Early Frasnian ostracods from the Arche quarry (Dinant Synclinorium, Belgium) and the *Palmatolepis punctata* Isotopic Event

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Ostracods from the Arche quarry at Frasnes are analysed. Twenty-seven species are recognised in the Chalon Member and in the very base of the Arche Member of the Moulin Liénaux Formation. Three new species: *Scrobicula gracilis*, *Microcheilinella archensis*, and *Bairdia* (*Rectobairdia*) *chalonensis*, and one subspecies *Plagionephrodes laqueus praelaqueus*, are proposed. The fauna is in the *Favulella lecomptei* Zone based on metacopid ostracods and belongs to the Eifelian Mega-Assemblage. Ostracods are indicative of a regressive trend from a moderately deep poorly oxygenated marine environment below fair weather wave base to very shallow well oxygenated and agitated environments. Comparison of the ostracod fauna present in the Arche quarry with faunas described from the Frasnes railway section and from the Lion quarry shows that ostracods did not suffer a crisis during the *Palmatolepis punctata* Conodont Zone and close to the Early–Middle Frasnian boundary.

Key words: Ostracoda, *Palmatolepis punctata* Event, palaeoecology, Dinant Synclinorium, Frasnian, Belgium.

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Introduction

In 2002, as part of a joint program of the Belgian National Foundation for Scientific research (FNRS) and the Polish State Committee for Research (KBN), it was decided to investigate the ostracod succession across the *Palmatolepis punctata* Isotopic Event in Poland (EU), Nevada (USA), and the type region for the Frasnian Stage (Belgium, EU). The results of the two first studies (Poland, Nevada) were reported in a special issue of Acta Palaeontologica Polonica (Casier et al. 2006; Głuchowski et al. 2006), but the study of ostracods present in Belgium has been postponed. The distribution of ostracods was insufficiently known close to the Early–Middle Frasnian boundary in the Dinant Synclinorium, and consequently it was decided to investigate two classic sections: the access path to the Arche Quarry and the Frasnes railway section. The latter section was a subject of studies, which results have just been recently published (Casier and Olempska 2008).

The goal of this paper is to establish an inventory of a rich and well preserved ostracod fauna present in the Chalon Member exposed in the access path to the Arche quarry. This member of the Moulin Liénaux Formation belongs to the *Pa. transitans* Zone (Boulvain et al. 1999), the last Early Frasnian conodont zone. Some rare ostracods present in the extreme base of the Arche Member of the same formation are also reported. Another goal of this study is to establish whether or not these ostracods suffered from a biotic change across the *Pa. punctata* Isotopic Event in the type region.

Institutional abbreviation.—IRScNB, Royal Belgian Institute of natural Sciences, Brussels, Belgium.

The Early–Middle Frasnian boundary and the *Palmatolepis punctata* Isotopic Event

The Early–Middle Frasnian boundary has been fixed recently at the base of the *Pa. punctata* conodont Zone by the Subcommission on Devonian Stratigraphy (SDS Business Meeting, Leicester, 2006). In the Dinant Synclinorium, the first occurrence of *Pa. punctata* is observed in the upper part of the Chalon Member of the Moulin Liénaux Formation (Boulvain et al. 1999). Recently Yans et al. (2007) demonstrated an abrupt and high-amplitude negative carbon isotopic excursion ($\delta^{13}C$ shift of -7‰) in the *Pa. punctata* Zone, corresponding probably to a world-wide perturbation in the earth-ocean system. Yans et al. (2007) suggested that this event is related to a catastrophic release of oceanic methane hydrate. They also suggest that, among other possibilities, an impact may have contributed to that carbon isotopic excursion. In the *Pa. punctata* Zone the Alamo Event is responsible for the deposition of a huge megabreccia in the eastern part of the Great Basin, Nevada (Sandberg and Warme 1993) caused by a marine impact (Morrow et al. 2005). The presence of entomozoid ostracods belonging to the *Franklinella latesulcata* Zone in the Alamo Breccia of the Tempiute Mountains in Nevada (Casier in Sandberg et al. 1997), in the Belgian Dinant Synclinorium (Bultynck et al. 2001) and in the Algerian Sahara (Casier 1983) was used by Casier et al. (2006) as evidence for the existence of a hypoxic event in the *Pa. punctata* Zone. These ostracods belong to the Myodocopid Mega-Assemblage and are indicative in the Devonian of hypoxic water conditions. Evidence of expanding anoxic conditions during the *Pa. punctata* Zone are also supported by geochemical and palynological investigations in the Kowala quarry, Holy Cross Mountains, Poland (Marynowski et al. 2008).

Geological setting

The Arche quarry (GPS: N 50°04’14"; E 4°29’57") is located 800 m southwest of Frasnes (Fig 1). The quarry is the stratotype for the base of the Moulin Liénaux Formation (Boulvain et al. 1999) and also the stratotype for its lower member, the Chalon Member. The Chalon crops out along the access path to the Arche quarry. The Chalon Member is composed of shales containing nodules and thin beds of argillaceous limestones that increase in number and in thickness upward. Above the Chalon, the 120-thick Arche Member is represented by a large bioherm with stromatactis, corals and stromatoporoids. The extreme base of the Arche Member develops in the upper part of the Chalon Member and consequently the top of that member, not visible along the access path to the quarry, has not been sampled. For the present study, only the Chalon Member (samples AR-06-1 to 28) and the extreme base of the Arche Member (samples AR-06-29 to 31) have been investigated for ostracods (Fig. 2).

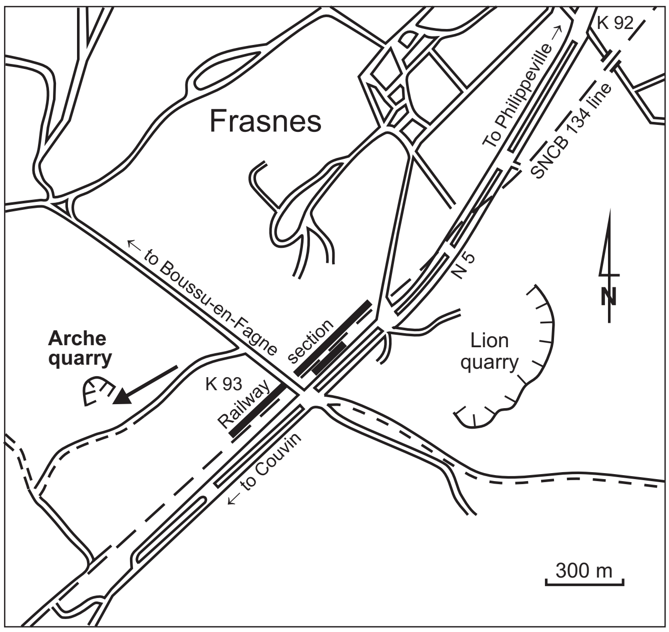

Fig. 1. Locality map of the Arche quarry, the Lion quarry and the Frasnes railway section; the access path to the Arche quarry indicated by arrow.

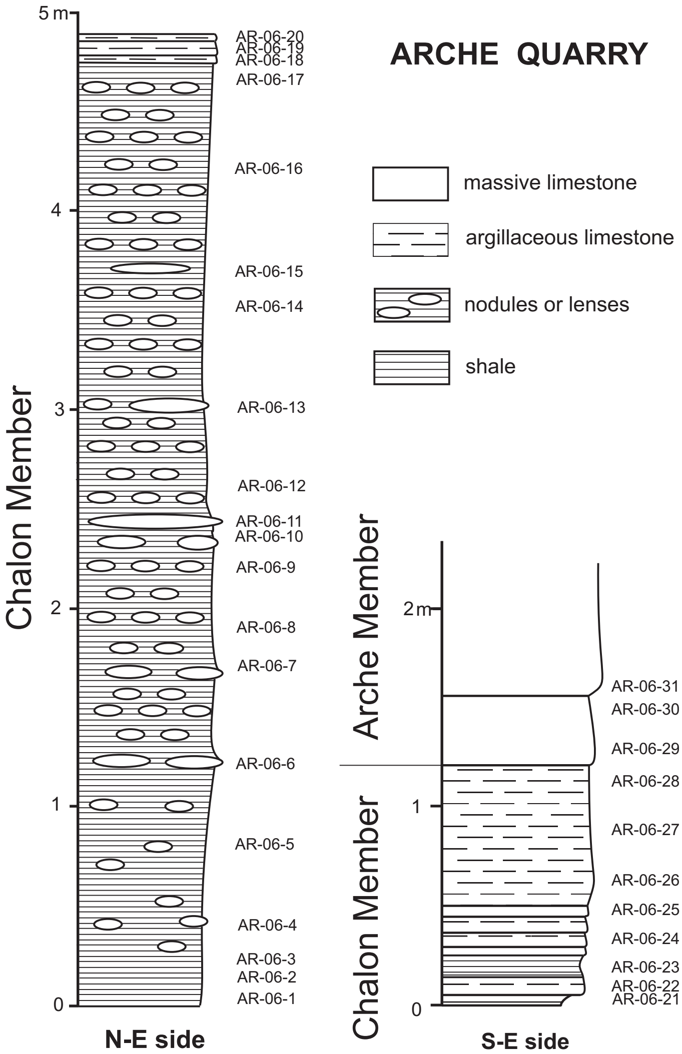

Fig. 2. Lithologic sections of the Chalon Member and of the extreme base of the Arche Member exposed on the north-eastern side and on the south-eastern side of the access path to the Arche quarry.

Previous studies on ostracods from the Chalon Member

Becker (1971) recorded *Amphissites* cf. *parvulus* (Paeckelmann, 1913), *Hollinella* (*Keslingella*) *praecursor* Pokorny, 1951, *Refrathella incompta* Becker, 1971, *Plagionephrodes laqueus* (Matern, 1929), *Favulella lecomptei* Becker, 1971, *Jenningsina lethiersi* Becker, 1971, *Acratia* sp. A, and *Cry-*

ptophyllus cf. *materni* (Bassler and Kellett, 1934) in the Chalon Member exposed in the access path to the Arche quarry.

From the same member in the Ermitage path at Boussu-en-Fagne, Casier (1977) mentioned *F. lecomptei*, *Adelphobolbina europaea* Becker and Bless, 1971, *A.* cf. *parvulus*, *Punctomosea weyanti* Becker, 1971 and *Cytherellina*? sp. B. Unfortunately the Ermitage path section has been covered by asphalt and is now inaccessible.

Material and methods

Thirty-one samples of approximately 500 g each and numbered AR-06-1 to 31 were extracted for the study, 20 on the northeast side of the access path, and 8 on the southwest side. The hiatus between these two sections is less than one meter. All the samples were crushed by a hydraulic press and samples collected from shales (AR-06-1 to 3) were directly sieved on 100 μm, 250 μm and 1600 μm mesh screens. The others were attacked with 99.8% glacial acetic, at nearly 90°C, for four days at a rate of eight hours a day. This hot acetolysis method has been described by Lethiers and Crasquin-Soleau (1988). The residues were sieved on the above mentioned screens. Then that part of the sample retained by the 1600 μm mesh screen was attacked by acid again and sieved on 250 μm and 1600 μm mesh screens only. The process was repeated for samples AR-06-22 to 27 but the residue was sieved on 250 μm and 1600 μm mesh screens only. About 825 carapaces, valves and fragments of ostracods identifiable at any taxonomic level were thus extracted.

Ostracods are absent or unidentifiable in the base of Chalon Member up to the sample AR-06-14. Their abundance is normal from sample AR-06-16 to sample AR-06-21, and also in the sample AR-06-25. They are abundant in samples AR-06-22, AR-06-23, and AR-06-26 to AR-06-28, and very scarce from sample AR-06-29 to sample AR-06-31.

A systematic list of identified ostracod taxa and their distribution in the access path section at the Arche quarry are reported in Appendix 1 and Table 1.

Table 1. Distribution of ostracods in the access path to the Arche quarry. The boundary between the Chalon Member and the Arche Member is between samples AR-06-28 and 29.

Sample no.	15	16	17	18	19	20	22	23	24	25	26	27	28	29	31
Bairdiacypris sp. B, aff. *B. martinae* Casier and Lethiers, 1997	?									•	•	•	•		
Uchtovia materni Becker, 1971		•	•	•		•	•	•			•	•	•		
Bairdiocypris sp. 5 sensu Magne (1964)		•	•	•	?	•	•				•	•	•		
Bairdiocypris sp. C		•	?				?			•	•		•	•	
Bairdiacypris breuxensis Casier and Olempska, 2008			?								•				
Healdianella? sp. B in Becker (1971)			?										?		
Plagionephrodes laqueus praelaqueus ssp. nov			•	•		•	•	•		•	•	•	•		
Bairdia (*Rectobairdia*) *chalonensis* sp. nov.			?			?	?	•	•		•	•	•		•
Plagionephrodes ineptus Becker, 1971						•									
Scrobicula gracilis sp. nov.						•		•							
Favulella lecomptei Becker, 1971						•	•	•			•	•	•		
Cryptophyllus materni (Bassler and Kellett, 1934)						?	•	•			•	•	•		
Microcheilinella archensis sp. nov.						?	•	•		•	•	•	•		
Cryptophyllus sp. A								•							
Bairdia (*Rectobardia*) *paffrathensis* Kummerow, 1953								•							
Punctomosea weyanti Becker, 1971								?							
Hypotetragona tremula Becker, 1971								•					•		
Bairdia (*Orthobairdia*) sp. B in Becker (1971)								•					•		
Bairdiacypris sp. D										•			•		
Acratia evlanensis Egorov, 1953											•				
Cavellina? sp. A											•				
Jenningsina lethiersi Becker, 1971											•				
Refrathella incompta Becker, 1971											•		•		
Acratia sp. indet.												•			
Bairdiacypris sp. indet.													•		
Schneideria groosae Becker, 1971													•		
Paraparchitidae? sp. indet. 2													•		

Systematic palaeontology

Class Ostracoda Latreille, 1802

Order Palaeocopida Henningsmoen, 1953

Suborder uncertain

Family Scrobiculidae Posner, 1951

Genus *Scrobicula* Posner, 1951

Type species: *Cytherella*? *scrobiculata* Jones, Kirkby and Brady, 1884.

Type locality: Not designated (East Kilbride, Lanarkshire or Robroystone, Lanarkshire), southern Scotland; Carboniferous Limestone series, Lower Carboniferous

Scrobicula gracilis sp. nov.

Fig. 3H–J.

2006 Paraparchitidae? sp. indet.; Głuchowski et al. 2006: fig. 2E.

Etymology: From the Latin *gracilis*—slim, thin. Referring to the fineness of the ornamentation.

Holotype: IRScNB n° b5062. Carapace. AR-06-20. Fig. 3H_1, H_2. L = 0.57 mm; H = 0.36 mm; W = 0.30 mm.

Type locality: Access path to the Arche quarry.

Type horizon: Chalon Member of the Moulin Liénaux Formation, Early Frasnian, Devonian.

Diagnosis.—Small leperditoid carapace with a slim depression and with a finely wrinkled ornamentation.

Material.—Six carapaces and valves (samples AR-06-20 and AR-06-23). The description is also based on several specimens from the Nismes section (study in progress) and from the Frasnes railway section (Casier and Olempska 2008).

Description.—Small preplete carapace with a slightly convex dorsal border and a delicately curved or nearly straight ventral margin. The anterior and the posterior margins are regularly rounded, but the curvature of the last one is more accentuated. The greater length is at mid-height, and the greater height is at the anterior third of the carapace. Both cardinal angles (about 150°) located in the anterior and posterior sixth of the length. The left valve is larger than the right valve, and in right lateral view projects all along the free and dorsal margins. The carapace is biconvex in dorsal view, moderately wide, with the greatest width located just posterior of mid-length. The straight hinge line is in a slim depression. The finely wrinkled ornamentation and the muscle scar are only faintly visible. The inner wrinkles are concentric around a circular muscle scar; the exterior wrinkles follow the contour of the free margin and terminate against the dorsal border. The ornamentation is comparable to finger-print ornamentation observed in many entomozoid ostracods.

Remarks.—The species is easily distinguishable from the majority of species belonging to the genus *Scrobicula* by its elliptical contour in dorsal view. Where the finely wrinkled ornamentation is preserved, *S. gracilis* differs from all the species of genus *Scrobicula*. In Belgium the species is also present in the Pont d'Avignon Member, in the Sourd d'Ave Member and in the Chalon Member exposed in the Nismes section (study in progress). *Paraparchites*? sp. A figured by Casier and Olempska (2008) from the Frasnes railway section belongs also to the new species. In that section, *S. gracilis* is present in the Ermitage Member and also in the Bieumont and Boussu-en-Fagne Members of the Middle Frasnian Grand Breux Formation. The Paraparchitidae? sp. indet. recorded by Głuchowski et al. (2006) from the middle Wietrznia Beds (*Pa. transitans* Conodont Zone) of the Wietrznia quarry in the Holy Cross Mountains, Poland, belongs to *S. gracilis*.

Order Podocopida Sars, 1866

Suborder Metacopina Sylvester-Bradley, 1961

Family Ropolonellidae Coryell and Malkin, 1936

Genus *Plagionephrodes* Morey, 1935

Type species: *Plagionephrodes uninodosus* Morey, 1935. Clark's Branch, Missouri, USA; upper Kinderhookian, Lower Mississippian.

Plagionephrodes laqueus praelaqueus ssp. nov.

Fig. 3L–N.

?1971 *Plagionephrodes laqueus* (Matern, 1929); Becker, 1971: table 1.

Etymology: From the Latin *prae*—before and *laqueus* = lace referring to the ornamentation of a species of *Plagionephrodes* described by Matern (1929). Referring to the fact that *Plagionephrodes laqueus praelaqueus* ssp. nov. and *P. laqueus laqueus* (Matern, 1929) belong to the same phylogenetic succession.

Holotype: IRScNB n° b5066. Carapace. AR-06-27. Fig. 3L_1, L_2. L = 0.78 mm; H = 0.49 mm; W = 0.22 mm.

Type locality: Access path to the Arche quarry.

Type horizon: Chalon Member of the Moulin Liénaux Formation, Early Frasnian, Devonian.

Diagnosis.—A small subspecies of *Plagionephrodes laqueus* characterised by an ornamentation composed of an anterior vertical ridge and a posterior spur on each valve separated by some other irregular ridges in the middle part of the carapace.

Material.—126 valves and carapaces (samples AR-06-17, 18, 20-23, 25-28).

Description.—Small preplete carapace with a slightly curved dorsal border extending from the anterior two-seventh of the greatest length almost to the posterior extremity. The hinge line is straight. The ventral margin is straight or gently concave. Anterior margin largely rounded sometimes forming an obtuse angle with the dorsal border, or exceptionally slightly angular at the extremity. Posterior margin more rounded than the anterior, and curvature more accentuate ventrally. The greatest length is at mid-height, and the greatest height is at two-seventh of the carapace length. The left valve is larger than the right, and projects greatly all along the free and dorsal margins in right lateral view. The overlap is important along the ventral border. The contour of the left valve is quite different. Its greatest height is slightly shifted posteriorly, and the anterior extremity is acuminate. The ornamentation is more developed on the right valve, and is composed of a vertical ridge located at the anterior quarter of the valves and of a spur in the posterior quarter of the length at mid-height. Some other irregular ridges are present in the middle part of the carapace,

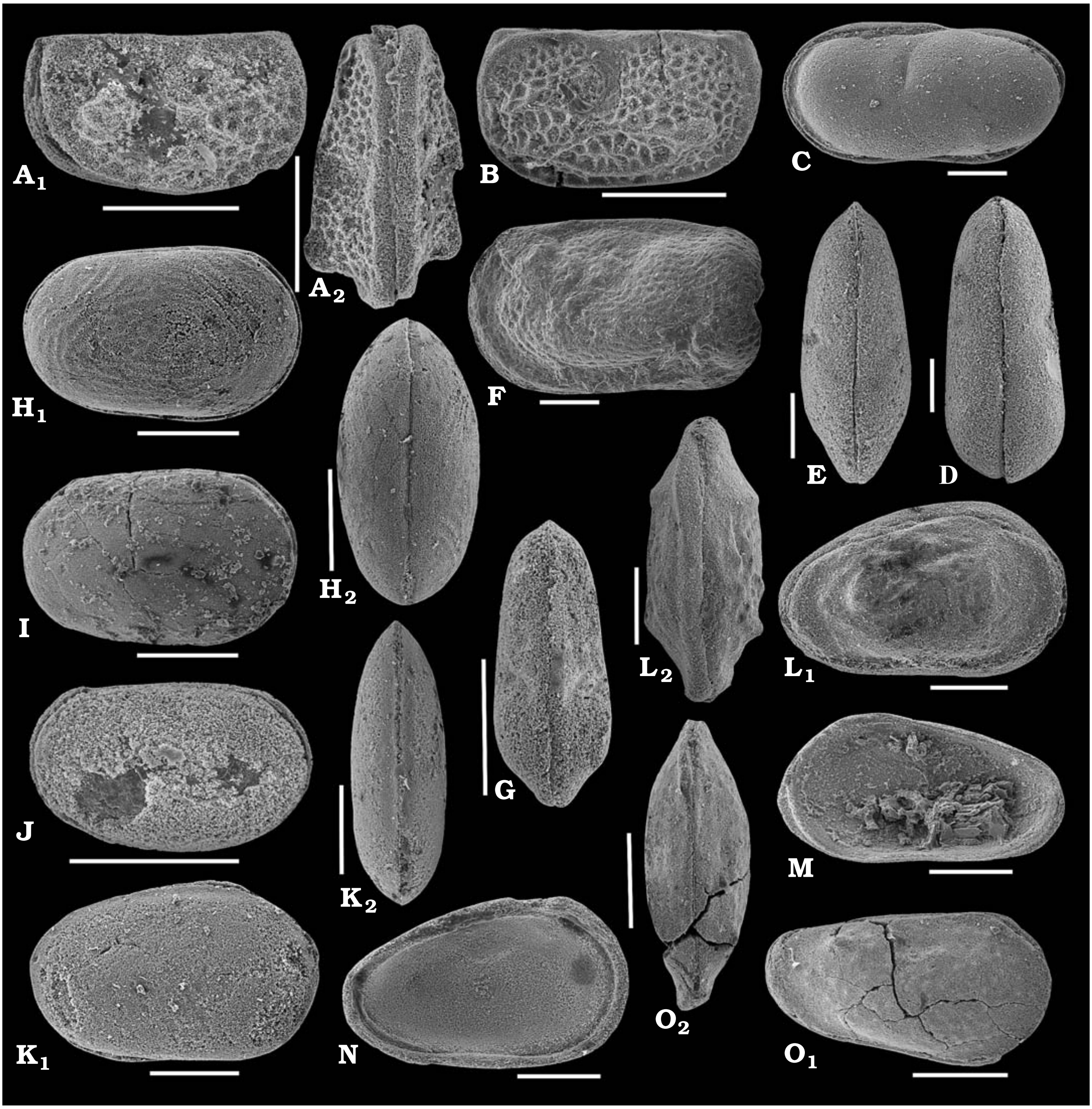

Fig. 3. Early Frasnian ostracods from the access path to the Arche quarry, Dinant Synclinorium, Belgium. **A**, **B**. *Refrathella incompta* Becker, 1971. **A**. Carapace in right (A_1) and dorsal (A_2) views. Sample AR-06-28. IRScNB n° b5055. **B**. Left valve. Sample AR-06-26. IRScNB n° b5056. **C**–**E**. *Uchtovia materni* Becker, 1971. **C**. Heteromorph carapace in left lateral view. Sample AR-06-26. IRScNB n° b5057. **D**. Heteromorph carapace in dorsal view. Sample AR-06-28. IRScNB n° b5058. **E**. Tecnomorph carapace in dorsal view. Sample AR-06-28. IRScNB n° b5059. **F**, **G**. *Hypotetragona tremula* Becker, 1971. **F**. Heteromorph carapace in left lateral view. Sample AR-06-23. IRScNB n° b5060. **G**. Tecnomorph carapace in dorsal view. Sample AR-06-28. IRScNB n° b5061. **H**–**J**. *Scobicula gracilis* sp. nov. **H**. Holotype. Carapace in left lateral (H_1) and dorsal (H_2) views. Sample AR-06-20. IRScNB n° b5062. **I**. Carapace in left lateral view. Sample NI-07-136 from the Sourd d'Ave Member in the Nismes section. IRScNB n° b5063. **J**. Carapace in left lateral view. Sample NI-07-12 from the Chalon Member in the Nismes section. IRScNB n° b5064. **K**. *Cavellina*? sp. A. Carapace in left (K_1) and dorsal (K_2) views. Sample AR-06-26. IRScNB n° b5065. **L**–**N**. *Plagionephrodes laqueus praelaqueus* ssp. nov. **L**. Holotype. Carapace in right lateral (L_1) and dorsal (L_2) views. Sample AR-06-27. IRScNB n° b5066. **M**. Internal view of right valve. Sample AR-06-17. IRScNB n° b5068. **N**. Internal view of left valve. Sample AR-06-18. IRScNB n° b5069. **O**. *Plagionephrodes ineptus* Becker, 1971. Carapace in right (O_1) and dorsal (O_2) views. Sample AR-06-28. IRScNB n° b5070. Scale bar 200 μm.

sometimes extending from the upper part of the anterior ridge to the postero-ventral sector. A slightly crenulated marginal rim is visible all along the free border, but it is more developed close to the extremities. In dorsal view, the contours of valves are nearly straight between the anterior ridge and the posterior spur, which are prominent. The position of the posterior spurs corresponds to the greatest width. The anterior and the posterior borders are well rounded but the surface before the anterior ridge and behind the dorsal spur is concave.

Remarks.—The new subspecies and *Plagionephrodes laqueus laqueus* (Matern, 1929) belong to the same phylogenetic succession. *P. laqueus laqueus* is known from the Middle Frasnian of Belgium and Boulonnais (France) (Becker 1971). This species is larger and possesses a strongly developed ornamentation composed of ridges forming a "ω" letter of the Greek alphabet, surmounted by a ridge parallel to the dorsal border. *Plagionephrodes ineptus* Becker, 1971, also from the Frasnian of the Dinant Synclinorium (Becker 1971), possesses a spur in the dorsal sector only. In Belgium, *P. laqueus praelaqueus* is also known from the Chalon Member, from the Sourd'Ave Member and from the Pont d'Avignon Member in the Nismes section (study in progress). The *P. laqueus* (Matern, 1929) specimen mentioned but not figured by Becker (1971) from the access path to the Arche quarry belongs probably to the new subspecies.

Suborder Podocopina Sars, 1866

Family Pachydomellidae Berdan and Sohn, 1961

Genus *Microcheilinella* Geis, 1933

Type species: *Microcheilus distortus* Geis, 1932. Indiana (USA); Salem Limestone, Upper Mississippian.

Microcheilinella archensis sp. nov.

Fig. 4F–J.

Etymology: After type locality.

Holotype: IRScNB n° b5077. Carapace. AR-06-27. Fig. 4G. L = 0.81 mm; H = 0.48 mm; W = 0.54 mm.

Type locality: Access path to the Arche quarry.

Type horizon: Chalon Member of the Moulin Liénaux Formation, Early Frasnian, Devonian.

Diagnosis.—Wide *Microcheilinella*, very asymmetric, especially in the postero-ventral sector. Thin crest parallel to the margin in the postero-ventral sector of the left valve and more rarely of the right valve.

Material.—71 valves and carapaces (samples AR-06-20?, 22, 23, 25–28).

Description.—Relatively large species of *Microcheilinella*; wider than high. Ventral and dorsal borders straight or very slightly convex. Anterior and posterior borders angular with the anterior extremity at third-height, and posterior extremity at mid-height. Antero-dorsal, postero-ventral, and postero-dorsal margins straight or slightly convex. Antero-ventral margin convex. Greatest height slightly before mid-length, and greatest length at half height. The left valve is larger than the right but their contours are similar. In right lateral view, the left valve projects greatly all along the free margin and the dorsal border, especially in the postero-ventral sector. In that sector, the projection is related to the presence of a thin crest parallel to the margin. Another more reduced crest also parallel to the free margin may be present in the postero-ventral sector of the right valve (Fig. 4I). Carapace biconvex in dorsal view except for the pinched extremities. The greatest width is located slightly behind the mid-length. The hinge line is straight, in a depression, and measures almost half the length. In anterior view the carapace is hearth-shaped. The surface of valves is smooth.

Remarks.—In right lateral view, the magnitude of the projection of the left valve in the postero-ventral sector distinguishes *M. archensis* from all the other species belonging to that genus. The species is known presently only from the type locality.

Family Bairdiidae Sars, 1888

Genus *Bairdia* McCoy, 1844

Subgenus *Bairdia* (*Rectobairdia*) Sohn, 1960

Type species: *Bairdia depressa* Geis, 1932. Indiana (USA); Salem Limestone, Upper Mississippian.

Bairdia (*Rectobairdia*) *chalonensis* sp. nov.

Fig. 4M–O.

Etymology: After type horizon.

Holotype: IRScNB n° b5083. Carapace. AR-06-23. Fig. $4M_1$, M_2. L = 1.19 mm; H = 0.62mm; W = 0.44 mm.

Type locality: Access path to the Arche quarry.

Type horizon: Chalon Member of the Moulin Liénaux Formation, Early Frasnian, Devonian.

Diagnosis.—Large and elongate, with an anterior extremity at two-third of the height, posterior point above midheight, dorsal margin straight to gently curved, median part of carapace finely pitted.

Material.—76 valves and carapaces (samples AR-06-17?, 20?, 22?, 23, 24, 26–28, 31).

Description.—Large and elongate *Bairdia* (*Rectobairdia*), with a nearly straight dorsal border parallel to the slightly concave ventral border. Dorsal part of the anterior border slightly concave and moderately inclined, and ventral part well rounded with an extremity forming a right angle at two-third of the height. Dorsal part of the posterior border also slightly concave but more inclined, and ventral part moderately curved with an acuminate extremity at mid-height. Greatest length at mid-height and greatest height at mid-length. The left valve is larger than the right, but their contours are similar except for the straight ventral border. In right lateral view, the left valve projects all along the free margin except in the antero-ventral sector. In dorsal view, the valves are symmetric, convex but slightly concave close to the acuminate extremities. The greatest width is at mid-length. The hinge line is sinuous. In ventral view, the right valve is flat very close to the ventral margin, and the overlap

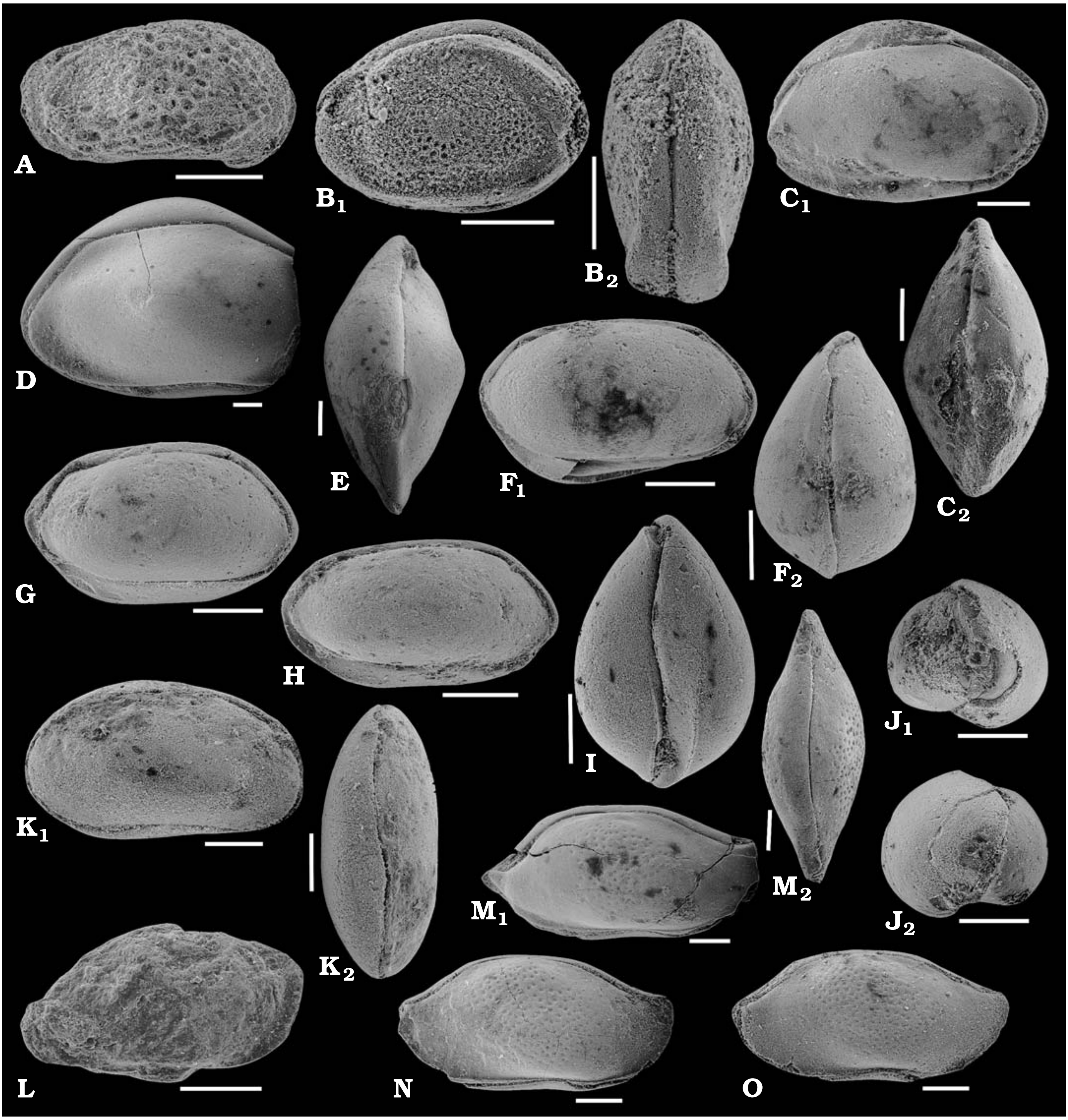

Fig. 4. Early Frasnian ostracods from the access path to the Arche quarry, Dinant Synclinorium, Belgium. **A**. *Jenningsina lethiersi* Becker, 1971. Poorly preserved carapace in right lateral view. Sample AR-06-26. IRScNB n° b5071. **B**. *Favulella lecomptei* Becker, 1971. Carapace in right (B_1) and dorsal (B_2) views. Sample AR-06-26. IRScNB n° b5072. **C**. *Bairdiocypris* sp. 5 sensu Magne (1964). Poorly preserved carapace in right (C_1) and ventral (C_2) views. Sample AR-06-17. IRScNB n° b5073. **D**, **E**. *Bairdiocypris* sp. C. **D**. Broken carapace in right lateral view. Sample AR-06-26. IRScNB n° b5074. **E**. Broken carapace in dorsal view. Sample AR-06-26. IRScNB n° b5075. **F**–**J**. *Microcheilinella archensis* sp. nov. **F**. Carapace in right lateral (F_1) and dorsal (F_2) views. Sample AR-06-26. IRScNB n° b5076. **G**. Holotype. Carapace in right lateral view. Sample AR-06-27. IRScNB n° b5077. **H**. Carapace in right lateral view. Sample AR-06-28. IRScNB n° b5078. **I**. Ventral view of a carapace. Sample AR-06-27. IRScNB n° b5079. **J**. Anterior (J_1) and posterior (J_2) views of a carapace. Sample AR-06-28. IRScNB n° b5080. **K**. *Healdianella*? sp. B in Becker (1971). Carapace in right (K_1) and dorsal (K_2) views. Sample AR-06-28. IRScNB n° b5081. **L**. *Bairdia* (*Rectobairdia*) *paffrathensis* Kummerow, 1953. Poorly preserved carapace in right lateral view. Sample AR-06-23. IRScNB n° b5082. **M**–**O**. *Bairdia* (*Rectobairdia*) *chalonensis* sp. nov. **M**. Holotype. Carapace in right lateral (M_1) and dorsal (M_2) views. Sample AR-06-23. IRScNB n° b5083. **N**. Carapace in right lateral view. Sample AR-06-26. IRScNB n° b5084. **O**. Carapace in right lateral view. Sample AR-06-26. IRScNB n° b5085. Scale bars 200 µm.

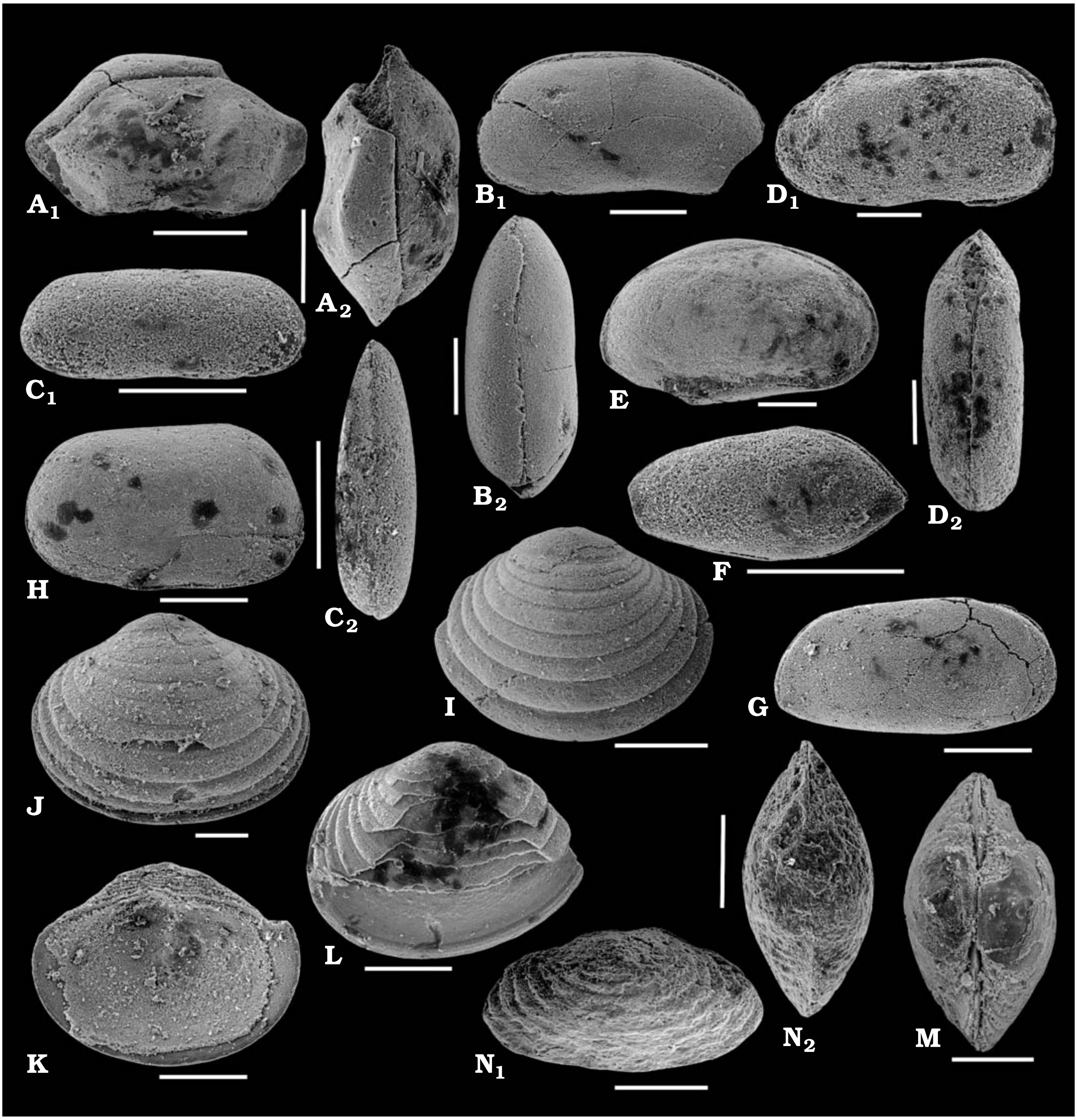

Fig. 5. Early Frasnian ostracods from the access path to the Arche quarry, Dinant Synclinorium, Belgium. **A**. *Bairdia* (*Orthobairdia*) sp. B in Becker (1971). Carapace in right (A_1) and dorsal (A_2) views. Sample AR-06-23. IRScNB n° b5086. **B**. *Bairdiacypris* sp. B, aff. *B. martinae* Casier and Lethiers, 1997. Carapace in right (B_1) and dorsal (B_2) views. Sample AR-06-28. IRScNB n° b5087. **C**. *Bairdiacypris* sp. D. Poorly preserved carapace in right (C_1) and dorsal (C_2) views. Sample AR-06-25. IRScNB n° b5088. **D**. *Bairdiacypris* sp. indet. Poorly preserved carapace in right (D_1) and dorsal (D_2) views. Sample AR-06-28. IRScNB n° b5089. **E**. *Bairdiacypris breuxensis* Casier and Olempska, 2008. Carapace in right lateral view. Sample AR-06-26. IRScNB n° b5090. **F**. *Acratia evlanensis* Egorov, 1953. Poorly preserved carapace in right lateral view. Sample AR-06-23. IRScNB n° b5091. **G**. *Acratia* sp. indet. Carapace in right lateral view. Sample AR-06-27. IRScNB n° b5092. **H**. *Schneideria groosae* Becker, 1971. Carapace in right lateral view. Sample AR-06-28. IRScNB n° b5093. **I–M**. *Cryptophyllus materni* (Bassler and Kellett, 1934). **I**. Valve. Sample AR-06-26. IRScNB n° b5094. **J**. Valve. Sample AR-06-26. IRScNB n° b5095. **K**. Internal view of a valve. Sample AR-06-27. IRScNB n° b5096. **L**. Broken valve showing the stack of moults. Sample AR-06-26. IRScNB n° b5097. **M**. Carapace in dorsal view. Sample AR-06-27. IRScNB n° b5098. **N**. *Cryptophyllus* sp. A. Valve in lateral (N_1) and dorsal (N_2) views. Sample AR-06-23. IRScNB n° b5099. Scale bars 200 μm.

Table 2. Ostracod species present in the Chalon Member of the access path to the Arche quarry (*Palmatolepis transitans* Conodont Zone), which are also found by Becker (1971) and Casier and Olempska (2008) in the Ermitage Member (*Palmatolepis punctata* Conodont Zone) of the Moulin Liénaux Formation or in the Bieumont Member (*Palmatolepis hassi* Conodont Zone) and Boussu-en-Fagne Member (*Palmatolepis hassi* and *Palmatolepis jamieae* conodont zones) of the Grand Breux Formation.

Chalon Member	Ermitage Member	Bieumont Member	Boussu-en-Fagne Member
Refrathella incompta Becker, 1971			•
Scrobicula gracilis sp. nov.	•	•	
Uchtovia materni Becker, 1971	•	•	•
Hypotetragona tremula Becker, 1971		•	•
Plagionephrodes laqueus (Matern, 1929)	•	•	•
Plagionephrodes ineptus Becker, 1971			•
Favulella lecomptei Becker, 1971	•	•	•
Jenningsina lethiersi Becker, 1971	•		•
Punctomosea weyanti Becker, 1971?	?	?	?
Healdianella? sp. B in Becker (1971)			•
Bairdia (*Rectobairdia*) *chalonensis* sp. nov.			•
Bairdia (*Rectobairdia*) *paffrathensis* Kummerow, 1953		•	•
Bairdia (*Orthobairdia*) sp. B in Becker (1971)		•	•
Bairdiacypris breuxensis Casier and Olempska, 2008		•	
Bairdiacypris sp. B, aff. *B. martinae* Casier and Lethiers, 1997	•	•	
Schneideria groosae Becker, 1971			•
Acratia evlanensis Egorov, 1953		•	•
Cryptophyllus materni (Bassler and Kellett, 1934)			•

of the left valve on the right is the greatest before the mid-length. Surface of the valves finely pitted.

Remarks.—*Bairdia* (*Rectobairdia*) sp. A of Becker (1971) from the Boussu-en-Fagne Member of the Grand Breux Formation exposed in the access path to the Lion quarry, at Frasnes, may belong to or be very close to *B.* (*R.*) *chalonensis*. The morphology of the carapace is the same in the two species except that the specimens collected by Becker (1971) are smooth.

Discussion

Palaeoecology.—The ostracod fauna present in the Chalon Member and in the extreme base of the Arche Member exposed in the access path to the Arche quarry belongs to the Eifelian Mega-Assemblage. Due probably to a high sedimentation rate (turbidite?) and (or) to the deepness, ostracods seem to be absent in the first 4.5 m (up to sample AR-O6-15) of the Chalon Member. However, in the upper part of the Chalon Member (samples AR-O6-16 to 27) ostracods are abundant and sometimes very abundant. In the top of the Chalon Member, the greater abundance and diversity of podocopid ostracod is indicative of a well oxygenated environment. In the lower part of the interval productive of ostracods *P. laqueus praelaqueus* is the most abundant species. In the middle portion its great abundance is shared with *M. archensis*, and finally in the upper part top of the Chalon, this last species and *B.* (*R.*) *chalonensis* dominate the ostracod fauna. This change in taxonomic composition and dominance is probably due in part to the increase of the water motion related to the shallowing. This is also confirmed by the increasing number of specimens belonging to *Uchtovia materni* Becker, 1971, and *Cryptophyllus materni* (Bassler and Kellett, 1934).

The composition of the ostracod fauna reported by Becker (1971) in the access path to the Arche quarry is quite different. Becker recorded eight species, of which only five are recognised in our study. We have not found *Amphissites* cf. *parvulus*, *Hollinella* (*Keslingella*) *praecursor*, or *Acratia* sp. A. The near absence of podocopids in the fauna reported by Becker (1971), which is composed almost exclusively of metacopid and palaeocopid species, is significant. The greater abundance of metacopids and palaeocopids compared to podocopids indicates a deeper, poorly oxygenated calm environment (Casier 1987). Consequently we surmise that his fauna was collected in the lower part of the Chalon Member, which would support our interpretation of a shallowing trend observed in the upper part of that member.

In the base of the Arche Member ostracods are scarce but that is generally the case in reefs. The rarity of ostracods in that kind of environment is in great part related to the water motion. Carapaces are frequently broken and (or) transported basinward.

Previous studies on ostracods related to the *Pa. punctata* Isotopic Event.—In Nevada some 26 taxa belonging to the

Eifelian Mega-Assemblage and generally indicative of very shallow semi-restricted water conditions were identified, from the Late *Pa. falsiovalis* to the Early *Pa. hassi* conodont Zones (Casier et al. 2006). Because of the rarity and low diversity of ostracods in samples collected from the lower part of the lower member of the Devils Gate Limestone it was not possible to demonstrate conclusively an extinction event close to the Alamo Event Bed. Nevertheless the greater abundance and diversity of ostracods above this bed seems to indicate that the Alamo Event did not result in significant extinction of ostracod taxa in this shallow water setting.

In Poland we have analysed Early and Middle Frasnian ostracods from Wietrznia in the Holy Cross Mountains (Głuchowski et al. 2006). Twenty three ostracod species assigned to thirteen named genera were distinguished in the Wietrznia quarry. This ostracod assemblage also belongs to the Eifelian Mega-Assemblage, and changes from moderately diverse in the lower part of the *Pa. transitans* Zone to poorly diverse in its higher part. The absence of ostracods in the uppermost part of the *Pa. transitans* Zone and in the *Pa. punctata* Zone may be related mostly to facies-controlled taphonomical and/or lowered frequency factors (Głuchowski et al. 2006). The absence of ostracods does not allow us to demonstrate an extinction event close to the Early and Middle Frasnian boundary in Poland.

Finally, a pronounced ostracod change across the Early–Middle Frasnian transition has been documented by Evdokimova (2006) in the northwest part of the East European Platform. Evdokimova recognized more than 80 ostracod species belonging to the Eifelian Mega-Assemblage in the Sargaevo and Semiluki Horizons. However, the significant changes in ostracod content found there are related to the transition from relatively shallow well oxygenated and sometimes semi-restricted environments in the Sargaevo Horizons to deeper settings in the Semiluki Horizon where the ostracods are more abundant, diversified and of course characterised by different species. This important change of environments is not favourable to demonstrate an extinction event close to the Early and Middle Frasnian boundary in the investigated region.

Ostracods and the *Pa. punctata* Isotopic Event in the type region.—The abrupt $\delta^{13}C$ isotopic excursion (from 5.85 ‰ to -1.2‰) observed in the *Pa. punctata* Zone by Yans et al. (2007) was measured in brachiopod shells extracted from the Ermitage Member, the uppermost member in the Moulin Liénaux Formation. Yans et al. (2007) think that the best explanation for the *Pa. punctata* Isotopic Event is a catastrophic release of oceanic methane hydrate triggered by Alamo (or other) impact, and (or) sudden initiation of a global warming. In order to appreciate the influence of the *Pa. punctata* Isotopic Event on ostracods, we have compared the fauna found in the access path to the Arche quarry (*Pa. transitans* Conodont Zone) with the faunas found in the Bieumont Member (*Pa. hassi* conodont Zone) and in the Boussu-en-Fagne Member (*Pa. hassi* and *Pa. jamieae* conodont zones) of the Grand Breux Formation (Table 2). These ostracod faunas are well known by the study of the Frasnes railway section (Casier and Olempska 2008) and of the access path to the Lion quarry (Becker 1971). Seventeen species (18 if we count some doubtful *Punctomosea weyanti* Becker, 1971) out of 25 species (we cannot count *Acratia* sp. indet. and *Bairdiacypris* sp. indet.) present in the Chalon Member of the access path to the Arche quarry are also present in the Bieumont or in the Boussu-en-Fagne Members of the Grand Breux Formation. Only *Plagionephrodes laqueus* is represented by another subspecies. With the exception of *Microcheilinella archensis* all the other species [*Bairdiocypris* sp. sensu Magne (1964), *Bairdiocypris* sp. C, *Cryptophyllus* sp. A, and Paraparchitidae? sp. indet 2] are known only by very rare or poorly preserved specimens. Consequently, we find no evidence that ostracod faunas suffered a crisis close to the Early–Middle Frasnian boundary.

Conclusions

The ostracod fauna present in the Chalon Member and in the extreme base of the Arche Member exposed in the access path to the Arche quarry belongs to the Eifelian Mega-Assemblage. In that section, ostracods are indicative of a regressive trend from a moderately deep, poorly oxygenated marine environment below fair weather wave base to shallow, well oxygenated and agitated environments. The studied section is entirely in the *Favulella lecomptei* Zone based on metacopid ostracods.

A comparison with faunas described from the Frasnes railway section (Casier and Olempska 2008) and from the access path to the Lion quarry (Becker 1971), shows that nearly all the ostracod species recognised in the Chalon Member of the Arche quarry, which belongs to the *Pa. transitans* Conodont Zone, are present in the Bieumont Member and in the Boussu-en-Fagne Member, which belong to the *Pa. hassi* and *Pa. jamieae* conodont zones. Consequently, we can state positively that ostracods do not suffer a crisis during the *Pa. punctata* Conodont Zone and close to the Early–Middle Frasnian boundary. That confirms that the changes observed close to that boundary in the Holy Cross Mountains in Poland (Głuchowski et al. 2006), in the Devils Gate section in Nevada (Casier et al. 2006) or in the northwest of the East European Platform (Evdokimova 2006) are related only to regional environmental changes. Referring to Sepkoski (1996) and McGhee (2001), Yans et al. (2007) noted also that the Early to Middle Frasnian interval is marked by very low extinction intensity in the world ocean.

An new analysis of carbon isotopes across the *Pa. punctata* Zone in the type region for the definition of the Frasnian stage is desirable even if the $\delta^{13}C$ isotopic negative excursion is found in Poland (Yans et al. 2007) and in China (Ma et al. 2008). The high-amplitude negative carbon isotopic excursion detected by Yans et al. (2007) in brachiopod valves may have been amplified by a short hiatus or may be related to the collection. The brachiopods used for the isotopic analysis by

Yans et al. (2007) were collected in the Ermitage path at Boussu-en-Fagne, a section that has been inaccessible for several tens of years.

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Appendix 1

Systematic list of identified ostracod taxa

Order Palaeocopida Henningsmoen, 1953
Suborder Palaeocopina Henningsmoen, 1953
Family Kirkbyellidae Sohn, 1961
Refrathella incompta Becker, 1971 (Fig. 3A, B)
Suborder Paraparchiticopina Gramm, 1975 in Gramm and Ivanov (1975)
Family Paraparchitidae Scott, 1959
Paraparchitidae? sp. indet. 2
Suborder uncertain
Family Scrobiculidae Posner, 1951
Scrobicula gracilis sp. nov. (Fig. 3H–J)
Suborder Platycopina Sars, 1866
Family Kloedenellidae Ulrich and Bassler, 1908
Uchtovia materni Becker, 1971 (Fig. 3C–E)
Family Cavellinidae Egorov, 1950
Cavellina? sp. A. (Fig. 3K)
Suborder Platycopina Sars, 1866?
Family Geisinidae Sohn, 1961
Hypotetragona tremula Becker, 1971 (Fig. 3F, G)

Order Podocopida Sars, 1866
Suborder Metacopina Sylvester-Bradley, 1961
Family Ropolonellidae Coryell and Malkin, 1936
Plagionephrodes laqueus praelaqueus ssp. nov. (Fig. 3L–N)
Plagionephrodes ineptus Becker, 1971 (Fig. 3O)
Family Thlipsuridae Ulrich, 1894
Favulella lecomptei Becker, 1971 (Fig. 4B)
Family Quasillitidae Coryell and Malkin, 1936
Jenningsina lethiersi Becker, 1971 (Fig. 4A)
Family Bufinidae Sohn and Stover, 1961
Punctomosea weyanti Becker, 1971
Suborder Podocopina Sars, 1866
Family Pachydomellidae Berdan and Sohn, 1961
Microcheilinella archensis sp. nov. (Fig. 4F–J).
Family Bairdiocyprididae Shaver, 1961
Bairdiocypris sp. 5 sensu Magne (1964) (Fig. 4C)
Bairdiocypris sp. C. (Fig. 4D, E)
Healdianella? sp. B in Becker (1971) (Fig. 4K)
Family Bairdiidae Sars, 1888
Bairdia (*Rectobairdia*) *paffrathensis* Kummerow, 1953 (Fig. 4L)
Bairdia (*Rectobairdia*) *chalonensis* sp. nov. (Fig. 4M–O)
Bairdia (*Orthobairdia*) sp. B in Becker (1971) (Fig. 5A)
Bairdiacypris sp. B, aff. *B. martinae* Casier and Lethiers, 1997 (Fig. 5B)
Bairdiacypris sp. D (Fig. 5C)
Bairdiacypris sp. indet. (Fig. 5D)
Bairdiacypris breuxensis Casier and Olempska, 2008 (Fig. 5E)
Schneideria groosae Becker, 1971 (Fig. 5H)
Family Acratiidae Gründel, 1962
Acratia evlanensis Egorov, 1953 (Fig. 5F)
Acratia sp. indet. (Fig. 5G)

Order Eridostraca Adamczak, 1961
Family Cryptophyllidae Adamczak, 1961
Cryptophyllus materni (Bassler and Kellett, 1934) (Fig. 5I–M)
Cryptophyllus sp. A (Fig. 5N)