

NEW MORPHOLOGICAL FEATURES OF *ARTHROPLEURA* SP. (MYRIAPODA, DIPLOPODA) BASED ON NEW SPECIMENS FROM THE UPPER CARBONIFEROUS OF LOWER SILESIA (POLAND)

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Pacyna, G., Florjan, S. & Borzęcki, R., 2012. New morphological features of *Arthropleura* sp. (Myriapoda, Diplopoda) based on new specimens from the Upper Carboniferous of Lower Silesia (Poland). *Annales Societatis Geologorum Poloniae*, 82: 121–126.

Abstract: New tergite fragments of *Arthropleura* were found at the Nowa Ruda mine (Lower Silesia, Poland), after more than seventy years since any previous discovery. The small dimensions of the preserved structures, in terms of the genus *Arthropleura*, and the characteristic features of tuberculation probably indicate that the remains do not belong to the type species *A. armata*, but they could represent a new species. The occurrence of round protrusions in the broken-off tubercles is another feature of the new specimens, which has not been mentioned in the earlier literature. Unfortunately, the scanty remains that we have at our disposal (only two specimens were found) are not sufficient for the proposal of a new species. The number of valid *Arthropleura* species requires further investigation, especially regarding the features, which are diagnostic for species. The tergites described have very numerous tubercles, which may have taxonomic value in species discrimination. Because the fossils were found on a dump, their exact stratigraphic position is not known. However, they occur together with index leaflets of the seed ferns *Paripteris gigantea* and *Linopteris* sp., which enabled the age determination of Upper Namurian - Lower Westphalian for the fossils studied. This new discovery of *Arthropleura* contributes to a better understanding of the genus and of the Carboniferous land fauna of Poland, which is otherwise poorly known. This is also the first, detailed description of *Arthropleura* remains from the Polish Carboniferous.

Key words: *Arthropleura*, Upper Carboniferous, Lower Silesia, Poland.

Manuscript received 5 January 2012, accepted 4 September 2012

INTRODUCTION

Arthropleura is one of the largest arthropods in the geological history of the Earth reaching 2–3 m in length (Braddy *et al.*, 2008). This is the reason for the continual research on it (Meyer, 1853; Jordan and Meyer, 1854; Kliver, 1883, 1884; Pruvost, 1930; Waterlot, 1934; Guthörl, 1936, 1938; Rolfe, 1969, 1985; Donovan, 2002; Kraus and Brauckmann, 2003). Its systematic position among arthropods is still under discussion (Rolfe and Ingham, 1967; Almond, 1985; Kraus and Brauckmann, 2003), but at present the overriding opinion is that it should be assigned to the Diplopoda (Kraus and Brauckmann, 2003; Kraus, 2005; Shear and Edgecombe, 2010). However, there are doubts concerning its kinships among Diplopoda and its extinct relatives, Eoarthropleurida and Microdecemplicida (Kraus and Brauckmann, 2003; Kraus, 2005). The best preserved remains of *Arthropleura* have been found in Upper Carboniferous and Lower Permian strata (Guthörl, 1940; Hahn *et al.*,

1986; Brauckmann *et al.*, 1997; Hannibal, 1997a, b; Schneider and Barthel, 1997; Proctor, 1998; Schneider and Werneburg, 1998; Kraus and Brauckmann, 2003). Some older, but doubtful remains, found in Upper Devonian strata, have also been referred to *Arthropleura* (Almond, 1985; Ross and Briggs, 1993). The tracks of this gigantic animal are well known and have been described frequently (Briggs *et al.*, 1979, 1984; Ryan, 1986; Pearson, 1992; Donovan, 2002; Morrissey and Braddy, 2004; Lucas *et al.*, 2005; Hannibal, 2007; Pollard *et al.*, 2008; Martino and Greb, 2009; Schneider *et al.*, 2010).

Arthropleura specimens have been found in the Lower Silesian Coal Basin since the 19th century, as in other Carboniferous coal basins in Europe. These finds have contributed to a better understanding of the genus (Roemer, 1880; Guthörl, 1936, 1938), but they have never been properly described or illustrated. The species *Arthropleura armata*, *A.*

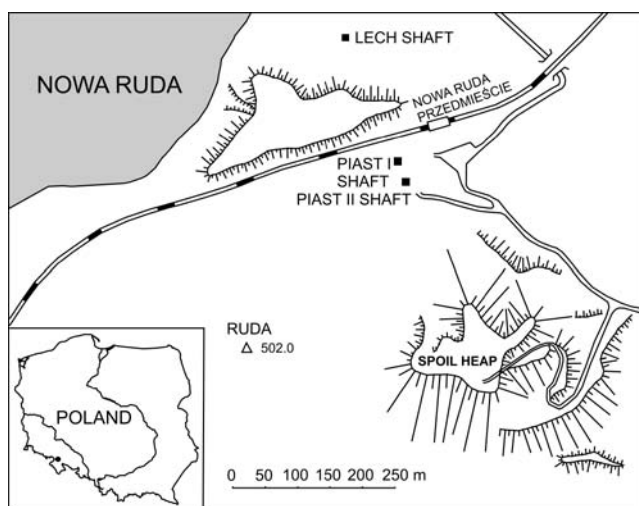


Fig. 1. Location of spoil heap at Nowa Ruda

maillieuxi, *Arthropleura* sp. were determined from Lower Silesia, and *Arthropleura* sp. from Upper Silesia (Gothan and Gropp, 1933; Guthörl, 1936; Hoehne, 1948). The genus *Arthropleura* is also well known from the Czech area of Upper Silesia and Lower Silesia (Řehoř and Řehořová, 1972; Štamberg and Zajíc, 2008). *Arthropleura armata* and *A. maillieuxi* were described from the “Nowa Ruda” mine (Guthörl, 1936). Since Hoehne’s work (1948), there have been no new data on *Arthropleura* from Poland. In the 1950s and 1960s, Sagan collected numerous, well preserved specimens of *Arthropleura* sp. from Lower Silesia, but he published only a brief note about his findings (Sagan, 1967). The Sagan collection is currently being researched, and the initial results have been presented by Zdebska *et al.* (2005). Kiepura *et al.* (2001) collated the information, published thus far, about Poland’s Carboniferous land fauna, but the genus *Arthropleura* was not mentioned. The only specimen of a Carboniferous myriapod, described in detail from Poland (Hannibal and Krzemiński, 2005; Zdebska *et al.*, 2005), belongs to the genus *Palaeosoma* (Diplopoda).

The new specimens discussed below were found on a spoil heap at the “Nowa Ruda” mine. Though only two specimens were found, they have contributed to a better understanding of the genus *Arthropleura* and the Carboniferous land fauna in Poland generally.

MATERIAL AND METHODS

Two fragments of tergites were found by R. Borzęcki on a spoil heap at the “Nowa Ruda” mine (Fig. 1) in 2010 (Lower Silesia, Poland) and are stored at the Muzeum Mineralów, Robert Borzęcki, in Kłodzko under the catalog numbers MMRB2010.06.16/527/0.00/a-b and MMRB 2010.07.25/564/0.00. They are preserved in black, coaly shale, together with some plant remains. Coal mining has now ceased in the Polish area of the Lower Silesia Coal Basin (Bossowski and Ihnatowicz, 2006). Therefore, new fossils can only be found on spoil heaps, in drill core and at a few natural outcrops, many of which are now inaccessible.

Stages and substages		Lithostratigraphic formations
Westphalian	Asturian	Glinik
	Bolsovia	Żacleń
	Duckmantian	
	Langsettian	
Namurian	Upper	Biały Kamień
	Middle	Wałbrzych
	Lower	

Fig. 2. Lithostratigraphic scheme of Nowa Ruda area (according Nowak, 1995, modified), showing probable position of horizon with *Arthropleura* specimens

As the fossils were discovered on a spoil heap, their exact stratigraphic position is not known (Fig. 2). Fortunately, some determinable plant remains accompany the *Arthropleura* remains. Index leaflets from the seed ferns *Paripteris gigantea* (Sternberg, 1823) Gothan, 1941 (Fig. 3) and *Linopteris* sp. have been recognized, and these permit an age determination for the fossils studied as Upper Namurian–Lower Westphalian (Gothan, 1941; Kotasowa and Migier, 1995) (Fig. 2).

The specimens were analyzed under a Nikon stereomicroscope SMZ 1000. In the specimen descriptions, we follow the anatomical terms, proposed by Kraus and Brauckmann (2003, fig. 1).

SYSTEMATIC PALEONTOLOGY

Phylum ARTHROPODA Latreille, 1829
 Superclass MYRIAPODA Latreille, 1796
 Class DIPLOPODA de Blainville (in Gervais, 1844)
 Order ARTHROPLEURIDA Waterlot, 1934
 Family ARTHROPLEURIDAE Zittel, 1885
 Genus *Arthropleura* Meyer, 1853
 Type species: *Arthropleura armata* Meyer, 1853

Arthropleura sp.
 Fig. 3A–C

Syntergite (specimen no. MMRB 2010.07.25/564/0.00)

Syntergite fragment (only positive preserved, visible from the dorsal side of the body), with the dimensions 28 mm by 21 mm (Fig. 3A), and roughly 20 traces of small tubercles, visible on the surface, with diameters at the base from 0.5 mm to 3 mm. These tubercles are irregularly distributed. Only one tubercle is clearly larger, and is 6 mm in diameter at the base. Some tubercles have broken-off tips and are truncated, because of this. Plant detritus is associated with the syntergite, with only leaflets of the seed fern *Paripteris gigantea* determinable (Fig. 3D).

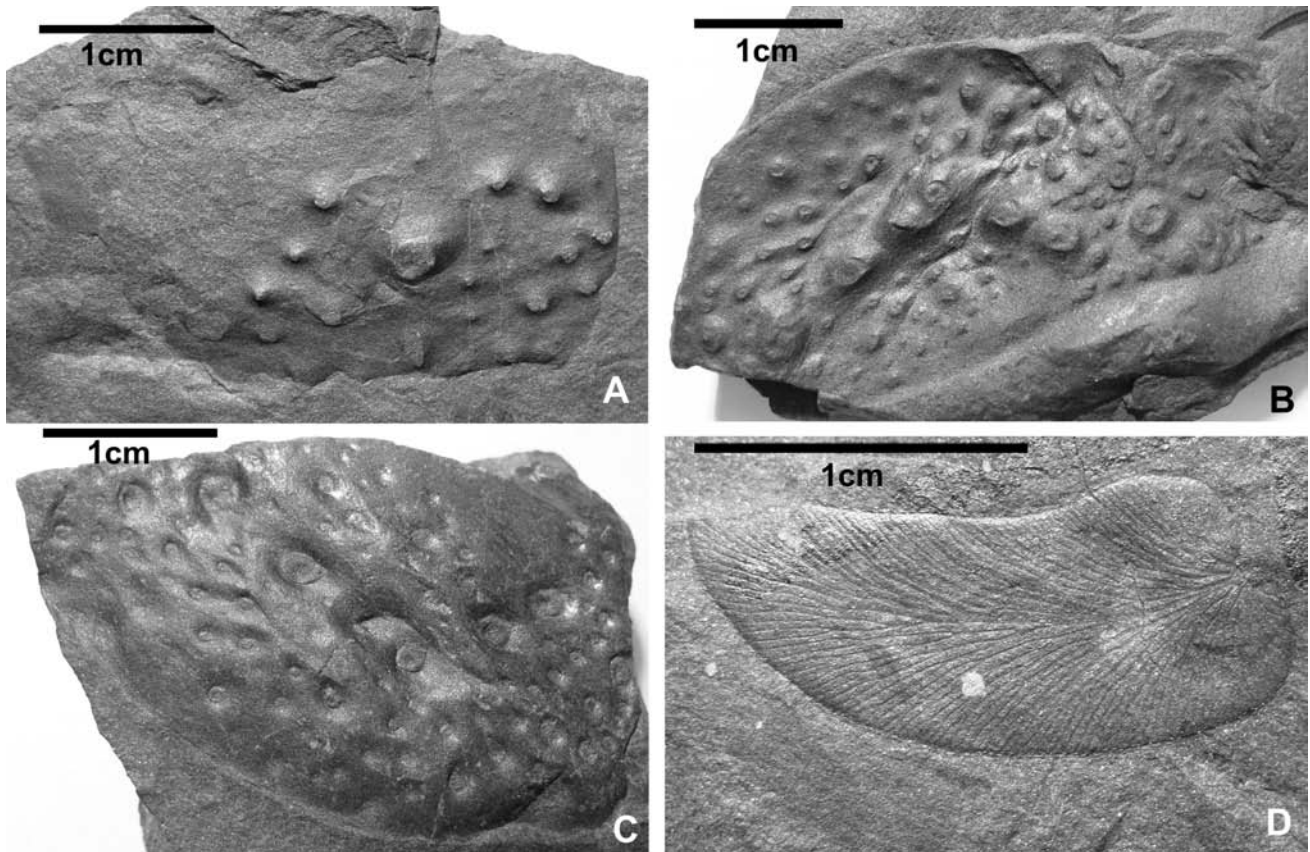


Fig. 3. Tergite fragments of *Arthropleura* sp. and associated plant fossil. **A.** Syntergite fragment (MMRB 2010.07.25/564/0.00, positive specimen). **B.** Right paratergite fragment (MMRB 2010.06.16/527/0.00/a, positive specimen). **C.** Right paratergite fragment (MMRB 2010.06.16/527/0.00/b, negative specimen). **D.** Leaflet of *Paripteris gigantea* (Sternberg, 1823) Gothan, 1941 (MMRB 2010.07.25/564/0.00)

The specimen was identified as a syntergite fragment, because of its preserved, somewhat rectangular shape (syntergite edges are not clearly visible) and clearly visible tubercles, directed to the rear (Hahn *et al.*, 1986; Brauckmann *et al.*, 1997; Schneider and Barthel, 1997; Schneider and Werneburg, 1998; Kraus and Brauckmann, 2003). The occurrence of only one large tubercle on the syntergite is an interesting feature of the fossil described here. In specimens described in earlier papers, there are more large tubercles on syntergites and they form an almost regular line near the rear edge of the syntergite (Waterlot, 1934; Hahn *et al.*, 1986; Brauckmann *et al.*, 1997; Kraus and Brauckmann, 2003). Here, too, the large tubercle is near the rear edge of the syntergite.

Paratergite (specimen no. MMRB 2010.06.16/527/0.00/ a-b)

An incomplete paratergite fragment (positive and negative preserved) with dimensions of 44 mm by 22 mm, visible from the dorsal side of the body. The whole paratergite surface has visible traces of over 70 tubercles from 0.6 mm to 3 mm in diameter at the base and a line of large tubercles, 6 mm in diameter at the base (Fig. 3B, C). Small tubercles are distributed over the whole paratergite surface at relatively even distances from each other; smaller ones occur more densely and larger ones more sparsely. Some tubercles have broken-off tips and are truncated, because of this. The tubercles with broken-off tips have roundish structures,

located centrally inside them. The imprint of the leaflet *Linopteris* sp. occurs with the fossil, together with plant detritus.

The specimen was identified as a paratergite fragment, because of its shape, which is typical for this structure (Hahn *et al.*, 1986; Brauckmann *et al.*, 1997; Schneider and Barthel, 1997; Schneider and Werneburg, 1998; Kraus and Brauckmann, 2003). Particularly characteristic is the paratergite's arched shape. The small dimensions and weak arching of the paratergite described allow us to suppose that it comes from the front or, more probably, the rear section of the animal, because paratergites are proportionally larger from the central section, and also strongly arched (Hahn *et al.*, 1986; Brauckmann *et al.*, 1997). An interesting feature of this paratergite is that the large tubercles do not form a regular line, but follow a stretched letter S. In the *Arthropleura* specimens, described from Germany, the large tubercles form a clear line (Hahn *et al.*, 1986; Brauckmann *et al.*, 1997; Schneider and Barthel, 1997; Schneider and Werneburg, 1998; Kraus and Brauckmann, 2003). This feature is particularly visible on small *Arthropleura* specimens from the formally undescribed species from Montceau-les-Mines (Kraus and Brauckmann, 2003; Kraus, 2005). In contrast to those specimens, large tubercles, following the shape of a stretched letter S, are visible on some French *Arthropleura armata* specimens, which were illustrated by Waterlot (1934). However, this feature is more strongly expressed in the material from Silesia. The occurrence of round protru-

sions in the broken-off tubercles is another essential feature of this specimen, which has not been mentioned previously in the literature. However, this feature is visible on some specimens, previously illustrated by Brauckmann *et al.* (1997, tab. 2, fig. 2). The feature is also visible on other specimens of *Arthropleura* from the Lower Silesian Coal Basin in the Sagan collection (Wałbrzych Museum). The real nature of this feature requires further investigation. At present, we are unable to decide whether it is a taphonomic feature or an organic feature of the tubercles.

Arthropleura fossils with numerous and size diversified tubercles, as in our specimens, were described and illustrated by Rößler and Schneider (1997), and they determined them to be *Arthropleura armata* Meyer, 1853. The specimens, described and illustrated by Hahn *et al.* (1986) and Brauckmann *et al.* (1997) as *Arthropleura armata*, have less numerous tubercles. If the number, size and arrangement of tubercles are taxonomically important for distinguishing species of *Arthropleura*, as Kraus and Brauckmann (2003) suggest, the specimens described by Rößler and Schneider (1997) may not belong to the species *Arthropleura armata*. The fossils, described by Rößler and Schneider (1997), have large tubercles, arranged differently on the paratergite, by comparison with these specimens from the Lower Silesian Coal Basin. In their specimens, tubercles are located probably very near the rear edge of the paratergite, although this is not certain, because those specimens are not well preserved.

The fossils from the Lower Silesian Coal Basin have tubercles, disposed the nearer back end of paratergite, but their arrangement in the shape of the letter S means that they extend to as much as half of the width. The species *A. maillieuxi* Pruvost, 1930, *A. mammata* (Salter, 1863) and *A. britannica* André, 1910 have a prominent, straight simple line of large tubercles on the paratergites, which distinguishes them from the material described (Salter, 1863; Woodward, 1872; Guthörl, 1936). In *A. britannica*, the shape of the paratergite is similar to the shape in the fossil described here. However, it is considerably larger in this species (Guthörl, 1936). The specimens from Spain, determined as *A. armata*, have tubercles on the paratergite, which are small and of dimensions between small and large and lack tubercles that are clearly large (Castro, 1997). In the *Arthropleura cristata* Richardson, 1959 from Westphalian D of Mazon Creek, small tubercles were only found in the front section of the paratergite; while very large tubercles cover the rest of the paratergite. The paratergite of this species is also considerably larger than the specimen described (Richardson, 1959; Hannibal, 1997a, b).

DISCUSSION AND CONCLUSIONS

This new discovery of *Arthropleura* contributes to a better understanding of the Carboniferous land fauna of Poland, otherwise poorly known. Only one, fragmentary specimen of *Arthropleura* has been found, preserved within a sideritic nodule from Sosnowiec (Upper Silesian Coal Basin), but it was misidentified as a eurypterid (Krawczyński *et al.*, 1997; Filipiak personal communication 2012). It is appro-

priate to note that these nodules contain the richest Carboniferous land and fresh-water fauna, discovered in Poland so far (Filipiak and Krawczyński, 1996; Pacyna *et al.*, 2004; Stworzewicz *et al.*, 2009). Because the *Arthropleura* specimens, noted earlier from the Polish Carboniferous (Roemer, 1880; Gothan and Gropp, 1933; Guthörl, 1936, 1938; Hoehne, 1948), were not properly described and illustrated, comparison with them is almost impossible. Two paratergites from Nowa Ruda, determined as belonging to *Arthropleura armata* species, were illustrated by André (1910). They have larger dimensions than our specimen. The tubercles of those paratergites are on average bigger and the large tubercles form straight line.

The number of valid *Arthropleura* species is a matter of debate. It requires further investigation, especially with regard to the features, which are diagnostic for species. Previously described species (all in the 19th and the beginning of the 20th century) do not have clear, diagnostic criteria (Calman, 1914; Guthörl, 1936; Richardson, 1956, 1959; Rolfe, 1969). Hence, in the case of the material being described, which is scanty (only two fragments of tergites), the species was not determined. The tergites described have very numerous tubercles, which may have taxonomic value (Kraus and Brauckmann, 2003). The small dimensions of the preserved structures, which are smaller than those of most specimens, referred to *Arthropleura armata* (but see Waterlot (1934) for small specimens, referred to *Arthropleura armata*). The characteristic features of tuberculation probably indicate that the remains do not belong to the species *A. armata*, but could represent a new species (Meyer, 1853; Jordan and Meyer, 1854; Kliver, 1883, 1884; Pruvost, 1930; Waterlot, 1934). The scanty remains we have at our disposal are not sufficient to support such a determination. The specimens may represent a species of *Arthropleura* with a comparatively small size of individuals, but it is worth noting that even smaller specimens have been described that were assigned to the genus *Arthropleura* (Waterlot, 1934; Kraus and Brauckmann, 2003). The small specimen of *Arthropleura* from Montceau-les-Mines (Massif Central, France) has long been interpreted as a juvenile (Briggs and Almond, 1984). However, Kraus and Brauckmann (2003) and Kraus (2005) showed, with regard to myriapod development, that this is not a juvenile specimen, but a different species, in which individuals were particularly small. The small specimen, described from England as a new species, *Arthropleura moyseyi* Calman, 1914, is now recognized generally as a juvenile specimen of *A. armata* (Rolfe, 1969). It is worth noting, however, that groups allied to *Arthropleura*, the extinct Eoarthropleurida and Microdecemplicida and the extant Pselaphognatha, are represented by small forms, several millimeters or so in length (Shear and Selden, 1995; Kraus and Brauckmann, 2003).

We are unable to decide whether the remains described represent fragments of exuviae or the animals themselves. The isolation of these remnants may show that they are fragments of exuviae, but the lack of the folding, characteristic for exuviae (Castro, 1997; Kraus and Brauckmann, 2003), and the very clear imprint of an unflattened paratergite, preserved (somewhat) in three dimensions, may show that these are parts of a once living animal, and not exuviae.

The matching relative proportions and dimensions of the remnants and also the similarity in their tuberculation may show that they are the remains of individuals of one species. The closeness of their occurrence and very similar manner of preservation might indicate that they even are the remnants of one animal.

Single leaflets from seed ferns occur with the *Arthropleura* remnants (Fig. 3D). These leaflets are the disintegration products of large, compound leaves, which might indicate that all the remains were transported some distance before fossilization. The damage to the syntergite might confirm this.

This new discovery of *Arthropleura* contributes to a better understanding of that genus and of the Carboniferous land fauna of Poland, which is otherwise poorly known. This is also the first detailed description of *Arthropleura* remains from the Polish Carboniferous.

Acknowledgements

We offer sincere thanks to Professor D. Zdebska (Jagiellonian University, Cracow) for discussion and critical comment, which helped improve this article. C. Brauckmann (TU Clausthal), J. Hannibal (Cleveland Museum of Natural History), R. Rößler (Museum für Naturkunde, Chemnitz) and P. Selden (University of Kansas) sent reprints of their papers, previously unavailable to the authors. Reviews by J. Hannibal, W. Krzemiński and P. Filipiak helped to improve this paper. We thank J. Madeja for help in the preparation of the drawings.

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