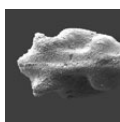


Stratigraphical distribution of Givetian ostracods in the type-area of the Fromelennes Formation (Fromelennes, Ardennes, France) and their relationship to global events

SÉBASTIEN MAILLET, CLAUDIA DOJEN & BRUNO MILHAU



Bed-by-bed sampling of three sections (Flohimont, Cul d'Houille and Nichet) exposing almost the entire Fromelennes Formation (Devonian, Middle and Late Givetian) in the historical type-area of the Givetian (Givet, Ardennes Department, France) provided more than 12,000 benthic ostracods. A high ostracod biodiversity is reported in these sections; 113 taxa are recognized of which 2 species are new: *Acrattia lucea* sp. nov. and *Orthocypris? cristae* sp. nov. The stratigraphical distribution of the ostracods shows the installation of a Givetian fauna close to the base of the Fromelennes Formation with many endemic taxa and its disappearance as well as its subsequent replacement with more cosmopolitan taxa at the top of the formation with Frasnian affinities. This distribution is closely related to the major events of the Middle and Late Givetian in the Ardennes: the transgression pulse at the top of the Mont d'Hours Formation, the global Taghanic Biocrisis and the global Givetian/Frasnian sea level rise. Climate change at the end of the Givetian possibly amplifies the effects of the sea level rise. The pattern of disappearance of many ostracod taxa in the Middle Givetian and their replacement by a new fauna as early as the Late Givetian is at least a supraregional phenomenon. *Orthocypris? cristae* sp. nov., *Kielciella arduennensis* Adamczak & Coen, 1992, *Jefina kaisini* Coen, 1985 and *Cavellina rhenana* Krömmelbein, 1954 are considered as regional to supraregional stratigraphic markers. We establish the presence of a Middle Givetian ostracod province on the Givetian carbonate platform. • Key words: ostracod province, palaeogeography, Fromelennes Fm. stratotype, Taghanic Biocrisis, regional extinction, faunal renewal, new species, Givetian carbonate platform, Devonian.

MAILLET, S., DOJEN, C. & MILHAU, B. 2013. Stratigraphical distribution of Givetian ostracods in the type-area of the Fromelennes Formation (Fromelennes, Ardennes, France) and their relationship to global events. *Bulletin of Geosciences* 88(4), 865–892 (12 figures, appendix). Czech Geological Survey, Prague. ISSN 1214-1119. Manuscript received February 27, 2013; accepted in revised form August 15, 2013; published online October 30, 2013; issued October 31, 2013.

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The Devonian is a period of dramatic climatic changes, during which Givetian greenhouse conditions change into icehouse conditions close to the Devonian/Carboniferous boundary (Caputo *et al.* 2008). This period is encompassed by the IGCP project 596 “Climate change and biodiversity patterns in the Mid-Palaeozoic”. This paper contributes to the project by documenting the ostracod fauna and its biodiversity in the historical type area of the Givetian, spanning a period during which several environmental and climatic events took place. The Taghanic Biocrisis (House 1985, Aboussalam & Becker 2011), a period of major fau-

nal change around the Middle/Late Givetian boundary, as well as the global sea level rise and climatic and sedimentary changes close to the Givetian/Frasnian boundary are of special interest, as these events are reflected in the ostracod distribution.

The studied area is located within the Dinant Synclinorium, which is known for its excellent Devonian outcrops including the historical type area of the Givetian in the French Ardennes. The penultimate of the six formations of the classical Givetian (Bultynck *et al.* 1991, Bultynck & Dejonghe 2001) is the Fromelennes Formation

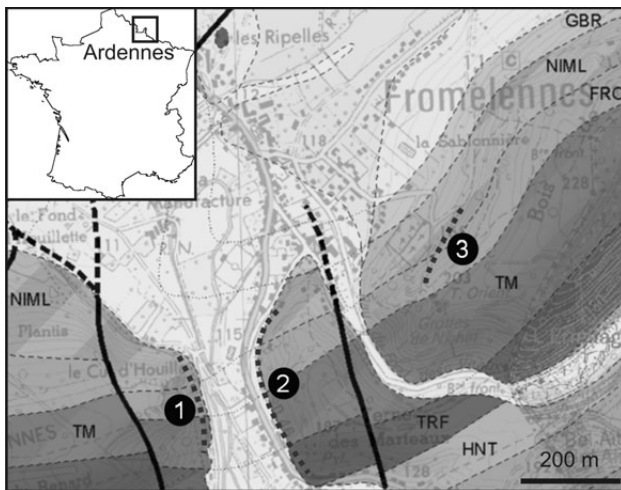


Figure 1. Locality map of the studied sections in the Fromelennes area. 1 – Cul d’Houille section; 2 – Flohimont section; 3 – Nichet section. Abbreviations: HNT – Hanonet Fm.; TRF – Trois-Fontaines Fm.; TM – Terres d’HOURS & Mont d’HOURS Fms; FRO – Fromelennes Fm. NIML – Nismes & Moulin Liénaux Fms; GBR – Grands Breux Fm.

(Fm.), whose ostracod distribution is studied in this paper. The stratotype of the Fromelennes Fm., composed of the Flohimont and the Cul d’Houille sections, and the recently newly described Nichet section (Maillet *et al.* 2011) have been sampled bed-by-bed. Together, these well-exposed sections cover the Fromelennes Fm. most completely across the entire historical type area of the Givetian. Although several studies on the Fromelennes fauna exist, ostracods from the Flohimont and the Cul d’Houille sections have not been studied in detail, and they have not been reported at all from the Nichet section. This study complements and advances existing ostracod studies from the area by presenting a detailed stratigraphical distribution. This distribution shows the combined effects of the Taghanic Biocrisis, the climate change during the Late Givetian and the sea level rise at the Givetian/Frasnian boundary which are confirmed by data from sedimentology (*e.g.* Pr at & Carliez 1994, Boulvain *et al.* 2009) and from other faunal groups (*e.g.* Coen-Aubert 2004; Pinte & Mistiaen 2009, 2010; Maillet & Milhau 2010). Thus, the study of the ostracods from the Givetian of the Ardennes not only reviews and complements the palaeontological knowledge on the Fromelennes Fm. in its type-area, but also confirms their value for understanding deep-time climate and environmental changes.

Geographical and geological setting

The three studied sections (Flohimont, Cul d’Houille and Nichet) are located in the “Pointe de Givet” natural reserve of the Ardennes Department in N France, about 3.6 km SE from the town of Givet, near the village of Fromelennes

(Fig. 1). The Cul d’Houille section is located along the western bank of the Houille stream (N 50°11’ 74”, E 4°85’ 52”), whereas the Flohimont section is sited eastwards (N 50°11’ 71”, E 4°85’ 77”), along the road D46 joining Fromelennes and Flohimont. The newly described Nichet section (Maillet *et al.* 2011) crops out along the way leading from Fromelennes to the Nichet cave (N 50°07’ 19”, E 4°51’ 51.5”).

The Givet region is the type area of the Givetian and belongs to the southern part of the Dinant Synclinorium. The latter is located in the northern part of the Ardennes allochthon and forms a part of the Rhenohercynian belt of the Mid-European Variscides (Pr at *et al.* 2006). In Givetian times, the area belonged to a wide carbonate platform (the “Givetian carbonate platform”, see Boulvain *et al.* 2009, Pr at & Mamet 1989), which extended on the northern passive margin of the Rheno-Hercynian Ocean (Sintubin 2008) along the southern margin of Laurussia (Fig. 2).

Two major transgressive events can be recognized in the Middle and Late Givetian of the Givet area (Milhau 1983a, Casier 1987, Boulvain *et al.* 2009, Casier & Pr at 2009, Maillet *et al.* 2010, Maillet & Milhau 2010). The first transgressive episode occurs around the Mont d’HOURS/Fromelennes Fms boundary, about 9 m below the base of the middle *P. varcus* (*P. ansatus*) Zone (see Gouwy & Bultynck 2003). This transgression can be recognized everywhere in the Ardennes and also in the Boulonnais (around the Griset/Blacourt Fms boundary). However, according to Bultynck *et al.* (2001), it does not correspond to the global Taghanic Onlap (Johnson 1970, House 1975; = transgressive episode IIa-Tagh in Aboussalam & Becker 2011), as it is older. The second transgression is connected with a global sea level rise around the Givetian/Frasnian boundary, which leads to the collapse of the Givetian carbonate platform and the disappearance of its reefal barriers (Boulvain *et al.* 2009, Casier 1987).

Between these transgressive episodes, the global Taghanic Biocrisis took place, seriously affecting the neritic faunas and leading to the disappearance of the provincialism of the marine fauna (May 1995; Bultynck *et al.* 2001; Aboussalam 2003; Coen-Aubert 2004; Pinte & Mistiaen 2009, 2010; Maillet & Milhau 2010).

Stratigraphic summary

The Cul d’Houille and Nichet sections mainly expose the Fromelennes Fm., but both expose also the upper part of the underlying Mont d’HOURS Fm., and the Nichet section exposes the base of the overlying Nismes Fm. The Flohimont section is the most extensive, covering the entire Givet Group (composed of the Trois-Fontaines Fm., the Terres d’HOURS Fm., the Mont d’HOURS Fm. and the

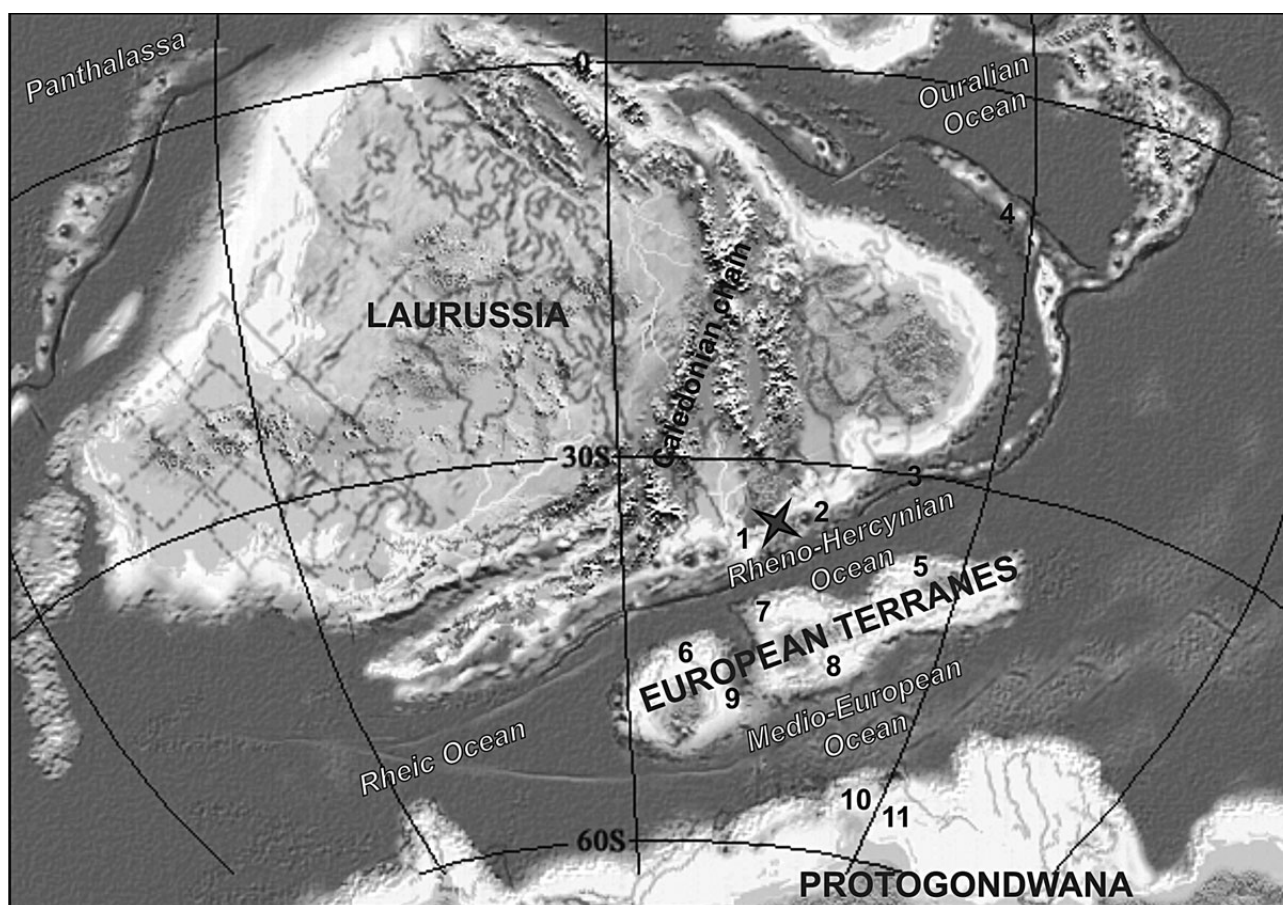


Figure 2. Middle Devonian palaeogeographic reconstruction (adapted from Blakey 2007). The star indicates the Ardennes location. 1 – Boulonnais; 2 – Eifel Hills, Sauerland and Bergisches Land; 3 – Holy Cross Mountains; 4 – Volga-Ural; 5 – Bohemian Massif; 6 – Asturias-León; 7 – Armorican Massif; 8 – Montagne Noire; 9 – Mouthoumet Massif; 10 – Tafilalt; 11 – Ougarta Range.

Fromelennes Fm.) and the base of the Frasnian Group (base of the Nîmes Fm.).

This paper is focused on the Middle to Late Givetian Fromelennes Fm. Due to faults and gaps, this formation is not completely exposed in any of these sections, but as they match very well, a composite stratigraphical column (Fig. 3) can be constructed. Likewise, the stratotype of the Fromelennes Fm. consists of the two complementary Flohimont and Cul d’Houille sections (Bultynck 1974, Bultynck *et al.* 1991). Detailed stratigraphical columns, faunal content and precise correlations of the sections as well as bed numbers for these three sections can be found in Hubert & Pinte (2009) and in Maillet *et al.* (2010, 2011).

The upper part of the Mont d’Hairs Fm. consists of massive reefal limestones of protected and restricted environments. Near the top of the formation the environment became progressively more open, and argillaceous limestone beds were deposited, showing the beginning of a major transgressive episode at the base of the Fromelennes Fm. (Boulvain *et al.* 2009, Maillet *et al.* 2010). The part of the Mont d’Hairs Fm. studied herein is of early Middle

Givetian age and belongs to the lower *Polygnathus varcus* (*Polygnathus rhenanus*) conodont Zone.

The overlying Fromelennes Fm. is about 140 meters thick and consists of alternating argillaceous and massive reefal limestones of neritic origin with rare siltstones. The formation is subdivided into three members: the Flohimont Member (Mb.) at the base, the Moulin Boreux Mb. in the middle and the Hulobiet Mb. at the top. The thickness of the Flohimont Mb. is about 30 m (Bultynck 1974; Maillet *et al.* 2010, 2011) consisting of argillaceous limestone beds, which display a major transgressive period that started in the top of the Mont d’Hairs Fm. The Moulin Boreux Mb. is characterized by nearly 85 m of fine-grained limestones indicating a comparatively restricted and quiet environment during a regressive phase. Emersion surfaces with paleosols and ripple-mark levels can also be observed (Préat & Carliez 1994, Boulvain *et al.* 2009). The Fort Hulobiet Mb. consists of about 25 m of argillaceous limestones and shales deposited during a phase of sea level rise, initiating a second major transgression (Givetian/Frasnian boundary global transgression). The entire formation

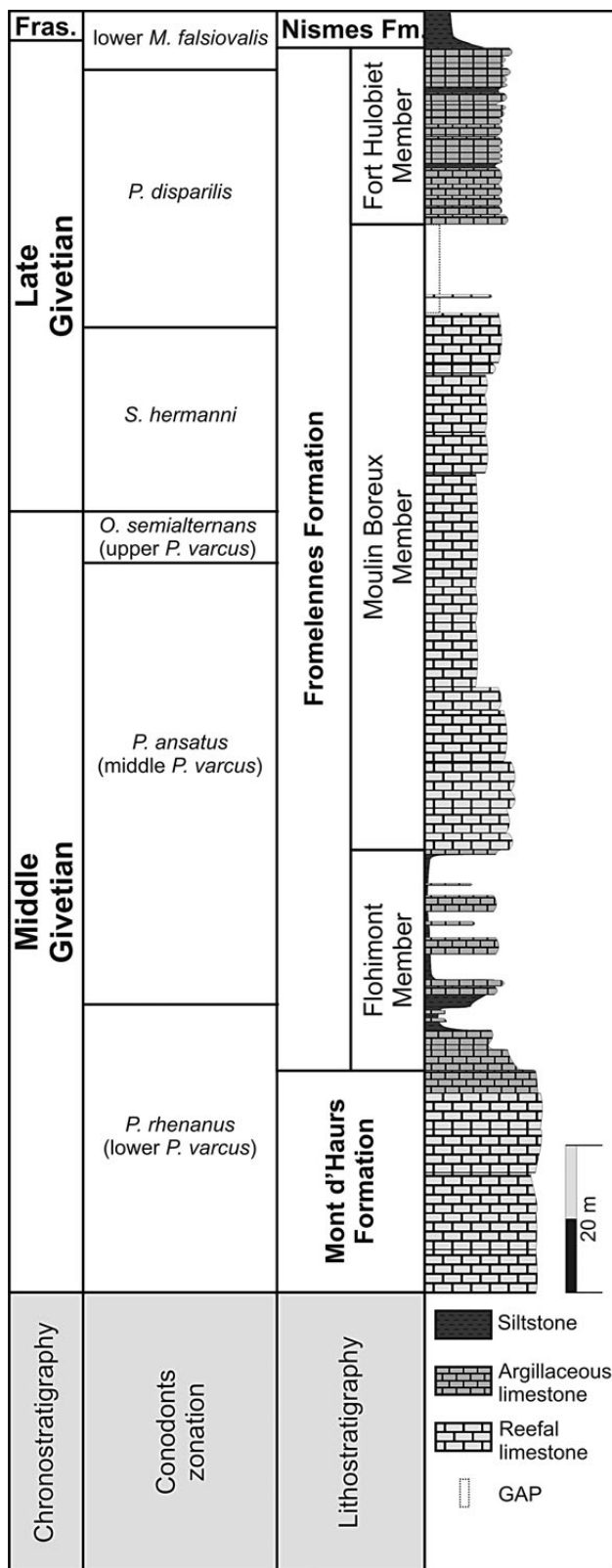


Figure 3. Fromelennes Formation composite stratigraphical column, standard conodont zonation and chronostratigraphy.

encompasses the Middle Givetian (uppermost lower *P. varcus* Zone) and the Late Givetian (uppermost part of *Klapperina disparilis* conodont Zone) (Gouwy & Bultynck 2003). The Middle/Late Givetian boundary is expressed by the transition from the upper *P. varcus* (*Ozarkodina semialternans*) to the *Schmidtnathus hermanni* conodont Zones (Gouwy & Bultynck 2003), as well as by the last occurrence of stringocephalid brachiopods in the lower part of the Moulin Boreux Mb. (Coen-Aubert 2004, Bultynck *et al.* 2001).

The overlying base of the Nismes Fm. is represented by less than a meter of siltstone, which is still of latest Givetian age (uppermost *K. disparilis* to lower *Mesotaxis falsiovalis* conodont Zones). The base of the Frasnian is reported in the first meter of the formation by Narkiewicz & Bultynck (2010) with first conodonts of the genus *Ancyrodella* (*A. binodosa*, *A. pristina* and *A. rotundiloba*), but could not be identified with certainty in the studied sections. However, position of the G/F boundary in the Ardennes is still in discussion (Casier & Pr eat 2009, Casier *et al.* 2013). Initially suggested to be in the lower part of the Nismes Fm., it is now believed to be closer to the lithostratigraphical boundary between the Fromelennes and the Nismes Fms. However, the occurrence of *Polyzygia beckmanni beckmanni* in the base of the Nismes Fm. confirms an age close to the Givetian/Frasnian boundary.

Previous work on ostracods from the Fromelennes Formation

Middle Devonian ostracods have been studied from several areas of the Ardennes, but a comprehensive study on the ostracods from the stratotype of the Fromelennes Fm. and the additional Nichet section with a synthesis of their stratigraphical distribution is presented here for the first time. So far, the most complete study on these ostracods in the Flohimont and the Cul d'Houille sections was the preliminary work of Milhau (1983a, 1983b).

Besides the work of Milhau, Magne (1964) mentioned some ostracods from the Fromelennes Fm. in the Cul d'Houille section, Coen (1985) figured some ostracods from the Flohimont Mb. in the Flohimont section, and Adamczak & Coen (1992) used some ostracods from the Flohimont section for their study on the ontogeny and morphofunctional anatomy of the primitiopsids. As regards the Givetian of the Dinant Synclinorium, *e.g.*, Casier (1987), Casier & Pr eat (2009) and Casier *et al.* (2013) studied the stratigraphic distribution and palaeoecology of ostracods around the Givetian/Frasnian boundary. Casier *et al.* (2010b, 2011a, b) and Casier & Pr eat (2013) did the same in the Early Givetian and reviews of Givetian ostracods have been compiled by Coen (1985), Casier (2008), Milhau (*in Brice & Mistiaen* 2008) and Milhau *et al.* (2013).

Material and methods

The three studied sections were sampled bed-by-bed except for the Moulin Boreux Mb. in which the lithofacies is unfavourable to collect ostracods (algal laminites, dolomitic limestones, emersion facies, etc.). About 12,350 carapaces, valves and fragments have been provided, of which about 8,900 specimens have been identified. In detail, there were:

- 7,100 ostracods within 113 out of 122 samples collected in the Cul d’Houille section.
- 4,900 ostracods within 111 out of 121 samples collected in the Flohimont section.
- 350 ostracods within 12 out of 15 samples collected in the Nichet section.

The calcareous ostracod valves and carapaces have been extracted from limestone samples by using the hot acetolysis method described, e.g., by Crasquin-Soleau *et al.* (2005). Images of gold plated specimens were made with the Environmental Scanning Electron Microscope (ESEM) Quanta 200 of the Université Lille1 des Sciences et Technologies. All samples are housed at the Faculté Libre des Sciences et Technologies of Lille. The figured material has been catalogued in the Collection d’Ostracodes de l’Université de Lille (C.O.U.L.); the individual numbers are indicated in the plate descriptions (Figs 4 to 8).

Systematic palaeontology (by S. Maillet)

In all, 113 ostracod taxa are reported, belonging to the orders Podocopida, Eridostracina and Palaeocopida, of which 42 are formally recognized and two new species are described (see below). All taxa are listed with their systematic position in the Appendix 1 and are figured (Figs 4 to 8).

Class Ostracoda Latreille, 1802
 Order Podocopida Müller, 1894
 Suborder Podocopina Sars, 1866
 Superfamily Bairdioidea Sars, 1888
 Family Bairdiidae Sars, 1888

Genus *Acratia* Delo, 1930

Type species. – *A. typica* Delo, 1930.

Diagnosis. – Bairdiidae “with highly arched dorsum and nearly straight ventral margin; anterior and posterior margin extremities located below mid-height; anterior end hook-like in shape, posterior end pointed” (Becker 2001, p. 272).

Range and occurrence. – (Lower) Devonian to Triassic, ?Upper Jurassic; worldwide (Becker 2001, p. 272).

Acratia lucea sp. nov.

Figure 4A–H

- 1964 *Acratia* sp. G1. – Magne, pl. 21, figs 102–104.
- v• 1983a *Acratia* sp. G1 *sensu* Magne (1964). – Milhau, pl. 1, fig. 27.
- v• 1988 *Acratia* sp. G1 *sensu* Milhau (1983). – Milhau, pl. 55, fig. 35.
- v• 1989 *Acratia* sp. G1 *sensu* Magne (1964). – Milhau in Brice *et al.*, p. 122.
- v• 1991 *Acratia* sp. A. – Casier in Casier & Préat, pl. 2, fig. 20.
- v• 2006 *Acratia* sp. G1 in Magne (1964). – Casier in Casier & Préat, pl. 4, fig. 5a, b.
- v ?2009 *Acratia* sp. indet. – Casier in Casier & Préat, pl. 7, fig. 5.
- v• 2010 *Acratia lucea* sp. nov. – Maillet, pl. 1, figs 1–8.
- v• 2011b *Acratia lucea* Maillet, 2010 nom. nud. – Casier in Casier *et al.*, pl. 3, fig. 11.
- v• 2013 *Acratia lucea* Maillet, 2010 nom. nud. – Casier & Maillet in Casier *et al.*, pl. 9, fig. O.
- v• 2013 *Acratia lucea* Maillet, 2010 nom. nud. – Casier in Casier & Préat, pl. 5, fig. 2.

Holotype. – Adult carapace (C.O.U.L. 501), 616 µm in length, 362 µm in height and 210 µm in width (Figs 4A, 9).

Paratypes. – Three juvenile carapaces and one large adult carapace (C.O.U.L. 502, 504, 505 and 506), 394 µm, 535 µm, 480 µm and 822 µm in length, 198 µm, 246 µm, 242 µm and 354 µm in height, respectively (Fig. 4B, D, E and F).

Type locality and type horizon. – Ardennes, Cul d’Houille section, Fromelennes Fm., Flohimont Mb. (Middle Givetian).

Material. – 26 carapaces, 4 valves and many fragments of juvenile and adult specimens.

Origin of name. – *Lucea*: latinized from “Luce”, my girlfriend’s first name to whom I dedicate this species for her field assistance.

Diagnosis. – A species of *Acratia* with a rather slender outline in lateral view (L/H ratio about 2:1). The valves are biconvex with a smooth surface. The dorsal margin is highly arched and has three convexity points. The ventral margin is convex with one distinct convexity point.

Description. – Slender carapace with an L/H ratio of about 2 : 1; smooth surface; outline biconvex in lateral, dorsal and ventral views, anteriorly and posteriorly acuminate; posterior tip with slight ventral and dorsal concavities (Fig. 9); left valve larger than right, with dorsal overreach

and ventral overlap each from the anterior to the posterior tip; bow-shaped projection on the closure line of the valves in ventral view; maximum length of carapace around twice the maximum of height; maximum width located at 2/5 of the anterior end in dorsal view; maximum height anterior, at about 1/3 of the maximum length; maximum length below mid-height, at about 1/3 of the maximum height from the ventral margin; depressed hinge line centered with a length of 1/3 of maximum length; dorsal margin highly arched with three distinct convexity points (Fig. 3): the first at about 1/6 of the maximum length and about 3/4 of the maximum height with an angle around 170°; the second at about 1/3 of the maximum length and at the maximum height with an angle around 150°; the third at about 3/4 of the maximum length and at about 3/4 of the maximum height with an angle around 155°; ventral margin with one convexity point within the first anterior third with an angle around 135°, migrating towards the anterior during the ontogenetic growth.

Comparisons. – This new species is comparable only to two species which were both described from the Frasnian of the Russian platform: *A. evlanensis* Egorov, 1953, from the Voronezh and Yevlanovo beds, and *A. schelonica* Egorov, 1953, from the Shelon beds, but the new species differs from *A. evlanensis* by a less slender shape, a more strongly curved dorsal margin and a weaker ventral overlap, and from *A. schelonica* Egorov, 1953 by sharper ends and a dorsal overreach. *A. lucea* differs from all other *Acratia* species through its general outline, its pronounced dorsal overreach and ventral overlap, the L/H and the L/W ratios and the ventral and dorsal convexity points.

Occurrence. – *A. lucea* is present in the Ardennes in the Dominant Synclinorium in the Trois-Fontaines Fm., the Terres d’Hairs Fm., the Mont d’Hairs Fm. and the Fromelennes Fm. (Flohimont Mb. and Fort Hulobiet Mb.) and in the Namur Synclinorium in the Névremont Fm. The species is also present in the Boulonnais in the Blacourt Fm. (Griset Mb. and Couderousse Mb.). *A. lucea* ranges from the *P. he-*

miansatus to the *K. disparilis* zones of the standard conodont biozonation.

Genus *Orthocypris* Kummerow, 1953

Type species. – *Bythocypris recta* (Kummerow, 1943).

Diagnosis. – Bairdiidae with extremely elongate, cylindrically shaped carapace (Becker 2001, p. 286).

Range and occurrence. – Upper Silurian–Upper Devonian; Eurasia, China (Becker 2001).

Orthocypris? cristae sp. nov.

Figure 7A–G

- 1983a *Podocopina* gen. indet. sp. A. – Milhau, pl. 1, figs 22, 23.
- 1983b *Podocopina* gen. indet. sp. A. – Milhau, pl. 10, figs 23–25.
- 1988 *Podocopina* gen. indet. sp. A. – Milhau, pl. 56, fig. 11.
- 2010 *Orthocypris? bicarinata* sp. nov. – Maillet, pl. 3, figs 10–14.
- 2013 *Orthocypris? bicarinata* Maillet, 2010 nom. nud. – Casier & Maillet in Casier *et al.*, pl. 10, fig. J.

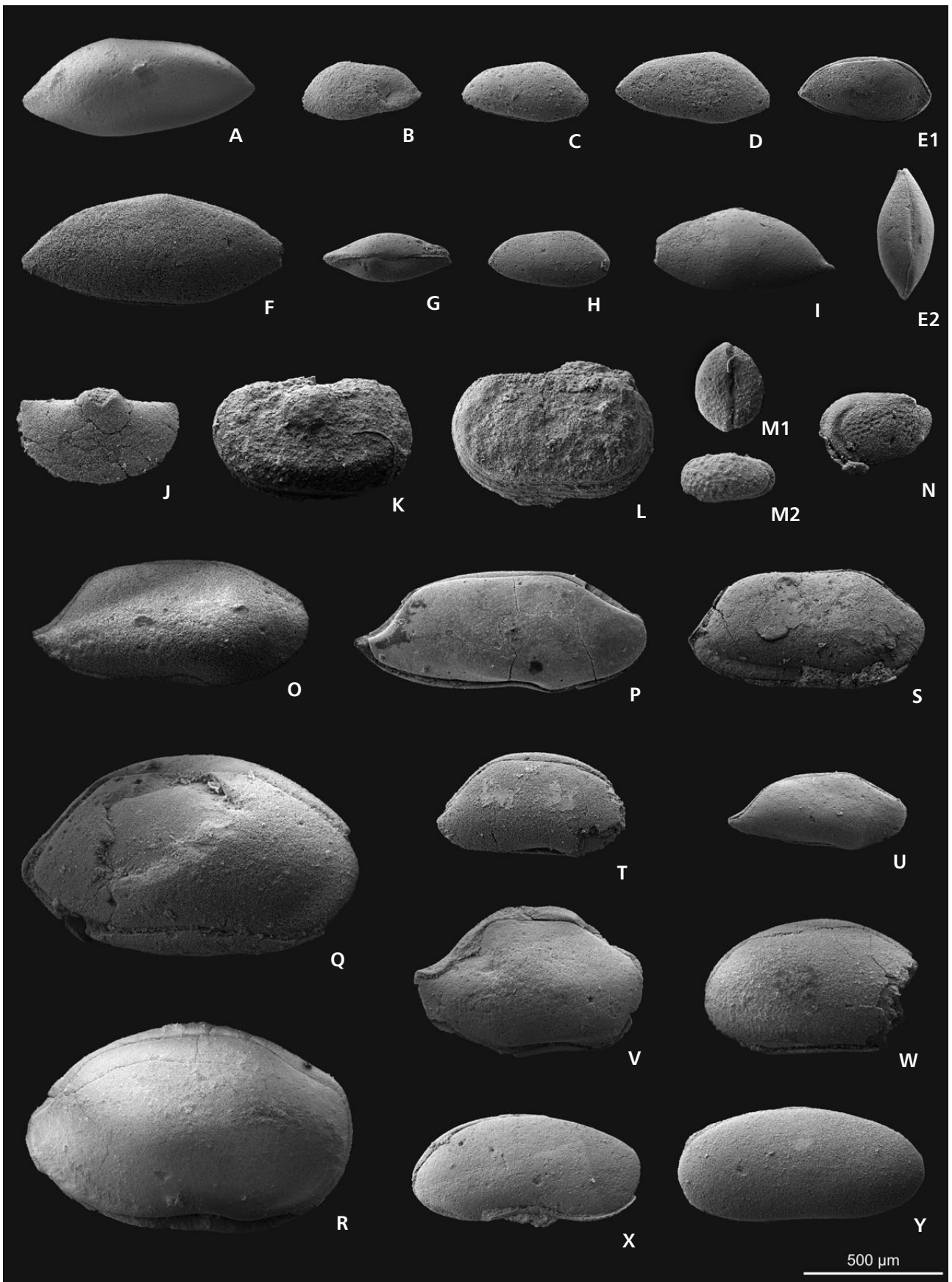
Holotype. – Adult carapace (C.O.U.L. 582), 494 µm in length; 296 µm in height and 269 µm in width (Figs 7A, 10).

Paratypes. – One juvenile carapace and two adult carapaces (C.O.U.L. 583, 585 and 587), 380 µm, 608 µm and 491 µm in length, 269 µm, 368 µm and 298 µm in height, respectively (Fig. 7B, D and F).

Type locality and type horizon. – Ardennes, Flohimont section, Fromelennes Fm., Flohimont Mb. (Middle Givetian).

Material. – 16 juvenile and adult carapaces.

Figure 4. Ostracods from the Fromelennes area. Abbreviations: CHL – Cul d’Houille section; FLO – Flohimont section; DV – dorsal view, VV – ventral view, lv – left valve, rv – right valve; MH – Mont d’Hairs Fm.; FRfl – Fromelennes Fm., Flohimont Mb.; FRmb – Fromelennes Fm., Moulin Boreux Mb.; FRfh – Fromelennes Fm., Fort Hulobiet Mb.; NSpa – Nismes Fm., Pont d’Avignon Mb. For the bed numbering, see Hubert & Pinte (2009) and Maillet *et al.* (2010, 2011). • A–H – *Acratia lucea* sp. nov.; A – holotype, CHL, 102’’a FRfl, lv, C.O.U.L. 501; B – paratype, CHL, 92’’bs, MH, lv, C.O.U.L. 502; C – CHL, 109’’c, FRfl, rv, C.O.U.L. 503; D – paratype, CHL, 190, FRfh, rv, C.O.U.L. 504; E1 – paratype, CHL, 109’’c, FRfl, lv; E2 – DV, C.O.U.L. 505; F – paratype, FLO, 130, FRfl, rv, C.O.U.L. 506; G – FLO, 113a, MH, VV, C.O.U.L. 507; H – CHL, 110’’b, FRfl, rv, C.O.U.L. 508. • I – *Acratia* sp. A, FLO, 113b, MH, rv, C.O.U.L. 509. • J – *Aechmina* sp. A, FLO, 120, FRfl, rv?, C.O.U.L. 510. • K – *Amphissites* aff. *parvulus* (Paeckelmann, 1913), FLO, 50’, FRfh, lv, C.O.U.L. 511. • L – *Amphissites* cf. *tener* Becker, 1964, CHL, 85’’st, MH, lv, C.O.U.L. 512. • M1 – *Ampuloides* sp.1 *sensu* Milhau, 1983, CHL, 92’’b, MH, rv; M2 – VV, C.O.U.L. 513. • N – *Asturiella* sp. A, FLO, 89’, NSpa, lv, C.O.U.L. 514. • O, P – *Bairdia paffrathensis* Kummerow, 1953; O – FLO, 126, FRfl, rv, C.O.U.L. 515; P – CHL, 179, FRfh, rv, C.O.U.L. 516. • Q – *Bairdia* cf. *plicatula* Polenova, 1952, CHL, 85’’, MH, rv, C.O.U.L. 517. • R – *Bairdia* cf. *siliklensis* Rozhdestvenskaya, 1962, FLO, 123, FRfl, rv, C.O.U.L. 518. • S – *Bairdia* sp. A, FLO, 102a, MH, rv, C.O.U.L. 519. • T – *Bairdia* sp. B, FLO, 90’, NSpa, rv, C.O.U.L. 520. • U – *Bairdia* sp. C, FLO, 124, FRfl, rv, C.O.U.L. 521. • V – *Bairdia* sp. *sensu* Coen, 1985, CHL, 207/208, FRfh, rv, C.O.U.L. 522. • W – *Bairdiacypris* aff. *breuxensis* Casier & Olempska, 2008, FLO, 89’, NSpa, rv, C.O.U.L. 523. • X – *Bairdiacypris* sp. A, CHL, 90’’, MH, rv, C.O.U.L. 524. • Y – *Bairdiacypris* sp. B, CHL, 215, MH, rv, C.O.U.L. 525.



Origin of name. – *Cristae*: from “*cristae*”, plural of *crista* (crest), alluding to the carapace ornamentation.

Diagnosis. – A questionable *Orthocypris*? with a smooth and suboval carapace and with a crista on the right valve running from the mid-dorsal to the posterodorsal area; right valves of adults sometimes with a second crista in the posteroventral area.

Description. – Ostracod with left valve slightly larger than right valve and with slight ventral overlap; smooth regular suboval carapace in lateral, dorsal and ventral views; L/H ratio about 1.5 to 1.8, L/W ratio about 1.8; maximal height located at mid-length; maximal length located at mid-height; right valve with a crista extending from a mid-dorsal to a posterodorsal area, particularly pronounced in juveniles; some right valves of adults with a second smaller crista running from the lower part of the mid-posterior area to the posteroventral area; in dorsal and ventral views, anterior and posterior margins form a regular circle bow; slightly bow-shaped projection of the left valve along the line of closure.

Remarks. – The assignment of the species to the genus *Orthocypris* is not without doubt, as the carapace is not very elongated. However, some other species of the genus such as *O. cicatricosa* Coen, 1985 share this feature.

The smaller crista on the right valve of adults can be interpreted either as sexual dimorphism or as ecomorphotypic ornamentation, but more specimens are necessary to test these hypotheses.

Comparison. – *O. ? cristae* sp. nov. is similar only to *O. cicatricosa* Coen, 1985 (Middle Givetian, Ardennes), which has also one crista, but orientated differently. Besides that, *O. ? cristae* differs from all others species of *Orthocypris* through its two cristae and by a less elongate carapace.

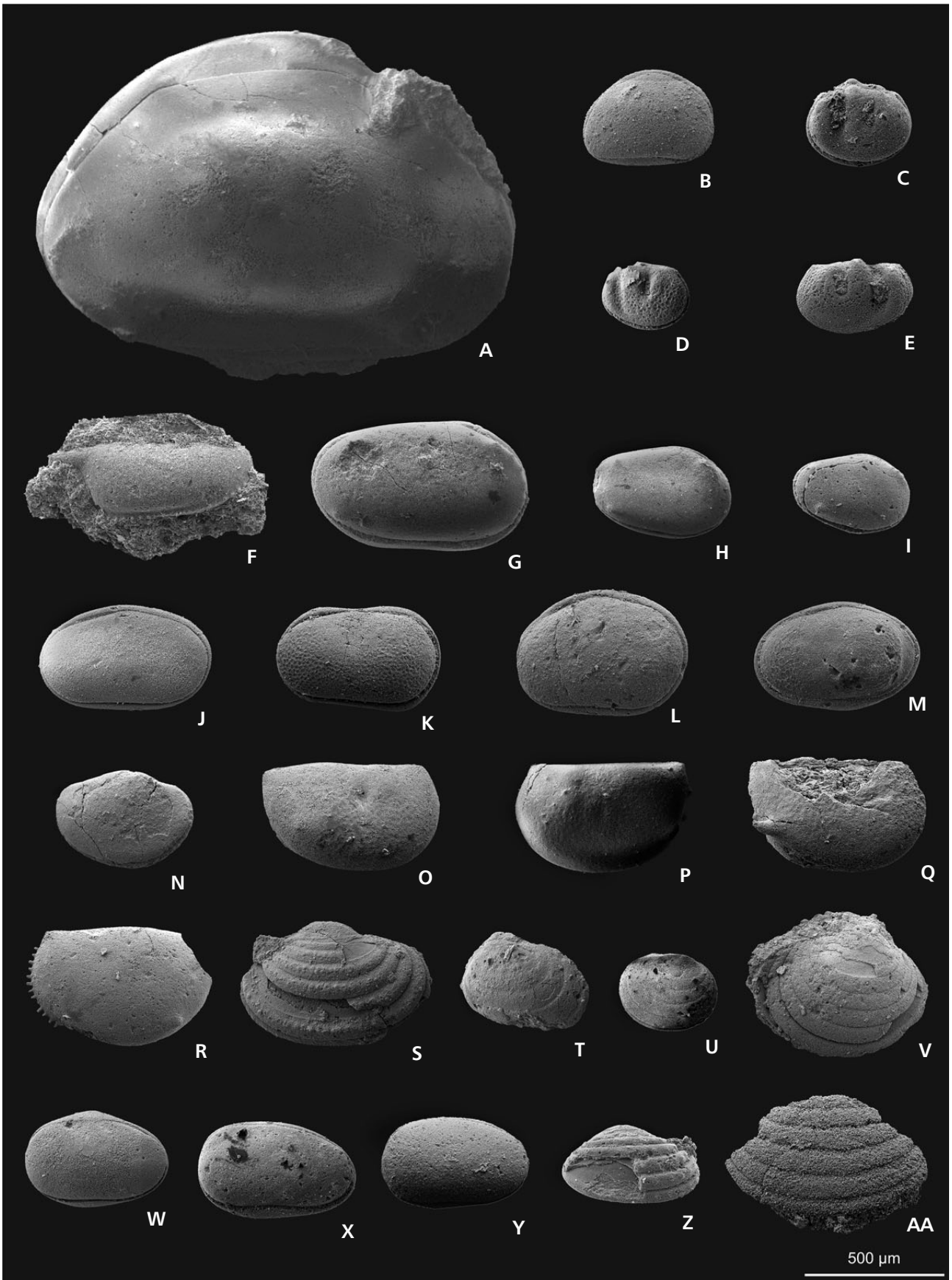
Occurrence. – *O. ? cristae* is present in the Ardennes in the upper part of the Mont d’Hairs Fm. and in the Fromelennes Fm. (Flohimont and Fort Hulobiet Mbs), and in the Boulonnais in the Blacourt Fm. (Coudrouse Mb). *O. ? cristae* ranges from the upper part of the lower *P. varcus* (*P. rhenanus*) to the *K. disparilis* zones of the standard conodont biozonation.

Stratigraphical distribution

The stratigraphical distribution of ostracods in the top of the Mont d’Hairs Fm. and in the Fromelennes Fm. shows two faunal intervals with distinctly different ostracod associations, both of which have high diversities (Fig. 11) (see below for a detailed description). The first one is found mainly in the deposits of the Middle Givetian Flohimont Mb. and the second one in the deposits of the Late Givetian Fort Hulobiet Mb. (Fig. 11). Inbetween these two intervals, the ostracods fauna has a low diversity and specimens are generally very rare, except for the top of the Moulin Boreux Mb. where several levels provided abundant *Cryptophyllus* sp. 3 *sensu* Magne, 1964. The two faunal intervals of high diversity correspond to the two major transgressive pulses in the Middle and the Late Givetian of the Givet area. The phase inbetween with low diversities and low numbers of individuals starts with a regressive pulse in the upper part of the Flohimont (Hubert & Pinte 2009, Maillet & Milhau 2010).

Therefore, this succession may be interpreted as phases of installation, stabilization and renewal of ostracod faunas during a major transgression-regression cycle as described by the sigmoid ranging concept of Devonian ostracods from platform sediments of Lethiers (1983a). The long time interval before the renewal of the fauna in the Late Givetian corresponds to sedimentary disturbances due to the Taghanic Biocrisis, during which fast alternations of T/R cycles resulted in very unstable environments (Préat & Carliez 1994; Boulvain & Coen-Aubert 1997;

Figure 5. Ostracods from the Fromelennes area. For explanation of the abbreviations and the bed numbering see the caption of Fig. 4. • A – *Bairdiocypris vastus* Polenova, 1952, CHL, 92’’bs, MH, rv, C.O.U.L. 526. • B – *Bairdiocypris* cf. *symmetrica* (Kummerow, 1953), CHL, 101’’st, MH, rv, C.O.U.L. 52. • C – *Balantoides brauni* (Becker, 1968), FLO, 112b, MH, lv, C.O.U.L. 528. • D – *Balantoides minimus* (Lethiers, 1970), CHL, 176, FRfh, lv, C.O.U.L. 529. • E – *Balantoides* sp. A, FLO, 114, FRfl, rv, C.O.U.L. 530. • F – *Baschkirina?* sp. indet., FLO, 112b, MH, rv, C.O.U.L. 531. • G, H – *Bufina* aff. *abbreviata* Peterson, 1966; G – FLO, 114a, FRfl, rv, C.O.U.L. 532; H – FLO, 113a, MH, rv, juvenile, C.O.U.L. 533. • I – *Bufina schaderthalensis* Zagora, 1968, FLO, 125, FRfl, rv, juvenile, C.O.U.L. 534. • J – *Cavellina devoniana* Egorov, 1950, FLO, 113c, MH, lv, C.O.U.L. 53. • K – *Cavellina rhenana* Krömmelbein, 1954, CHL, 181, FRfh, lv, female, C.O.U.L. 536. • L – *Cavellina* cf. *macella* Kummerow, 1953, CHL, 111’’a, FRfl, lv, C.O.U.L. 537. • M – *Cavellina* sp. II *sensu* Groos, 1969, FLO, 122, FRfl, lv, C.O.U.L. 538. • N – *Coeloenellina minima* (Kummerow, 1953), CHL, 85’’, MH, lv, C.O.U.L. 539. • O – *Coryellina cybaea* (Rozhdestvenskaya, 1959), FLO, MH, 108a, rv, C.O.U.L. 540. • P – *Coryellina* cf. *curta* (Rozhdestvenskaya, 1959), Flo, 112b, MH, lv, C.O.U.L. 541. • Q – *Coryellina?* sp. A, FLO, 106, MH, rv, C.O.U.L. 542. • R – *Coryellina?* sp. B, CHL, 178, FRfh, rv, C.O.U.L. 543. • S – *Cryptophyllus* aff. *materni* Bassler & Kellet, 1934, FLO, 89’, NSpa, rv?, C.O.U.L. 544. • T – *Cryptophyllus* sp. 3 *sensu* Magne, 1964, FLO, 146, FRmb, lv?, C.O.U.L. 545. • U – *Cryptophyllus* sp. G *sensu* Magne, 1964, FLO, 113a, MH, rv?, C.O.U.L. 546. • V – *Cryptophyllus* sp. B, CHL, 92’’a, MH, rv?, C.O.U.L. 547. • W – *Cytherellina obliqua* (Kummerow, 1953), FLO, 121, FRfl, rv, C.O.U.L. 548. • X – *Cytherellina* cf. *groosae* Coen, 1985, CHL, 109’’b, FRfl, rv, C.O.U.L. 549. • Y – *Cytherellina* cf. *perlonga* (Kummerow, 1953), CHL, 101’’, MH, rv, C.O.U.L. 550. • Z – *Eridoconcha?* cf. *granulifera* (Adamczak, 1961), FLO, 126, FRfl, lv?, C.O.U.L. 551. • AA – *Eridoconcha?* sp. A, FLO, 104c, MH, lv?, C.O.U.L. 552.



Coen-Aubert 2004; Pinte & Mistiaen 2009, 2010; Maillet & Milhau 2010; Brice *et al.* 2012). Regarding the lithology, the thickness and duration of the series is 140 m, encompassing Middle and Late Givetian (see Fig. 3) and therefore 3,5 to 4 Ma (Becker *et al.* 2012). The sedimentation rate does not vary significantly and can therefore be neglected as a factor influencing the diversity of the Fromelennes ostracods. A forthcoming publication will include analyzes and interpretation of the ostracod biodiversity pattern on the entire Givetian platform as regards global extinctions and regional to supraregional refuge areas during the Givetian bioevents.

The first of the two distinct ostracod faunas occurs from the top of the Mont d’Hairs Fm. almost up to the top of the Flohimont Mb. and therefore corresponds to the first major transgressive phase in the Givetian of the Ardennes. The faunal succession starts with a low diversity assemblage, which corresponds to the assemblage 1 of Milhau (1983a). Common species are benthic shallow water taxa belonging to the Eridostraca and Podocopina, with abundant *Coeloenellina minima* (Kummerow, 1953), *Bairdiocypris vastus* Polenova, 1952, *Bairdia paffrathensis* Kummerow, 1953 and *Microcheilinella cf. amaliae* Kummerow, 1953.

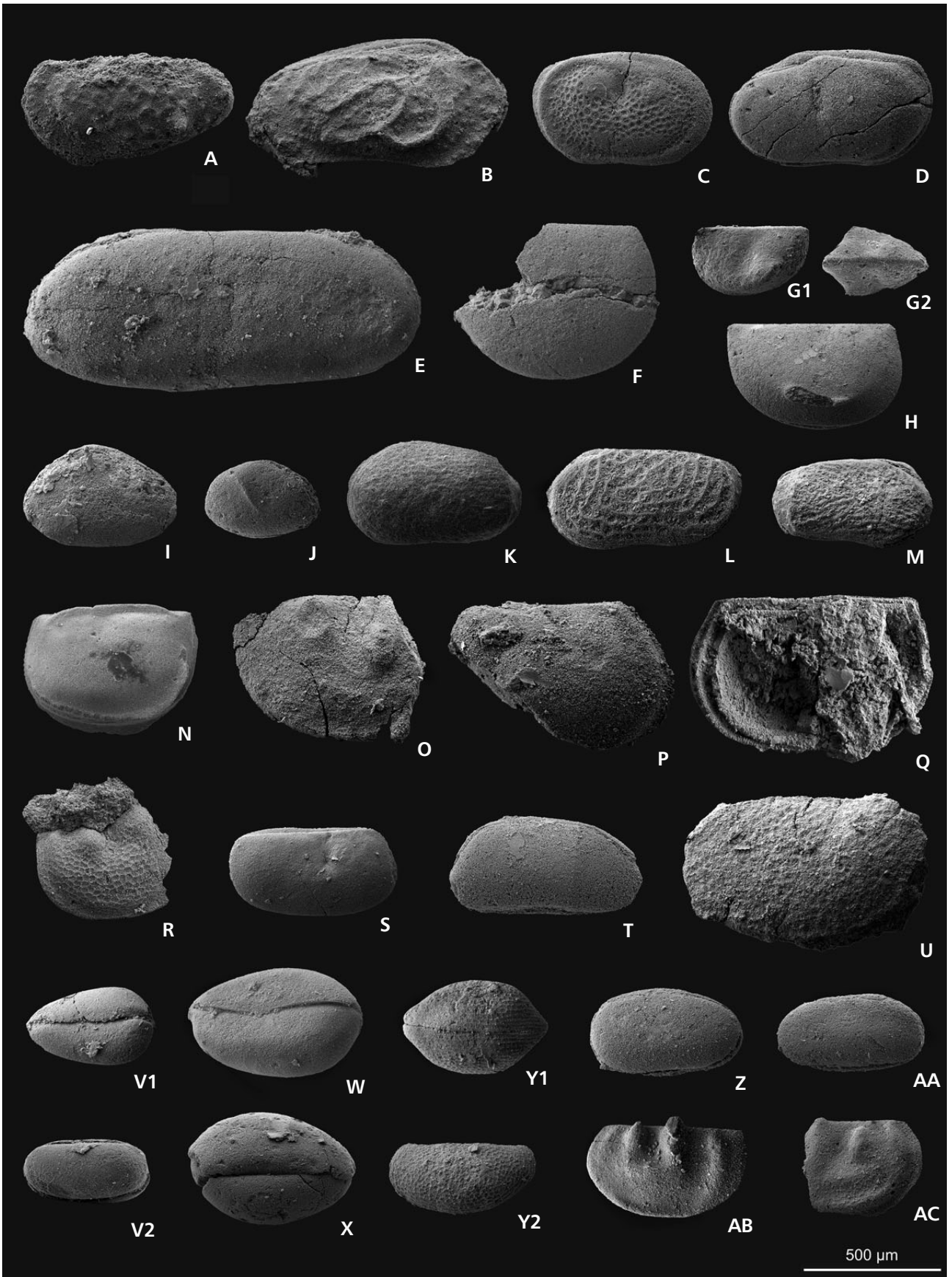
This first assemblage is then partly replaced and completed by species of the assemblage 2 of Milhau (*ibid.*), including Palaeocopina, Metacopina and Platycopina. *Quasillites fromelennensis* Milhau, 1983, *Poloniella tertia* Krömmelbein, 1953, *Balantoides brauni* (Becker, 1968), *Bufina aff. abbreviata* Peterson, 1966, *Jenningsina heddebauti* Milhau, 1983 and *Cavellina devoniana* Egorov, 1950 are the dominant species of this assemblage. The fauna is still a shallow water benthic community with taxa endemic to the Givetian platform, but the occurrence of many Metacopina associated with comparatively few thick-shelled Podocopina indicates an increase of the waterdepth. This deepening is also shown by the increase of ostracod diversity just above the first ten meters of the

studied series, from about 20 to more than 65 taxa (Fig. 11). Of these, 48 are already known in the Ardennes from the earliest Givetian onward, but most of them do not appear in the Mont d’Hairs Fm. because of perireefal environments with too shallow waterdepths. A sedimentation pattern with more argillaceous input and a general diversification of macro- and microfaunas of open marine environments (*e.g.* Hubert & Pinte 2009; Maillet *et al.* 2010, 2011) confirms the deepening. In the terms of Lethiers’ (1983a) ranging concept this increase in ostracod diversity can be interpreted as phase 1a: the installation of fauna A during the beginning of a transgression. This first phase is characterized by short ranging taxa such as *Ampuloides sp. 1 sensu* Milhau, 1983 or *Tubulibairdia sp. A*. Locally short ranging taxa in the sections are *e.g.* *Coelonellina minima* (Kummerow, 1953) or *Bairdia cf. siliklensis* Rozhdestvenskaya, 1962, but they are known from the earliest Givetian of the Ardennes onward and occur, due to the transgressive-regressive sequences, periodically in the series (see Casier *et al.* 2010b, 2011a, 2011b, 2013).

In the first half of the subsequent Flohimont Mb. only a few additional ostracod taxa appear. The fauna now matches entirely with the assemblage 2 of Milhau (1983a) and still contains typical Givetian species, such as *Quasillites fromelennensis* Milhau, 1983, *Coryellina cybaea* (Rozhdestvenskaya, 1959), *Bufina schaderthalensis* Zagora, 1968, *Kielciella arduennensis* Adamczak & Coen, 1992, *Balantoides brauni* (Becker, 1968), *Poloniella tertia* Krömmelbein, 1953, *Parabolbinella coeni* Casier, 2011 or *Jenningsina heddebauti* Milhau, 1983. Moreover, most of these taxa are endemic to the Givetian carbonate platform and show relatively long stratigraphical ranges.

We interpret this period as phase 2a of Lethiers’ ranging concept: the phase of stabilization, which took place during the maximum transgression and is characterised by high diversities and long ranging ostracod taxa. However, no sedimentological evidence for this maximum has been

Figure 6. Ostracods from the Fromelennes area. For explanation of the abbreviations and the bed numbering see the caption of Fig. 4. • A, B – *Euglyphella europaea* Coen, 1985; A – CHL, 166, FRfh, lv, juvenile, C.O.U.L. 553; B – FLO, 87’, FRfh, rv, C.O.U.L. 554. • C – *Evlanella germanica* Becker, 1964, CHL, 167, FRfh, rv, C.O.U.L. 555. • D – *Evlanella sulcellina* Becker, 1964, FLO, 58, FRfh, rv, C.O.U.L. 556. • E – *Fabalicypis?* sp. A, FLO, 63’, FRfh, lv, C.O.U.L. 557. • F – *Fellerites* sp. A, FLO, 113b, MH, C.O.U.L. 558. • G1 – *Gravia schallreuteri* (Becker, 1970b), FLO, 108b, MH, lv; G2 – DV, C.O.U.L. 559. • H – *Gravia?* sp. A, FLO, 112b, MH, rv, C.O.U.L. 560. • I – *Healdianella* sp. A, FLO, 90’, NSpa, rv, C.O.U.L. 561. • J – *Jefina cf. romei* Coen, 1985, FLO, 113b, MH, lv, C.O.U.L. 562. • K – *Jenningsina catenulata* (Van Pelt, 1933), FLO, 115, FRfl, lv, C.O.U.L. 563. • L – *Jenningsina heddebauti* Milhau, 1983, FLO, 126, FRfl, lv, C.O.U.L. 564. • M – *Jenningsina paffrathensis* Krömmelbein, 1954, FLO, 88’, FRfh, rv, C.O.U.L. 565. • N – *Kielciella arduennensis* Adamczak & Coen, 1992, FLO, 113, MH, lv, male, C.O.U.L. 566. • O – *Kozłowskiella boloniensis* Milhau, 1983, CHL, 109’’h, FRfl, rv, C.O.U.L. 567. • P, Q – *Kozłowskiella plana* (Kummerow, 1953); P – CHL, 189, FRfh, lv, C.O.U.L. 568; Q – *Kozłowskiella plana* (Kummerow, 1953), CHL, 189, FRfh, nested right valves, C.O.U.L. 569. • R – *Kozłowskiella?* sp. A, CHL, 109’’h, FRfl, rv?, C.O.U.L. 570. • S – *Knoxiiella* sp. 1 *sensu* Milhau, 1983, FLO, 112a, MH, rv, C.O.U.L. 571. • T, U – *Macrocypris?* sp. A, T – FLO, 60’, FRfh, rv?, C.O.U.L. 572; U – FLO, 129, FRfl, rv?, C.O.U.L. 573. • V1 – *Microcheilinella aff. ventrosa* Polenova, 1960, CHL, 91’’, MH, VV; V2 – rv, C.O.U.L. 574. • W – *Microcheilinella aff. amaliae* Kummerow, 1953, CHL, 92’’bs, MH, VV, C.O.U.L. 575. • X – *Microcheilinella cf. clava* (Kegel, 1932), CHL, 55/56, FRmb, DV, C.O.U.L. 576. • Y1 – *Microcheilinella* sp. B, FLO, 85’, FRfh, VV; Y2 – lv, C.O.U.L. 577. • Z – *Microcheilinella sp. sensu* Coen, 1985, FLO, 88’, FRfh, rv, C.O.U.L. 578. • AA – *Microcheilinella sp. B sensu* Casier & Préat, 1991, CHL, 178, FRfh, rv, C.O.U.L. 579. • AB – *Nodella faceta* Rozhdestvenskaya, 1972, CHL, 182, FRfh, lv, female, C.O.U.L. 580. • AC – *Nodella hamata* Becker, 1968, FLO, 89’, NSpa, rv, C.O.U.L. 581.



found in the lithology and it is not described in the literature to our knowledge. Regarding this fact and the general ostracod composition, which is not suspected to change much within a neritic shelf area below wave base, we assume that the deepening on the carbonate platform was only moderate.

In the upper part of the Flohimont Mb., the number of ostracod taxa significantly decreases, especially among the shallow water ostracods from the inner platform (Fig. 11). Some beds yielded a few Platycopina characteristic of semi-restricted environments (Eifelian assemblage I *sensu* Casier 2008) dominated *e.g.* by abundant *Cavellina devoniana* Egorov, 1950 and *Evlanella germanica* Becker, 1964; some beds are barren in ostracods. Due to its ostracod content, this part is interpreted as the phase 3a of Lethiers (1983a): the phase of extinction of fauna A, with a decrease of diversity due to a marine regression. The lithology of brachiopod-rich argillaceous limestones (Préat *et al.* 2006) reflects the regression only slightly with shaly intervals at the top of the Flohimont Mb., but the full extent of it is not seen lithologically before the Moulin Boreux Mb. with biostromal and massive cryptalgal limestones. However, the assumption of a regression beginning in the top of the Flohimont Mb. is corroborated by very abundant gastropods of semi-restricted environment and algae (indicating very shallow water) whereas other macro- and micro-faunas are rarer and have a low diversity (Maillet *et al.* 2010).

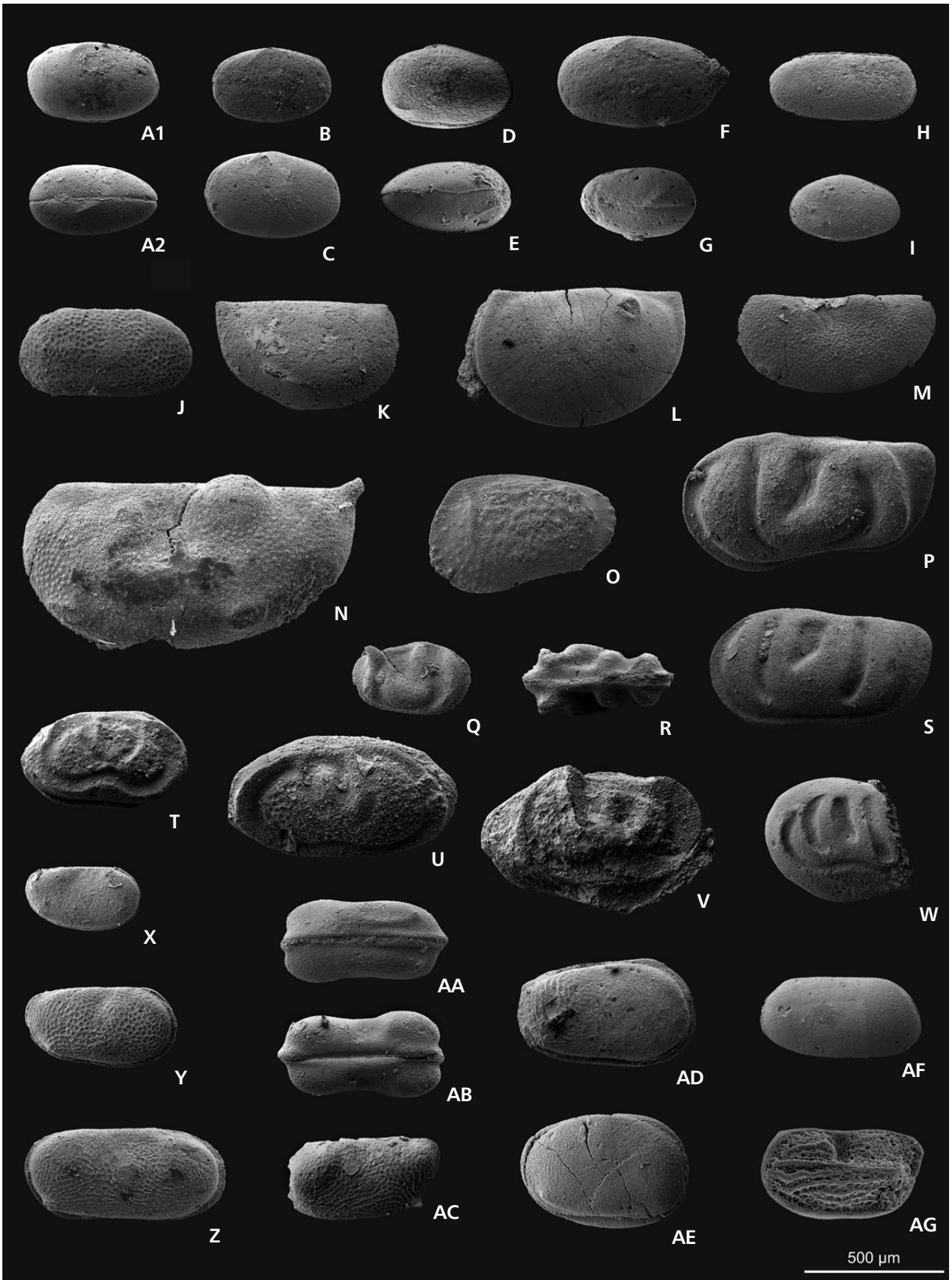
The topmost Flohimont Mb. and the subsequent strata of the entire Moulin Boreux Mb. are almost barren of ostracods as the area was situated in a semi-restricted back-reef environment (Préat & Carliez 1994). Other faunal elements except algae, rugose corals and stromatoporoids (Hubert & Pinte 2009, Maillet *et al.* 2011) are also rare, too. The rare and always badly preserved ostracods of the Moulin Boreux Mb. are bairdiids and microcheilinellids, which are typical

of fore-reef agitated environments (*e.g.* Becker 1971a, Casier 2008) and which are therefore allochthonous; no ostracods characterizing a back-reef facies have been found. Autochthonous faunas of semi-restricted environments occur only at the top of the Flohimont Mb. (see above) and in the uppermost part of the Moulin Boreux Mb. and consist of extremely rich but monospecific faunas of *Cryptophyllus* sp. 3 *sensu* Magne, 1964. In the Moulin Boreux Mb. they occur just before the onset of the characteristic Frasnian faunas. Similar accumulations are reported from the Blacourt Fm. in the Boulonnais (Magne 1964, Brice *et al.* 1976, Milhau 1988, Brice *et al.* 2012) and also from the base of the Famennian in Sinsin in the Ardennes (Casier & Devleeshouwer 1995). Consequently, *Cryptophyllus* sp. 3 can be considered as an opportunistic and pioneer species in disturbed environments.

The long absence of ostracods is not in correspondence with the ranging concept of Lethiers (1983a), which suggests the installation of a new fauna B immediately after the extinction of the fauna A (phase 3a), thus starting a new cycle (phase 1b). But the concept is based on undisturbed successions whereas in the sections studied herein, the consequences of the Taghanic Biocrisis, such as sea-level oscillations from back-reef to sebkha facies with some emersion phases, coupled with an increase of turbidity and salinity fluctuations (see Préat & Carliez 1994; Boulvain & Coen-Aubert 1997; Coen-Aubert 2004; Boulvain *et al.* 2009; Pinte & Mistiaen 2009, 2010; Maillet & Milhau 2010) hindered the installation of a new fauna. Moreover, numerous endemic species of the Givetian inner platform disappear around the Middle/Late Givetian boundary. More than 80% of the typical Givetian species have not been found in the younger strata of these sections, a phenomenon also known from the Boulonnais.

Not until the Fort Hulobiet Mb. does the progressive recovery and installation of a new ostracod fauna (phase 1b

Figure 7. Ostracods from the Fromelennes area. For explanation of the abbreviations and the bed numbering see the caption of Fig. 4. • A–G – *Orthocypris? cristae* sp. nov.: A1 – holotype, FLO, 130, FRfl, rv; A2 – DV, C.O.U.L. 582; B – paratype, CHL, 109''b, FRfl, rv, C.O.U.L. 583; C – CHL, 102''a, FRfl, rv, C.O.U.L. 584; D – paratype, FLO, 126, FRfl, rv, C.O.U.L. 585; E – paratype, FLO, 130, FRfl, VV, C.O.U.L. 586; F – paratype, FLO, 130, FRfl, rv, C.O.U.L. 587; G – paratype, FLO, 130, FRfl, DV, C.O.U.L. 588. • H – *Orthocypris* cf. *kummerowi* Zbikowska, 1983, FLO, 89', NSpa, rv, C.O.U.L. 589. • I – *Orthocypris cicatricosa* Coen, 1985, FLO, 113b, MH, rv, C.O.U.L. 590. • J – *Ovatoquasillites* cf. *nismesensis* Casier in Casier & Préat, 2009, FLO, 58', FRfh, lv, C.O.U.L. 591. • K – *Parapribylites hanaicus* Pokorný, 1951, FLO, 130, FRfl, rv, C.O.U.L. 592. • L – *Parapribylites* cf. *costatus* (Glebovskaya & Zaspelova, 1959), FLO, 111, MH, lv, C.O.U.L. 593. • M, N – *Parabolbinella coeni* Casier, 2011; M – FLO, 129, FRfl, rv, juvenile, C.O.U.L. 594; N – FLO, 125, FRfl, lv, C.O.U.L. 595. • O – *Plagionephrodes laqueus praelaqueus* Casier & Olempska, 2008, FLO, 88', FRfh, lv, C.O.U.L. 596. • P–R – *Poloniella tertia* Krömmelbein, 1953; P – FLO, 113b, MH, lv, female, C.O.U.L. 597; Q – FLO, 126, FRfl, rv, juvenile, C.O.U.L. 598; R – CHL, 99'', MH, DV, juvenile, C.O.U.L. 599. • S – *Poloniella claviformis* (Kummerow, 1953), FLO, 113b, MH, lv, C.O.U.L. 600. • T – *Polyzygia beckmanni antecedens* Zagora, 1968, FLO, 88', FRfh, lv, C.O.U.L. 601. • U, V – *Polyzygia beckmanni beckmanni* Krömmelbein, 1954; U – FLO, 90', NSpa, rv, elongated morph, C.O.U.L. 602; V – FLO, 90', NSpa, rv, stocky morph, C.O.U.L. 603. • W – *Polyzygia neodevonica* Matern, 1929, FLO, 90', NSpa, lv, C.O.U.L. 604. • X–AB – *Quasillites fromelennensis* Milhau, 1983; X – FLO, 114a, FRfl, rv, juvenile, C.O.U.L. 605; Y – FLO, 114b, MH, rv, male, C.O.U.L. 606; Z – FLO, 107, MH, rv, male, C.O.U.L. 607; AA – FLO, 113b, MH, DV, female, C.O.U.L. 608; AB – 1983, FLO, 113b, MH, VV, female, C.O.U.L. 609. • AC – *Quasillites?* sp. A, CHL, 109''h, FRfl, rv, C.O.U.L. 610. • AD – *Quasillites lecomptei* Coen, 1985, FLO, 119st, FRfl, rv, C.O.U.L. 611. • AE – *Quasillites* cf. *fromelennensis* Milhau, 1983, FLO, 40', FRfh, lv, C.O.U.L. 612. • AF – *Rectella trapezoides* Zaspelova, 1959, FLO, 57', FRfh, rv, C.O.U.L. 613. • AG – *Refrathella struvei* Becker, 1967, FLO, 130, FRfl, lv, C.O.U.L. 614.



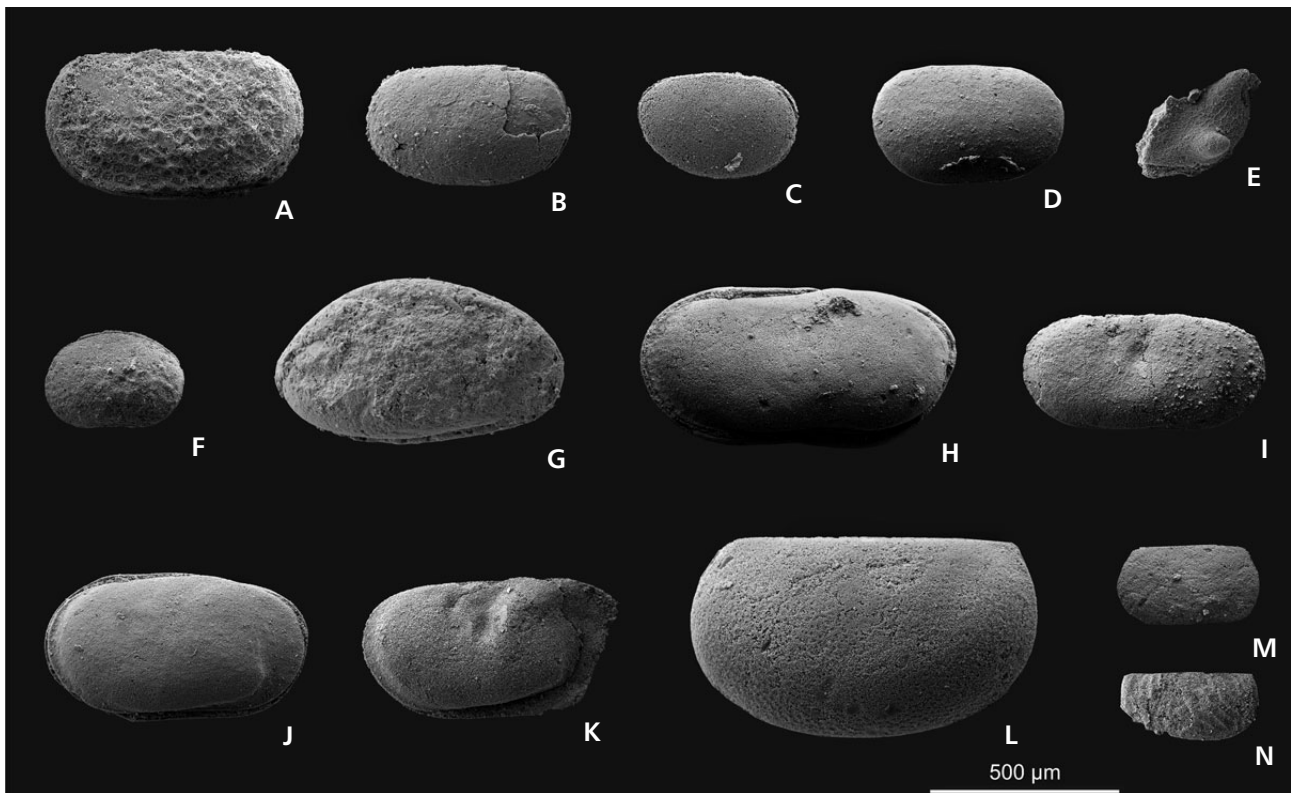


Figure 8. Ostracods from the Fromelennes area. For explanation of the abbreviations and the bed numbering see the caption of Fig. 4. • A – *Roundyella patagiata* (Becker, 1964), FLO, 49', FRfh, lv, C.O.U.L. 615. • B – *Roundyella?* sp. A, CHL, 209, FRfh, rv?, C.O.U.L. 616. • C – *Samarella* cf. *laevinodosa* Becker, 1964, FLO, 113b, MH, lv, C.O.U.L. 617. • D – *Scrobicula gracilis* Casier & Olempska, 2008, FLO, 88', FRfh, lv, C.O.U.L. 618. • E – *Semibolbina?* sp. A, CHL, 215, FRfh, fragment, C.O.U.L. 619. • F – *Silenites?* sp. A, CHL, 101'', MH, rv, C.O.U.L. 620. • G – *Tubulibairdia* sp. A, CHL, 100'', MH, rv, C.O.U.L. 621. • H – *Uchtovia abundans* Pokorný, 1951, FLO, 56', FRfh, lv, male, C.O.U.L. 622. • I – *Uchtovia materni* Becker, 1971, FLO, 89', NSpa, rv, C.O.U.L. 623. • J – *Uchtovia refrathensis* (Krömmelbein, 1954), FLO, 40', FRfh, lv, C.O.U.L. 624. • K – *Uchtovia?* sp. A, FLO, 115, FRfl, rv, C.O.U.L. 625. • L – *Urtella* cf. *adamczaki* Becker, 1970b, FLO, 124, FRfl, lv?, C.O.U.L. 626. • M – *Youngiella* sp. A, FLO, 105, MH, rv, C.O.U.L. 627. • N – *Youngiella* sp. 5 *sensu* Magne, 1964, FLO, 78', FRfh, rv, C.O.U.L. 628.

of Lethiers 1983a) take place, indicating the major transgression close to the Givetian/Frasnian boundary. After the long regressive phase with disturbed environments and the extinction of many endemic benthic ostracods, cosmopolitan species immigrate and recolonize the new habitats. As at the top of the Moulin Boreux Mb. with *Cryptophyllus* sp. 3, some beds at the base of the Fort Hulobiet Mb. are dominated by *Cavellina rhenana* Krömmelbein, 1954, suggesting the environment remains semi-restricted and quite unstable. Higher in the Fort Hulobiet Mb., the taxa already have a Frasnian character, such as *Plagionephrodes laqueus praelaqueus* Casier & Olempska, 2008, *Nodella faceta* Rozhdestvenskaya, 1972, *Jenningsina paffrathensis* Krömmelbein, 1954, *Uchtovia refrathensis* (Krömmelbein, 1954), *Euglyphella europaea* Coen, 1985, *Balanoides minimus* (Lethiers, 1970) and *Cryptophyllus* aff. *materni* Bassler & Kellett, 1934. The ostracod fauna corresponds to the third assemblage of Milhau (1983a). The occurrence of the geographically widespread *Polyzygia beckmanni beckmanni* Krömmelbein, 1954 confirms an age close to the Givetian/Frasnian boundary.

Stratigraphical markers

Four ostracod taxa of the Fromelennes Fm. show regional stratigraphic value as regards other areas in the Ardennes (Lethiers 1974, 1984; Milhau 1983a, 1983b; Coen 1985; Casier 1987, 2008; Casier & Prétat 1991, 2006, 2009) as well as the nearby Boulonnais (Magne 1964; Milhau 1983a, b, 1988; Lethiers 1982) and Eifel Hills (Krömmelbein 1954):

– *Orthocypris? cristae* sp. nov. is considered as a preliminary stratigraphical marker for the Middle to Late Givetian of the Givetian carbonate platform, as it has a range from the lower *P. varcus* Zone (Middle Givetian) and *K. disparilis* Zone (Late Givetian) and is reported in three localities of the Ardennes: the Flohimont and Cul d'Houille sections (Milhau 1983b, this paper), the Burnot section (Maillet 2010) and in the Late Givetian Blacourt Fm. (Milhau 1983a, 1988) in the Boulonnais area.

– *Kielciella arduennensis* Adamczak & Coen, 1992 is also a possible stratigraphical marker for the Middle and

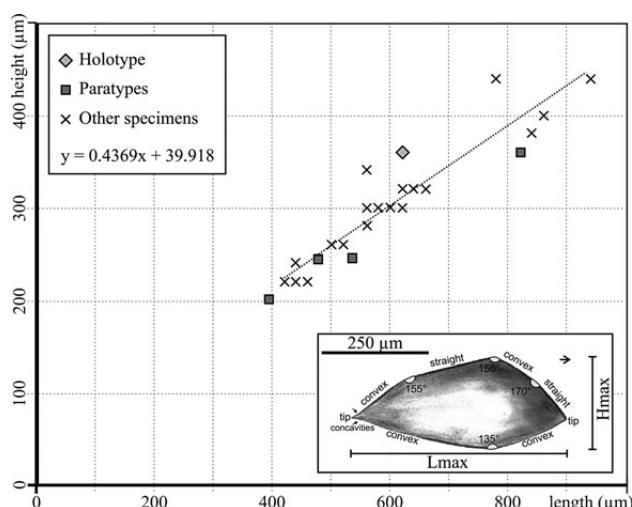


Figure 9. Height/length diagram for *Acratia lucea* sp. nov.

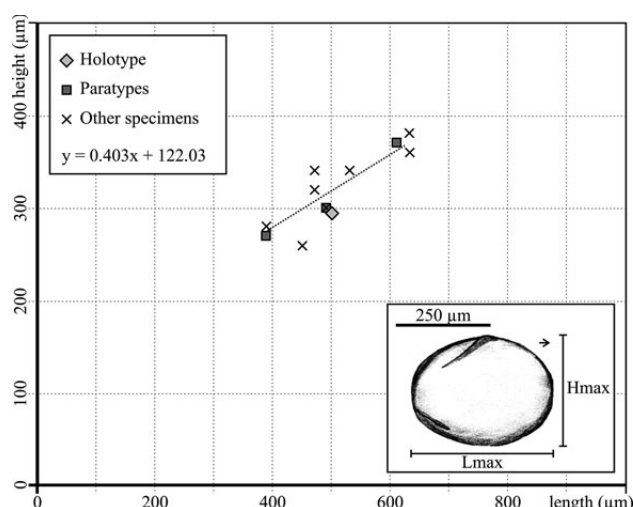


Figure 10. Height/length diagram for *Orthocypris? cristae* sp. nov.

Late Givetian of the Ardennes area within the Givetian carbonate platform. It is reported so far from the Flohimont section (Adamczak & Coen 1992, Coen 1985, this paper), the Cul d'Houille section (this paper) and the Burnot section (Maillet 2010).

– *Jefina kaisini* Coen, 1985 is known so far only from the Fromelennes Fm. (Coen 1985, this paper: Flohimont section and Cul d'Houille section) and is therefore considered as a preliminary stratigraphic marker in the region.

– *Cavellina rhenana* Krömmelbein, 1954 is a stratigraphical marker for the Late Givetian of the Rheno-Hercynian area with occurrences in the Boulonnais (Milhau 1988: top of the Blacourt Fm.), in the Eifel Hills (Krömmelbein 1954: upper Plattenkalk) and in the Ardennes (Milhau 1983a; Maillet 2010; Maillet *et al.* 2011, 2012; this paper: Fromelennes Fm., Fort Hulobiet Mb.).

Further studies on other sections are necessary to test the stratigraphical value of these species and to get more information on their local ranges.

Faunal relations and palaeogeographic implications

A comparison of the composition of the Givetian ostracods from the Fromelennes area with other Givetian ostracod records in Europe and northern Africa (Fig. 12) reflects distinctly the palaeogeography (Fig. 2). The faunal relationships with nearby areas on the Givetian platform (Préat & Mamet 1989) are close and confirm a distinctive faunal province during the Givetian. Naturally the relationships of shallow water taxa become weaker with increasing distance from the Ardennes, as are the areas around the Laurussian continent, the European terranes and northern Peri-Gondwana. However, there are still some common

species between all these regions (see below) showing the migration paths of benthic ostracods and, consequently, that the separating oceans must have been narrow and only moderately deep.

The closest faunal relations exist between the Ardennes and the Boulonnais (Ferques Massif) areas in France and the Eifel Hills, Bergisches Land and Sauerland areas in Germany (Fig. 12). This mirrors their close geographical positions in Givetian times on the same carbonate platform at the southern border of Laurussia (Fig. 2; Stampfli *et al.* 2002). These strong affinities between the Ardennes, the Boulonnais and the German Rhenish Slate Mountains have also been shown by Coen (1985). On a genus level, the Boulonnais shares about 72% (38/53 genera found in the Fromelennes area), and the German Rhenish Slate Mountains about 65% of the taxa (34/53 genera), with the Fromelennes area. On species level, the Boulonnais has the closest relations with about 43% (49/113 species) of common ostracods (Magne 1964; Lethiers 1970, 1982; Milhau 1983a, b, 1988; Coen 1985). The German Rhenish Slate Mountains shares about 38% (43/113 species) of ostracod species (Kummerow 1953; Becker 1964, 1965a, b, 1967, 1968a, b, 1969, 1970, 1971a; Groos 1969) with the studied area (Fig. 12). Endemic taxa in the Rheno-Hercynian area such as *Acratia lucea* sp. nov., *Balantoides brauni* (Becker, 1968), *Cavellina rhenana* Krömmelbein, 1954, *Cryptophyllus* sp. 3 *sensu* Magne, 1964, *Cytherellina obliqua* (Kummerow, 1953), *Euglyphella europaea* Coen, 1985, *Evlanella germanica* Becker, 1964, *Jenningsina heddebauti* Milhau, 1983, *Kozłowskiella boloniensis* Milhau, 1983, *Orthocypris cicatricosa* Coen, 1985, *Orthocypris? cristae* sp. nov., *Parabolbinella coeni* Casier, 2011, *Quasillites fromelennensis* Milhau, 1983, *Quasillites lecomptei* Coen, 1985, *Roundyella patagiata* (Becker, 1964), *Uchtovia materni*

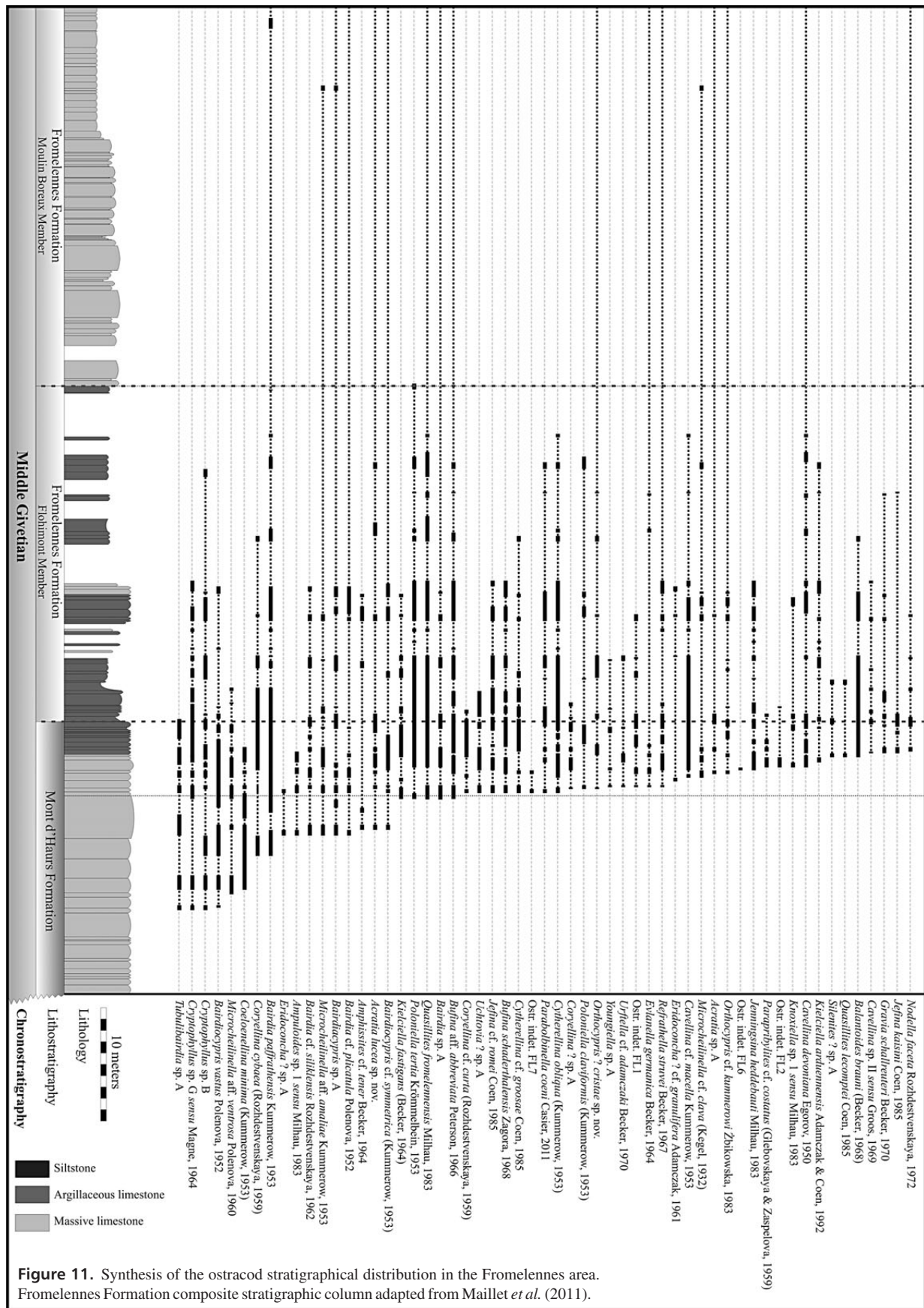


Figure 11. Synthesis of the ostracod stratigraphical distribution in the Fromelenes area. Fromelenes Formation composite stratigraphic column adapted from Mailliet *et al.* (2011).

A

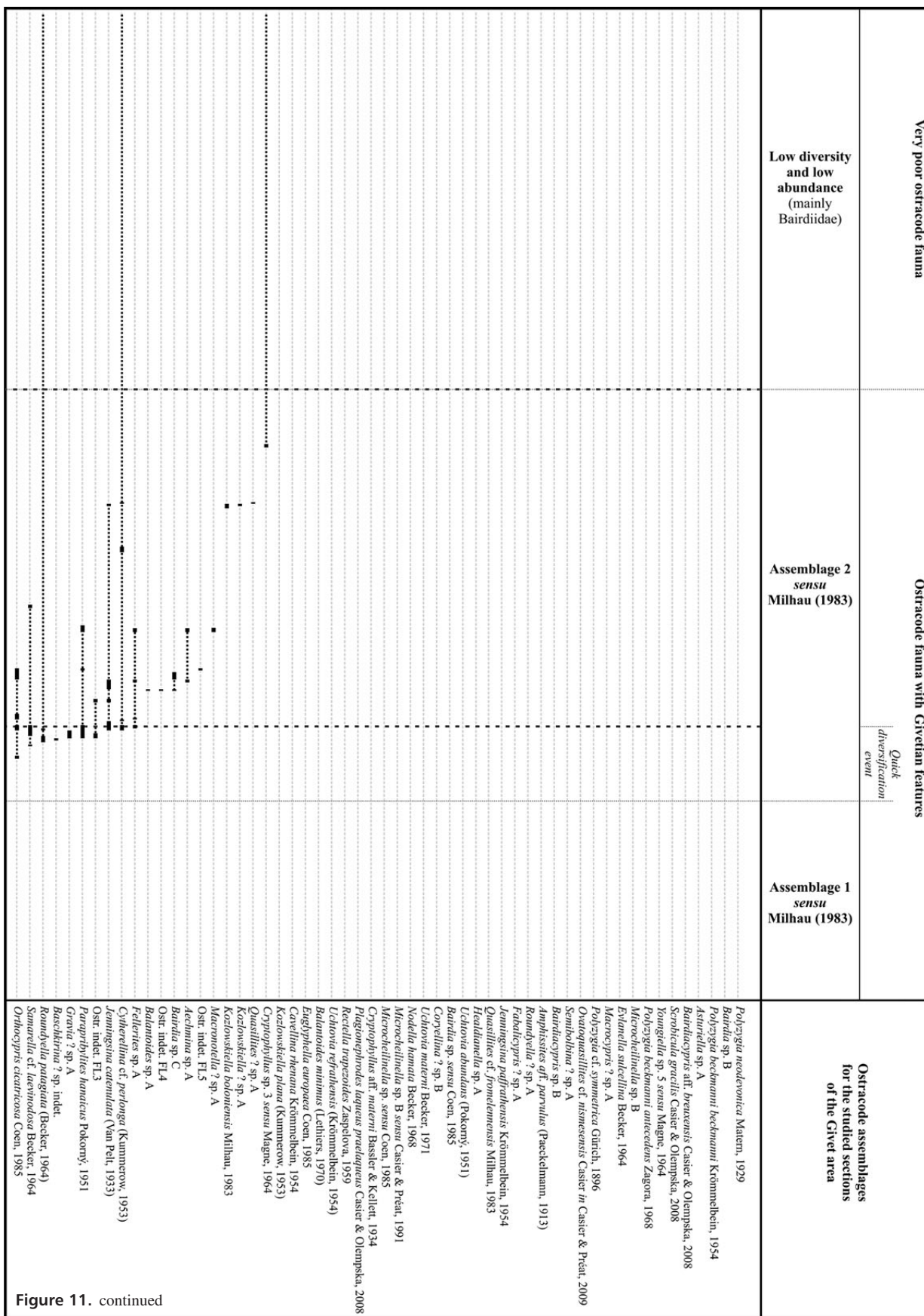


Figure 11. continued

B

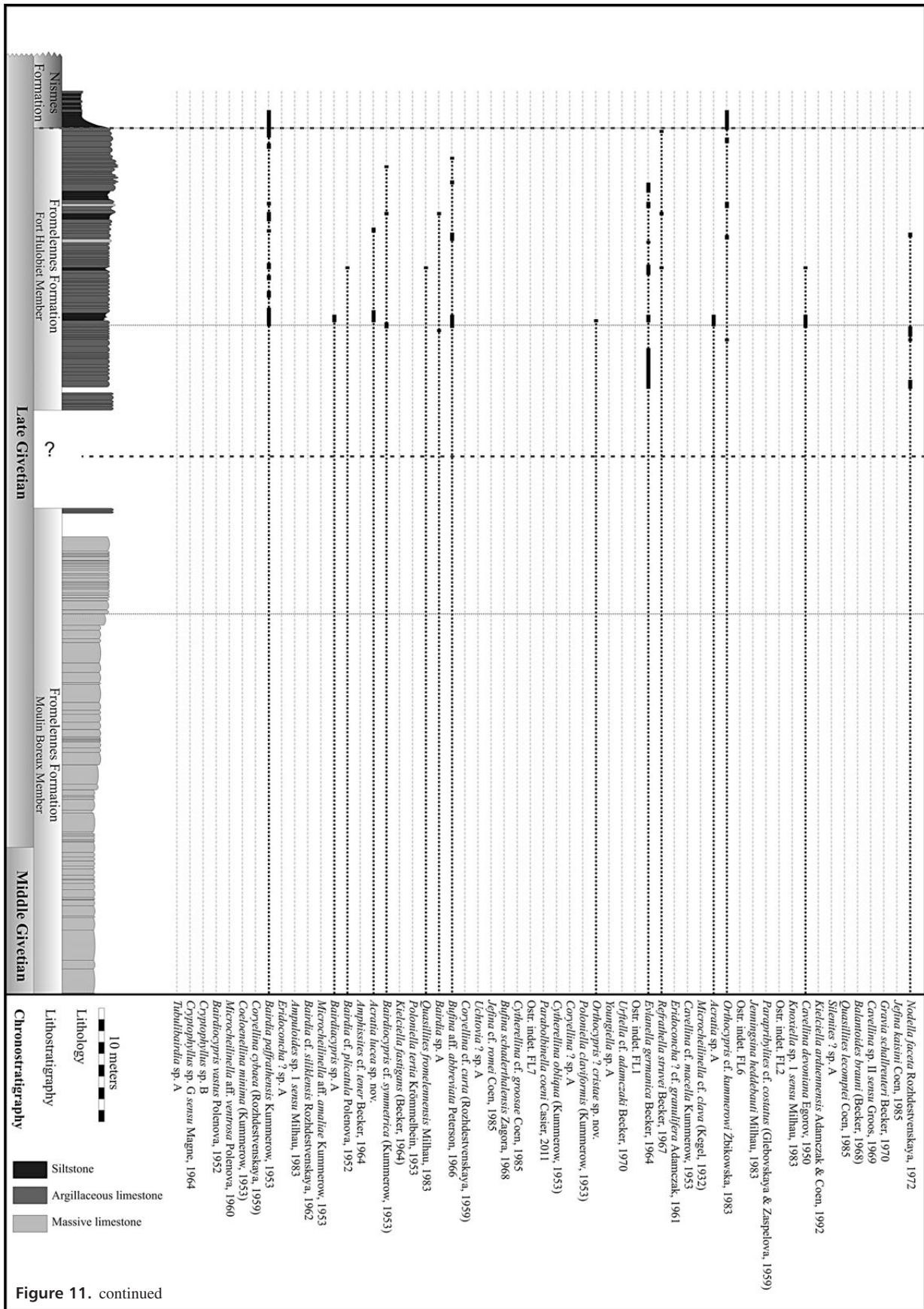


Figure 11. continued

C

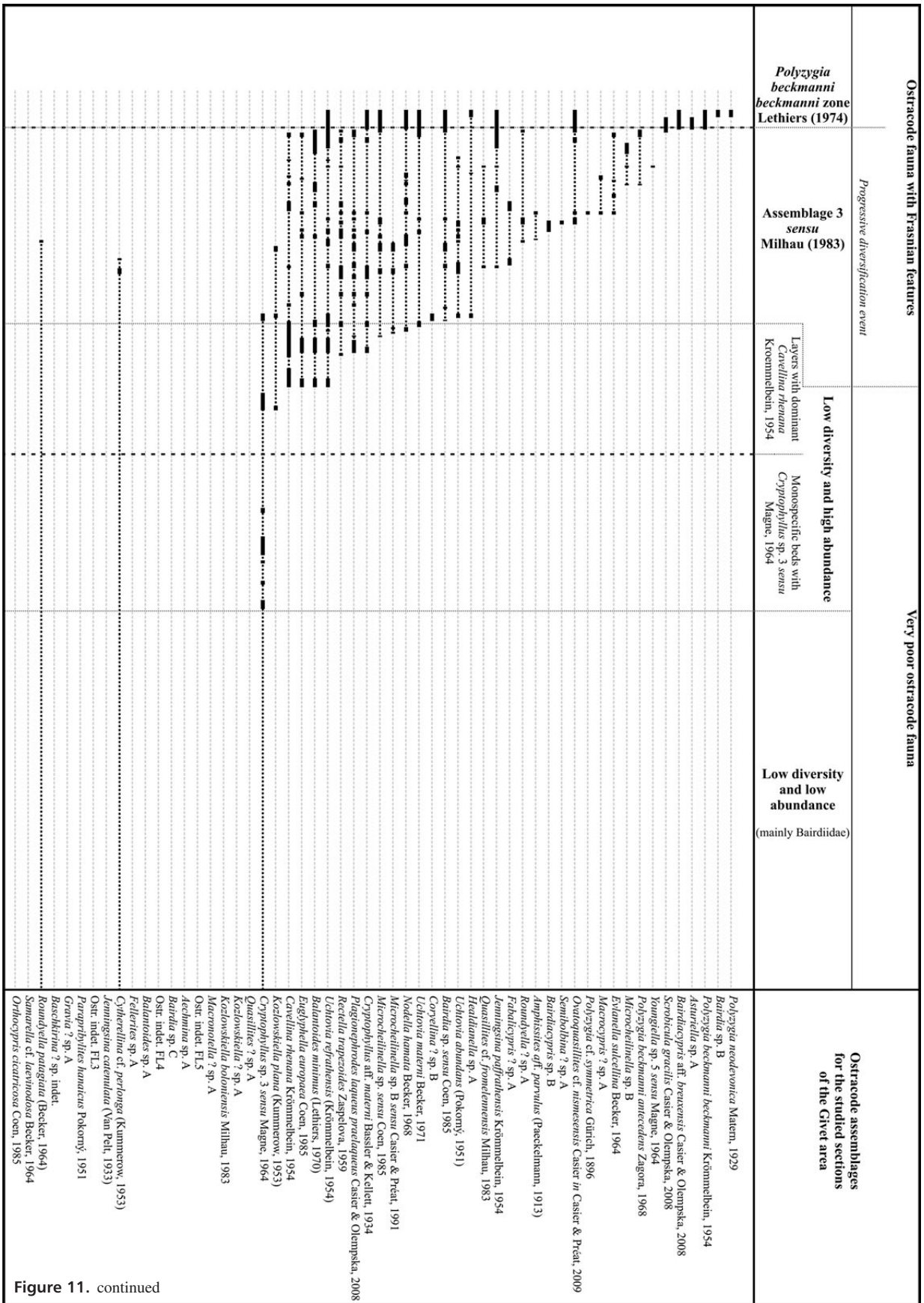


Figure 11. continued

D

Becker, 1971 or *Urftella adamczaki* Becker, 1970 corroborate the palaeogeographic proximity.

The ostracod fauna of the Holy Cross Mountains (Příbyl 1953; Adamczak 1968, 1976; Zagora 1968; Olempska 1979; Żbikowska 1983; Malec & Racki 1993) shows also a close relation to the Ardennes with nearly 75% of shared genera, which corroborates the position of both areas on the same platform. On a species level, however, not even a quarter of the taxa occur in both regions, reflecting the long palaeogeographic distances between the areas (Fig. 2). Species only known from the Rhenish area and Poland are *Samarella* cf. *laevinodosa* Becker, 1964, *Uchtovia abundans* (Pokorný, 1951), *Bufina schaderthalensis* Zagora, 1968 or *Coelonellina minima* (Kummerow, 1953), whereas *Bairdia paffrathensis* Kummerow, 1953, *Bairdiocypris vastus* Polenova, 1952 or *Cavellina devoniana* Egorov, 1950 are more cosmopolitan.

Givetian ostracods described in the Volga and Ural areas in Russia (Egorov 1950, 1953; Polenova 1952, 1953, 1960; Zaspelova 1952, 1959; Rozhdestvenskaya 1959, 1962, 1972) show only a vague relationship with the Fromelennes area. Less than a quarter of taxa are shared at both genus and species levels (Fig. 12), which indicates the greater palaeogeographic distance to the Ardennes.

The European Terranes including the areas of Cantabria (Asturias, Leòn), the Armorican Massif, the Montagne Noire and the Mouthoumet Massif (France) were situated during the Givetian inbetween the large continents of Laurussia and Gondwana (Fig. 2; Stampfli *et al.* 2002). Due to the palaeoecological barriers, the faunal relationships of benthic ostracods are not very close but they still existed. By comparison with the other areas of the European Terranes, the ostracods of the Montagne Noire (Casier & Pr  at 1996, 2007) show so far the closest relations to the Fromelennes area: about 34% of the genera are common in both areas, but only three species are shared (Fig. 12). As regards Asturias-Leòn, the Armorican Massif and the Mouthoumet Massif, the database is insufficient to compare the faunal inventory as only a few Givetian ostracods have been reported (Becker 1988, Bessiere & Lethiers 1985, Lethiers & Racheboeuf 1993, Michel 1972, Milhau 1996).

Several Middle Devonian ostracods of Bohemia are described by Pokorný (1951), Příbyl (1951) and Šlechta (1996), but only 4 species and 13 genera are common with the studied area, and moreover these are widespread and long-ranging taxa within the Devonian. These vague relationships might either be the result of missing data or they could support the hypothesis of an independent Bohemian Terrane (Perunica; cf. Cocks & Torsvic 2006).

Givetian ostracods from the shallow sea deposits around Gondwana are known from three localities: Milhau (1996) and Casier *et al.* (2010a) reported faunas from the Tafilalt (Morocco), Casier & Pr  at (1997) studied faunas from the north-western Meseta in Morocco and Le F  vre

(1963, 1971) as well as Casier (1983, 1985, 1986) described ostracods from Ougarta (Algeria). The Tafilalt has about 38% of common genera with the Fromelennes area (20/53 genera found in the Fromelennes area are shared), but only *Polyzygia beckmanni beckmanni* Kr  mmelbein, 1954, *Polyzygia neodevonica* Matern, 1929, *Polyzygia symmetrica* G  rich, 1896, *Jenningsina catenulata* (Van Pelt, 1933) and *Refrathella struvei* Becker, 1967 are shared species. The north-western Meseta has about 50% of common genera (27/53 genera) with the Fromelennes area, but only 10% of common species [11(+3?)/113]. The Ougarta area has about 26% of common genera (14/53 genera are shared) with the Fromelennes area and shares only *Cytherellina* cf. *perlonga* (Kummerow, 1953) and *Polyzygia neodevonica* G  rich, 1896 on a species level. But, the stratigraphically important species of *Polyzygia* corroborate the faunal exchange between the shallow marine areas of the Givetian platform in the south of Laurussia and the shelf areas of the north of Gondwana (see *e.g.* Michel 1972; Lethiers 1982, 1983b; Dojen *et al.* 2010).

Discussion

The composition of the ostracod faunas from the Fromelennes area shows major changes from the Middle to the Late Givetian, which are most probably closely related to the major transgressions and to the global Taghanic Biocrisis.

With the first Middle Givetian transgression from the top of the Mont d'Hours Fm. to the beginning of the Flohimont Mb., a typical Givetian benthic ostracod fauna with many endemic species and with close relationships to other faunas on the Givetian platform is present. Many of these open-marine taxa of this Givetian fauna are known from the earliest Givetian and reappear at each transgressive pulse (*e.g.*, Casier *et al.* 2010b, 2011a, b, 2013). Accordingly, the semi-restricted taxa of this Givetian fauna reappear during the regressive phases until the beginning of the Taghanic Biocrisis.

Due to the Taghanic Biocrisis which is related to stressful environments of rapid sea-level oscillations, turbidity and salinity variations, many Givetian taxa of the inner platform (especially endemic ones) disappear. Many species (80%) have their last occurrence at least within the Rheno-Hercynian zone, probably even globally. By contrast, euhaline and open-marine generalists belonging to the Bairdiidae (Casier 1987, 2008), some opportunistic Platycopina and also some Metacopina living in deeper environments (*ibid.*), persist until the latest Givetian. However, the strata of the Moulin Boreux Mb. (late Middle Givetian to earliest Late Givetian) are almost barren of ostracods. As for other marine faunas (*e.g.* May 1995, House 2002, Aboussalam 2003, Baird & Brett 2008, Aboussalam & Becker 2011) the Taghanic Biocrisis leads

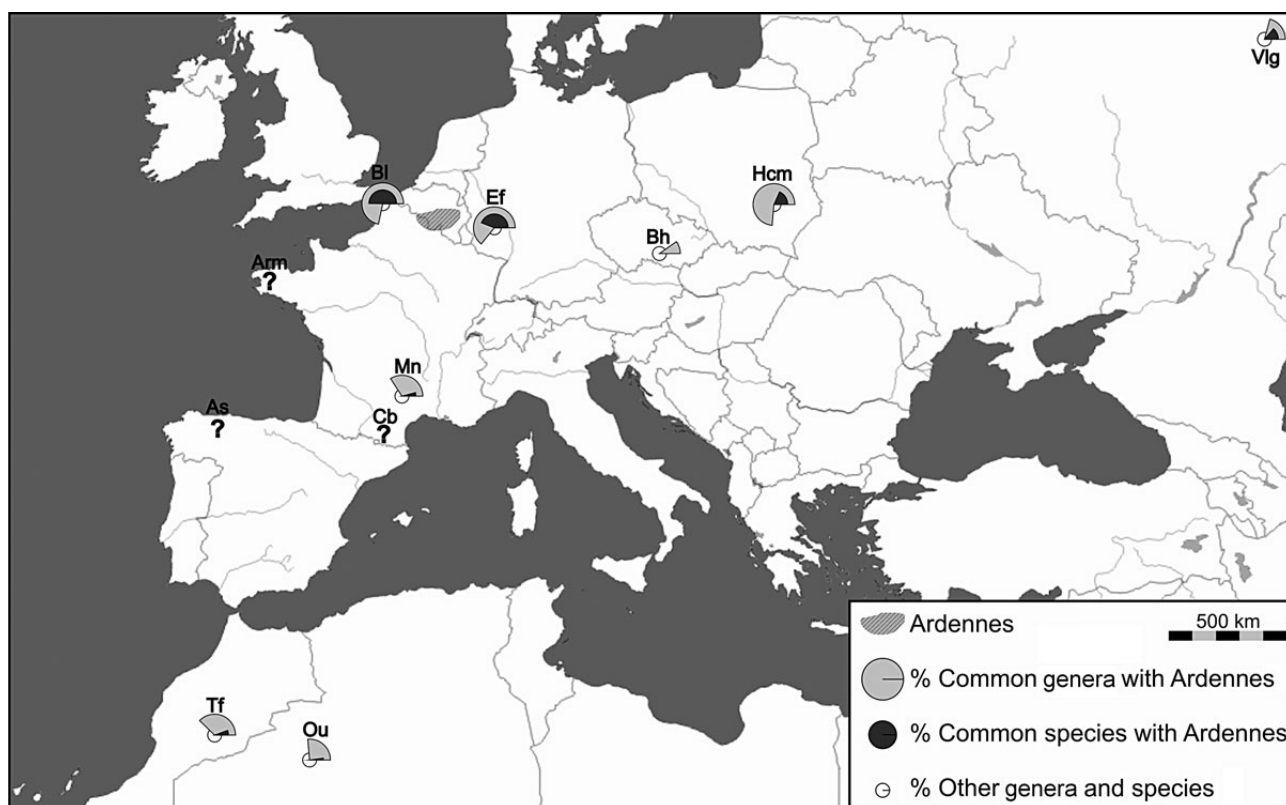


Figure 12. Faunal affinities with other places in Europe and northern Africa. Abbreviations: Arm – Armorican Massif; As – Asturias; Bh – Bohemian Massif; Bl – Boulonnais; Cb – Mouthoumet Massif; Ef – Eifel Hills, Sauerland and Bergisches Land; Hcm – Holy Cross Mountains; Mn – Montagne Noire; Ou – Ougarta; Tf – Tafalalt; Vl – Volga-Ural.

to a reduction in provincialism among the benthic ostracod community. Due to the Givetian/Frasnian transgression and the subsequent drowning of the Givetian carbonate platform (Boulvain *et al.* 2009) the geographical barriers are removed and more cosmopolitan ostracod taxa can now immigrate in the Late Givetian (Lethiers 1983b). This new fauna shows Frasnian affinities as it yields only a few typical Givetian taxa but many ostracods which have their acme in the Frasnian, such as *Polyzygia beckmanni* Krömmelbein, 1954, *Polyzygia neodevonica* Matern, 1929, *Scrobicula gracilis* Casier & Olempska, 2008 and *Uchtovia materni* Becker, 1971. This change in the faunal composition is possibly amplified by the climate becoming more arid at the end of the Givetian (Marshall *et al.* 2011, Casier *et al.* 2013), which causes warmer water temperatures, an increase in continental erosion and therefore a higher detrital influx to the shelf (Boulvain *et al.* 2009).

Our own studies (unpublished) indicate that the disappearance of “Givetian” benthic ostracod faunas during the Middle and Late Givetian and their replacement by “Frasnian” faunas by the end of the Givetian can also be found in other sections of the Ardennes and in Algeria (Saoura). Moreover, the comparison of Devonian faunas

described from the Boulonnais, Germany, Poland and Algeria also show a different composition of “Givetian” and “Frasnian” faunas. Due to insufficient data, it cannot be proven if the faunal replacement commenced by the Late Givetian in all these areas. But, it can be said due to the correlation of dating and palaeogeography it is most likely a supraregional or even a global phenomenon linked to the Taghanic Biocrisis and the Givetian-Frasnian sea level rise.

Conclusions

The composition of the benthic ostracod faunas from the Ardennes significantly changed in the period between the Middle and the Late Givetian. This change is most probably a consequence of the global Taghanic Biocrisis and of the sea level rise close to the Givetian/Frasnian boundary, which caused the disappearance of the endemic Givetian fauna during the Middle and Late Givetian and its replacement by a more cosmopolitan fauna with Frasnian affinities as early as the latest Givetian. The influence of the sea level rise is possibly amplified by the climate change at the end of the Givetian.

This pattern of disappearance in the Middle Givetian related to the Taghanic Biocrisis and the replacement of the

fauna in the Late Givetian during the beginning of the Givetian/Frasnian boundary transgression is clearly a supraregional phenomenon. Detailed studies on other areas exposing the Middle/Late Givetian time period are needed to confirm a possible global pattern.

Orthocypris? cristae sp. nov. and *Kielciella arduennensis* Adamczak & Coen, 1992 are considered as stratigraphical markers for the Middle to Late Givetian of the Givetian platform. *Cavellina rhenana* Krömmelbein, 1954 occurs only in the Late Givetian of the Rheno-Hercynian area and *Jefina kaisini* Coen, 1985 is a regional marker for the Fromelennes Fm.

A Middle/Late Givetian faunal province on the carbonate platform of the northern Rhenohercynian margin is confirmed by close relationships between the ostracod taxa from the Ardennes and those from the Boulonnais (France), the other areas of the Rhenish Massif (e.g. Eifel Hills in Germany) and the Holy Cross Mountains (Poland). Faunal interactions during the Givetian also exist between this platform, the European Terranes (e.g. Armorica, Iberia) and the northern margin of Gondwana, suggesting the existence of narrow oceans between these continents.

Acknowledgments

This paper is a contribution to IGCP 596 “Climate change and biodiversity patterns in the Mid-Palaeozoic”. We appreciate the assistance of P. Deville (Laboratoire de Paléontologie Stratigraphique FLST/ISA, Lille) in the field and for hot acetolysis. We are also particularly grateful to J.-P. Nicollin (Laboratoire de Paléontologie Stratigraphique FLST/ISA, Lille) and to V. Perrier (University of Leicester) for their advice and help to improve the manuscript and to P. Recourt (Université Lille 1 Sciences et Technologies) for the ESEM micrographs. Thanks go to C.E. Bennett (University of Leicester) and A. Lord (Senckenberg Institute, Frankfurt) for their help to improve the English language of the manuscript. Thanks to the Institut Catholique de Lille for the financial support of this project. We also thank the Office National des Forêts (O.N.F.), the Conservatoire des Espaces Naturels de Champagne-Ardenne (C.E.N.C.A.) and the Ardennes prefecture for the sampling authorizations in the Pointe de Givet reserve, as well as the Fromelennes town council and the residents living near outcrops, and particularly M. Vigneron, owner of the Nichet caves. Finally, we would like to thank J.-G. Casier (Institut Royal des Sciences Naturelles de Belgique, Bruxelles) and C. Klug (Paleontological Institute and Museum, University of Zurich, Switzerland) for reviewing the manuscript.

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Appendix 1. Systematic position of ostracodes taxa from the Fromelennes area.

- Class Ostracoda Latreille, 1802
- Suborder Eridostracina Adamczak, 1961
- Family Cryptophyllidae Adamczak, 1961
- Cryptophyllus* aff. *materni* Bassler & Kellett, 1934 (Fig. 5S)
- Cryptophyllus* sp. 3 *sensu* Magne, 1964 (Fig. 5T)
- Cryptophyllus* sp. G *sensu* Magne, 1964 (Fig. 5U)
- Cryptophyllus* sp. B (Fig. 5V)
- Eridoconcha?* cf. *granulifera* Adamczak, 1961 (Fig. 5Z)
- Eridoconcha?* sp. A (Fig. 5AA)
- Order Palaeocopida Henningsmoen, 1953
- Suborder Palaeocopina Henningsmoen, 1953
- Superfamily Beyrichioidea Matthew, 1886
- Family Beyrichiidae Matthew, 1886
- Kozłowskiella boloniensis* Milhau, 1983 (Fig. 6O)
- Kozłowskiella plana* (Kummerow, 1953) (Fig. 6P, Q)
- Kozłowskiella?* sp. A (Fig. 6R)
- Superfamily Aparchitoidea Jones, 1901
- Family Rozhdestvenskayitidae McGill, 1966
- Fellerites* sp. A (Fig. 6F)
- Family Aparchitidae Jones, 1901
- Macronotella?* sp. A (Fig. 6U)
- Superfamily Drepanelloidea Ulrich & Bassler, 1923
- Family Aechminellidae Sohn, 1961
- Balantoides brauni* (Becker, 1968) (Fig. 5C)
- Balantoides minimus* (Lethiers, 1970) (Fig. 5D)
- Balantoides* sp. A (Fig. 5E)
- Superfamily Nodelloidea Becker, 1968
- Family Nodellidae Zaspelova, 1952
- Nodella faceta* Rozhdestvenskaya, 1972 (Fig. 6AB)
- Nodella hamata* Becker, 1968 (Fig. 6AC)
- Superfamily Aechminacea Bouček, 1936
- Family Aechminidae Bouček, 1936
- Aechmina* sp. A (Fig. 4J)
- Superfamily Hollinoidea Swartz, 1936
- Family Hollinidae Swartz, 1936
- Subfamily Falsipollicinae Bless & Jordan, 1971
- Parabolbinella coeni* Casier, 2011 (*in* Casier et al. 2011a) (Fig. 7M, N)
- Semibolbina?* sp. A (Fig. 8E)
- Superfamily Kirkbyoidea Ulrich & Bassler, 1906
- Family Kirkbyellidae Sohn, 1961
- Refrathella struvei* Becker, 1967 (Fig. 7AG)
- Family Amphissitidae Knight, 1928
- Amphissites* aff. *parvulus* (Paeckelmann, 1913) (Fig. 4K)
- Amphissites* cf. *tener* Becker, 1964 (Fig. 4L)
- Family Scrobiculidae Posner, 1951
- Scrobicula gracilis* Casier & Olempska, 2008 (Fig. 8D)
- Roundyella patagiata* (Becker, 1964) (Fig. 8A)
- Roundyella?* sp. A (Fig. 8B)
- Superfamily Primitiopsacea Swartz, 1936
- Family Primitiopsidae (Primitiopsinae) Swartz, 1936
- Parapribylites hanaicus* Pokorný, 1951 (Fig. 7K)
- Parapribylites* cf. *costatus* (Glebovskaya & Zaspelova, 1959 *in* Zaspelova 1959) (Fig. 7L)
- Kielciella arduennensis* Adamczak & Coen, 1992 (Fig. 6N)
- Kielciella fastigans* (Becker, 1964)
- Family Urtellidae Becker, 1970
- Urftella* cf. *adamczaki* Becker, 1970 (Fig. 8L)
- ?Family Pribylitidae Pokorný, 1958
- Coryellina cybaea* (Rozhdestvenskaya, 1959) (Fig. 5O)
- Coryellina* cf. *curta* (Rozhdestvenskaya, 1959) (Fig. 5P)
- Coryellina?* sp. A (Fig. 5Q)
- Coryellina?* sp. B (Fig. 5R)
- Gravia schallreuteri* Becker, 1970 (Fig. 6G)
- Gravia?* sp. A (Fig. 6H)
- Superfamily Youngiellacea Kellett, 1933
- Family Youngiellidae Kellett, 1933
- Youngiella* sp. 5 *sensu* Magne, 1964 (Fig. 8N)
- Youngiella* sp. A (Fig. 8M)
- Suborder Paraparchitocopina Gramm & Ivanov, 1975
- Superfamily Paraparchitoidea Scott, 1959 (Sohn, 1971)
- Family Paraparchitidae Scott, 1959
- Samarella* cf. *laevinodosa* Becker, 1964 (Fig. 8C)
- Coeloenellina minima* (Kummerow, 1953) (Fig. 5N)
- Order Podocopida Müller, 1864
- Suborder Podocopina Sars, 1866
- Superfamily Bairdioidea Sars, 1888
- Family Bairdiidae Sars, 1888
- Bairdia paffrathensis* Kummerow, 1953 (Fig. 4O, P)
- Bairdia* cf. *plicatula* Polenova, 1952 (Fig. 4Q)
- Bairdia* cf. *siliklensis* Rozhdestvenskaya, 1962 (Fig. 4R)
- Bairdia* sp. A (Fig. 4S)

- Bairdia* sp. B (Fig. 4T)
Bairdia sp. C (Fig. 4U)
Bairdia sp. *sensu* Coen, 1985 (Fig. 4V)
Bairdiacypris aff. *breuxensis* Casier & Olempska, 2008 (Fig. 4W)
Bairdiacypris sp. A (Fig. 4X)
Bairdiacypris sp. B (Fig. 4Y)
Fabaliocypris ? sp. A (Fig. 6E)
Acratia lucea sp. nov. (Fig. 4A–H)
Acratia sp. A (Fig. 4I)
Orthocypris? *cristae* sp. nov. (Fig. 7A–G)
Orthocypris cicatricosa Coen, 1985 (Fig. 7I)
Orthocypris cf. *kummerowi* Żbikowska, 1983 (Fig. 7H)
- Superfamily Bairdiocypridoidea Shaver, 1961
 Family Pachydomellidae Berdan & Sohn, 1961
Tubulibairdia sp. A (Fig. 8G)
Microcheilinella aff. *ventrosa* Polenova, 1960 (Fig. 6V)
Microcheilinella aff. *amaliae* Kummerow, 1953 (Fig. 6W)
Microcheilinella cf. *clava* (Kegel, 1932) (Fig. 6X)
Microcheilinella sp. B (Fig. 6Y)
Microcheilinella sp. B *sensu* Casier & Pr at, 1991 (Fig. 6AA)
Microcheilinella sp. *sensu* Coen, 1985 (Fig. 6Z)
Ampuloides sp. 1 *sensu* Milhau, 1983 (Fig. 4M)
- Family Rectellidae Neckaya, 1966
Rectella trapezoides Zaspelova, 1959 (Fig. 7AF)
- Family Bairdiocyprididae Shaver, 1961
Bairdiocypris vastus Polenova, 1952 (Fig. 5A)
Bairdiocypris cf. *symmetrica* (Kummerow, 1953) (Fig. 5B)
Healdianella sp. A (Fig. 6I)
Silenites? sp. A (Fig. 8F)
Baschkirina? sp. indet. (Fig. 5F)
- Family Macrocyprididae M ller, 1912
Macrocypris? sp. A (Fig. 6T)
- Suborder Metacopina Sylvester-Bradley, 1961
 Superfamily Healdioidea Harlton, 1933
 Family Healdiidae Harlton, 1933
Cytherellina obliqua (Kummerow, 1953) (Fig. 5W)
Cytherellina cf. *groosae* Coen, 1985 (Fig. 5X)
Cytherellina cf. *perlonga* (Kummerow, 1953) (Fig. 5Y)
- Superfamily Thlipsuroidea Ulrich, 1894
 Family Quasillitidae Coryell & Malkin, 1936
Quasillites fromelennensis Milhau, 1983 (Fig. 7X–AB)
Quasillites lecomptei Coen, 1985 (Fig. 7AD)
- Quasillites* cf. *fromelennensis* Milhau, 1983 (Fig. 7AE)
Quasillites? sp. A (Fig. 7AC)
Jenningsina catenulata (Van Pelt, 1933) (Fig. 6K)
Jenningsina heddebauti Milhau, 1983 (Fig. 6L)
Jenningsina paffrathensis Kr ommelbein, 1954 (Fig. 6M)
Jefina kaisini Coen, 1985
Jefina cf. *romei* Coen, 1985 (Fig. 6J)
Ovatoquasillites cf. *nismesensis* Casier in Casier & Pr at (2009) (Fig. 7J)
- Family Bufinidae Sohn & Stover, 1961
Bufina schaderthalensis Zagora, 1968 (Fig. 5I)
Bufina aff. *abbreviata* Peterson, 1966 (Fig. 5G, H)
- Family Ropolonellidae Coryell & Malkin, 1936
Euglyphella europaea Coen, 1985 (Fig. 6A, B)
Plagionephrodes laqueus praelaqueus Casier & Olempska, 2008 (Fig. 7O)
- Family Thlipsuridae Ulrich, 1894
Polyzygia beckmanni antecedens Zagora, 1968 (Fig. 7T)
Polyzygia beckmanni beckmanni Kr ommelbein, 1954 (Fig. 7U, V)
Polyzygia neodevonica Matern, 1929 (Fig. 7W)
Polyzygia cf. *symmetrica* G rlich, 1896
Asturiella sp. A (Fig. 4N)
- Suborder Platycopina Sars, 1866
 Superfamily Cytherelloidea Sars, 1866
 Family Cavellinidae Egorov, 1950
Cavellina devoniana Egorov, 1950 (Fig. 5J)
Cavellina rhenana Kr ommelbein, 1954 (Fig. 5K)
Cavellina cf. *macella* Kummerow, 1953 (Fig. 5L)
Cavellina cf. sp. II *sensu* Groos, 1969 (Fig. 5M)
- Superfamily Kloedenelloidea Ulrich & Bassler, 1908
 Family Kloedenellidae Ulrich & Bassler, 1908
Poloniella claviformis (Kummerow, 1953) (Fig. 7S)
Poloniella tertia Kr ommelbein, 1953 (Fig. 7P–R)
Uchtovia abundans (Pokorn y, 1951) (Fig. 8H)
Uchtovia materni Becker, 1971 (Fig. 8I)
Uchtovia refrathensis (Kr ommelbein, 1954) (Fig. 8J)
Uchtovia? sp. A (Fig. 8K)
Evlanella germanica Becker, 1964 (Fig. 6C)
Evlanella sulcellina Becker, 1964 (Fig. 6D)
- Family Knoxitidae Egorov, 1950
Knoxiiella sp. 1 *sensu* Milhau, 1983 (Fig. 6S)