Westphalian xiphosurans (Chelicerata) from the Upper Silesia Coal Basin of Sosnowiec, Poland

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The xiphosurans *Bellinurus lunatus* (Martin, 1809) and *Euproops rotundatus* (Prestwich, 1840) are described from sideritic concretions hosted by the Orzesze Beds (Westphalian B) in the Polish region of the Upper Silesia Coal Basin. Associated flora and fauna include terrestrial plant remains and a single palaeodictyopteran insect nymph. As no marine influences are known in this area since the Namurian A, these xiphosurans were probably fresh-water organisms.

Key words: Xiphosura, Carboniferous, Westphalian, Upper Silesia, Poland.

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Introduction

Fossil xiphosurans (horseshoe crabs) have drawn the attention of evolutionary biologists for some time as they represent one of the most conservative lineages in the animal world (Fisher 1984). Very little has changed in their morphology since the end of the Palaeozoic. The group was the most diverse, both anatomically and ecologically, in the Late Carboniferous.

Although uncommon as fossils, they have been reported from a number of sites in Europe: Ireland, England, Belgium, France, Germany, and the Czech Republic (Anderson 1994; Anderson & Horrocks 1995; Oplustil 1985; Prantl & Přibyl 1955; Přibyl 1967; Raymond 1944; Schultka 1994) and North America: Illinois (Anderson 1994; Fisher 1979; Raymond 1945), Montana (Schram 1979), and Canada (Jones & Woodward 1899). In central Europe, the most extensive Late Carboniferous continental deposits occur in the Upper Silesia Coal Basin of Poland and Czech Republic. The earliest discoveries of xiphosurans from this area were reported by

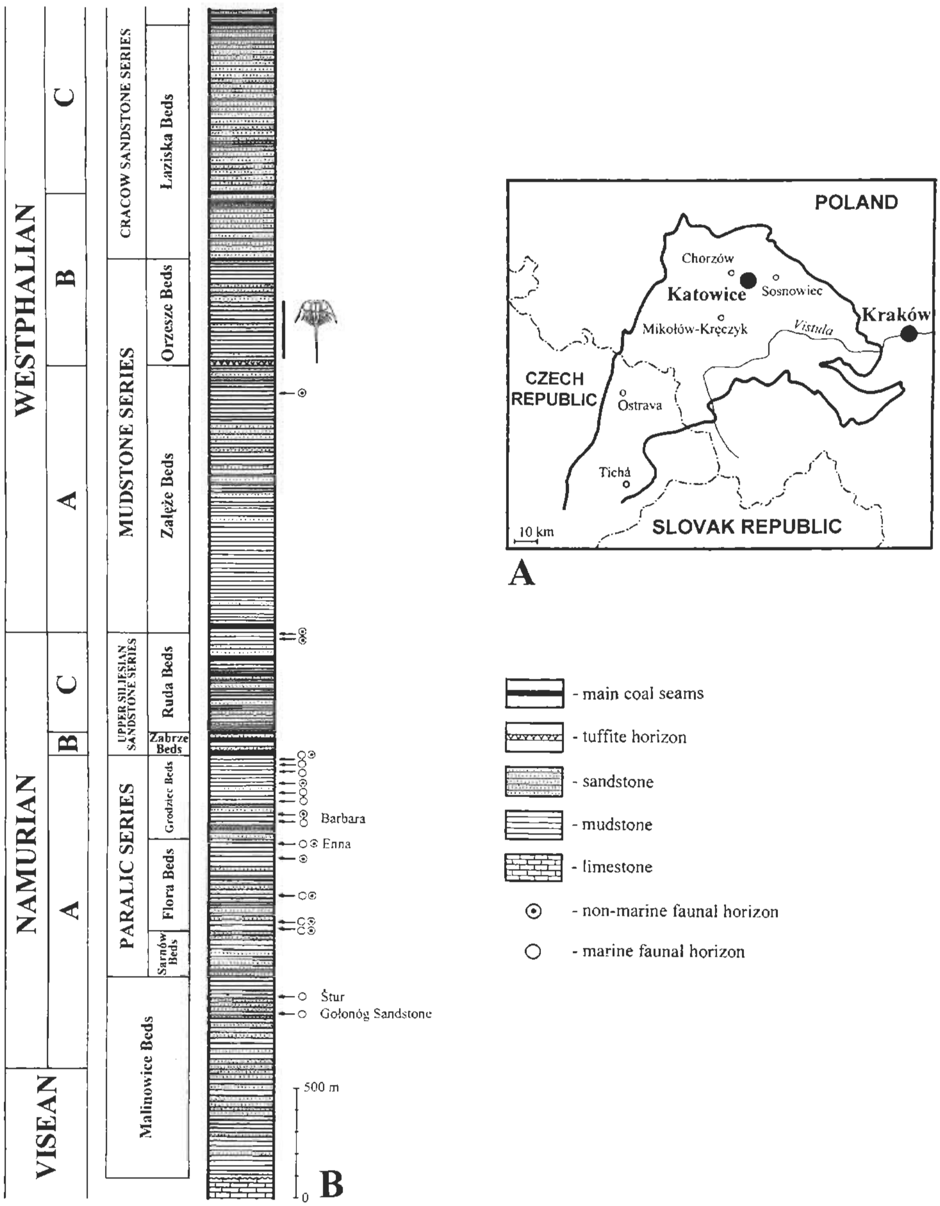


Fig. 1. **A**. Localities of Westphalian xiphosurans in the Upper Silesia Coal Basin. Small empty circles indicate localities with body-fossils or tracks of xiphosurans. **B**. Generalized stratigraphic sequence of the Carboniferous formations in the Upper Silesia Coal Basin (after Kotas 1995) with the likely stratigraphic position of the xiphosuran fossils.

Roemer (1883). He described a new species *Bellinurus silesiacus* from the Chorzów coal mine (Fig. 1). Prantl & Přibyl (1955) described two more species of *Bellinurus*: *B. lunatus* (Martin, 1809) and *B. sustai* (Prantl & Přibyl, 1955), and *Moravurus rehori* Přibyl, 1967 from the Late Carboniferous in the Tichá borehole. Eleven new specimens of xiphosurans, preserved in sideritic concretions have recently been collected from the Orzesze Beds of the Polish part of the basin. This material provided the basis for the present work.

Material studied and stratigraphy

The specimens studied were found in sideritic nodules on the dump belonging to the 'Porąbka-Klimontów' coal mine in Sosnowiec (Fig. 1A) (Filipiak & Krawczyński 1995). Therefore it is difficult to estimate their exact stratigraphic position. We suppose, however, that the waste is derived from the Orzesze Beds of early Westphalian B age (Fig. 1B).

The investigated material is deposited at the Faculty of Earth Sciences, Silesian University, Sosnowiec (abbreviated GIUS) and in the private collections of Mr. M. Gwoździewicz, M.Sc., 41-219 Sosnowiec, ul. Kielecka 28/69 (GW) and Mr. E. Opalski, 41-219 Sosnowiec, ul. Lenartowicza 136/153 (OP). The specimens stored in private collections have duplicates which are housed at the University collection.

Preservation of the material

Five nearly completely preserved individuals of *Euproops* and six equally well-preserved specimens of *Bellinurus* are at our disposal. The xiphosurans are three-dimensionally preserved in sideritic nodules. This mode of preservation provides more details of delicate exoskeleton features than typical compressions or imprints in shales. On the other hand, xiphosurans from concretions rarely show all the appendages in place and of complete length (e.g., ophthalmic spines). Fragile appendages are usually broken and separated by intervening matrix (Anderson 1994). The state of preservation is variable, some specimens are preserved completely (even with traces of walking legs, imprinted on the prosoma; Fig. 3E–F), some represent only fragments of individuals.

The original material of exoskeleton is not preserved. The xiphosurans are preserved as imprints of their external and internal surfaces. A gap is sometimes present between the imprints, which is usually filled with kaolinite and crystalline pyrite.

Sideritic nodules from the 'Porąbka-Klimontów' coal mine range from a few centimetres to 20 cm in diameter. They may contain fragmented terrestrial plants (lycopod cones and leaves, *Calamites* sp., *Sigillaria* sp., and unidentifiable macrofloral remains). A well-preserved palaeodictyopteran nymph has been found in one of the nodules. In general, however, most nodules lack macrofossils.

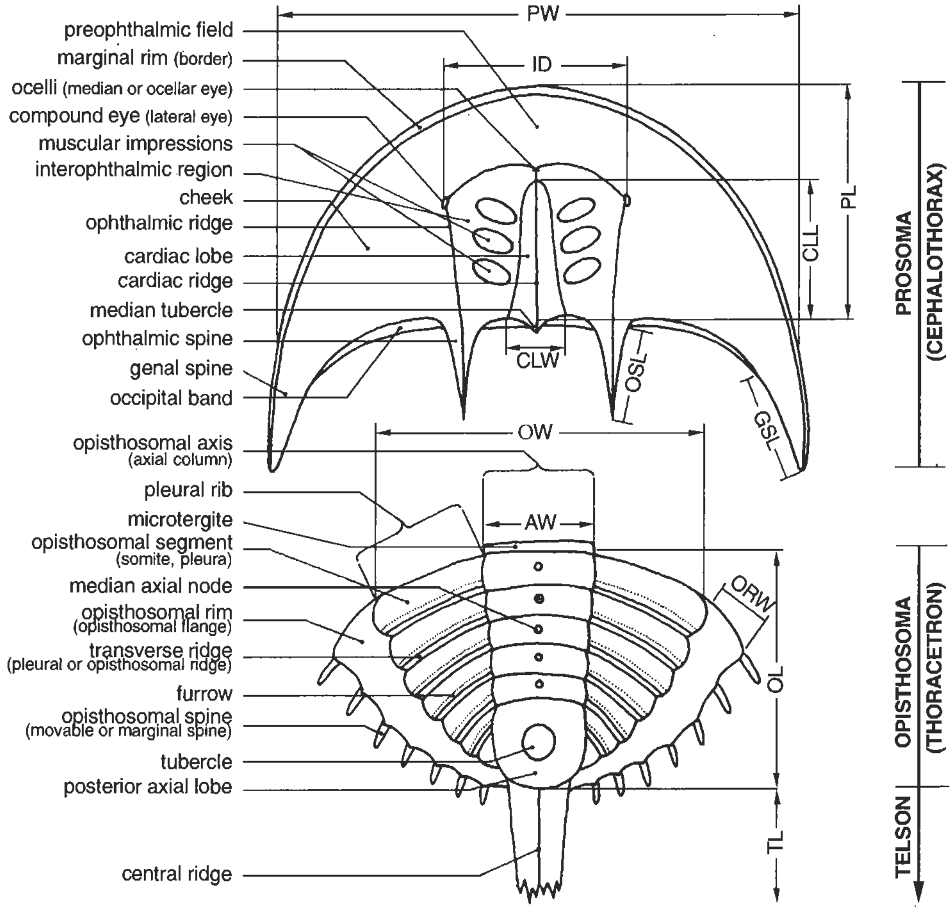
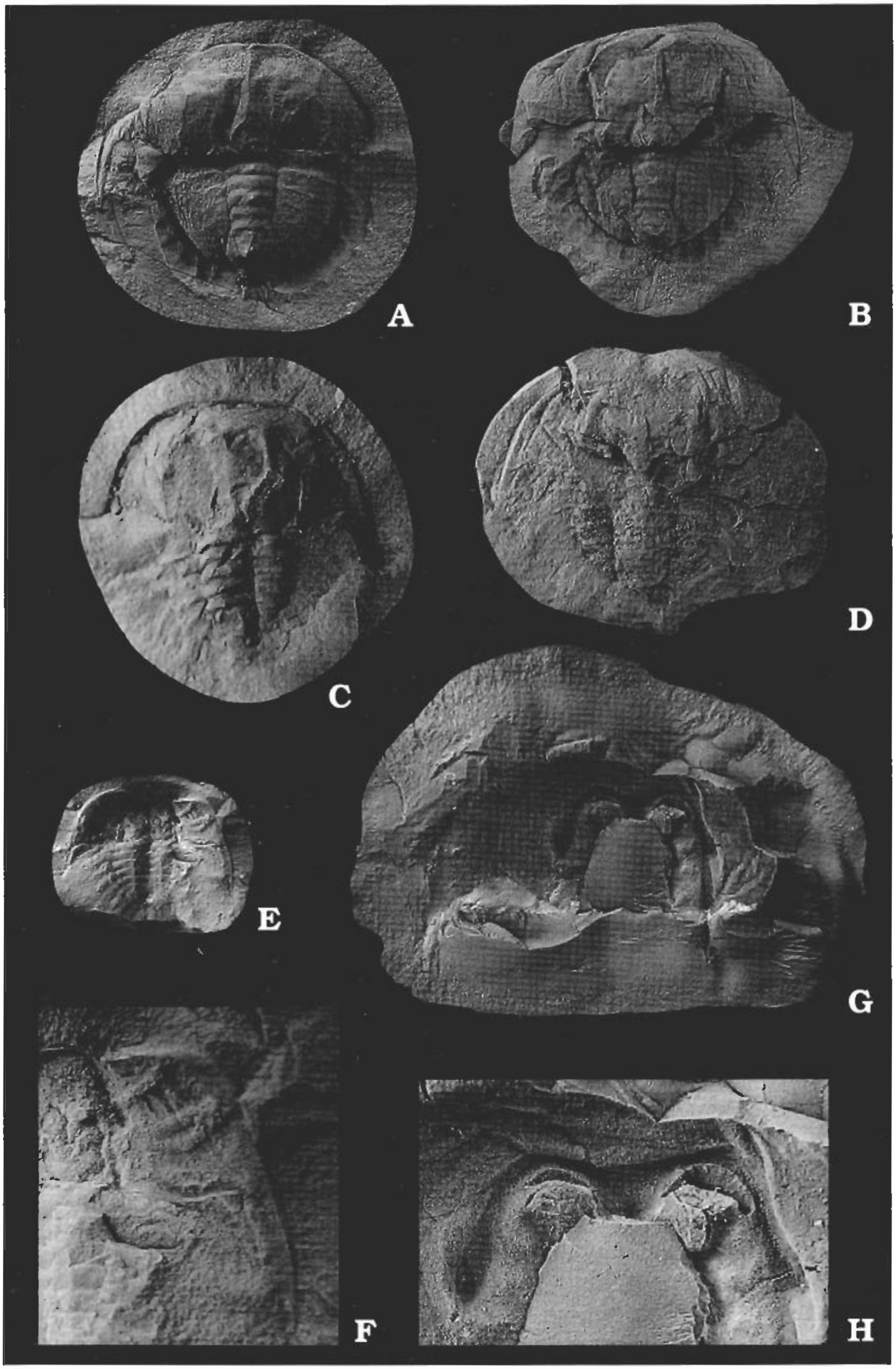


Fig. 2. Terminology of exoskeletal structures in Carboniferous xiphosurans and location of measurements (after Ambrose & Romano 1972, modified). Key to symbols: PW — prosomal width, PL — prosomal length, ID — interocular distance, CLL — cardiac lobe length, CLW — cardiac lobe width, OSL — opisthosomal spine length, GSL — genal spine length, OW — opisthosomal width, AW — axial width, OL — opisthosomal length, ORW — opisthosomal rim width, TL — telson length.

Morphology of Silesian xiphosurids

The terminology which is used in describing anatomical parts of the xiphosuran body has been generally adopted from Størmer (1955), Ambrose & Romano (1972), and Bergström (1975). All the morphological terms and their more common synonyms are shown in the diagram (Fig. 2).

Fig. 3. **A–B**. *Euproops rotundatus* (Prestwich, 1840), GW/1 and GW/2. **C–H**. *Bellinurus lunatus* (Martin, 1809), GW/3 (**C**), GIUS 5-842/4 (**D**), juvenile specimen OP/1 (**E**) and details of its prosoma with leg imprints (**F**); incomplete prosoma GIUS 5-843/5 (**G**) and its ophthalmic ridge with visible tuberculation (**H**). **A–D**, **G** × 1.2; **E** natural size, **F** × 3, and **G** × 2.


A
B
C
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Class Xiphosura Latreille, 1802
Order Xiphosurida Latreille, 1802
Family Euproopidae Eller, 1938
Genus *Euproops* Meek, 1867
Type species: *Euproops danae* (Meek & Worthen, 1865).

Euproops rotundatus (Prestwich, 1840)

Figs 3A–B, 4.

Limulus rotundatus; Prestwich, 1840: pl. 41: 5, 6.

Prestwichia rotundata (Prestwich, 1840); Woodward 1867: p. 32, pl. 1: 2.

Prestwichinella rotundata (Prestwich, 1840); Woodward 1918: p. 469.

Euproops rotundatus (Prestwich, 1840); Størmer 1955: fig. 12.

Material. — Three almost complete specimens: GW/1 (internal and external moulds), GW/2 (internal mould), GIUS 5-840/2 (internal and external moulds) and two incomplete internal moulds: GIUS 5-839/1, GIUS 5-841/3. See Table 1 for dimensions and Fig. 4 for reconstruction.

Description. — The semicircular prosoma is twice to three times wider than long. The concave relatively narrow cardiac lobe is located in the axial part of prosoma and widens posteriorly. The cardiac ridge (in the axial part of cardiac lobe) forms a median tubercle on the posterior part of the prosoma; in its anterior part, more or less directly across the eyes, it bifurcates into two arched ophthalmic ridges. The eyes are localized in the corner of the ophthalmic ridges. From this point, the ophthalmic ridges run to the posterior part of the prosoma and form two long ophthalmic spines which reach back to the posterior of the opisthosoma (Fig. 3B). Three pairs of delicate, convex, indistinct muscular impressions are visible in the interophthalmic region. The first external pair forms a low ridge across the cardiac lobe. The prosoma is armed on both sides with long, narrow genal spines, parallel to the long axis of the body. The opisthosoma is oval in outline. The width of its central part (excluding the opisthosomal rim) is approximately equal to its length. The opisthosoma consists of eight distinguishable segments; a microtergite of the first axial segment (Fig. 3A), which connects the prosoma with the opisthosoma, is present. The opisthosomal axis consists of six segments (excluding the microtergite). The first five represent a continuation of the subdivision of pleurae, whilst the last three are fused together. The axial column is narrowest at the level of the fourth and fifth segments. Small median axial nodes occur on the second and fourth segments. The posterior axial lobe bears a large and prominent, sharp tubercle. Distinct transverse ridges with tuberculations occur at the boundaries of the opisthosomal segments. A broad opisthosomal rim runs around all the opisthosoma up to the base of the telson where the rim completely disappears. Short opisthosomal spines occur at the prolongation of the transverse ridges. The telson is incompletely preserved in all the specimens. However, it appears to have a central, axial ridge.

Discussion. — Xiphosurans were identified by comparison with the reconstructions by Prestwich (1840: pl. 41: 5, 6), Størmer (1955: fig. 12) and

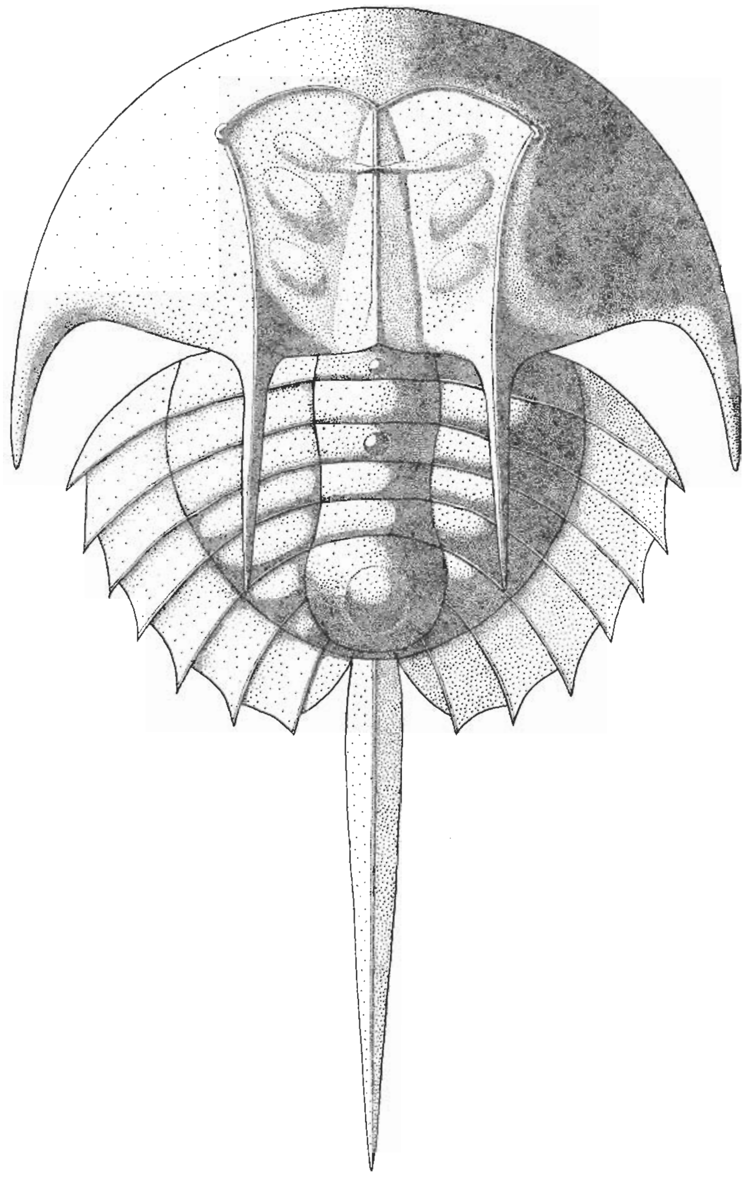

Fig. 4. Reconstruction of *Euproops rotundatus* (Prestwich, 1840) in dorsal view; × 3.

the diagnosis of *E. danae* (Meek & Worthen, 1865) by Anderson (1994). *Euproops rotundatus* differs from *Euproops danae* (Meek & Worthen, 1865) mainly in having the broad opisthosomal rim with short spines around the opisthosoma. *E. danae* has a narrow opisthosomal rim formed by the widened bases of relatively long opisthosomal spines (see Anderson 1994).

Table 1. Measurements of *Euproops rotundatus* and *Bellinurus lunatus* specimens (in mm) from the Orzesze Beds of 'Porąbka-Klimontów' mine in Sosnowiec.

Specimens	*Euproops rotundatus*				*Bellinurus lunatus*				
	GIUS 5-839/1	GW/1	GIUS 5-840/2	GW/2	OP/1	GIUS 5-845/7	GW/3	GIUS 5-842/4	GIUS 5-843/5
Prosomal length	15	17	14	13	9	10	15	15*	21
Prosomal width	29*	38	35	29	20	28	31	32	48
Cardiac lobe width	6	6	5	5	2	5	5	–	9*
Cardiac lobe length	7	7	7	8	2.5	–	9	–	11
Interocular distance	15	17	18	16	8	18	15	14	19
Opisthosomal length	12	15	13	12	9	13	13	15	–
Opisthosomal width	19	21	22	19	13	15	17	17	–
Axial width	5	5	6	5	4	7	6	7	–
Genal spine length	–	9*	10	7	7	–	8	8	8*
Opisthosomal spine length	–	11	6*	–	3	7	–	10	5*
Opisthosomal rim width	–	5	5	4					
Telson length	–	8*	9*	–	6*	–	–	–	–

* incomplete
– not preserved

Occurrence. — South Wales, the Pennant Series and the Upper Coal Series (Zone of *A. tenuis*) (Dix & Pringle 1930); northern France and adjacent portions of Belgium (Westphalian) (Pruvost 1930); England, Rochdale (Late Carboniferous — Sparth Bottom) (Baldwin 1902); the Upper Silesia Coal Basin (Sosnowiec), the Orzesze Beds (Westphalian B).

Family Bellinuridae Zittel & Eastmann, 1913
Genus *Bellinurus* Pictet, 1846
Type genus: *Bellinurus trilobitoides* (Buckland, 1837).

Bellinurus lunatus (Martin, 1809)

Figs 3C–H, 5.

Enthomolithus (Monoculites) lunatus Martin, 1809; pl. 45: 4.

Bellinurus lunatus (Martin, 1809): Pruvost 1930: p. 198, pl. 12: 7, 8.

Bellinurus lunatus (Martin, 1809): Prantl & Přibyl 1955: p. 385, pl. 1: 1, 2 (with synonymy).

Material. — Four almost complete specimens: OP/1 and GW/3 (both as internal and external moulds), GIUS 5-842/4 and GIUS 5-845/7 (both as internal moulds); one well-preserved external mould of the prosoma: GIUS 5-843/5 and one incomplete internal mould of the prosoma: GIUS 5-844/6. See Table 1 for dimensions and Fig. 5 for reconstruction.

Description. — The length of the semicircular prosoma is twice to three times smaller than its width. The narrow cardiac lobe is widest in the posterior part of prosoma. In its anterior part it forms highly convex arched ophthalmic ridges which curve in the posterior part. The compound eyes

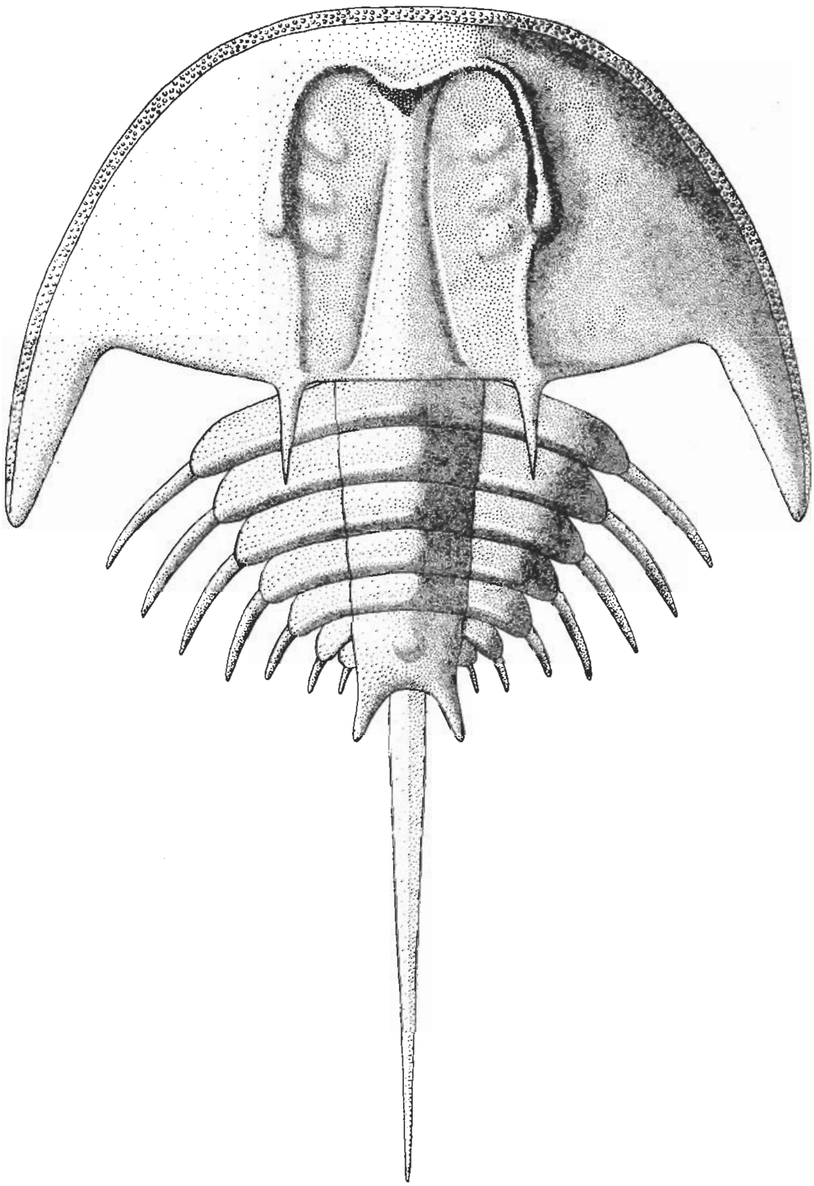

Fig. 5. Reconstruction of *Bellinurus lunatus* (Martin, 1809) in dorsal view; × 3.

are located on the ophthalmic ridges half way to prosoma. From this place the ophthalmic ridges slightly curve towards the cardiac lobe and create long ophthalmic spines in the posterior part of the prosoma. A delicate tuberculation occurs on the internal surface of the ophthalmic ridges. Three pairs of muscular impressions are seen in the anterior part of the interophthalmic ridge. A marginal rim with a delicate tuberculation occurs around the prosoma. On both sides, the prosoma has elongate genal spines parallel to the sagittal plane. They reach a length equal to half the length of the opisthosoma. The triangular opisthosoma is almost equal in length to prosoma. It consists of eight segments; the first (microtergite) has not been recognized in our specimens. The opisthosomal axis tapers to the posterior part of the carapace and consists of six elements. The last element (posterior axial lobe) has a large tubercle and creates two small marginal spines. A minute solitary tubercle is developed on the remaining five elements of the axial column. A roll-shaped callosity stretches along the posterior margin of each tergite and extends from the pleura to the end of each spine. The telson is preserved only proximally, with a recognizable central ridge in most of our material.

Discussion. — Most of the *Bellinurus* species were erected in the late ninteenth and early twentieth century (Roemer 1883; Baldwin 1903, 1905; Dix & Pringle 1930; Eller 1938). At that time the recognition of many species was based on morphological features, which Anderson (1994) has shown, using *Euproops* as an example, to be of taphonomic origin. Anderson is preparing a major revision of the taxonomy of the genus *Bellinurus* (letter communication 1995), studying the holotypes of the entire British Late Carboniferous material.

The specimens studied display differences in size (Table 1) but are all included in *B. lunatus* (Martin, 1809) for the following reasons. They match other members of this species described by Baldwin (1905) and Prantl & Přibyl (1955), and the age of the Silesian population agrees well with the occurrence of *B. lunatus*. A comparison with *B. silesiacus* (Roemer, 1883) is rather difficult because of the superficial description and too general reconstruction of the species. Notably, it occurs in the Namurian C, thus it is stratigraphically older than our specimens.

Occurrence. — England, Rochdale (Late Carboniferous — Sparth Bottom) (Baldwin 1905); the Upper Silesia Coal Basin: Horní Suchá near Ostrava, the Czech Republic (the Karviná Beds — Westphalian A) and Sosnowiec, Poland (the Orzesze Beds — Westphalian B).

Palaeoecological remarks

As both genera are represented in sideritic nodules, almost certainly from the same rock unit, it seems clear that the environmental setting which they inhabited was at least closely similar. Preservation of the entire individuals may indicate a quiet sedimentation regime in a calm basin, and well-preserved terrestrial flora indicates an anoxic environment within the sediment. The origin of sideritic nodules is certainly connected with carbonate precipitation in an aquatic environment around decaying organic particles (Woodland & Stenström 1979).

Those Carboniferous xiphosurans are generally associated with brackish or fresh-water environments (Anderson 1994; Fisher 1979). As the latest marine ingressions in the Upper Silesia Coal Basin are known from the Namurian A, the younger sediments (starting from the Namurian B) have to be of fresh-water origin (Fig. 1). Głuszek (1995) described a trace fossil association which has been found in sandstones from the Orzesze Beds in the central part of the basin (Mikołów-Kręczyk quarry; Fig. 1). The assemblage consists of bivalve resting traces (*Lockeia* isp.), and traces produced by annelids, nematomorphs, probably insect nymphs and other arthropods, among them probably xiphosurids.

There are different opinions concerning the habitat of *Euproops*. Størmer (1955) claimed that these xiphosurans were restricted exclusively to an aquatic environment. Todd (1991) and Anderson (1994) suggested that they could probably emerge from the water for brief periods of time. Fisher (1979) suggested that Carboniferous xiphosurids could have lived from several hours to several days in a wet subaerial environment as well. The palaeoecology of *Bellinurus* remains unknown. However, Hardy (1970) attributed traces encountered in a similar setting to *Bellinurus*. Whichever is the case, these animals were associated with shallow water, non-marine habitat as evidenced by the lack of marine biota and the presence of terrestrial plants and insects in the xiphosurid-bearing nodules from the Orzesze Beds.

Acknowledgements

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Mieczogony (Chelicerata; Xiphosura) z westfalu B Górnośląskiego Zagłębia Węglowego

PAWEŁ FILIPIAK i WOJCIECH KRAWCZYŃSKI

Streszczenie

W polskiej części Górnośląskiego Zagłębia Węglowego, na hałdach Kopalni Węgla Kamiennego „Porąbka-Klimontów" w Sosnowcu, w konkrecjach sferosyderytowych warstw orzeskich (westfal B) znaleziono dwa gatunki mieczogonów: *Bellinurus lunatus* (Martin, 1809) i *Euproops rotundatus* (Prestwich, 1840). Oprócz mieczogonów w sferosyderytach występują szczątki roślin (*Calamites* sp., *Sigillaria* sp. oraz *Lepidostrobus* sp.) i nimfy owadów z grupy Palaeodictyoptera. Ponieważ ostatnie morskie ingresje na obszarze Górnośląskiego Zagłębia Węglowego datowane są na namur A, można wnioskować, że rozpatrywany zespół skamieniałości związany był ze środowiskiem słodkowodnym. Prawie kompletnie zachowane odciski pancerzy mieczogonów wskazują na spokojne środowisko sedymentacji w źle przewietrzanym basenie.