones in the Czaple Quarry B (photo by M. Wypych)

Leszczyński (2010) studied the Żerkowice Member exposed in the Rakowice Małe and Żerkowice quarries. The Coniacian sandstones of the Żerkowice Member exposed in the Czaple quarries (Figs. 2 and 3) are fine to medium-grained arenites (see Milewicz, 1997). Sedimentary structures within them are not easily visible. Parallel lamination, ripple marks and large-scale cross-stratification occur locally. The laminae dip mainly to the south and south-east, towards the shore of the basin (Leszczyński, 2010). The thickness of individual sandstone beds is up to a few metres. In their upper part, the sandstones are covered with a limonite crust (see Leszczyński, 2010). According to the author cited, the Coniacian sandstones are interpreted as bar and storm deposits.

A part of the Cretaceous sedimentary sequence has been uplifted and eroded due to tectonic Turonian–Paleogene activity (Solecki, 1994). The present remains of the North Sudetic and Intra Sudetic Cretaceous basins originally formed a narrow, shallow marine strait (Scupin, 1910, 1936) being influenced by both the Boreal and Tethyan realms (Fig. 4). The northeastern and southwestern boundaries of this strait are marked by non-depositional areas of the so-called Eastern and Western Sudetic islands, ESI and WSI respectively (Biernacka, 2012). From the palaeogeographic point of view, the sites under investigation were located at the northwestern outlet of a shallow connection where deltaic to shallow marine clastic sedimentation prevailed (Wilmsen et al., 2014).

DESCRIPTION OF THE TRACE FOSSILS

Rosarichnoides igen. nov.

Derivation of name. – After the rosary-shaped form in which the type ichnospecies occurs, Greek ichnos = trace, and -oides – after ancient Greek “likeness”.

Type ichnospecies. – Rosarichnoides sudeticus isp. nov., type and only known ichnospecies.

Diagnosis. – A rosary-shaped and unbranched structure, which consists of regularly and alternately placed chambers (swellings) and constrictions. Chambers are spherical, elongated to pear-shaped. The burrow is without any wall and has a passive, structureless fill, similar to the host sediment. The surface of the burrow is unornamented, and rough rather than smooth.

Comparison with other ichnogenera. – Rosarichnoides morphologically resembles ophiomorphids in comprising tunnels with swellings (‘turn-arounds’). The presence of large swellings (diameter up to 7 cm), a passive fill and lack of a wall are similar to Thalassinoides saxonicus (Geinitz, 1842). By contrast with the characteristic T- or Y-shaped branchings of Thalassinoides (e.g., Myrow, 1995), Rosarichnoides is unbranched. The only very large Thalassinoides saxonicus was recently reported by Göhler (2011a, b) from the Cenomanian of Saxony (Germany), illustrated mainly by drawings. Its dimensions, especially of the swollen chamber (up to 7 cm), are similar to those of our specimen. It differs from Rosarichnoides in having branches and a single swelling at the end of the tunnel. In comparison to Ophiomorpha Lundgren, 1891, the new ichnogenus does not have a pelleted wall (see Frey et al., 1978). Rosarichnoides also does not possess as abundant scratch-chains (distinctive, longitudinal ridges) as does Spongeliomorpha Sartora, 1887.

This new ichnogenus shows some similarities to Type II (multiple-resting-place type) specimens of Psilonichnus quietis Myint, 2001 in having swollen chambers connecting with tunnels (Myint, 2001: fig. 2B). The swellings of this Psilonichnus have four different shapes (Myint, 2001: fig. 5), but only one of them (Myint, 2001: fig. 5B) resembles swellings of Rosarichnoides. However, in comparison to the oval to pear-shaped chambers of Rosarichnoides, this type of swelling in Psilonichnus is distinctly semi-triangular shaped (e.g., Myint, 2001: fig. 5B). In addition, these swellings are pointed in the same direction and the constrictions of Psilonichnus quietis are much longer than those of Rosarichnoides. On the other hand, the diameter of the new ichnogenus is twice as large as is Psilonichnus quietis.

Regular bulb-shaped swellings also characterize Asterosoma ludwigiae Schlirf, 2000, but these radiate from a circular central axis and have internal concentric structures (see Neto de Carvalho and Rodrigues, 2007). Rosarichnoides differs from Asterosoma in having a different orientation and in the shape (pear-shaped) of the swollen chambers, which are structureless.

A similar morphology of the burrow, which consists of a cylindrical tunnel with regularly distributed chambers, is seen in Halimedides Lorenz von Liburnau, 1902. In comparison to
Rosarichnoides this ichnogenus has heart-shaped chambers (two chambers symmetrically and bilaterally distributed on the both sides of tunnel; see Gaillard and Olivero, 2009: figs. 10, 15-17) and much smaller dimensions (up to 2.5 mm tunnel diameter, 100 mm length of tunnel).

A rosary-like trace (resembling pearls) of unknown origin (see Häntzschel, 1975: fig. 43/3; Uchman, 1998: fig. 11) is also seen in Hormosiroidea Schaffer, 1928. This consists of very small hemispherical or spherical chambers (up to 1 cm) connected by a horizontal thin string (diameter up to 2 mm). It differs from Rosarichnoides not only in dimensions, but also in the different shape of the bulbs, and in the occurrence of additional oblique strings, locally branched, emerging from the chambers. Additionally, the surface of some specimens of Hormosiroidea is coarsely granulose.

Rosarichnoides sudeticus isp. nov. (Fig. 5A–L)

?partim 1842 Spongites Saxonicus m. Schultze – Geinitz, p. 96, Taf. XXIII, fig. 2.
?partim 1852 Spongia saxonica Geinitz (Cylindrites spongioides Göppert) – Otto, p. 20–21, Taf. 6, fig. 1.
?partim 1909 Cylindrites spongioides Goepp. emend. – Richter, p. 8–11, Taf. XI, fig. 1.

Type material and occurrence. – Holotype – one specimen (natural cast of the burrow) figured in Figure 5A and its eight parts figured in Figure 5B–I, a private collection of A.M. Sroka now housed at the Geological Museum of the University of Wrocław (MGUWr 6650s). The specimen has been extracted from an isolated block of medium-grained sandstone in the Czaple Quarry B (Fig. 1B), Coniacian in age, North Sudetic Synclinorium.

Derivation of name. – After the Sudety Mountains, the region where the species was found.

Diagnosis. – The burrow consists of asymmetrical, mainly pear-shaped chambers connecting with a tunnel. The constrictions are distinctly shorter than the swellings (chambers). The diameter of the swellings is over twice as large as the diameter of the constrictions. The surface of the trace fossil is rather rough, mostly unornamented, but local sand knobs, furrows and ridges can be present.

description. – The orientation of the specimen studied is unfortunately unknown, because it was found in a sandstone block. It comprises a sand-filled burrow, with alternating swellings and constrictions and lacking branches. This large burrow is 127 cm long, but this is not the total length, because the specimen is broken at both ends. It consists of 8 asymmetrical, spherical to pear-shaped chambers (swellings), 5.6–6.4 cm across, and constrictions between them, which are 2.06–2.86 cm across (Fig. 5A; Table 1). The chambers are arranged on both sides of the tunnel at different angles (Fig. 5A). Their length (parameter c; Fig. 6) varies from 9.55 to 12.5 cm (Table 1). The constrictions are 2.6–8.5 cm long. Parameter b1/a1 varies from 2.2 to 2.8 (Fig. 6; Table 1). The burrow is elliptical or rarely circular in cross-section and its parameter a1/a2...
Fig. 5. Rosarichnoides sudeticus igen. et isp. nov. from the Czaple Quarry B, housed at the Geological Museum of the University of Wroclaw (MGUWr 6650s)

A – the whole specimen (eight elements); B–I – isolated fragments of Rosarichnoides sudeticus igen. et isp. nov. illustrated in order from 1 (B) to 8 (I); J – cross-section of the constriction (fragment of the burrow shown in Fig. 5I); K, L – longitudinal sections of the swollen chamber illustrated in Figure 5B; f – furrow, g – sand granule (knob), r – ridge
varies from 0.94 to 1.17; parameter a3/a4 is between 0.89–1.32 and parameter b1/b2 varies from 1.06 to 1.32 (Table 1; Fig. 6).

For parameters see Figure 6.

The burrow is without any wall or lining. The cross-sections of the burrow show that the fill is passive and structureless (Fig. 5J–L), the same as the host rock. The outer surface is rather rough and usually lacks ornamentation. Four indistinct oval sand knobs (measuring 0.5/0.7 cm; 0.6/1 cm; 0.9/1 cm; 0.7/1.2 cm) have been observed on two swellings (Fig. 5G). On the outer surface of the swellings, rare furrows, 2-5 cm long, are also present (Fig. 5E). They are variously oriented, mostly obliquely, and they might be poorly preserved scratch traces. Additionally, one short thin “ridge”, 3 cm long and ~2 mm wide, occurs on the surface of a swelling (Fig. 5H).

Discussion. – Designation of the studied specimen was difficult because the most similar forms were described or illustrated in 19th and at the beginning of the 20th centuries. These forms are incomplete, showing various preservation conditions and were classified in different taxonomic groups. However, part of Göppert’s 19th century collection was re-discovered in the Geological Museum of the University of Wrocław, which allowed observation of some details on the real specimens and comparison with the form studied.

Similar forms, undoubtedly trace fossils, probably Thalassinoides, were first described by Schulze (1760: tab. 2, figs. 1–5) as crinoid remains or cavities left by vagile starfish. This ichnotaxon was originally described by Geinitz (1842) as a sponge, Spongites saxonius. However, only one of his specimens is unbranched and has two spherical swellings (Taf. 23, fig. 2) and the other (Taf. 23, fig. 1) is branched and has a narrow longitudinal ridge on the upper part and a clearer granular ornamentation. The latter specimen was ascribed by Kennedy (1967) to Thalassinoides saxonius, while the first one was included in Ophiomorpha nodosa. In our opinion, the last assignment should be revised. Geinitz’s specimen (tab. 1, fig. 2) is unbranched and has alternating oval swellings and constrictions, similar to Rosarichnoides sudeticus isp. nov., which indicates the affiliation to this ichnogenus.

Granular ornamented forms with swollen and narrowing chambers were also described by Göppert (1842) as the fucoid alga Cylindrites spongoides (tabs. XLVI/1–5; XLVIII/1–2, p. 115), but they are undoubtedly ichnofossils. According to Kennedy (1967), Göppert’s figures 1–4 in tab. XLVI may show crustacean burrows, possibly Ophiomorpha. We agree with his opinion. Additionally, a part of the Göppert’s Wrocław collection, which has not been published, supports this view. Specimens (cat. no. MGUWr – 2883p from Bohemia, MGUWr – 7372p from Saxony, MGUWr – 5648p from Bystrzyca Klodzka) assigned to Cylindrites spongoides Göpp. have some features of ophiomorphids (Fig. 7A–D). Three of them (2883p – two specimens; 7372p; Fig. 7A, D) are horizontal tunnels (from 2 to 4 cm across) with Y-shaped bifurcations and granulated walls, which are characteristic of Ophiomorpha (see Bromley and Frey, 1974; Frey et al., 1978). One of them (5648p; Fig. 7B, C) is a fragment of a much thinner tunnel (1.3 cm across), 22 cm long, with one flat extended chamber (3.5 cm across), which displays a poorly visible granulated wall. It is probably Ophiomorpha too.

According to many authors (e.g., Gibert and Ekdale, 2010; Wiest et al., 2016), Thalassinoides never possesses pellet walls. It is not excluded that the difficulties in recognition of these ichnotaxa are caused by the possibility that some of them are transitional forms between Thalassinoides and Ophiomorpha (see Uchman, 1991).
Göppert (1847) described other specimens of Cylindrites spongioides from the Quadersandstein (Turonian) of Bystrzyca Kłodzka. However, they have characteristic plant structures on the surface and in our opinion might be considered as algae; Göppert (1847), in describing fucoids (algae), cited ?Spongites saxonicus. One specimen from Göppert's Wrocław collection from Harz (cat. no. MGUWr – 5569p; Fig. 7E) is similar. It is 10.3 cm long, 1.7–2.8 cm across. It has a carbonized wall with a regular structure (alternately arranged knobs), and is probably of plant origin.

Otto (1852: Taf. VI, figs. 1–3) illustrated Spongia saxonica Geinitz (Cylindrites spongioides Göppert) from the Quadersandstein at Banewitz near Dresden. Only his specimen shown in fig. 1 is unbranched, rather smooth and has four spherical swollen chambers. Otto (1852) interpreted it as probably a juvenile form of Spongia saxonica Geinitz. In our opinion this specimen might represent Rosarichnoides sudeticus igen. et isp. nov. Kennedy (1967) cited two other branched Otto specimens illustrated on figures 2 and 3 on Taf. VI as synonyms of Thalassinoides saxonicus (Geinitz).

Dunker (1856) described Cylindrites spongioides (s. 183, Taf. XXXV, fig. 5) as algae from Blankenburg (Harz, Saxony, Germany). This specimen, with granulated swellings, is the most similar to Göppert’s forms (1842) and belongs probably to Ophiomorpha.

Unbranched, rather smooth forms similar to Rosarichnoides sudeticus isp. nov., but with only one swollen chamber were reported by Frič (1883) and Dettmer (1912) from the Cretaceous of the Bohemian Basin (the Turonian of Miada Boleslav) and Saxony (the Cenomanian and Turonian) respectively. Frič (1883) described Spongites saxonicus Gein. (fig. 128) and classified it within the Coelenterata, whereas Dettmer (1912) figured two specimens of Spongites saxonicus Geinitz (=Cylindrites spongioides Göppert; Taf. VIII, figs. 5, 6) and in-
cluded them within the fucoides (algae). These sketched specimens are fragmentarily preserved and have longer constrictions than swollen chambers. Additionally, the shape of their swollen chambers is slightly different (symmetrical, more spherical than pear-shaped) than the chambers of Rosarichnoides sudeticus. The state of preservation of these specimens does not allow for assignation to Rosarichnoides sudeticus, but they might belong to this ichnogenus. The other Dettmer (1912) specimen of Spongites saxonicus Geinitz (=Cylindrites spongoides Göppert) is branched (Taf. VIII, fig. 4), without swollen chambers, and resembles Thalassinoides.

Počta (1885) described Spongites saxonicus (without any illustrations) as sponges (Ceratospongiæ) = “body bulge-shaped or cylindrical, bifurcated with large, elongated swollen nodes from the Kreideformation of Bohemia”. This description is in agreement with typical features of Thalassinoides. Richter (1909) described Cylindrites spongoides Göppert, emend. as plant remains and illustrated them in Taf. XI–XIII, but only figure 1 in Taf. XI might be regarded as probably Rosarichnoides sudeticus igen. et isp. nov., while other three specimens (Taf. XI/fig. 7, Taf. XII/fig. 5, Taf. XIII/6) seem similar to Ophiomorpha as noted by Kennedy (1967). Richter’s specimen shown in figure 1 (Taf. XI) is unbranched, has a rather rough surface and consists of two pear-shaped swollen chambers connecting with a constricted tunnel, but by contrast with Rosarichnoides the constrictions are longer than the swellings.

Häntzschel (1962) included Spongites saxonicus Geinitz and Cylindrites spongoides Göppert in Ophiomorpha, while Spongites saxonicus Geinitz (nomen nudum), Cylindrites spongoides Göppert (nom. nud.) and ?Aschemonia Dettmer, 1915 in Thalassinoides. Kennedy (1967) provided a detailed synonymy of Thalassinoides saxonicus, but he incorrectly listed some names, pages or figures in the synonymy list. He designated as lectotype of this ichnosenes one specimen of Spongites saxonicus Geinitz, 1842 (only fig. 1 in Geinitz). The identification of the best specimens of T. saxonicus in Kennedy’s opinion (Kennedy, 1975: pl. 5, fig. 2; pl. 6, fig. 3) is difficult because they are covered with Chondrites isp. Häntzschel (1975) included Spongites saxonicus Geinitz, 1842 (partim) and Cylindrites spongoides Göppert, 1842 (partim) in Ophiomorpha. Spongites was illustrated by Häntzschel (1975) only by a drawing (fig. 1/74). The author included T. saxonicus (Häntzschel, 1975; fig. 70/2b) in Thalassinoides. Worth noticing that fig. 70/2a, described as Thalassinoides sp., is the same as fig. 1/74 illustrated as „Spongites” (see Häntzschel, 1975). In the diagnosis of the ichnogenus, the author cited typical swellings at points of branching or elsewhere. He also noted that rare transitional forms with the tuberculate structure of Ophiomorpha have been described.

The names Spongites and Cylindrites are not available, as they are pre-occupied. The genus Spongites Kützing, 1841 is assigned to algae (see Woelkerling, 1985) and the genus Cylindrites Sowerby, 1824 represents gastropods (Kennedy, 1967; Kollmann, 2002; Morris and Lycett, 2015).

T r a c e m a k e r a n d e t h o l o g y. – The specimen studied resembles modern crustacean burrows. The most complex burrow systems typical of ophiomorphids are produced by members of the decapod infraorders Gebiidea and Axidea (formerly known as thalassinideans, see Hyžný et al., 2015 and references therein). One of the most characteristic features of these infraorders is the presence of swellings (mostly interpreted as turn-arounds).

A classification of “thalassinidean” shrimp burrows based on morphological and ecological characteristics was proposed by Griffiths and Suchanek (1991). Geometrically Rosarichnoides sudeticus igen. et isp. nov. shows similarities to Type 2 (simple branches) made by deposit feeders, which produce mounds of sediment at their opening and usually do not store seagrass in burrow chambers. This type of burrow is a simple, twisting shaft, vertically oriented, with swollen chambers. In the upper part of the burrow a Y-shaped connection to the sediment surface is observed (Griffits and Suchanek, 1991). This last feature is missing in our material, probably due to its incompleteness. Though the position of the specimen studied is unknown, it is not excluded that it was vertically oriented. The Griffiths and Suchanek (1991) generalized model was criticized by some authors (Dworschak and Ott, 1993; Nickell and Atkinson, 1995; Gilbert and Ekdale, 2010; Hyžný et al., 2015) due to some features, such as the lack of mounds at the openings and number of openings in the fossil record and the difficulty of assigning certain species to a burrow type.

Ethologically, Rosarichnoides igen. et isp. nov. represents a fodiichnion, however an agrichnion is not excluded. It seems that it is a record of a simple process of burrowing through sediments in search for food. Nevertheless such numerous and regularly distributed swollen chambers suggest the possibility of the storage of seagrass or algae, or even of gardening behaviour on the burrow chamber walls. However, there is no other evidence for these behaviours. Most callianassids are assumed to be deposit feeders and in this case they create complicated burrow systems (Hyžný and Klompmaier, 2015 and references therein). Studies on modern crustaceans (e.g., Stamhuis et al., 1996) show that they usually represent a mixture of feeding strategies.

The tracemaker of the new ichnogenus was rather a deposit or detritus feeder, which probably could leave the burrow to collect organic material for later consumption. The possible producer of this burrow was a decapod crustacean (ghost or mud shrimp or crab). According to Griffiths and Suchanek (1991), 72% of the “Callianassa” species (infraorder Axidae) construct Type 2 (simple branches) of the burrows. Some of the contemporary mud shrimp burrows studied by Sepahvand et al. (2014) show a similar morphology to Rosarichnoides (a single oblique shaft with multiple turning chambers – see fig. 4 therein). Their producer is the gebiidean Upogebia carnicauda, the burrows of which vary depending on the habitat type and on the physical characteristics of the sediments. According to Hyžný (2011) the members of the Gebiidea and Axidea are known to construct very complex burrow systems which can reach >1 m in depth. Some resemblance to the semitriangular swellings of Type II of Psilonichnus quietis Myint, 2001 (see fig. 5B therein), which was produced by deposit feeding/or scavending brachyuran crabs, also suggest these organisms as the potential tracemakers of Rosarichnoides.

The role of the swollen chambers in crustacean burrowing has been discussed by many authors (e.g., D’Alessandro and Bromley, 1995; Stamhuis et al., 1996; Dworschak, 2001; Lewy and Golding, 2006). Swellings are mainly interpreted as turn-arounds, where a tracemaker could change its direction of movement. Other ethological behaviors have also been proposed (reproduction, meeting, brooding, nursery, storage). Gaillard and Olivero (2009) also proposed farming behaviour for the similar burrow Halimedides. According to Myint (2009), the swollen chambers of Type II of Psilonichnus quetis might have played different roles than turn-arounds. They are interpreted as: pauses during the process of burrowing, shelter for the trace-maker, space utilization (in some cases for breeding) and the position of greatest stability against collapse. Gaillard and Olivero (2009) suggested that the configuration of the chambers along the tunnel in Halimedides was organized for the ventilation of the burrow system. These authors, as well as Lukeneder et al. (2012), connected the densely and sparsely...
chambered burrows with various oxygenation levels of the sea floor and the character of the substrate (stiffground to firmground).

Among contemporary macrofaunal burrows, Koo and Koh (2013) described a burrow of the polychaete Periserrula leucophryna, which consists of a main vertical, unbranched shaft with several bulges (diameter up to 10 cm) for turn-around. Despite its general similarity to Rosarichnoides, this type of burrow has distinct characteristics. Its shaft is slightly sinuous, the constrictions are much longer and bulges have an irregular/oval shape and a thin short “peduncle”. For these reasons such a trace maker (a polychaeta) could not produce Rosarichnoides.

Ichnogenus Thalassinoides Ehrenberg, 1944
thalassinoides paradoxicus (Woodward, 1830) (Fig. 8A)

1967 Thalassinoides paradoxicus (Woodward), Kennedy, p. 142–148, pl. 3, pl. 4, pl. 8, fig. 5, pl. 9, fig. 2, text-figs 4, 5A, B. 2011 Thalassinoides paradoxicus (Woodward), Tiwari et al., p. 113, pl. 4e.

Material. – One specimen found in the Żerkowice Quarry, Coniacian, North Sudetic Synclinorium.

Diagnosis. – “Sparsely to densely but irregularly branched, subcylindrical to cylindrical burrows oriented at various angles with respect to bedding; T-shaped intersections are more common than Y-shaped bifurcations, and offshoots are not necessarily the same diameter as the parent trunk” (after Howard and Frey, 1984: 213).

Description. – The specimen studied is a horizontal, irregularly branched, cylindrical and unlined burrow with a T-rather than Y-shaped branching pattern. It has variable diameter (1.0–3.0 cm) and rare swellings. The visible length is 25 cm. At the end of the burrow, Y-shape branching appears. Two T-shaped branchings are also observed (Fig. 8A). The burrow fill is the same as the host rock. The irregular pattern of branching and variable diameter allows it to be assigned to Thalassinoides paradoxicus.

Remarks. – Thalassinoides is interpreted as a fodinichnion (Bromley, 1996), domicichnion (Myrow, 1995) and occasionally agrichnion (Ekdale and Bromley, 2003). According to Bautista et al. (2016), Thalassinoides is regarded mostly as fodinichnion. Thalassinid shrimps, ghost shrimps, lobsters, crayfish, crabs as well as fish, anemones and enteropneusts are mainly suggested as the potential trace makers (Frey et al., 1984; Myrow, 1995; Kim et al., 2002; Ekdale and Bromley, 2003; Neto de Carvalho et al., 2007).

This eurybathic ichnotaxon may occur in the Psilonichnus, Cruziana, and even in the Teredoites ichnofacies (MacEachern et al., 2007, 2012). It appears also in the Nereites and Zoophycos ichnofacies. It may characterize firmgrounds (Glossofunktioles ichnofacies) and hardgrounds (Trypanites ichnofacies; Myrow, 1995).

This ichnogenus occurs in different marine environments, more commonly in shallow marine settings (Ekdale and Bromley, 2003; Rodríguez-Tovar and Uchman, 2004a, b, 2010; Malpas et al., 2005). In siliciclastic storm deposits, Thalassinoides is abundant from the distal lower shoreline to offshore settings (Pemberton et al., 2012). Thalassinoides is known from the Cambrian to the Recent (Myrow, 1995; Sprechmann et al., 2004; Mángano and Buatois, 2016), but is most abundant in the Mesozoic and the Cenozoic (Rodríguez-Tovar and Uchman, 2004a, b).

DESCRIPTION OF THE ASSOCIATED FOSSILS

Type: Mollusca
Class: Bivalvia
Order: Praecardioida
Family: Inoceramidae Zittel, 1881
Genus: Inoceramus Sowerby, 1814
Inoceramus kleini Müller, 1888 (Fig. 8C)

1912–3 Inoceramus kleini Müll. var – Scupin’s, p. 209, Taf. 11, fig. 4a, b.
1934 Inoceramus kleini Müller – Andert, p. 115–117, Taf. 4, figs. 9–11, Taf. 5, figs. 1–2.
1960 Inoceramus kleini Müller – Radwańska, tab. 1, fig. f.
1991 Inoceramus kleini Müller – Tarkowski, p. 109–110, tabl. 13, fig. 7; tabl. 14, figs. 2, 3.
1996 Inoceramus kleini Müller – Walaszczyk, p. 386, fig. 8E.

Material. – One external imprint of a right valve found in the Czaple Quarry A (Fig. 1B).

Description. – The valve is very convex, small, with a strong and sharp beak. Axial length is 7 cm. Secondary axis is ~5.5 cm. Ventral margin is gently rounded. Hinge line is partially visible. Ornamentation of the valve consists of concentric and regular rugae. The ribs are 0.5–0.8 cm apart. The specimen does not differ from similar specimens described by Scupin (1912–1913), Radwańska (1960), Tarkowski (1991) and Walaszczyk (1996).

Occurrence. – Scupin (1912–13) described this species from the upper Coniacian of the North Sudetic Synclinorium (Gaszów, formerly Gehnsdorf). Radwańska (1960) cited this taxon from the Coniacian of the Upper Nysa Klodzka Graben. According to Tarkowski (1991), this species occurs in the lower Coniacian of East Europe, the middle Coniacian of the Opole Trough, the Coniacian of Germany and Poland. Walaszczyk (1996) described I. kleini from the lower middle Coniacian of Saxony and Bohemia. Walaszczyk et al. (2004) cited early forms of Inoceramus kleini, from the upper lower and lower middle Coniacian of the Euramerican biogeographic region.

Inoceramus sp. (Fig. 8B)

Material. – One specimen of a left valve, the Czaple Quarry A (Fig. 1B).

Description. – Large, convex valve, with a strong beak. Axial length is 20 cm. Secondary axis is ~14 cm. Ventral margin is gently rounded. Hinge line is partially visible. Ornamentation of the valve consists of concentric, regular rugae (up to 1.5 cm spacing), which are poorly visible due to the state of preservation.

Remarks. – The specimen is very similar to Scupin’s form (1912–13: Taf. 9, fig. 14) of the upper Coniacian of Czaple (former Hockenau). The author described large inoceramids, which are 18–24 cm long as Inoceramus nov. spec. (ex. aff.
The poor state of preservation of our specimen does not allow determination at the species level.

Types: Echinodermata
Class: Asteroidea
Order: Paxillosida
Family: Astropectinidae Gray, 1840
Genus: Astropecten Gray, 1840
Astropecten scupini Andert, 1934 (Fig. 8D, E)

1912–13 Astropecten nov.spec. – Scupin, p. 256, Taf. 15, fig. 5.
1934 Astropecten scupini sp. – Andert, p. 71, Taf. 19, fig. 24.

Material. – One imprint of the oral part of the endoskeleton found in the Czaple Quarry B (Fig. 1B).

Description and remarks. – Pentagonal form with well-preserved marginal spines. Its arms are elongate and pointed. The diameter is 16 cm and the length of the arm from the centre is ~8 cm. The ambulacral groove is only partially preserved. Mouth is not visible.

Occurrence. – Scupin (1912–13) described this species from the upper Coniacian of Czaple (Huckenau) of the North Sudetic Synclinorium. Andert (1934) cited this taxon from the upper Turonian of Saxony and Sudetes, and Soukup (1938) from the upper Turonian of Jičín (Czech Republic).

PALAEOENVIRONMENT

In the Coniacian sandstone of the Żerkowice Member (Czaple and Żerkowice quarries), a poor assemblage of fossils and trace fossils was found. Among them the interesting crustacean burrows *Rosarichnoides sudeticus* igen. et isp. nov. and
Thalassinoides paradoxicus (Woodward, 1830) are present. A very well-preserved starfish Astropecten scupini Andert, 1934 and some inoceramids I. kleini Müller, 1888 and Inoceramus sp. were also found. The most probable trace-makers of the new ichnogenus Rosarichnoides belong to decapod crustaceans (shrimps or true crabs), which are important elements of marine as well as brackish and freshwater environments (Dworschak, 2000; Hyžný et al., 2015; Dworschak (2000) cited the worldwide distribution of recent, vs. and geologic mud shrimps in all oceans from temperate, tropical and subtropical latitudes (60° north and south). According to Dworschak (2000, 2005), 95% of known callianassid crustacean species inhabit shallow-water (0–200 m) environments. Most of the fossil ghost shrimps have been reported from shallow-water deposits and they are the most important bioturbators (see Hyžný and Kloomaker, 2015). Burrowing crabs are typical of intertidal areas (upper-intertidal zone) and they do not build their burrows below the fair-weather wave-base (see Hyžný et al., 2015 and reference therein).

Thalassinoides is a common trace fossil in the Cruziana ichnofacies. It characterizes mainly the proximal Cruziana ichnofacies (see ictinological-sedimentological model of Pemberton et al., 2001, 2012), which is located in the distal lower shoreface. The occurrence of Thalassinoides in such an environment (distal lower shoreface/upper offshore) was reported by several authors (e.g., Uchman and Krenmayr, 2004; Perversier et al., 2011; Angulo and Buatois, 2012). Individual occurrences of this ichnogenus may be found in shallower settings such as the upper and middle shoreface (Leszczyński, 2010; Buatois and Mángano, 2011; Mayoral et al., 2013). Thalassinoides is an indicator of a well-oxygenated environment (Buatois and Mángano, 2011) and its most probable producers (shrimps) prefer shallow water of normal salinity (Weimer and Hoyt, 1964; Frey et al., 1978).

In the Sudetes, Thalassinoides has been described from the Carboniferous by Muszer and Uglik (2013), from the Middle Triassic, Lower Muschelkalk (Chrzastek, 2013a) and from the Upper Cretaceous (Rótnicka, 2005; Leszczyński, 2010; Chrzastek, 2013b, c; Chrząstek and Solczerski, 2016). Rótnicka (2005) cited this ichnogenus from the Cenomanian and Turonian in the Stolowe Mountains (Intra-Sudetic Synclinorium) from offshore/shelf settings. Leszczyński (2010) recorded this ichnogenus from the Żerkowice Member (Rakowice Male, Conianian), from foreshore to upper shoreface deposits, and from the Nowogrodziec Member (Rakowice Male, Santonian) from a coastal plain setting. Chrząstek (2013b, c) and Chrząstek and Solczerski (2016) described this ichnogenus from the middle Turonian and Coniacian of the Upper Nysa Kłodzka Graben (Bystrzyca, Długopole, Idźkow, Stary Waliszów) from lower shoreface to upper offshore deposits.

Inoceramids (Inoceramus klein and Inoceramus sp.), as found in the Coniacian sandstones, are very common and cosmopolitan in Mesozoic marine shelf environments (see Ozanne and Harries, 2002; Kumaga et al., 2011; Chrząstek, 2012). As eurytopic organisms they had broad ecological tolerances and are known from well-oxygenated, shallow marine to poorly oxygenated, deep-marine settings (Harries and Ozanne 1998; Ozanne and Harries, 2002).

The presence of the starfish Astropecten scupini also suggests shallow marine settings. Asteropecten used to occur in abundance down to a water depth of 50 m (Beddingfield and McClintock, 1993). According to Villier et al. (2004), asteropectenids are found predominantly in shallow shelf environments (shoreface). These starfish are well-adapted to soft-bottom substrates, being detritivores and predators of gastropods, bivalves and crustaceans (Caregnato et al., 2009; Blake and Guensburg, 2016). According to these authors, starfish (including asteropectenids) live in up to 30 m water depth, in some cases up to ~80 m. However, Baeta et al. (2016) reported Astropecten from the nearshore to offshore (5–150 m) with small individuals prevailing in the nearshore (5–50 m), and larger forms in the deeper areas (50–150 m). The presence of the starfish Astropecten scupini suggests a shoreface setting.

Leszczyński (2010) interpreted the Coniacian sandstones of the Żerkowice Member as bar and storm deposits, which were deposited mainly in the foreshore to upper shoreface setting. This is supported by opposite directions of large-scale cross-stratification, which indicate significant variations in wave/current direction and occasionally energetic hydrodynamic conditions. However, Leszczyński (2010), who studied the deposits of the Rakowice Quarry, stated that in the adjacent quarry at Żerkowice a more diverse assemblage of trace fossils occurs, in which horizontal burrows Ophiomorpha and Thalassinoides prevail. This suggests short calmer periods and periodic conditions characteristic of the distal expression of the Skolithos ichnofacies (Leszczyński, 2010), located in the middle shoreface setting.

Our studies are in agreement with the sedimentological analysis of Leszczyński (2010). In the Czaple quarries we observed fine-grained, well-sorted quartz sandstones with the same sedimentary structures as Leszczyński (2010) described, which are represented by planar stratification, ripple marks and large-scale cross-stratification. In most cases the sandstones are structureless. HCS (hummocky cross-stratification) was not found. In our opinion, sedimentation took place above the fair-weather wave base, in a moderate to high energy environment with some calmer episodes.

The assemblage of trace and body fossils studied is of low diversity. As Leszczyński (2010) stated, “the rarity of trace fossils in the Żerkowice Member may result from low stability of the sandy substrate caused by high water energy and deficiency of food in the depositional environment”. The presence of the trace fossils studied (Rosarichnoides sudeticus, Thalassinoides paradoxicus) and body fossils (starfish Astropecten scupini, inoceramids: Inoceramus klein, Inoceramus sp.) suggests deposition of the Coniacian sandstones in a shallow-marine environment, probably upper part of the shoreface. Recently, Chrząstek and Wypych (2016) reported a more diverse trace fossil assemblage from the Coniacian sandstones of the Czaple–Nowa Wieś Grodziska quarries, comprising Planolites, Phycodes, Gyrochorte, Ophiomorpha and Thalassinoides that together point to shoreface environments. On the basis of previous sedimentological and ichnological studies (Leszczyński, 2010; Chrząstek and Wypych, 2016) as well as our studies, it can be concluded that the sedimentation of the Żerkowice Member sandstones is typical of a soft-bottom, well-oxygenated and normal salinity shallow marine environment, above the fair-weather wave base (up to the middle shoreface).

CONCLUSIONS

The unique trace fossil described as Rosarichnoides sudeticus igen. et isp. nov. has been found in the Coniacian sandstones of the North Sudetic Synclinorium (Rakowice Wielkie Formation, Żerkowice Member, Czaple Quarry B). Rosarichnoides is interpreted as a characteristic rosy-shaped, unbranched and unswelled burrow, which consists of alternating asymmetrical oval to pear-shaped chambers (swellings) and constrictions. Its fill is passive and structureless,
similar to the host sediment. The surface of the burrow is rough rather than smooth, but some ridges and sand knobs or furrows may occur. This new ichnogenus is distinguished from other ichnotaxa by a lack of branching, and the different orientation and shape of swellings. It may be considered a representative of an “ophiomorph” group. Based on burrow morphology the trace-maker of *Rosarichnoides* may have been a deposit or de-tritus feeder among decapod crustaceans (most probably a shrimp or crab). Additionally, *Thalassinoides paradoxicus* (Woodward, 1830) as well as the starfish *Astropecten scupini* Andert, 1934, *inoceramids Inoceramus kleinii* Müller, 1888, *Inoceramus* sp. have also been encountered.

The trace fossil assemblage and macrofossils support the palaeoenvironmental interpretation of the the Żerkowice Member by Leszczyński (2010). The Coniacian sandstones studied were probably deposited in the foreshore to middle shoreline (archetypal Skolithos ichnofacies). Sedimentation took place in a shallow epicontinental sea, above the fair-weather wave base. Waters were well-oxygenated (*Thalassinoides*) and of normal salinity (shrimp, starfish). The sedimentation of the sandstones studied was related to the regression that started after uplift of the southeastern part of the North Sudetic Basin.

**Acknowledgements.** All specimens studied were made available by courtesy of the Kamieniarz Czaple Company. The authors thank very much A. Uchman for insights which were very helpful to recognize the study specimen. We wish to thank V. Śimo for helpful remarks and M. Myint and D. Olivero for publications. We are also grateful to K. Pluta for some photographs of the specimens studied. Thanks are also given to the reviewers D. Knaust, C. Neto de Carvalho and A. Uchman for their helpful remarks. This research was financed by the grants ING UWr 0401/1017/16.

**REFERENCES**

Alberti, F. 1834. Beitrag zu einer Monographie des bunten Sandsteins, Muschelkalks und Keupers, und die Verbindung-dieser. Verlag Cotta, Stuttgart u. Tübingen, I–XX: 1–366.

Andert, H. 1934. Die Kreideablagierungen zwischen Elbe und Jeschken. Teil 3: Die Fauna der obersten Kreide in Sachsen, Böhmen und Schlesien. 159: 1–477.

Angulo, S., Buatois, L.A., 2012. Ichnology of a Late Devo-nian-Early Carboniferous low-energy seaway: the Bakken Forma-tion of subsurface Saskatchewan, Canada: assessing paleoenvironmental controls and biotic responses. Palaeoge-ography, Palaeoclimatology, Palaeoecology, 315–316: 46–60.

Baeta, M., Galimany, E., Ramón, M., 2016. Growth and reproductive biology of the sea star *Astropecten aranciacus* (Echinodermata, Asteroidea) on the continental shelf of the Catalan Sea (northwestern Mediterranean). Helgoland Marine Research, 70: 1–22.

Baranowski, Z., Haydukiewicz, A., Kryza, R., Lorenc, S., Muszyński, A., Solecki, A., Urbanek, Z., 1990. Outline of the geology of the Góry Kaczawskie (Sudetes, Poland). Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 179: 223–257.

Beddingfield, S.D., McClintock, J.B., 1993. Feeding mechanism of the sea star *Astropecten articulatus* (Echinodermata: Asteroidea); an evaluation of energy-efficient foraging in a soft-bottom predator. Marine Biology, 115: 669–676.

Beláustegui, Z., Gibert, J.M.de, López-Blanco, M., Bajo, I., 2014. Recurrent constructional pattern of the crustacean burrow *Sinusichnus sinuosus* from the Paleogene and Neogene of Spain. Acta Palaeontologica Polonica, 59: 461–474.

Beláustegui, Z., Muniz, F., Mángano, M.G., Buatois, L.A., Domnéech, R., Martinell, J., 2016. *Lepeichnus giberti* igen. nov. isp. nov. from the upper Miocene of Lepe (Huelva, SW Spain): evidence for its origin and development with proposal of a new concept, ichnogeny. Palaeogeography, Palaeoclimatology, Palaeoecology, 452: 80–89.

Beyer, K., 1933. Das Liegende der Kreide in den Nordsudeten. Neues Jahrbuch für Mineralogie, Beilage-Band, B 69: 450–508.

Beyer, K., 1934. Zur kimmerischen Faltung in den Nordsudeten. Zeitschrift der Deutschen Geologischen Gesellschaft, 86: 702–702.

Beyrich, E., 1849. Das Quadersandsteingebirge in Schlesien. Zeitschrift der Deutschen Geologischen Gesellschaft, 1: 390–393.

Beyrich, E., 1855. Ueber die Lagerung der Kreideformation im schlesiischen Gebirge. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 26: 57–80.

Biemacka, J., 2012. Provenance of Upper Cretaceous quartz-rich sandstones from the North Sudetic Synclinorium, SW Poland: constraints from detrital tourmaline. Geological Quarterly, 56 (2): 315–332.

Blake, D.B., Guensburg, T.E., 2016. An asteroid (*Echinodermata*) faunule from the Oxfordian-Portlandian (Upper Jurassic) of Montana. Journal of Paleontology, 90: 1160–1168.

Bromley, R.G., 1996. Trace-Fossil Biology, Taphonomy and Appli-cations. Chapman and Hall, London.

Bromley, R.G., Frey, R.W., 1974. Redescription of the trace fossil *Gyrotholithes* and taxonomic evaluation of *Thalassinoides, Ophiomorpha* and *Spongeliomorpha*. Bulletin of the Geological Society of Denmark, 23: 311–335.

Buatois, L.A., Mängano, M.G., 2011. Ichnology: Organism-Substrate Interactions in Space and Time. Cambridge University Press.

Buatois, L.A., Carmona, N.B., Curran, H.A., Neto, R.G., Mängano, M.G., Wetzel, A., 2016. The Mesozoic marine revo-lution. In: The Trace-Fossil Record of Major Evolutionary Events, 2: Mesozoic and Cenozoic (eds. M.G. Mängano and L.A. Buatois): 19–134. Springer, Heidelberg.

Caregnato, F.F., Wiggers, F., Tarasconi, J.C., Veitenheimer-Mendes, I.L., 2009. Taxonomic composition of mollusks collected from the stomach content of *Astropecten brasilienis* (*Echinodermata: Asteroidea*) in Santa Catarina, Brazil. Revista Brasileira de Biociências, 7: 252–259.

Chamberlain, C.K., Baer, J.L., 1973. *Ophiomorpha* and a new thalassinid burrow from the Permian of Utah. Brigham Young University, Geology Studies, 20: 79–94.

Chrzastek, A., 2002. Stratigraphy and sedimentation conditions of *Roet* and Lower Muschelkalk of the North Sudetic Basin (in Pol-ish with English summary). Acta Universitatis Wratlaviensis 2383, Prace Geologiczno-Mineralogiczne, 73: 1–128.

Chrzastek, A., 2012. Palaeoentology of the Middle Turonian lime-stones of the Nysa Kłodzka Graben (Sudetes, SW Poland); biostatigraphical and palaeoecological implications. Geolo-gos, 18: 83–109.

Chrzastek, A., 2013a. Trace fossils from the Lower Muschelkalk of Raciborowice Górne (North Sudetic Synclinorium, SW Poland) and their palaeoenvironmental interpretation. Acta Geologica Polonica, 63: 315–353.

Chrzastek, A., 2013b. Middle Turonian trace fossils from the Bystrzyca and Długopole sandstones in the Nysa Kłodzka Graben (Sudetes, SW Poland). Geological Quarterly, 57 (3): 443–466.

Chrzastek, A., 2013c. Rekonstrukcja paleosrodowiska górnokredowych zlepieńców idzikowskich na podstawie...
skamieniałości sładowych (rów Nysy Kłodzkiej, Idzików) (w Pol-

ish). In: Aktualizm i antyaktualizm w paleontologii (eds. M.
Kędzierski i B. Kołodziej), XXII Konferencja Naukowa Sekcji
Paleontologicznej PTG, Tyńcze 27–30.IX.2013: 10–11.

Chrząstek, A., Solczerski, R., 2016. Crustacean burrows from the
Lower Idzków Beds (Stary Waliszów, Upper Nysa Klodzka
Graben) (in Polish). In: XXIII Konferencja Naukowa Sekcji
Paleontologicznej Polskiego Towarzystwa Geologicznego,
abstrakty (eds. K. Pawłowska i D. Pawłowski), Poznań
21–23.09.2016: 25–26.

Chrząstek, A., Wypych, M., 2016. Trace fossils from the quartz
sandstones (Coniacian) from the North Sudetic Synclinorium
(Czaple) (in Polish). In: XXIII Konferencja Naukowa Sekcji
Paleontologicznej Polskiego Towarzystwa Geologicznego,
abstrakty (eds. K. Pawłowska i D. Pawłowski), Poznań
21–23.09.2016: 27–28.

D'Alessandro, A., Bromley, R.G., 1995. A new ichnospecies of
Spongeliomorpha from the Pleistocene of Sicily. Journal of Pa-
leontology, 69: 393–398.

Dettmer, F., 1912. Sponges saxonicus Geinitz und die
Fucoidalfrage. Neues Jahrbuch für Mineralogie, Geologie und
Paläontologie, 1912 (2): 114–126, http://kreidefossilien.de/1724

Dettmer, F., 1915. Neues zum Fucoidenproblem. Gentrallblatt für
Mineralogie, Geologie und Paläontologie, 285–287.

Dunker, W., 1856. Ueber mehrere Pflanzenreste aus dem
Quadersandsteine von Blankenburg, 4: 179–183.

Dworschak, P.C., 2000. Global diversity in the Thallassinidea
(Decapoda). Journal of Crustacean Biology, 20: 238–245.

Dworschak, P.C., 2001. The burrows of Calianassa lymnata
(Petalona, 1792) (Decapoda: Thalassinidea). Marine Ecology,
22: 155–166.

Dworschak, P.C., 2005. Global diversity in the Thallassinidea
(Decapoda: Axiidea: Callianassidae) as producers of an Up-
per Miozän von Burgschleinitz beschrieben Gangkernen
und Bauten dekapoder Krebse. Paläontologische Zeitschrift,
11: 199–229.

Ehrenberg, K., 1944. Ergänzende Bemerkungen zu den seinerzeit
aus dem Miozän von Burgschleinitz beschrieben Gangkernen
und Bauten dekapoder Krebse. Paläontologische Zeitschrift,
11: 251–254.

Ekdale, A.A., Bromley, R.G., 2003. Paleoethologic interpretation of
complex Thallassinoides in shallow-marine limestones. Lower
Ordovician, southern Sweden. Palaeogeography, Palaeo-
climatology, Palaeoecology, 192: 221–227.

Frey, R.W., Curran, H.A., Pemberton, S.G., 1984. Tracemaking ac-
tivities of crabs and their environmental significance: the
ichnogenus Paliconichus. Journal of Paleontology, 58:
333–350.

Frey, R.W., Howard, J.D., Pryor, W.A., 1978. Ophiomorpha: its
morphologic, taxonomic and environmental significance.
Palaeogeography, Palaeoclimatology, Palaeoecology, 23:
199–229.

Frič, A., 1883. Studien im Gebiete der Böhmischen
Kreideformation. Paläontologische Untersuchungen der
einzelnen Schichten. III. Die Iser Schichten. Mit 132 Textfiguren.
Archiv für die naturwissenschaftliche Landesdurchforschung
innerhalb von Böhmen (Commissions-Verlag Fr. Rivaç), Prague, 5:
http://kreidefossilien.de/299

Fürsch, F.T., 1973. A revision of the trace fossils Spongeliomorpha,
Ophiomorpha and Thallassinoides. Neues Jahrbuch für
Geologie und Paläontologie, Monatshefte: 719–735.

Gaillard, C., Olivero, D., 2009. The ichnogenus Hallimedies in Cre-
taceous pelagic deposits from the Alps: environmental and
ethological significance. Palaois, 24: 257–270.

Geinitz, H.B., 1842. Die sächs.-böhmische Schweiz, die
Oberlausitz und das Innere von Böhmen. In: Charakteristik
der einzelnen Schichten. III. Die Iserschichten. Mit 132 Textfiguren.
Archiv für die naturwissenschaftliche Landesdurchforschung
innerhalb von Böhmen (Commissions-Verlag Fr. Rivaç), Prague, 5:
http://kreidefossilien.de/299

Göhler, T., 2011a. Eine komplizierte Garagentage im
Grabungssystem Thalassinoides saxonicus (Geinitz) aus
dem tidal beeinflussten unteren Ober-Cenomanium des Tharandt
Waldes. Beiträge zur Geologie der Sächsischen Kreide, 7–9:
49–58.

Göhler, T., 2011b. Betrachtungen einiger Grabgangstücke [u.a.
Ophiomorpha nodosa Lundgren und Thalassinoides saxonicus
(Geinitz)] aus Oberenonenanen Sandsteinen des Tharandt
Waldes. Beiträge zur Geologie der Sächsischen Kreide, 7–9:
59–64.

Göppert, J.H.R., 1842. Über die fossile Flora der
Quadersandsteinformation in Schlesien – als erster Beitrag zur
Flora der Tertiärgebilde. Novorum Actorum Academiae
Caesareae Leopoldino-Carolinae Naturae Curiosum
[Verhandlungen der kaiserlichen leopoldinisch-carolinischen
Akademie der Naturforscher] (Eduard Weber) Breslau und
Bon, 19: 99–134, http://kreidefossilien.de/1726

Göppert, J.H.R., 1847. Zur Flora des Quader-Sandsteins in
Schlesien, als Nachtrag zu der früher erschienen Abhandlung
über den selben Gegenstand. Novorum Actorum Academiae
Caesareae Leopoldino-Carolinae Naturae Curiosum
[Verhandlungen der kaiserlichen leopoldinisch-carolinischen
Akademie der Naturforscher] (Eduard Weber) Breslau und
Bon 14: 353–365, http://kreidefossilien.de/1727

Gray, J.E., 1840. A synopsis of the genera and species of the class
Hyppostoma Asterias (Linn.). Annals and Magazine of Natural
History, 6: 275–290.

Griffis, R.B., Suchanek, T.H., 1991. A model of burrow architecture
and trophic modes in thalassinidean shrimp (Decapoda:
Thalassinidea). Marine Ecology Progress Series, 79: 171–183.

Häntzschel, W., 1962. Part W. Miscellanea. Trace Fossils and
Problematica. In: Treatise on Invertebrate Paleontology (ed.
R.C. Moore). Geological Society of America and University of
Kansas Press.

Häntzschel, W., 1975. Part W. Miscellanea. Supplement 1. Trace
Fossils and Problematica. In: Treatise on Invertebrate Paleon-
tology (ed. C. Teichert). Geological Society of America and Uni-
versity of Kansas, Lawrence and Boulder.

Harries, P.J., Ozanne, C.R., 1998. General trends in predation and
parasitism upon inoceramids. Acta Geologica Polonica,
48: 377–386.

Holdefeiss, G., 1915. Das Triaevorkommen von Gross-Hart-
mannsdorf in Niederschlesien. Jahresbericht der Schlesischen
Gesellschaft für vaterländische Kunst, 92: 1–23.

Howard, J.D., Frey, R.W., 1984. Characteristic trace fossils in
nearshore to offshore sequences, Upper Cretaceous of east-
central Utah. Canadian Journal of Earth Sciences, 21:
200–219.

Hyžný, M., 2011. In situ mud shrimps (Decapoda: Axiidea:
Callianassidae) preserved within their burrows from the middle
Miocene of the Central Paratethys. Bulletin of the Mizunami
Fossil Museum, 37: 37–46.

Hyžný, M., Klompmaker, A.A., 2015. Systematics, phylogeny, and
taphonomy of ghost shrimps (Decapoda): a perspective from the
fossil record. Arthropod Systematics & Phylogeny, 73:
401–437.

Hyžný, M., Šimo, V., Starek, D., 2015. Ghost shrimps (Decapoda:
Axiidea: Callianassidae) as producers of an Upper Miocene
trace fossil association from subtillar deposits of Lake Pannon
(Vienna Basin, Slovakia). Palaeogeography, Palaeoclimatology,
Palaeoecology, 425: 50–66.

Kennedy, W.J., 1967. Burrows and surface traces from the Lower
Chalk of southern England. Bulletin of the British Museum (Nat-
ural History) Geology London, 15: 125–167.

Kim, J.-Y., Kim, K.-S., Pickerill, R.K., 2002. Cretaceous nonmarine
trace fossils from the Hasandong and Jinju Formations of the
Namhae Area, Kyongsangnam-do, southeast Korea. Ichnos,
9: 41–60.
Milewicz, J., 2002. Gastropods from the Lower Cretaceous of Vorarlberg, Austria. A systematic review. Annalen des Naturhistorischen Museums in Wien, 103A: 23–73.

Koo, B.J., Koh, C.-H., 2013. Oxygen penetration through Invertebrate burrow walls in Korean tidal flat. Ocean Science Journal, 48: 329–338.

Kumagae, T., Maeda, H., Komatsu, T., 2011. Paleoecology of Inoceramus amakusensis Nagao et Matsumoto, 1940 (Bivalvia) in a Late Cretaceous shallow clastic sea: the Himenoura Group, Kyushu, Japan. Cretaceous Research, 32: 738–749.

Kützing, F.T., 1841. Über die “Polyperiades calcifères” des Lamouroux. In: Zu der öffentlichen Prüfung sämtlicher Classen der Realschule zu Nordhausen 1841 (ed. F.T. Kützing): 3–34. Realschule, Nordhausen.

Lepper, J., Rambow, D., Röhling, H.-G., 2002. Der Buntsandstein in der Stratigraphischen Tabelle von Deutschland. Newsletters on Stratigraphy, 13: 129–142.

Leszczyński, S., 2010. Coniacian-Santonian paralic sedimentation in the Rakowice Male area of the North Sudetic Basin, SW Poland: sedimentary facies, ichnological record and palaeoecological reconstruction of an evolving marine embayment. Annales de l’Institut Geologique Polonais, 80: 1–24.

Lewy, Z., Goldring, R., 2006. Campanian crustacean burrow system from Israel with brood and nursery chambers representing communal organization. Palaeontologia, 49: 133–140.

Lorenz von Liburnau, J.R., 1902. Ergänzung zur Beschreibung der fossilen Halimeda fuggeri: Sitzungsberichte der kaiserlich-königlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Klasse, 111: 685–712.

Lukeneder, A., Uchman, A., Gaillard, C., Olivero, D., 2012. The late Barremian Halimediidae horizon of the Dolomites (Southern Alps, Italy). Cretaceous Research, 35: 199–207.

Lundgren, B., 1988. Studier öfver fossilförande lösa block. Geologiska Föreningen i Stockholm Förhandlinger, 13: 111–121.

MacEachern, J.A., Pemberton, S.G., Gingras, M.K., Bann, K.L., 2007. The ichnofacies paradigm: a fifty-year retrospective. In: Trace Fossils. Concepts, Problems, Prospects (ed. W. Miller III): 52–77. Elsevier.

MacEachern, J.A., Bann, K.L., Gingras, M.K., Zonneveld, J.-P., Dashtgard, S.E., Pemberton, S.G., 2012. The ichnofacies paradigm. Developments in Sedimentology, 64: 103–138.

Malpas, J.A., Gawthorpe, R.L., Pollard, J.E., Sharp, I.R., 2005. Functional morphology of thalassinidean shrimp burrows and trophic modes of three thalassinidean shrimp species, and a new approach to the classification of thalassinidean shrimp morphology. Marine Ecology Progress Series, 282: 181–197.

Neto de Carvalho, C.N., Viegas, P.A., Cachão, M., 2007. Glyptolithes as a multipurpose burrow: an ethologic approach. Revista Brasileira de Paleontologia, 10: 157–168.

Nickell, L.A., Atkinson, R.J.A., 1995. Functional morphology of burrows and trophic modes of three thalassinidean shrimp species, and a new approach to the classification of thalassinidean shrimp morphology. Marine Ecology Progress Series, 128: 181–197.

Menning, M., Deutsche Stratigraphische Kommission, 2012. Erläuterung zur Stratigraphischen Tabelle von Deutschland Kompakt 2012 [Explanation notes to the Stratigraphic Table of Germany Compact 2012]. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 163: 385–409.

Milewicz, J., 1956. Zabarzenie utworów kredowych w Rakowicach Małych (in Polish). Przegląd Geologiczny, 4: 361–364.

Milewicz, J., 1965. Facies of the Upper Cretaceous in the eastern part of the North Sudetic Basin (in Polish with English summary). Biuletyn Instytutu Geologicznego, 170: 15–80.

Milewicz, J., 1978. Distribution of Cretaceous rocks in the North-Sudetic Basin (in Polish with English summary). Kwartalnik Geologiczny, 23 (4): 819–826.

Milewicz, J., 1985. A proposal for formal stratigraphic subdivision of the infill of the North Sudetic Depression (in Polish with English summary). Przegląd Geologiczny, 33: 385–390.

Milewicz, J., 1997. Upper Cretaceous of the North-Sudetic depression (litho-and biostratigraphy, paleogeography, tectonics and remarks on raw material (in Polish with English summary). Acta Universitatis Wratislavensis, Prace Geologiczo-Minerologiczne, 59: 5–58.

Morris, J., Lycett, J., 2015. A monograph of the Mollusca from the Great Oolite. Cambridge Library Collection, 1. Chiefly from Minchinhampton and the coast of Yorkshire. Cambridge University Press.

Musstow, R., 1968. Beitrag zur Stratigraphie und Palaögeographie der Oberkreide und des Albs in Ostbrandenburg und der östlichen Niederlausitz. Geologie, 17: 1–71.

Muszner, J., Ugliki, M., 2013. Palaeoenvironmental reconstruction of the Upper Visean Patapnia Beds (Bardo Unit, Polish Sudetes) using ichnological and palaeontological data. Geological Quarterly, 57 (3): 365–384.

Müller, G., 1888. Beiträge zur Kenntnis der oberen Kreideformation am nördlichen Harzrand. Jahrbuch der Preussischen Geologischen Landesanstalt und Berg academie, 8: 372–456.

Myint, M., 2001. Psilonichnus quiets i isp. nov. from the Eocene Iwaki Formation, Shiramizu Group, Joban Coal Field, Japan. Ichnos, 8: 1–14.

Myint, M., 2009. The Psilonichnus ichnofacies: an example from the Iwaki Formation, Shiramizu Group, Joban Coal Field, Japan. SEPM Special Publications, 91: 1–7.

Myrow, P.M., 1995. Thalassinoidea and the enigma of Early Paleozoic open-framework burrow systems. Palaios, 10: 58–74.

Neto de Carvalho, C., Rodrigues, N.P.C., 2007. Compound Asterosoma ludwigiae Schliff, 2000 from the Jurassic of the Lustrian Basin (Portugal): conditional strategies in the behavior of Crustacea. Journal of Iberian Geology, 33: 295–310.

Neto de Carvalho, C.N., Viegas, P.A., Cachão, M., 2007. Thalassinoidea and its producer: populations of Mecochirus buried within their burrow systems, Boca do Chapim Formation (Lower Cretaceous), Portugal. Palaios, 22: 104–109.

Netto, R.G., Buatois, L.A., Méndez, M.G., Balistieri, P., 2007. Co-evolution of the Mollusca from the Minchinhampton and the coast of Yorkshire. Cambridge Library Collection, 1: Chiefly from Minchinhampton and the coast of Yorkshire. Cambridge University Press.

Pemberton, S.G., MacEachern, J.A., Dashtgard, S.E., Bann, K.L., Gingras, M.K., Zonneveld, J.-P., 2012. Shorefaces. De-

Pemberton, S.G., Spila, M., Pulham, A.J., Saunders, T., Pemberton, S.G., MacEachern, J.A., Robbins, D., Sinclair, I.K., 2001. Ichnology and sedimentology of shallow to marginal marine systems. Ben Nevis & Avalon Reservoirs, Jeane Dame Arc Basin. Geological Association of Canada, Short Course Notes, 15: 1–343.

Pemberton, S.G., MacEachern, J.A., Dashtgard, S.E., Bann, K.L., Gingras, M.K., Zonneveld, J.-P., 2012. Shorefaces. Developments in Sedimentology, 64: 563–603.

Perverser, P., Uchman, A., 2007. A new Y-shaped trace fossil attributed to upogebiid crustaceans from Early Pleistocene of Italy. Acta Palaeontologica Polonica, 54: 135–142.

Perverser, P., Uchman, A., Hohenegger, J., Dominici, S., 2011. Ichnological record of environmental changes in Early Quarternary (Gelasian-Calabrian) marine deposits of the Strione section, Northern Italy. Palaios, 26: 578–593.

Pérez, P., 1852. Beiträge zur Kenntnis der Spongen der Böhmischen Kreideformation. III Abtheilung: Terebratulinae, Monactinellidae, Calicospongiae, Ceratopongiæ, Nachtrag. 26 Fig im Text. Abhandlungen der königlichen böhmischen
Sowby, J. 1824 (continued by Sowby J.) (1812–46). The mineral conchology of Great Britain. 7. London.

Speckmann, P., Gaucher, C., Blanco, G., Montaña, J., 2004. Stromatolitic and trace fossils community of the Cerro Victoria Formation, Arroyo del Soldado Group (Lowermost Cambrian, Uruguay). Gondwana Research, 7: 753–766.

Stamhuis, E.J., Reede-Dekker, T., Etten Y van, Wiljes, J.J. de, Videler, J.J., 1996. Behaviour and time allocation of the burrowing shrimp Callianassa subterranea (Decapoda, Thalassinidea). Journal of Experimental Marine Biology and Ecology, 204: 225–239.

Tarkowski, R., 1991. Stratigraphy, macrofossils and palaeogeography of the Upper Cretaceous from the Opole Trough (in Polish with English summary). Scientific Bulletins of Stanislaw Stasic Academy of Mining and Metallurgy, 1404, Geology, 51: 1–156.

Tiwari, R.P., Rajkonwar, C., Lalchawmawii, Malsawma, P.L.J., Ratle, V.Z., Patel, S.J., 2010. Trace fossils from Bhuban Formation, Surma Group (Lower to Middle Miocene) of Mizoram India and their palaeoenvironmental significance. Journal of Earth System Science, 11: 1127–1143.

Uchman, A., 1991. “Shallow water” trace fossils in Palaeogene flysch of the southern part of the Magura Nappe, Polish Outer Carpathians. Annales Societatis Geologorum Poloniae, 61: 61–75.

Uchman, A., 1995. Taphonomy and palaeoecology of flysch trace fossils: The Marnoso-arenacea Formation and associated faunas (Miocene, Northern Apennines, Italy). Beringeria, 15: 3–115.

Uchman, A., 1998. Taphonomy and ethology of flysch trace fossils: Revision of the Marian Książkiewicz collection and studies of complementary material. Annales Societatis Geologorum Poloniae, 68: 105–218.

Uchman, A., Krenmayr, H.G., 2004. Trace fossils, ichnofabrics and sedimentary facies in the shallow marine Lo Miocene Molasse of Upper Austria. Jahrbuch der Geologischen Bundesanstalt, 144: 233–251.

Villier, L., Kutscher, M., Mah, C.L., 2004. Systematics and palaeoecology of middle Toarcian Asteroidea (Echinodermata) from the „Seuil du Poitou”, Western France. Geobios, 37: 807–825.

Walaszczyk, I., 1996. Inoceramids from Kreibitz-Zittauer area (Saxon and northern Bohemia): revision of Andert’s (1911) descriptions. Paläontologische Zeitschrift, 70: 367–392.

Walaszczyk, I., 2008. North Sudetic Basin (Outer Sudetic Cretaceous). In: The Geology of Central Europe (ed. T. McCann), 2 (Mesozoic and Cenozoic): 959–960. The Geological Society of London, London.

Walaszczyk, I., Kopavich, L.F., Oliferiev, A.G., 2004. Inoceramid/foraminiferal succession of the Turonian and Coniacian (Upper Cretaceous) of the Briansk region (Central European Russia). Acta Geologica Polonica, 54: 569–581.

Weimer, R.J., Hoyt, J.H. 1964. Burrows of Callianassa mayor Say, geologic indicators of littoral and shallow neritic environments. Journal of Paleontology, 38: 761–767.

Wiest, L.A., Buynevich, I.V., Grandstaff, D.E., Terry Jr., D.O., Maza, Z.A., Lacovara, K.J., 2016. Ichnological evidence for endobenthic response to the K-Pg event, New Jersey, U.S.A. Paläontologische Zeitschrift, 11: 231–241.

Wilmsen, M., Uličny, D., Koš ák, M., 2014. Cretaceous basins of Central Europe: deciphering effects of global and regional processes – a short introduction. Zeitschrift der Deutschen Geologischen Gesellschaft, 165: 495–499.

Woelkerling, W.J., 1985. A taxonomic reassessment of Spongites (Corallinaceae, Rhodophyta) based on studies of Kützing’s original collections. British Phycological Journal, 20: 123–153.

Woodward, S., 1830. A Synoptic Table of British Organic Remains. London & Norwich.