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LATE DEVONIAN (FRASNIAN) ASTEROPYGINE TRILOBITES FROM THE FRASNES AREA, SOUTHERN BORDER OF DINANT SYNCLINORIUM, BELGIUM

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(4 figures and 4 plates)

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ABSTRACT. The Frasnian representatives of Asteropyginae in the Frasnes area (south Belgium) have long been relatively well-documented when compared to other trilobites in the Devonian of the Ardennes (Belgium, northern France). However, examination of the type material and new collecting by the authors indicate that a taxonomic review has become necessary. Two new species of *Bradocryphaeus* are recorded, *B. vanherlei* sp. nov. and *B. neptuni* sp. nov.; one additional species, *B.* sp. 20, is known from the pygidium alone. New material is recorded of *Bradocryphaeus maillieuxi* (Richter & Richter), which has hitherto been scantily illustrated in the literature. The cephalon of *Heliopyge helios* (Richter & Richter) is redescribed on the basis of new specimens and its holotype pygidium refigured.

KEYWORDS: Trilobita, Acastidae, Devonian, Ardennes.

RESUME. Trilobites asteropyginés dans le Dévonien supérieur (Frasnien) de la région de Frasnes, bord sud du Synclinorium de Dinant, Belgique. Les représentants frasniens des Asteropyginae de la région de Frasnes (sud de la Belgique) ont longtemps été relativement bien documentés en comparaison des autres trilobites dévoniens de l'Ardenne (Belgique, nord de la France). Une révision taxinomique de ces trilobites est apparue nécessaire avec l'analyse du matériel type et de nouvelles récoltes effectuées par les auteurs. Deux nouvelles espèces de *Bradocryphaeus* ont été enregistrées, *B. vanherlei* sp. nov. et *B. neptuni* sp. nov. ; une espèce additionnelle, *B.* sp. 20, est uniquement connue par son pygidium. De nouveaux spécimens illustrent *Bradocryphaeus maillieuxi* (Richter & Richter), qui était jusqu'à présent peu figuré dans la littérature. La description du céphalon de *Heliopyge helios* (Richter & Richter) est corrigée sur la base de nouveaux spécimens et son holotype pygidium refiguré.

MOTS-CLÉS: Trilobita, Acastidae, Dévonien, Ardenne.

1. Introduction

Of the trilobite families that survived the mid-Givetian Taghanic Event only Scutelluidae, Acastidae, Aulacopleuridae and Proetidae have been recorded from Frasnian strata in the Ardennes. A member of Harpetidae which was recently discovered in the Frasnes area (AVV, pers. comm. with T. Holemans, Bertem) is the first tangible evidence for the presence of this family here in the Frasnian. During this period the Ardennes were situated on the southern margin of the Old Red Continent (Laurussia). A 5,000 km^2 large carbonate platform developed here comprising lagoons to outboard ramp environments and biostromes (e.g. da Silva & Boulvain, 2004; Boulvain & da Silva, 2008). In the Frasnes area on the southern border of the Dinant Synclinorium, Frasnian deposits are part of an external ramp featuring comparatively high accommodation and periods of sea-level rise (e.g. da Silva & Boulvain, 2004; Coen-Aubert & Boulvain, 2006). Carbonate mounds, some of which have been interpreted as atolls (e.g. Boulvain *et al.*, 2004, 2005), developed recurrently when the sea-level was relatively stable but were subsequently drowned and buried through the deposition of shales. The different groups of trilobites that inhabited these environments each had their own preferences for facies: scutelluids are commonly associated with carbonate mounds (e.g. Maillieux, 1912, 1913, 1927; van Viersen & de Wilde, 2010) whereas acastids and proetids frequent the shales and limestones (e.g. Maillieux, 1927; Crônier & van Viersen, 2007). Aulacopleurids, despite being rare, are not confined to any particular environment (e.g. Maillieux, 1927; van Viersen & Prescher, 2007).

The present note focuses on the middle Frasnian members of Asteropyginae (Acastidae) in the Frasnes area. Most of these trilobites were already described in detail by Richter & Richter (1926) and they have long been among the best documented Devonian trilobites from the Ardennes. Examination of the type material in the collections of the Institut royal des Sciences naturelles de Belgique and additional sampling by the authors from

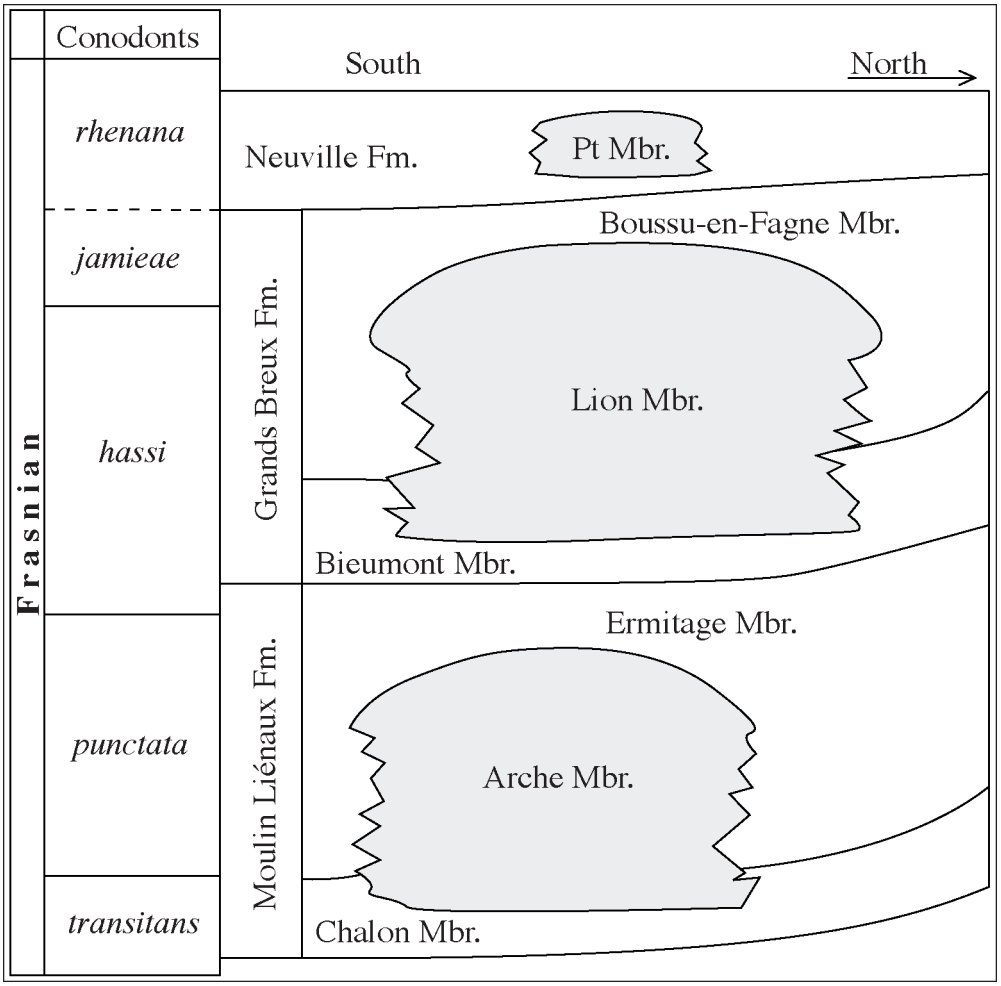

Figure 1. Frasnian formations in Belgium, after Bultynck & Dejonghe (2001). Abbreviation: Pt Mbr. (Petit-Mont Member).

three outcrops in the Frasnes area, however, suggest that a taxonomic update is needed.

2. Geological context

The Frasnian on the southern border of the Dinant Synclinorium is comprised of (from bottom to top) the Nismes, Moulin Liénaux, Grands Breux, Neuville and Matagne formations. In the investigated area, the Moulin Liénaux Formation is subdivided into the Chalon, Arche and Ermitage members (Fig. 1).

Our investigations concerned mainly the trilobites that occur in the greenish shales of the Ermitage Member (former Assise de Frasnes, F2e, zone à *Leiorhynchus formosus*) (2.1 and 2.2). According to Casier & Olempska (2008) the lower–middle Frasnian boundary was pinpointed by the SDS at the base of the *punctata* conodont Zone. This means that the age of the trilobites from the Ermitage Member is approximately early middle Frasnian (Fig. 1). Richter & Richter (1926) recorded three species of Asteropyginae from the Ermitage Member in the Frasnes area. These are *Heliopyge helios* (Richter & Richter, 1926), *Bradocryphaeus maillieuxi* (Richter & Richter, 1926) and specimens which they identified as the German species *Bradocryphaeus supradevonicus* (Frech, 1888); these last are reassigned here to *Bradocryphaeus vanherlei* sp. nov.

Another *Bradocryphaeus* species, *B. neptuni* sp. nov., comes from the overlying Grands Breux Formation (*hassi* conodont Zone) in Frasnes (2.3). The age of this unit is middle Frasnian according to Bultynck & Dejonghe (2001).

2.1 Loc018, Nismes

This locality is an embankment of the Ermitage Member of the Moulin Liénaux Formation, adjacent to a rural promenade just east of the town of Nismes (Fig. 2). Coordinates are N50°04.726', E4°33.573', according to van Viersen & Prescher (2007). The outcrop has been exposed for at least a decade which led to extensive fissures in the rocks. Though they are abundant, trilobite specimens are usually tectonically distorted, partially exfoliated and broken into pieces. *Bradocryphaeus* is the commonest trilobite genus and is represented here by two species, *B. maillieuxi* and *B. vanherlei* sp. nov. *Heliopyge helios* and especially *Cyphaspis* sp. D of van Viersen & Prescher (2007) are rare and only known from loose sclerites.

Loc018 lies on the edge of "les Abannets", a small nature reserve which is the type locality of *B. maillieuxi* and *H. helios* (see Richter & Richter, 1926). Most of Richter & Richter's type material is kept in the Maillieux collection of the Institut royal des Sciences naturelles de

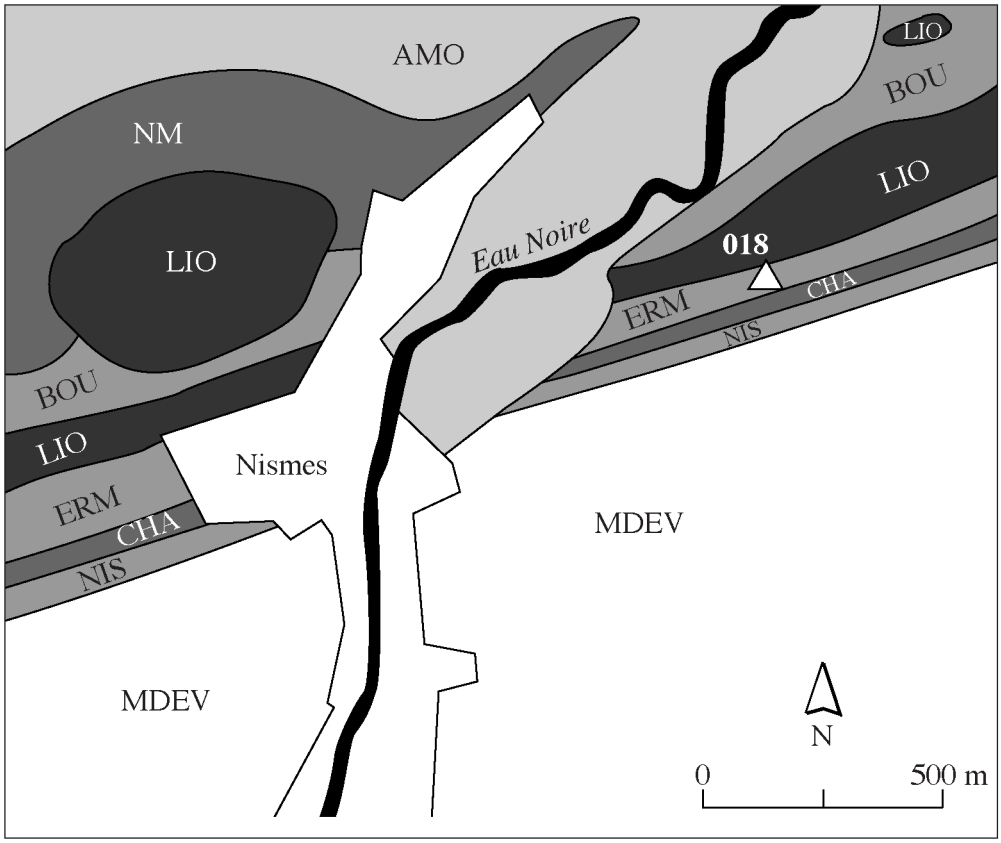

Figure 2. Map indicating locality Loc018. Abbreviations: MDEV (Middle Devonian), NIS (Nismes Formation), CHA (Moulin Liénaux Formation; Chalon Member), ERM (Moulin Liénaux Formation; Ermitage Member), LIO (Grands Breux Formation; Lion Member), BOU (Grands Breux Formation; Boussu-en-Fagne), NM (Neuville and Matagne formations), AMO (modern deposits).

Belgique, where its provenance is named "Pl. Olloy 463" on the associated labels. The holotype pygidium of *B. maillieuxi* is housed by the Forschungsinstitut und Naturmuseum Senckenberg in Frankfurt am Main (Basse & Weddige, 2004).

2.2 Loc020, Frasnes

Temporary trench in the Ermitage Member of the Moulin Liénaux Formation by the side of the road, just south of Frasnes (Fig. 3). This site was accessible for a brief period

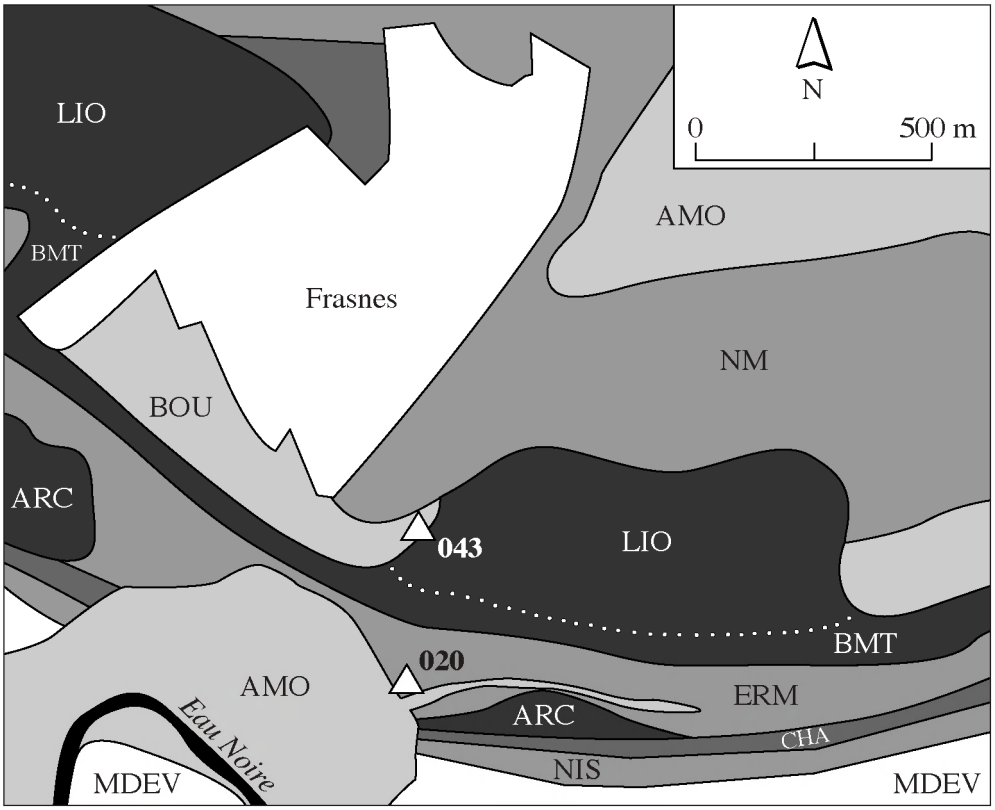

Figure 3. Map indicating localities Loc020 and Loc043. Abbreviations (in addition to Fig. 2): ARC (Moulin Liénaux Formation; Arche Member), BMT (Grands Breux Formation; Bieumont Member).

in 2004 during the construction of a fence. Trilobites are moderately rare and mostly very poorly preserved. Only a single usable pygidium was recovered which is designated *Bradocryphaeus* sp. 20.

2.3 Loc043, Frasnes, "ancienne carrière du Lion"

Abandoned Lion quarry (Fig. 3) in which the Grands Breux Formation outcrops, encompassing argillaceous limestones (Bieumont Member), a 120 to 250 m thick bioherm (Lion Member), and shales (Boussu-en-Fagne Member). The quarry is well-known for its bioherm and was already mentioned in the older literature (e.g. Maillieux, 1913) and more recently by Boulvain *et al.* (1999) and Coen-Aubert & Boulvain (2006), among others. The holotype specimen of *Bradocryphaeus neptuni* sp. nov. was found along the northernmost of three paths leading into the Lion quarry but not *in situ*. Its origin is probably the Boussu-en-Fagnes Member.

3. Systematic palaeontology

The specimens were whitened with ammonium chloride and magnesium oxide prior to photography unless stated otherwise. They are deposited in the Institut royal des Sciences naturelles de Belgique (IRSNB), Natuurhistorisch Museum Maastricht (NHMM) and Université des Sciences et Techniques de Lille (USTL).

Family Acastidae Delo, 1935
Subfamily Asteropyginae Delo, 1935

Discussion. Members of this subfamily in the Ardenno-Rhenish Mountains were mainly benthic trilobites that preferred near-coastal environments with terrigenous detritic influx (Morzadec, 1992). This is demonstrated well in Belgium by the wide distribution of the group in Lower Devonian sandy and shaly clastic sequences (Crônier & van Viersen, 2007; van Viersen & Prescher, 2009). Asteropyginae is rare in the Middle Devonian except in the lower Eifelian terrigenous shales of the Jemelle Formation (Vieux Moulin Member) that outcrop just west of Vireux-Molhain, northern France (Crônier & van Viersen, 2008; Dumoulin & Blockmans, 2008). According to Morzadec (1992), the development of carbonate platforms in the Ardenno-Rhenish Mountains during the Lower Givetian was unfavourable to Asteropyginae. Noteworthy is a cephalon of *Gudralisium* sp. from Resteigne illustrated by Daumeries (2007, pp. 203, 204, unnumb. figs) which demonstrates the presence of Asteropyginae in the upper Hanonet or basal Trois-Fontaines Formation (AVV, pers. comm. with D. Lelubre (Obourg) who recovered this specimen from the Resteigne quarry) and thus, in the Lower Givetian in Belgium.

Palaeogeographic distribution of Asteropyginae greatly benefited from eustatic sea level rises that commenced in the Givetian. Genera such as *Bradocryphaeus* and *Heliopyge* spread in the Middle East and western Europe (e.g. Morzadec, 1992, 2002; Chlupáč et al., 2000) including Belgium. The development of dark shales (Matagne Formation) in southern Belgium during the Upper Frasnian is the result of large-scale anoxia attributed to the Kellwasser Event (e.g. Coen-Aubert & Boulvain, 2006). In Belgium, no asteropygine is known from these or higher levels, suggesting that the group was unable to adapt to the changing environment here. However, the occurrence of *Bradocryphaeus feisti* Morzadec, 1992 in outer shelf deposits directly below the Upper Kellwasser Level in the Montagne Noire (Feist, 1991) demonstrates the versatileness of some members of Asteropyginae and their ability to occupy new habitats.

Genus *Bradocryphaeus* Haas & Mensink, 1970

Synonyms. Quadratispina Gandl, 1972, by subjective synonymy (Arbizu, 1977).

Type species. Cryphaeus supradevonicus Frech, 1888 from the Frasnian of Germany.

Discussion. Lieberman & Kloc (1997) restricted *Bradocryphaeus* to *Neocalmonia (Bradocryphaeus) afghanica* Haas & Mensink, 1970 and the type species because at least some of the taxa assigned to it by earlier workers lack (1) the third pair of pygidial pleural lappets projecting furthest posteriorly, (2) a fifth pair of pygidial pleural lappets that merges with the terminal pygidial axis, (3) a narrow terminal pygidial lappet, and (4) a prominent constriction of the pygidial axis posterior to the fifth axial ring. It appears that Lieberman & Kloc (1997), who had based their analysis of *Bradocryphaeus* exclusively on *N. (B.) afghanica* (*ibid.*, p. 55), did not notice that the type species of *Bradocryphaeus* actually has the fourth pair of pygidial pleural lappets projecting furthest posteriorly. Some of the features that were claimed by these authors to diagnose *Bradocryphaeus* are also found in species other than the two they assigned to it, including *B. maillieuxi*. Furthermore, the type species of *Neocalmonia*, *N. quadricosta* Pillet, 1969, has the third pair of pygidial pleural lappets projecting furthest posteriorly and so this feature is symptomatic of that genus rather than *Bradocryphaeus*. A comprehensive analysis of *Bradocryphaeus* and *Heliopyge* will be conducted in a forthcoming paper by one of us (AB). Present assignments of species to these and allied genera are maintained, albeit provisionally.

According to Lieberman & Kloc (1997), *Bradocryphaeus* is known in the Givetian and the Frasnian in Belgium. However, *B. supradevonicus* is exclusively Frasnian in age and considered herein to be restricted to the Eifel. *Neocalmonia (Bradocryphaeus) afghanica* is restricted to the Givetian in Afghanistan but was regarded by Morzadec (2002) as a member of *Heliopyge* (we agree with Haas & Mensink, 1970 and Lieberman & Kloc, 1997 who assigned this species to *Bradocryphaeus*). Basse (2003, pl. 27, figs. 459, 460) illustrated two pygidia from the "Givetian or Frasnian in the vicinity of Nismes" that he designated *Bradocryphaeus* cf. *hispanica* (Richter & Richter, 1926). These pygidia are principally different from the species that we record herein in bearing median

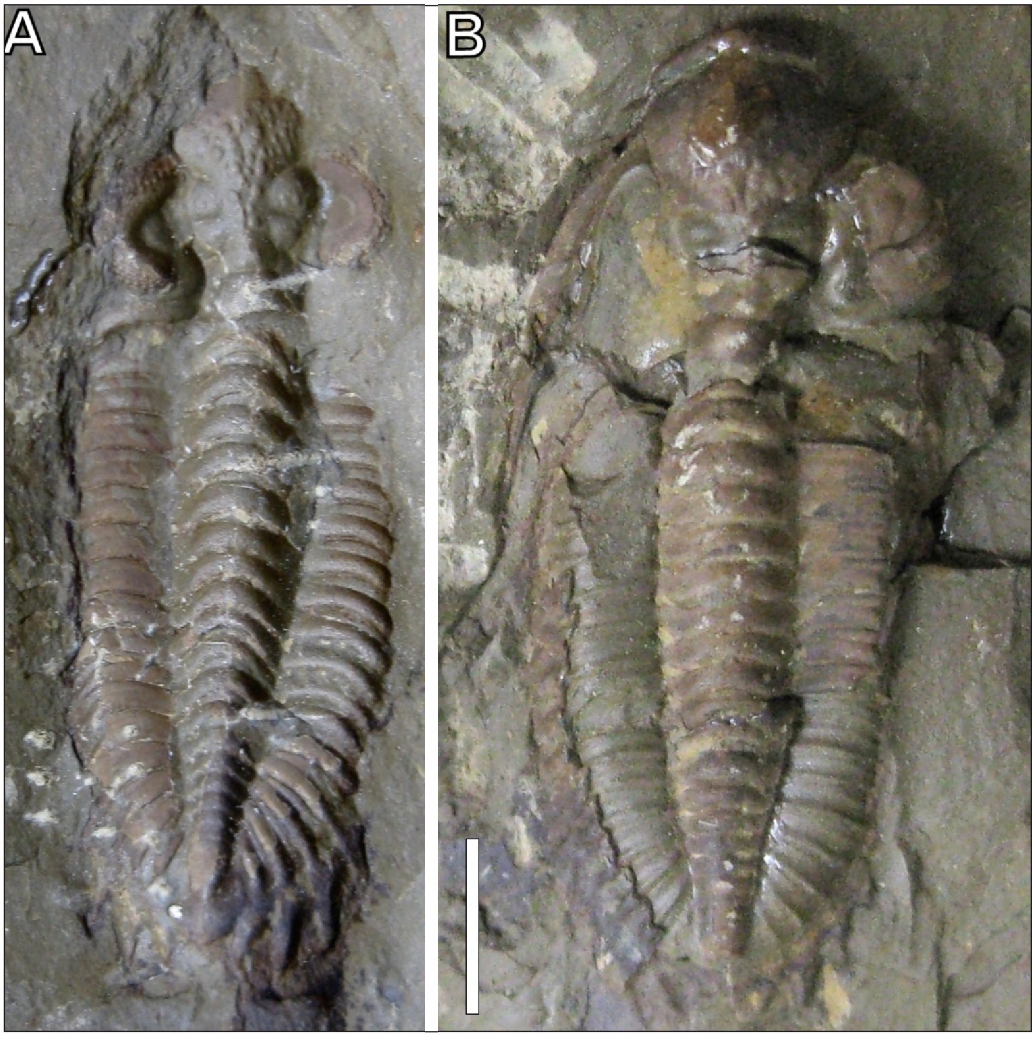

Figure 4. IRSNB a12787, external mould of a complete specimen (A) and IRSNB a12788, partially exfoliated, com-plete exoskeleton (B) of *Bradocryphaeus mail-lieuxi* (Richter & Richter, 1926), from the Ermitage Member of the Moulin Liénaux Formation in Pl. Olloy 463, Nismes (type locality). These specimens irrevocably link typical features of the cephalon and the pygidium of *B. maillieuxi*, including the high parabolic cephalic outline, large tubercles on the glabella anterior to S0, six pairs of pygidial pleurae, and short pygidial pleural spines. Specimens were left untreated for photography. Scale bar represents 5 mm.

nodes on the axis. According to our knowledge, *Bradocryphaeus* has not been recorded from the Givetian in Belgium with certainty.

Bradocryphaeus maillieuxi (Richter & Richter, 1926)
(Pl. 1, Figs A-K; Fig. 4)

* 1926 *Asteropyge (Asteropyge) maillieuxi* Richter & Richter, pp. 219-222, pl. 12, figs 34-36.
v 1927 *Asteropyge (Asteropyge) maillieuxi* R. et E. Richter; Maillieux, pp. 82, 83, pl. 4, fig. 5a.
1928 *Asteropyge (Asteropyge) maillieuxi* Rud. & E. Richter; Richter & Richter, pp. 110, 111.
1970 *N. (B.) maillieuxi* (R. & E. Richter); Haas & Mensink, p. 16.
1970 *N. (B.) maillieuxi* (Rud. & E. Richter); Haas, p. 114.
1972 *N. (B.) maillieuxi* (Rud. & E. Richter); Gandl, p. 144.
1975 *N. (Br.) maillieuxi* (Rud. & E. Richter); Hahn & Hahn, p. 27.
1977 *Bradocryphaeus maillieuxi* (R. & E. Richter); Arbizu, p. 92.
1983 *Bradocryphaeus maillieuxi* (R. & E. Richter); Smeenk, p. 414, fig. 5.
2000 *Bradocryphaeus mailleuxi* (sic); Chlupáč *et al.*, p. 91, fig. 2.
2003 *B. maillieuxi* (Richter & Richter); Basse, p. 114.
2004 *Bradocryphaeus maillieuxi* (Richter & Richter); Basse & Weddige, p. 149.
2007 *Bradocryphaeus maillieuxi*; Crônier & van Viersen, p. 481.
2007 *Bradocryphaeus maillieuxi* R & E Richter (sic); Daumeries, pp. 226, 227, unnumb. figs [reproductions of the original drawings by the Richters and a photo of pygidium NHMM 2010015 (then priv. coll. AVV)]
2007 *Bradocryphaeus maillieuxi* (Richter & Richter); van Viersen & Prescher, p. 158.

Material. NHMM 2010016, 2010017, USTL 0030, 0031, four cephala; NHMM 2010014, 2010015, USTL 0025-0027, five pygidia; from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes. IRSNB a12787, external mould of a complete specimen; IRSNB a12788, partially exfoliated complete specimen; from the Ermitage Member of the Moulin Liénaux Formation in Pl. Olloy 463, Nismes (type locality).

Discussion. The original description of this species by Richter & Richter (1926, pp. 219-222) is retained. Poor photographs of *Bradocryphaeus maillieuxi* were published by Maillieux (1927, pl. 4, fig. 5a) and Smeenk (1983, p. 414, fig. 5) figured a pygidium. We hope that the additional

illustrations, especially of the cephalon, will be helpful. Furthermore, two topo- and stratotypical complete specimens are recorded to substantiate the association of the cephalon and the pygidium of this species for the first time.

For a comparison with co-occurring *Bradocryphaeus vanherlei* sp. nov. in Loc018, see below.

Bradocryphaeus vanherlei sp. nov.
(Pl. 2, Figs A-M)
v e.p. 1926 *Asteropyge (Asteropyge) supradevonica* (Frech); Richter & Richter, pp. 215-218, pl. 12, figs. 30, 31.
v 1927 *Asteropyge (Asteropyge) supradevonica* Frech (sic); Maillieux, p. 81, pl. 4, fig. 2.
e.p. 1975 *N. (Br.) supradevonica* (Frech); Hahn & Hahn, p. 27, pl. 1, fig. 8.
2007 *Bradocryphaeus supradevonicus*; Crônier & van Viersen, p. 481.
2007 *Bradocryphaeus* cf. *supradevonicus* (Frech); van Viersen & Prescher, p. 158.

Etymology. After Willy Vanherle, who has contributed much to the knowledge of the Frasnian fauna in Belgium and who kindly donated numerous trilobite specimens for the present and other studies.

Holotype. NHMM 2010023, pygidium (Pl. 2, Figs J, M).

Paratypes. NHMM 2010018, 2010019, 2010025, three cephala; NHMM 2010024, one external mould of a cephalon plus silicone cast; NHMM 2010022, USTL 0008, 0009, three pygidia; NHMM 2010020, 2010021, USTL 0028, three external moulds of pygidia plus silicone casts; all from type locality and horizon.

Type locality and horizon. Loc018, Nismes; Ermitage Member of the Moulin Liénaux Formation.

Diagnosis. Cephalon is entirely covered with closely spaced, very fine granules. Cephalic border is narrow (sag., exsag.) anterior to the glabella and somewhat widened (tr.) lateral to the eye. Subocular ridge is rudimentary yet accentuated by dense granulation. Fifth pair of pygidial pleural spines is about twice as long as associated pygidial pleural ribs.

Description. Cephalon is broadly rounded subtriangular; slightly pointed medially but without an anterior ledge. Glabella is moderately weakly vaulted (sag., tr.). Glabella anterior to S0 is as long (sag.) as wide (tr.); widest (tr.) adjacent to anterior extreme of librigena. Axial furrows moderately deep, diverging throughout but curved around lateral glabellar lobes. S0 is narrow (sag., exsag.); S1 short and slightly curved; S2 straight (tr.) and abaxially indiscernible; S3 backward curved adaxially. Occipital ring is about as wide (sag.) as glabella across L2 (tr.), ascending high above the rest of the glabella; L1 is rudimentary; L2 and L3 are weakly inflated and remain lower than central part of glabella. Expressively angular frontal glabellar lobe smoothly dropping in height towards anterior border but is well-demarcated anteriorly and laterally by distinct grooves. Eye is not particularly high, comprising maximally five (possibly six) lenses per dorsoventral file. Maximum width (tr.) of palpebral lobe is about 1.5 times that of L3. Librigenal field is weakly vaulted abaxial to the eye. Lateral border is dorsally flattened. Lateral border furrow is shallow. Genal field is wide (tr.) in front of the eye. Posterior border runs subtransversally. Genal spines are moderately long (more or less equalling sagittal length of cephalon) and thin.

Pygidium is smoothly rounded to slightly subtriangular; on average 1.5 times wider (tr.) than long (sag.). Posteriorly proportionally tapering, slightly convexly rounded (tr.) axis comprised of ten axial rings, the first five of which are medially anteriorly curved; the remaining rings are straightened (tr.) and demarcated by shallow, straight, groove-like furrows. Five pairs of weakly curved pleurae which are devoid of sculpture and with rib segmentation of the *supradevonicus*-type. First pleura is about 2 times longer than fifth. Proximal tip of fifth pleura reaches fifth axial ring. Posterior pleural bands are three times larger (exsag.) than anterior bands, extended onto pygidial border and continue as pleural spines. First pleural spine is short; backwardly curved. Second pleural spine is moderately long; almost straight. Third pleural spine is similar to second but slightly longer. Fourth pleural spine is somewhat thicker than third and clearly longer; running subexsagitally. Fifth pleural spine pair is straight; converges; and is about as long as first spine pair. Terminal lappet is short, acuminate and triangular. Borders and spines are covered with densely-spaced, small granules.

Discussion. In redescribing *Bradocryphaeus supradevonicus*, Richter & Richter (1926) did not distinguish between specimens from Nismes and topotypical ones from Oos in the Eifel. This classification has been widely adopted in the literature since. Kowalski (1990, fig. 42) illustrated a complete specimen and Basse (2003, pl. 27, figs. 444-455) cephala and pygidia of *B. supradevonicus* from Oos which, in our view, are distinctly different from the specimens from Nismes. These last are therefore reassigned to *Bradocryphaeus vanherlei* sp. nov. Both species share a number of characters such as the fourth pleural spine being about as long as the pygidial axis (sag.) excluding the articulating half ring; the posterior band of the fifth pygidial pleura touching the fifth axial ring; and the posterior pygidial pleural bands of both taxa being similarly shaped. *Bradocryphaeus supradevonicus* is principally different from *B. vanherlei* sp. nov. in having a cephalon with a high parabolic outline; tubercles on the glabella anterior to S0; a broad (tr.) subocular groove that is abaxially demarcated by a prominent subocular ridge; a broader (sag., exsag.) cranidial border anterior to the glabella which is narrower (tr.) lateral to the eye; longer, distally inward curved genal spines; the fifth pair of pygidial pleural spines is shorter than the associated pleural ribs. The same characters may

be used to contrast *B. maillieuxi* with *B. vanherlei* sp. nov. in addition to the development in *B. maillieuxi* of a sixth pair of pygidial pleurae; short, keel-shaped pygidial pleural spines with broader bases; posterior bands of fifth pygidial pleural pair touching the axis posterior to the fifth ring. Given that (1) two distinct types of cephala and pygidia (representing two species) are known from the Ermitage Member directly east of Nismes and (2) the cephalon and pygidium of one of these species, *B. maillieuxi*, are correctly associated (Fig. 4) it is conservative to assume that our cephala and pygidia of *B. vanherlei* sp. nov. are correctly assigned to this second species.

Bradocryphaeus mosanus (Richter & Richter, 1926) was originally described from the middle Frasnian in Givet (France) and Boussu-en-Fagne (Belgium). According to Richter & Richter (1926), their species is different from *B. supradevonicus* (*sensu* Richter & Richter, 1926) as follows: less posteriorly directed pygidial pleurae, always with a well-developed sixth pair; pygidial pleural spines originate close to one another, taper quickly and sword-like, and are clearly keel-like shaped; the terminal pygidial spine is wider, not at all keel-like, and prolonged into a long, sharp tip; granules are already discernible at 4× magnification; on the cephalon, the keel around the eye lies deeper, closer to the lateral border, and the visual surface is higher. Examination of the type material in the IRSNB has led us to the conclusion that this comparison is weakly defined since only the two pygidia from Givet (holotype IRSNB a7789) and Boussu-en-Fagne (paratype IRSNB a7790) that were figured by the Richters (*ibid.*, pl. 12, figs. 32, 33) show all of the pygidial characters that were described by these authors. There are also cephala in the IRSNB which according to their labels belong to *B. mosanus*, but these are all poorly preserved so that they cannot be compared with *B. vanherlei* sp. nov. other than that they appear to have a well-developed subocular ridge.

The Université de Liège houses numerous sclerites from the Frasnian in the Hotton area which are labelled "*Cryphaeus valleeanus* Dewalque", a *nomen nudum* following Asselberghs (1912, pp. 39, 40) and Richter & Richter (1926, p. 213), and opposed to Daumeries (2007, p. 223) who placed it in synonymy of *Bradocryphaeus hispanica*. This material includes large pygidia with six pairs of pleurae and that bear a resemblance to the holotype of *B. mosanus*. A redescription of *B. mosanus* will be required on the basis of new specimens from the type locality in order to conduct a comprehensive comparison with the material from Boussu-en-Fagne, Nismes and Hotton.

Bradocryphaeus neptuni sp. nov.

(Pl. 3, Figs G, H; Pl. 4, Figs C-J)

Etymology. After Neptune (Neptunus), Roman god of water and the sea, and the eponymous "Grottes de Neptune" which are adjacent to the Lion quarry.

Holotype. USTL 0001, cephalon (Pl. 4, Figs C, D, E, G).

Paratypes. USTL 0023, paratype pygidium on the same rock slab as the holotype. NHMM 2010029, 2010030, two topotypical pygidia collected by R. Walter from the Boussu-en-Fagne Member of the Grands Breux Formation in 1962.

Type locality and horizon. Loc043, Frasnes; probably Boussu-en-Fagne Member of the Grands Breux Formation.

Diagnosis. Cephalon is strongly vaulted (tr.), rounded subtriangular in outline. Glabella anterior to S0 is covered with moderately closely spaced, moderately large tubercles. Visual surface comprising maximally 7 lenses per dorsoventral file. Fixigenae bear small pits; librigenae are devoid of sculpture. Subocular ridge is very well-developed. Pygidium with short (tr.), narrow (exsag.) fenestrae adaxially.

Description. Cephalon has a rudimentary anterior ledge in front of the glabella. Glabella anterior to S0 is slightly wider (tr.) than long (sag.); widest (tr.) adjacent to anterior extreme of librigena; dorsally flattened centrally (sag., tr.). Axial furrows moderately deep, exsagittally running lateral to L1, from there diverging until halfway along L3 (exsag.) and converging again towards S3. S0 is narrow (sag., exsag.); S1 crescent-shaped; S2 weakly curved and abaxially indiscernible; S3 almost straight. Occipital ring is about as wide (sag.) as glabella across L2 (tr.), ascending high above the rest of the glabella; L1 is rudimentary; L2 and L3 are dorsally flattened, forming a subhorizontal plane together with central part of glabella. Angular frontal glabellar lobe dropping in height proportionally towards anterior border but is well-demarcated abaxially by steep edges. Facial suture smoothly diverging between α and β; then slightly converging on γ. Postocular suture is smoothly sinusoidal. Eye is high, parabolic in outline. Maximum width (tr.) of palpebral lobe is equal to that of L3. Subocular ridge and groove are particularly well-developed. Librigenal field is very steep abaxial to the eye. Lateral border is dorsally flattened; slightly sloped; of steady width (tr.) near the eye and slightly narrower in front of the frontal glabellar lobe. Lateral border furrow is shallow but well-defined by a slope change between genal field and lateral border. Genal field is wide (tr.) in front of the eye. Posterior border runs subtransversally; slightly broadening (exsag.) abaxially. Genal spines are only known from specimens in private collections and similar to that of *Bradocryphaeus vanherlei* sp. nov.

Pygidium: see discussion.

Discussion. *Bradocryphaeus neptuni* sp. nov. is a rare species yet specimens other than the ones recorded herein were found in the Lion quarry. Unfortunately, all of these including a complete specimen in the collection of J. van den Wijngaard (AVV, pers. comm.), remain in private hands. However, the new species does not come

particularly close to any of the previously recorded species of this genus in the Ardennes. Only its pygidium is generally similar to that of *B. vanherlei* sp. nov. yet easily distinguished through its more widely rounded outline, the presence of fenestrae, and proximally robuster pleural spines.

Bradocryphaeus sp. 20
(Pl. 3, Figs A, C, D)

Material. NHMM 2010028, internal and external moulds of a pygidium; from the Ermitage Member of the Moulin Liénaux Formation in Loc020, Frasnes.

Discussion. The pygidium of *B.* sp. 20 bears a close resemblance to that of *Bradocryphaeus maillieuxi* but is different in having thinner pleural spines and five in stead of six pairs of pleurae. Additional specimens will be needed to assess the identity of this species.

Genus *Heliopyge* Haas & Mensink, 1970

Synonyms. *Alcaldops* Arbizu, 1977, by subjective synonymy (Morzadec, 1983).

Type species. *Asteropyge (Comura) helios* Richter & Richter, 1926 from the Frasnian of Belgium.

Discussion. Lieberman & Kloc's (1997) diagnosis of *Heliopyge* is not followed here for reasons already discussed by van Viersen & Prescher (2007). According to Morzadec (2002), *Heliopyge* is characterised by a pygidium with fenestrae and five pairs of pleural spines. As stated above, *Bradocryphaeus neptuni* sp. nov. also shows these characters which indicates that their combination is not restricted to species of *Heliopyge*.

Heliopyge helios (Richter & Richter, 1926)
(Pl. 3, Figs B, E, F; Pl. 4, Figs A, B, K)
v* 1926 *Asteropyge (Comura) helios* Richter & Richter, pp. 223-225, pl. 12, figs 37-39.
v 1927 *Asteropyge (Comura) helios* R. et E. Richter; Maillieux, p. 83, pl. 4, fig. 6.
1928 *Asteropyge (Comura) helios* Rud. & E. Richter; Richter & Richter, pp. 110, 113.
1961 *C. (C.) helios* R. et E. Richter (sic); Pillet, p. 110.
1970 *Neocalmonia (Heliopyge) helios* (R. & E. Richter); Haas & Mensink, p. 21.
1970 *N. (H.) helios* (Rud. & E. Richter); Haas, pp. 107, 115, 116.
1972 *Neocalmonia (Heliopyge) helios* (Rud. & E. Richter); Gandl, p. 141.
1975 *N. (H.) helios* (Rud. & E. Richter); Hahn & Hahn, p. 27, pl. 1, fig. 9.
1983 *H. helios*; Morzadec, p. 150.
2000 *Heliopyge helios*; Chlupáč *et al.*, p. 91, fig. 2.
2007 *Heliopyge helios*; Crônier & van Viersen, p. 481.
e.p. 2007 *Heliopyge helios* R & E Richter (sic); Daumeries, pp. 232, 233, unnumb. figs [reproductions of the original drawings by the Richters and a photo of a pygidium of *Bradocryphaeus*]
2007 *H. helios*; van Viersen & Prescher, p. 158.
v 2009 *Heliopyge helios*; Bonino & Kier, pl. 156, fig. c [photo of a pygidium from Loc018 (priv. coll. of AVV)]

Material. IRSNB a7808, holotype external (Pl. 4, Fig. A) and internal moulds of a pygidium (we provide here the first photographic material of the holotype); IRSNB a7807, paratype internal mould of a (juvenile?) complete specimen; IRSNB a12786, internal and external moulds of a cephalon; from the Ermitage Member of the Moulin Liénaux Formation in Pl. Olloy 463, Nismes (type locality). USTL 0002, one cephalon; NHMM 2010026, 2010027, two partial cephala; from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes.

Description. Cephalon is rounded subtriangular in outline, bearing a short, flattened anterior ledge in front of the glabella. Glabella anterior to S0 is slightly longer (sag.) than wide (tr.); centrally (sag., tr.) flattened; widest (tr.) lateral to anteriormost point of genal field. Axial furrows deep, exsagittal near S1, smoothly outward curved around S2 and S3. S0 is narrow (sag., exsag.) and deep; S1 crescent-shaped; S2 straight, abaxially indiscernible; S3 straightened to slightly sinusoidal; occipital ring is about half as long (sag.) as anterior glabellar lobe, ascending high above the rest of the glabella; L1 rudimentary; L2 and L3 dorsally flattened; angular anterior glabellar lobe descending proportionally anteriorly but well-demarcated abaxially by steep edges. Facial suture smoothly diverging between α and β; then slightly converging on γ. Postocular suture is smoothly sinusoidal. Eye is incompletely known, its outline is parabolic (tr.). Palpebral lobe is as wide (tr.) as half the glabella (tr.) along L3. Subocular groove and ridge are weakly developed. Genal field is vertical under the eye. Lateral border is dorsally flattened; of a constant width (tr.) near the eye; slightly broadening only anteriorly and posteriorly; extended as a strip onto the genal spine but rapidly tapering backwards at the cost of the similarly extended posterior border. Lateral border furrow is shallow but well-defined because of a slope change between genal fields and lateral border. Genal field is narrow (tr.) in front of the eye. Posterior border is subtransverse; slightly broadening (exsag.) abaxially. Posterior border furrow is deep, subtransverse. Genal spine is developed as a long flange (2.5 times longer than the cephalon), proximally outward directed and distally faintly inward curved. Tubercles are scattered centrally on the glabella, on the anterior glabellar lobe, L2, L3, and smaller ones on occipital ring and L1. Coarse, large granules are present on the inner part of the genal spine and very fine granules are present on the lateral border.

Pygidium with a triangular outline; about 1.5 times wider (tr.) than long (sag.). Axis is narrow (tr.), representing maximally a quarter of the pygidial width (tr.); well-differentiated from postaxial field; comprising 12 rings plus a terminal piece (11+1 in smaller specimens). Anterior six inter-ring furrows are broad (sag., exsag.) and slightly

anteriorly curved; remaining inter-ring furrows are narrow (sag. exsag.) and straight (tr.). Axial furrows are less convergent posteriorly from sixth ring. Pleural field is composed of six pleurae; the first is twice as long as the fifth. Anterior and posterior pleural bands are curved and sloped in lateral view; anterior pleural bands are lower and twice as thin (exsag.) as posterior pleural bands. Pleural furrows rather faint and thin. Interpleural furrows are indistinguishable due to the exceedingly well-developed fenestrae which extend across the entire pleural field (tr.). There are five pairs of pleural spines that originate mostly from the posterior pleural bands and, to some extent, from the anterior pleural bands. The first pleural spine is about 1.5 times longer than the associated pleura. The fourth pleural spine is longest; more than four times longer than the associated pleura. The fifth pleural spine is twice as thin as the fourth. Terminal lappet is elongated teardrop-shaped; thinner than fifth pleural spine. All spines are covered with fine granules.

Discussion. Richter & Richter (1926) based their illustrations and description of the cephalon and thorax of *Heliopyge helios* on one of the paratypes, a small, internal mould of what is probably a juvenile specimen (see Pl. 4, Fig. K). We record here the cephalic remains of three large holaspides and provide an emended description of the cephalon (the description of the pygidium by Richter & Richter is mostly sustained except that note is made of the particularly well-developed fenestrae which were not mentioned by the Richters at all). Among the most important differences with the cephalon as the Richters depicted it are the exceedingly broad (tr.) palpebral lobes with sharply curved facial suture near δ; the presence of an anterior ledge in front of the glabella; long genal spines; the absence of a median node on the occipital ring. The eyes are mostly broken off in our specimens, suggesting that they are high as shown by the paratype complete specimen and indicated in the drawing by the Richters from 1926.

Heliopyge helios is highly endemic. Eighty years after its original description it has only been found directly east of Nismes and is still the sole *Heliopyge* species known from Belgium. The genus has not been recorded in the Eifel. None of the *Heliopyge* species from Spain, France (Massif armoricain) and Iran appear to be particularly close to *H. helios* except for Morzadec's (1983) *Heliopyge* aff. *helios* from the Lower Frasnian in the Massif armoricain. Both species share the comparatively long pygidial pleural spines the fourth pair of which projects furthest posteriorly and, perhaps more compellingly, the well-developed fenestrae (*ibid*., p. 150). According to Morzadec, the French taxon is different in having ten axial rings that each bear a median tubercle whereas the Belgian taxon has twelve axial rings without median tubercles.

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PLATE 1

Bradocryphaeus maillieuxi (Richter & Richter, 1926) from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes.

A, B, E. cephalon, NHMM 2010017, in dorsal (A), lateral (B) and anterior (E) views.
C, D, F, G. cephalon, NHMM 2010016, in dorsal (C), lateral (D), anterior (F) and oblique anterolateral (G) views.
H-J. pygidium, NHMM 2010014, in dorsal (H), posterolateral (I) and posterior (J) views.
K. pygidium, NHMM 2010015, in dorsal view.

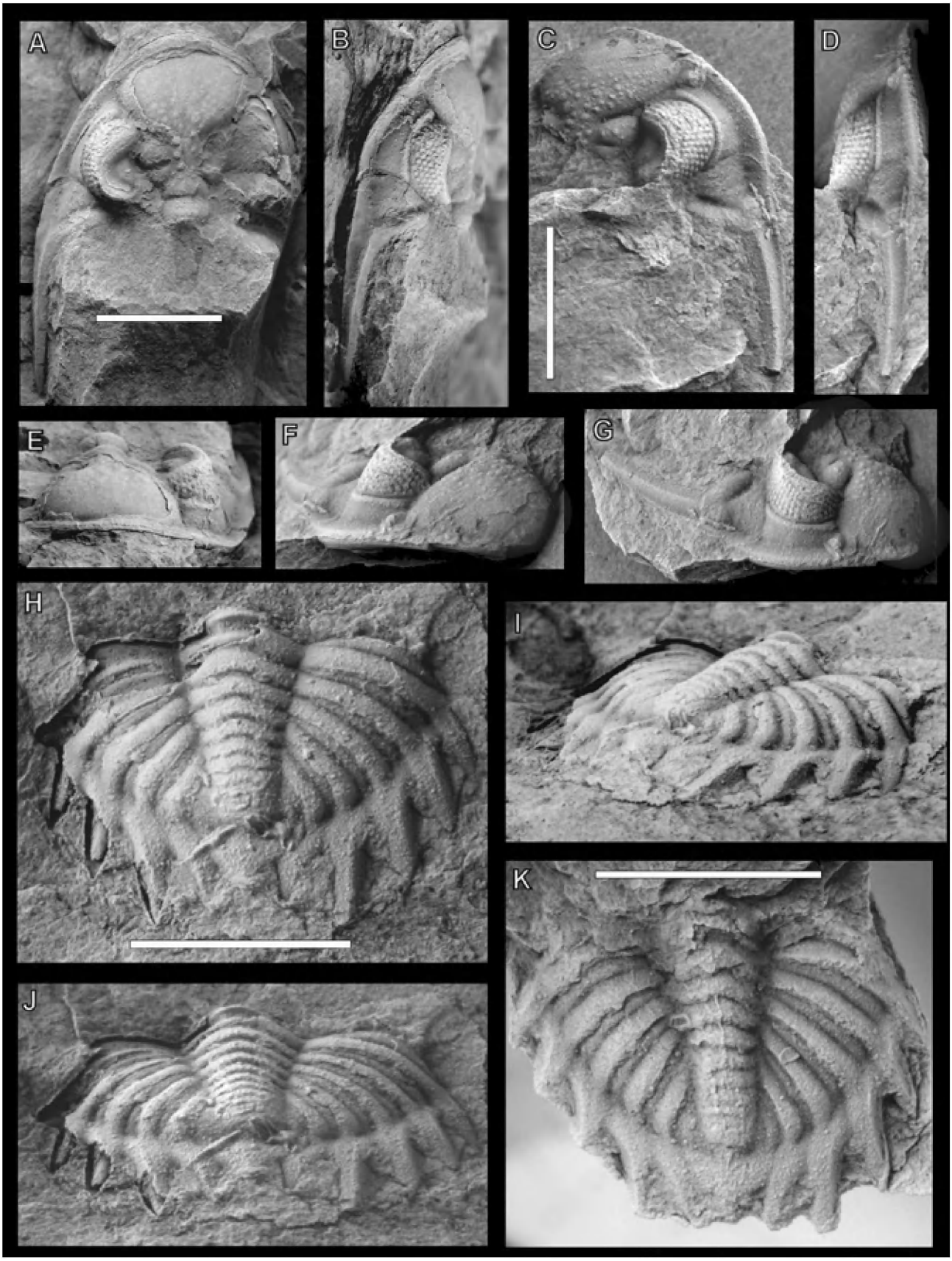
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PLATE 2

Bradocryphaeus vanherlei sp. nov. from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes.

A-D. paratype cephalon, NHMM 2010018, in dorsal (A), lateral (B), anterior (C) and oblique anteriorolateral (D) views.
E. paratype cephalon, NHMM 2010019, in dorsal view.
F, G. paratype silicone cast of external mould of a pygidium, NHMM 2010020, in dorsal (F) and posterior (G) views.
H, I, K. paratype silicone cast of external mould of a pygidium, NHMM 2010021, in dorsal (H), posterolateral (I) and posterior (K) views.
J, M. holotype pygidium, NHMM 2010023, in dorsal (J) and posterior (M) views.
L. paratype pygidium, NHMM 2010022, in dorsal view.

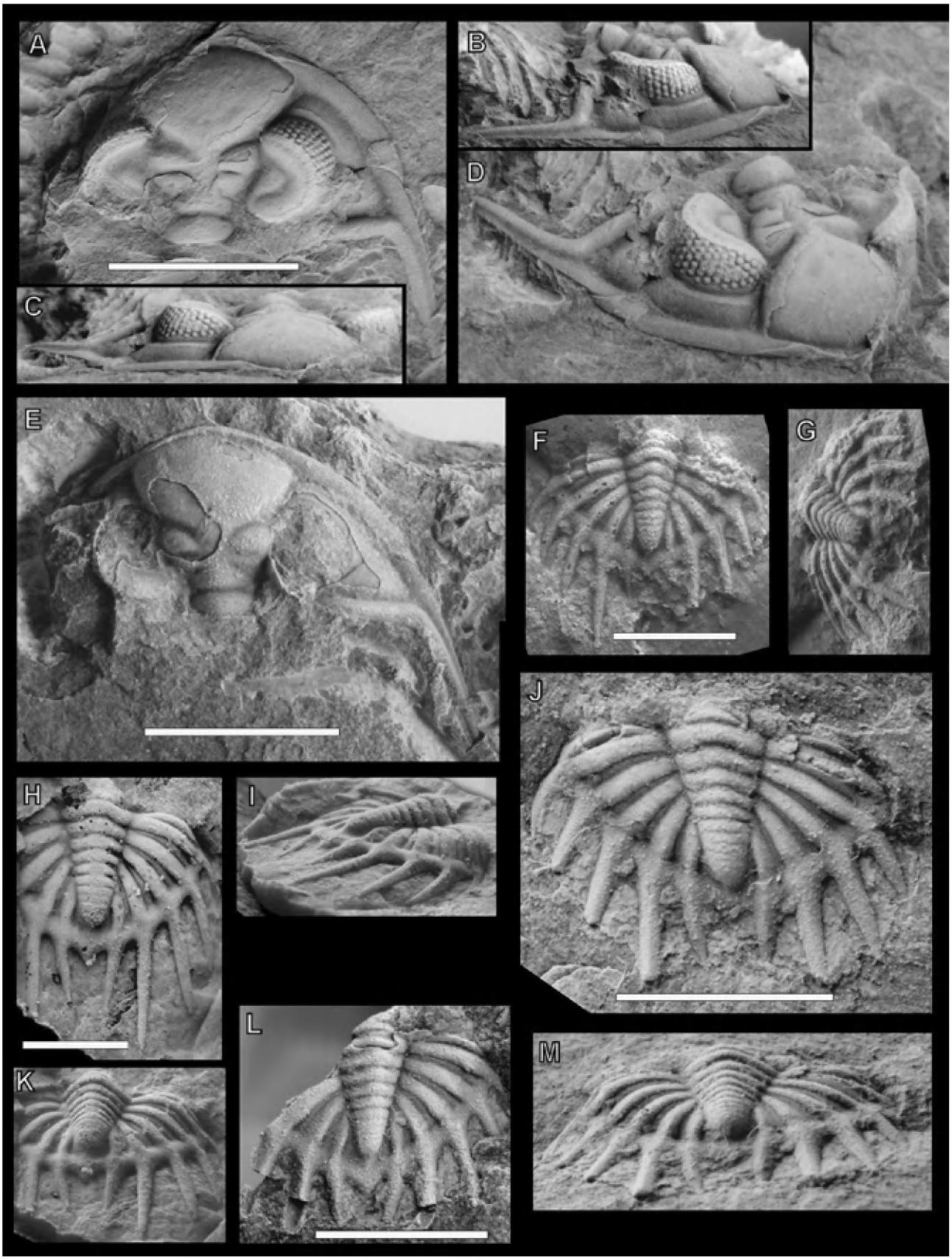
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PLATE 3

Bradocryphaeus sp. 20 from the Ermitage Member of the Moulin Liénaux Formation in Loc020, Frasnes.

A, C, D. silicone cast of external mould of a pygidium, NHMM 2010028, in dorsal (A), posterior (C), and oblique lateral (D) views.

Heliopyge helios (Richter & Richter, 1926) from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes.

B. disarticulated cephalon, NHMM 2010026, in dorsal view.
E, cephalon, USTL 0002, in dorsal view.

Heliopyge helios (Richter & Richter, 1926) from the Ermitage Member of the Moulin Liénaux Formation in Pl. Olloy 463, Nismes (type locality).

F. cephalon, IRSNB a12786, oblique lateral view.

Bradocryphaeus neptuni sp. nov. from the Boussu-en-Fagne? Member of the Grands Breux Formation in Loc043, Frasnes.

G. paratype pygidium, USTL 0023, in dorsal view.

Bradocryphaeus neptuni sp. nov. from the Boussu-en-Fagne Member of the Grands Breux Formation in Loc043, Frasnes.

H. paratype pygidium, NHMM 2010030, in dorsal view. Specimen was left untreated prior to photography.

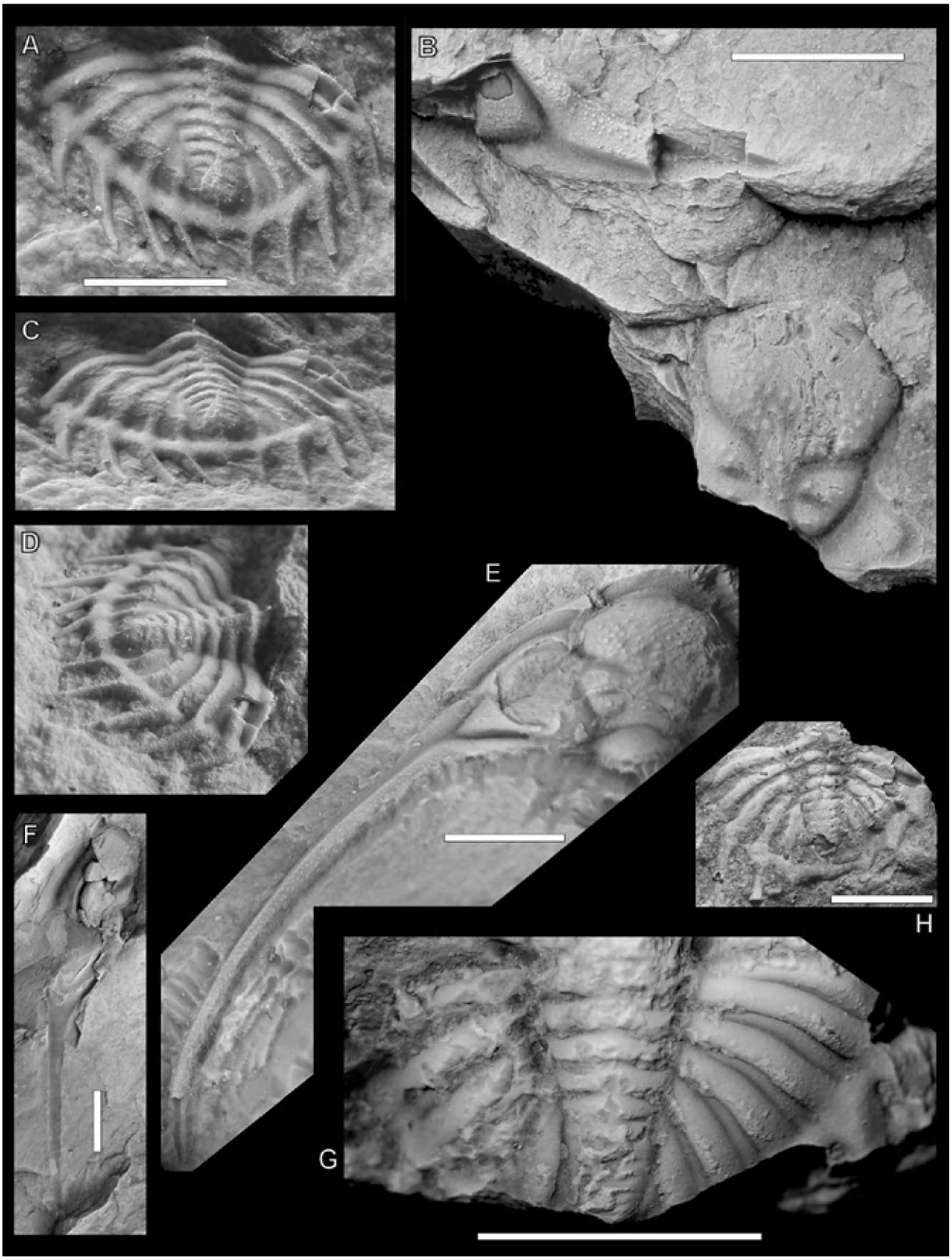
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PLATE 4

Heliopyge helios (Richter & Richter, 1926) from the Ermitage Member of the Moulin Liénaux Formation in Pl. Olloy 463, Nismes (type locality).

A. holotype external mould of a pygidium, IRSNB a7808, in dorsal view (= basis for reconstruction of pygidium by Richter & Richter, 1926, pl. 12, fig. 38).
K. paratype internal mould of a (juvenile?) complete specimen, IRSNB a7807, in dorsal view (= basis for reconstruction of cephalon by Richter & Richter, 1926, pl. 12, fig. 37).

Heliopyge helios (Richter & Richter, 1926) from the Ermitage Member of the Moulin Liénaux Formation in Loc018, Nismes.

B. incomplete cephalon, NHMM 2010027, in dorsal view.

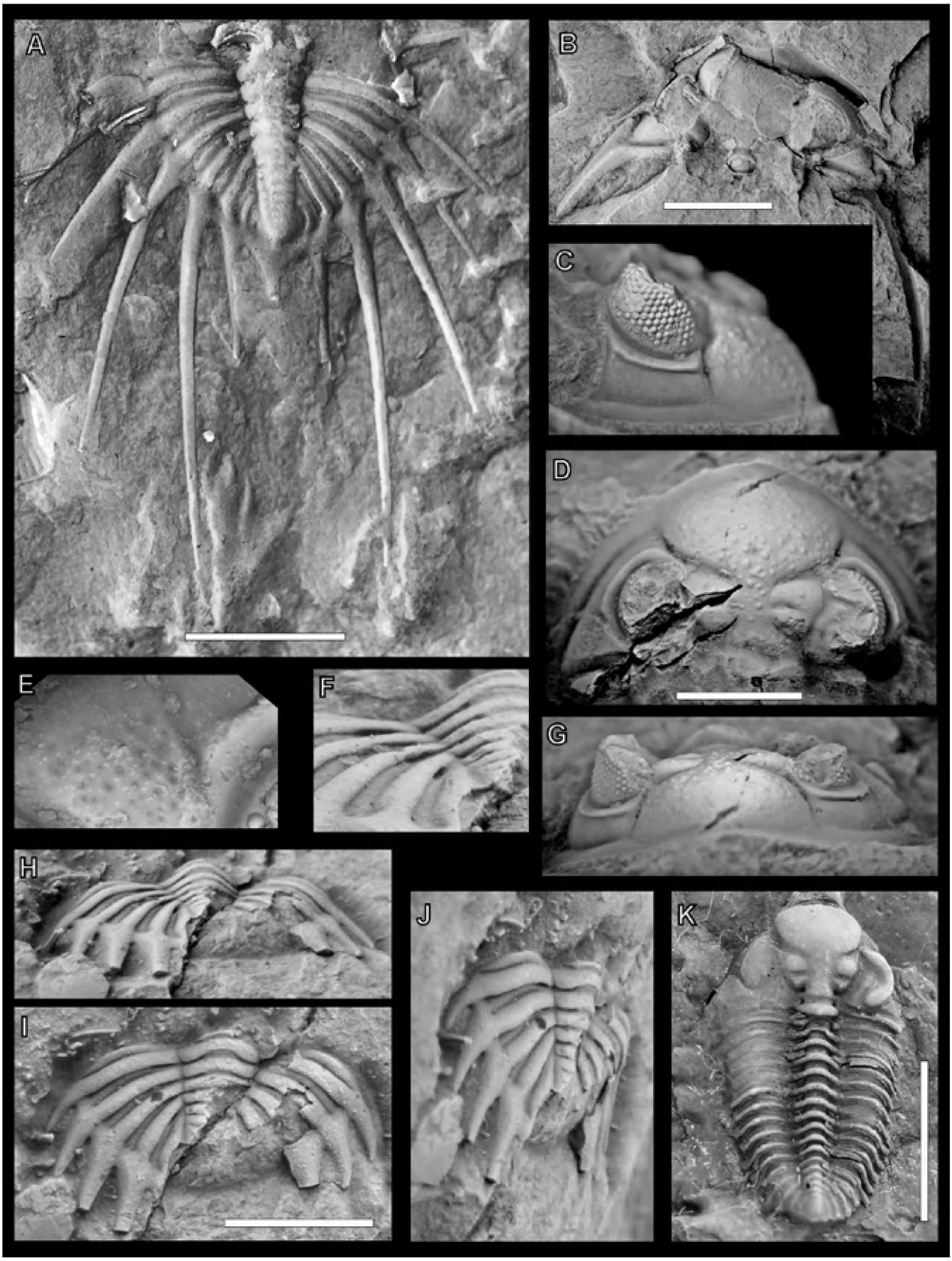
Bradocryphaeus neptuni sp. nov. from the Boussu-en-Fagne? Member of the Grands Breux Formation in Loc043, Frasnes.

C, D, E, G. holotype cephalon, USTL 0001, in lateral (C), dorsal (D), and anterior (G) views, and close-up of left fixigena (E).

Bradocryphaeus neptuni sp. nov. from the Boussu-en-Fagne Member of the Grands Breux Formation in Loc043, Frasnes.

F, H-J. paratype pygidium, NHMM 2010029, close-up of left pleural field (F), and in posterior (H), dorsal (I), and oblique lateral (J) views.

All scale bars represent 5 mm.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