Late Givetian to Middle Frasnian ostracods from Nismes (Dinant Synclinorium, Belgium) and their lithological context

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Abstract

About 2,450 carapaces, valves and fragments of ostracods have been extracted from 94 samples collected in the Fromelennes, Nismes and Moulin Liénaux Formations at Nismes, close to Frasnes (southern border of the Dinant Synclinorium, Belgium). Sixty-three taxa belonging to the Eifelian Mega-Assemblage are recognized. The only significant change as deduced from the ostracod fauna is the progressive transition from lagoonal and semi-restricted environments to open-marine environments in the upper part of the Fromelennes Fm. The *Polyzygia beckmanni beckmanni* Zone and the *Favulella lecomptei* Zone established on metacopid ostracods are recognized at Nismes, and the simultaneous occurrence of these two species in a sample collected in the upper part of the Sourd d'Ave Mbr implies the emendation of the definition of the *P. beckmanni beckmanni* Zone. The new definition is: presence of *P. beckmanni beckmanni* before the first occurrence of *F. lecomptei*. A new species, *Ovatoquasillites nismesensis* nov. sp., is described. The sedimentological analysis confirms that the transition of the Givetian and Frasnian stages does not correspond to a particular event. The evolution of the lithological curve across the Givetian / Frasnian boundary allows the recognition of 5 sequences recording a general drowning of the Givetian carbonate platform. No effective barrier system was active at that time suggesting that the Givetian carbonate platform was already dismantled prior to its definitive drowning.

Keywords: Ostracods, Microfacies, Palaeoecology, Givetian, Frasnian, Dinant Synclinorium, Belgium.

Résumé

Environ 2.450 carapaces, valves et fragments d'ostracodes ont été extraits de 94 échantillons récoltés dans les formations de Fromelennes, de Nismes et du Moulin Liénaux à Nismes situé à proximité de Frasnes (extrémité méridionale du Synclinorium de Dinant, Belgique). Soixante-trois taxa appartenant au Méga-Assemblage de l'Eifel sont reconnus. Le seul changement important au sein de la faune ostracodique s'observe dans la partie supérieure de la Formation de Fromelennes. Il s'agit du passage progressif d'environnements lagunaires et semi-restreints à des environnements marins francs. La Zone à *Polyzygia beckmanni beckmanni* et la Zone à *Favulella lecomptei* établies sur les ostracodes métacopides sont reconnues à Nismes, et la présence simultanée de ces deux espèces guides dans un échantillon récolté au sommet du Membre du Sourd d'Ave, implique que la définition de la Zone à *P. beckmanni beckmanni* doit être modifiée en «présence de *P. beckmanni beckmanni* avant l'apparition de *F. lecomptei*». Une nouvelle espèce, *Ovatoquasillites nismesensis* nov. sp., est décrite. L'analyse sédimentologique confirme que la transition du Givétien au Frasnien ne correspond pas à un événement particulier. L'évolution de la courbe lithologique à travers la limite Givétien / Frasnien permet la reconnaissance de 5 séquences témoignant de la submersion générale de la plate-forme carbonatée givétienne. Aucun système de barrière n'est actif à cette époque, ce qui suggère que la plate-forme givétienne était déjà démantelée avant sa submersion définitive.

Mots-clefs: Ostracodes, Microfaciès, Paléoécologie, Givétien, Frasnien, Synclinorium de Dinant, Belgique.

Introduction

In order to define more precisely the stratigraphical distribution of ostracods at the base of the Frasnian in the Dinant Synclinorium and also to establish if whether or not they suffered a crisis close to the Givetian / Frasnian boundary, three sections were studied at Nismes, a little village close to Frasnes. The first and main section exposes the upper part of the Fromelennes Fm (Givetian), and the stratotype for the Nismes Fm (Givetian and Frasnian). The two other sections expose the Chalon Mbr belonging to the Moulin Liénaux Fm, which overlaps the Early / Middle Frasnian boundary. This boundary has recently been placed at the base of the *punctata* conodont Zone by the International Subcommission on Devonian Stratigraphy (SDS Business Meeting, Leicester, 2006).

The main section at Nismes has been described by

BULTYNCK (1982), BULTYNCK & COEN (*in* BOULVAIN *et al.*, 1999) and BULTYNCK *et al.* (2001) and studied for ostracods by COEN (1982, 1985, 1987). In the southern border of the Dinant Synclinorium, ostracods are also known close to the Givetian / Frasnian boundary in the Sourd d'Ave section, at Ave-et-Auffe (CASIER, 1977, 1987a; MILHAU, 1983a), and in the Fromelennes section, close to Givet (MILHAU, *Ibid.*).

The second goal of the paper is to specify the sedimentological evolution close to the Givetian / Frasnian boundary.

The Nismes sections - General setting

Three sections have been investigated at Nismes in terms of ostracod content and sedimentology. The first and main section (GPS: N 50°04'26"; E 04°32'45"; Fig. 1, point 1) located approximately 250 m SW of Nismes village centre, and above the resurgence of the Eau Noire River, exposes the upper part of the Fromelennes Fm (top of the Givet Group),

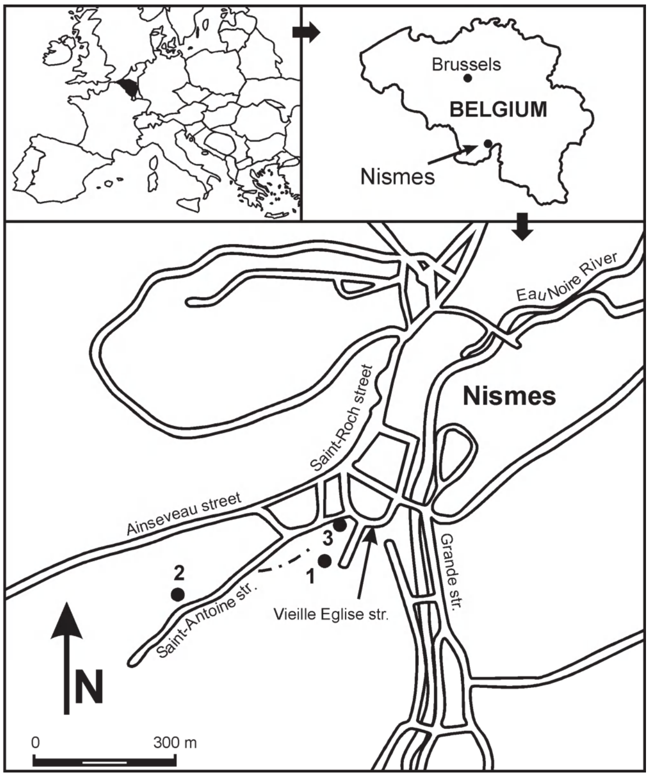

Fig. 1 — Locality map of the three investigated sections. 1: main section showing the upper part of the Fromelennes Fm and the stratotype for the Nismes Fm; 2: section in an underwood showing the top of the La Prée Mbr and the lower part of the Chalon Mbr, which belongs to the Moulin Liénaux Fm; 3: section in the upper part of the Chalon Mbr located under the ruin of a XVIIth church.

and the stratotype for the Nismes Fm (base of the Frasnes Group) (BULTYNCK , 1982; GODEFROID & JACOB, 1986; BULTYNCK *et al.*, 1987, 1988; VANDELAER *et al.*, 1989; BOULVAIN *et al.*, 1999).

The main section (Figs 3, 4) has been chosen in 1966 by the Subcommission on Devonian Stratigraphy (SDS) as an auxiliary stratotype for the Givetian / Frasnian boundary in neritic facies (BULTYNCK & COEN *in* BOULVAIN *et al.*, 1999). However, its exact temporal relationships with the GSSP for the Givetian / Frasnian boundary defined at the Puech de la Suque in the Montagne Noire, France is still in debate (KLAPPER, 2000). The main section encompasses the 15 last meters of the Fort Hulobiet Mbr, which belongs to the Fromelennes Fm, and is composed of a succession of pluri-decimetric limestone beds. The overlying Nismes Fm consists of the Pont d'Avignon Mbr (1.4 m of nodular limestones), the Sourd d'Ave Mbr (11 m of greenish or brownish shales containing rare calcareo-argillaceous nodules at the base, and calcareous lenses increasing in thickness in the upper part), and the La Prée Mbr (about 30 m of greenish or brownish shales with rare calcareo-argillaceous nodules).

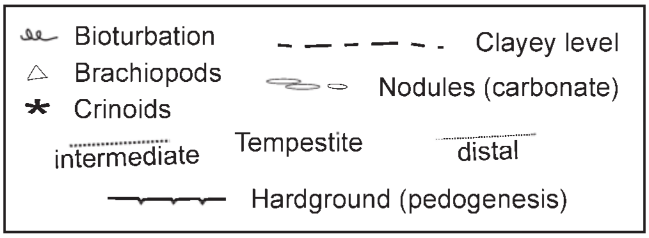

Fig. 2 — Key to symbols used in Figures 3, 4 and 5.

The second section (GPS: N 50°04'24"; E 04°32'34"; Fig. 1, point 2) is located in an underwood, 350 m WSW from the main section. This very discontinuous section (Fig. 5, studied by VANDELAER *et al.*, (1989), exposes the top of the shaly La Prée Mbr, and the first 25 m of the Chalon Mbr. The latter, belonging to the Moulin Liénaux Fm, is essentially shaly, with only few limestone beds occurring in the underwood. VANDELAER *et al.* (1989) stated that *Palmatolepis punctata* is absent in these limestones and consequently assumed that the section is still Early Frasnian in age.

The third section (GPS: N 50°04'27"; E 04°32'47"; Fig. 1, point 3) is located in the Nismes village, under the ruin of a XVIIth century church. The section exposes about 2.3 m of shales and calcareous shales belonging to the upper part of the Chalon Mbr. VANDELAER *et al.* (1989) assigned it to the Middle Frasnian *Palmatolepis punctata* conodont Zone

Rock and facies analysis of the main section (A. PRÉAT)

The studied series, more than 47 meters thick, consists of two lithological parts: the lower part exposes 15 m

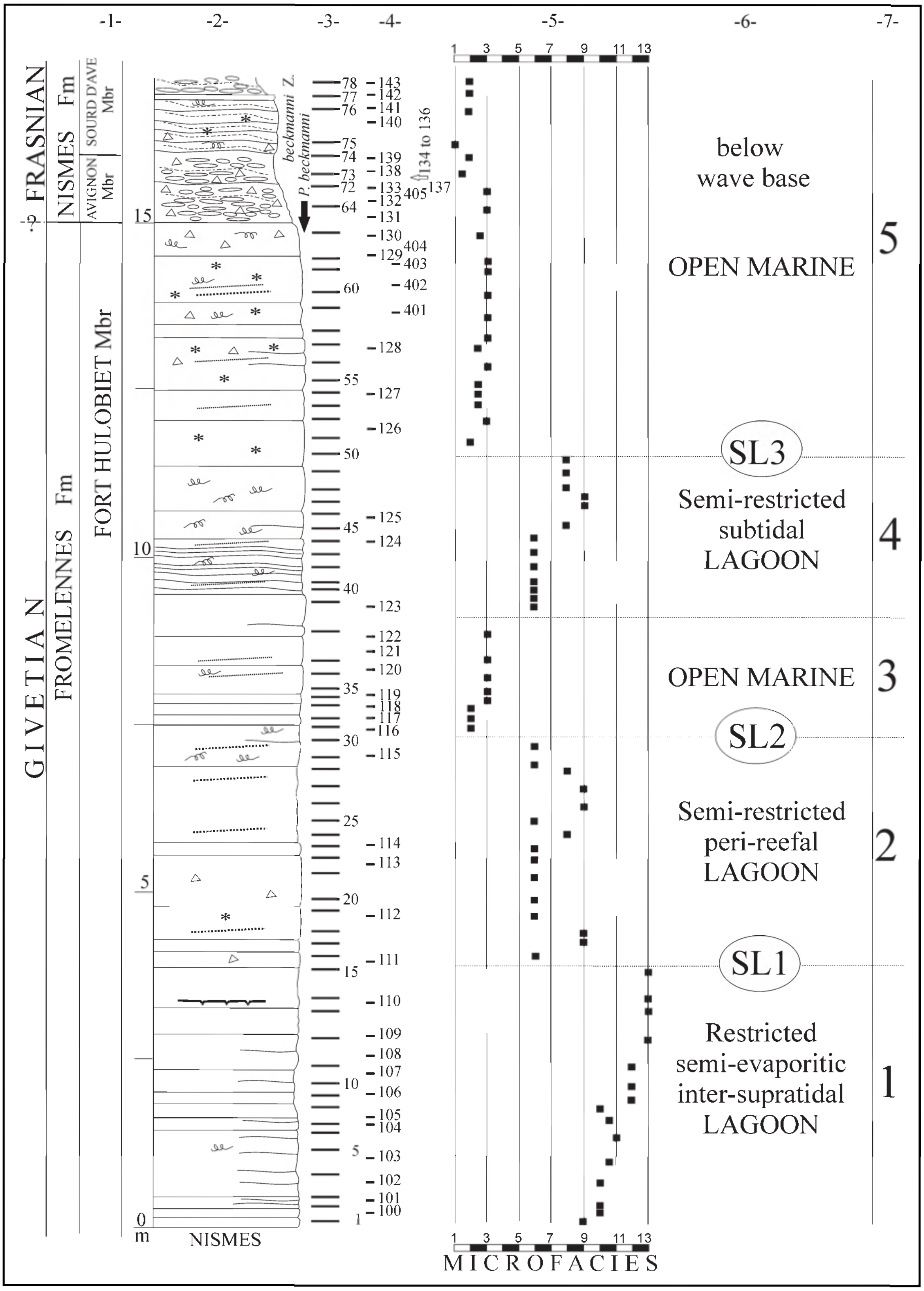

Fig. 3 — Lithological column of the Nismes main section up to the base of the Sourd d'Ave Mbr. Columns: (1) stratigraphy (The Givetian / Frasnian boundary is abitrarily fixed at the Givet Group / Frasnes Group boundary, see conclusions); (2) lithologic log; (3) position of samples for thin section analysis; (4) ostracod sample position; (5) microfacies standard sequence after PRÉAT & MAMET (1989); (6) sedimentological interpretation; (7) sequence analysis. Double sampling has been carried out near the Givetian / Frasnian transition (samples 60 to 71 overlap samples 58 to 64). See column (3). See Fig. 2 for the key of symbols.

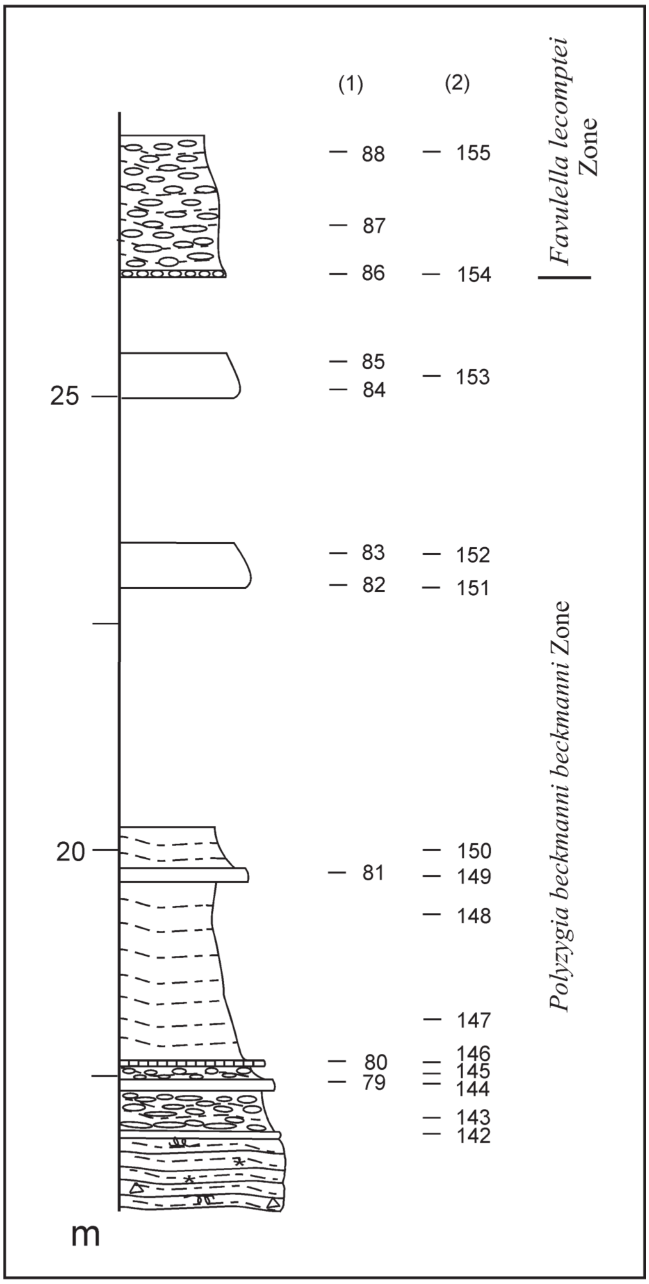

Fig. 4 — Lithological column of the Sourd d'Ave Mbr in the Nismes main section. Location of samples 79-88 collected for the sedimetological analysis (1) and 144 to 155 for the study of ostracods (2). See Fig. 2 for key to symbols.

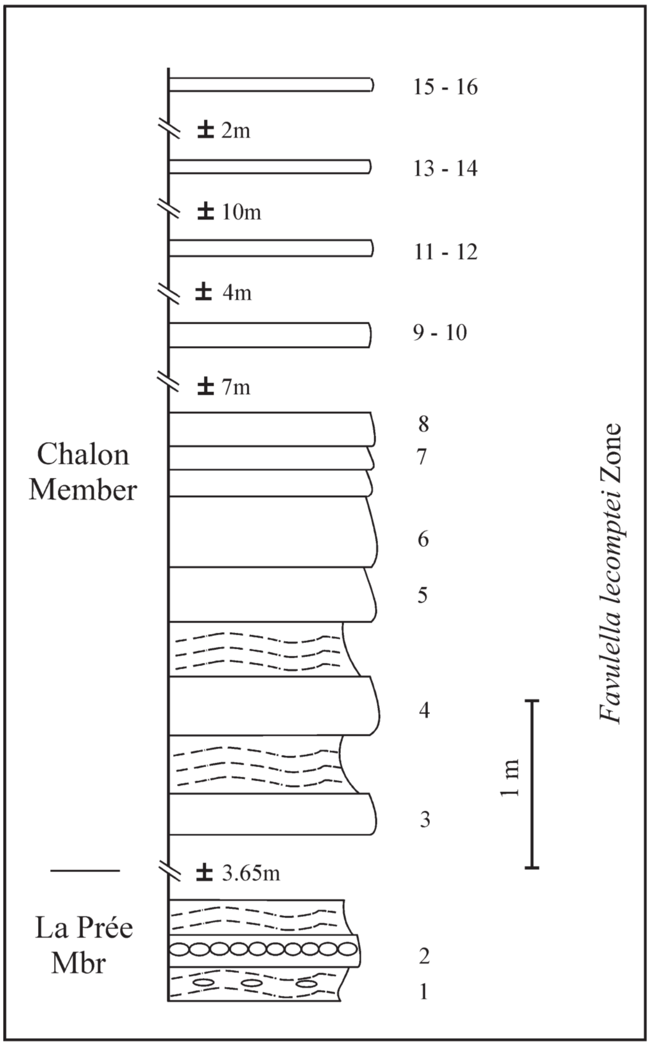

Fig. 5 — Section in the underwood after figure NIS4 of Bultynck & Coen *in* Boulvain *et al.,* (1999). See Fig. 2 for the legend of symbols. Location of samples collected for the study of ostracods. The positions of samples 9 to 16 are approximative.

of thin to medium bedded fine-grained homogeneous greyish limestones (Fromelennes Fm), and the upper part is composed of at least 32 m of brownish nodular shales and homogeneous shales with thin interstratified limestone beds (Nismes Fm). The transition between these two parts is marked by the nodular limestones of the Pont d'Avignon Mbr (Fig. 3). In the field, only the upper part of the Fromelennes Fm shows abundant crinoids and brachiopods, whereas these are rare in the basal 5 meters of the section. The nodular limestones of the Pont d'Avignon Mbr are particularly rich in brachiopods and the overlying shales of the Sourd d'Ave Mbr are homogeneous without important macrofauna. The stratification of the series is regular. Ninety-five samples have been collected (Figs 2, 4) for petrographic analysis in order to constrain the paleoenvironments.

Préat & Mamet (1989) developed a standard microfacies sequence of 13 major microfacies types (MF) for the French-Belgian Givetian of the Dinant Synclinorium and correlated them with the corresponding microfacies of the idealized standard microfacies (SMF) sequence of WILSON (1975). PRÉAT & MAMET's standard sequence (1989) is adopted in the present paper because the Givetian and Frasnian microfacies of the Nismes section are similar to the ones described by these authors, although a few microfacies have not been identified (MF4, MF5 and MF7). The reason for their absence will be discussed below. This way to proceed has the advantage to make comparison or discussion easier between various profiles in the Devonian carbonates of the Dinant Synclinorium.

Microfacies description

Open-marine below or within the storm wave base (MF1, 2, 3)

Microfacies type 1 (or MF1)

Description: shaly, clayey and silty microbioclastic mudstones-wackestones with very thin (< 1 mm) levels of bioclastic wackestones-packstones. Bioclasts consist mainly of echinoderms (crinoids with perforations), brachiopods, ostracods, pelecypods and rare bryozoans and styliolinids (Pl. 1, Figs 1-2). The matrix is commonly burrowed, with accumulation of silty quartz gains and microbioclasts, and could be slightly to strongly microsparitized (Pl. 3, Figs 1, 5). The microspar is fine-grained (10 μm) and consists of irregular calcitic or iron-dolomitic rhombs. The matrix contains fine-grained pyrite (5-10 μm) and abundant pyritospheres of the same type as those described by CASIER *et al.* (2004). Pressure solution processes are well developed in the clayey facies developing a 'pseudonodular texture' with anastomosing seams. This microfacies is only present in the Nismes Formation.

Microfacies type 2 (or MF2)

Description: clayey and silty burrowed bioclastic wackestones and packstones. Organisms are varied and occur as large unmicritized or slightly micritized fragments in millimetric laminae (up to 2 mm thick) or in small irregular lenses (Pl. 1, Figs 3, 4). They consist of echinoderms (mainly crinoids), brachiopods, ostracods, bryozoans, pelecypods and rare styliolinids. A few bioclasts are corroded and blackened ('black grains') by small-sized pyrite, other bioclasts (crinoids, pelecypods) are bioperforated (Pl. 3, Fig. 2). Millimetric bioturbation features with abundant concentric figures obliterate the primary laminations. The micritic matrix can be rich in fine-grained fragments of organic matter. Pyrite and pyritospheres could be abundant and display various morphotypes including filaments similar to those described by CASIER & PRÉAT (2006). Pressure solution seams are well expressed in the wackestone facies.

Microfacies type 3 (or MF3)

Description: laminar bioclastic packstones. The bioclasts are diversified and coarser than in the previous facies: they range from a few millimetres to a few centimetres and consist of echinoderms (mainly crinoids), brachiopods (with spines), mollusks (pelecypods and gastropods), ostracods, a few bryozoans and tentaculitids and rare encrusting serpulids. The bioclasts are well sorted and could exhibit a bimodal distribution with larger and entire shells (brachiopods and mollusks, some with geopetal structure) 'floating' in a medium-grained laminar bioclastic packstone (Pl. 1, Figs 5-6). Rare peloids are associated in thicker bioclastic laminations. Pyritospheres are as abundant as in MF1 and 2, and associated with 'blackened' fine-grained encrustations on large bioclasts or with iron infiltration of the bioclasts or corrosion of crinoids, mollusks and brachiopods (Pl. 3, Figs 3-4) (MAMET & PRÉAT, 2005; CASIER & PRÉAT, 2006). The pyrite can consist of filaments with diameters ranging from 5 to 10 μm and lengths reaching 100 μm. The filaments are observed in the micrite matrix and in the bioclasts. The bioclasts could be micritized and perforated, the holes being circular (1 to 2 mm in diameter). The bioclasts form millimetric to centimetric layers (0.5 to 2 cm), the thicker ones being frequently amalgamated. They display weak or high oblique stratifications or form elongated lenses. Bioturbation is present, but less pronounced that in previous microfacies. The matrix is locally slightly clayey and irregular pressure solution seams develop a pseudonodular structure. The matrix can be recrystallized in a homogeneous fine-grained calcititic microspar. The brachiopod fragments can be very abundant as the molluscan ones, forming thin 'coquina beds'. The matrix as well the bioclasts (brachiopods, crinoids and mollusks) is partly infested by fungal hyphae (Pl. 3, Figs 7-8).

Open-marine, peri-reefal near or within the fair-weather wave base (MF4, 5, 6 and 7)

Microfacies types 4 and 5 (*sensu* the Givetian standard sequence of PRÉAT & MAMET, 1989) are not observed in the series. This point will be discussed later.

Microfacies type 6 (or MF6)

Description: floatstones and rudstones with corals (tabulata visible on Pl. 1, Fig. 7, and rugosa), microbreccia, gastropods, pelecypods, ostracods, a few brachiopods and peloids. The fragments of corals are centimetric and the specimens are heavily encrusted by other corals and lamellar stromatopores, or micritized and partly encrusted by cyanobacteria (*Bevocastria*-type). Microbreccia are subrounded, plurimillimetric to centimetric and consist of homogeneous blackish mudstone. The gastropods are filled with sediment of same texture as the one forming the microbreccia. The micritic matrix of the sediment contains plurimillimetric to centimetric geopetal cavities filled with a peloidal wackestone and microbreccia forming an 'internal sediment'. Larger irregular dissolution cavities are also present and filled with a fine-grained brownish microspar or with large white equigranular calcite cement. Pyrite is abundant as well-formed cubes (200 – 300 µm) in the matrix or at the contact between the matrix and bioclasts. Fine framboidal pyrite (5 – 10 µm) is also abundant in the micrite with dendritic pyrite tufts, which have been apparently disturbed by bioturbation (Pl. 3, Fig. 6). They are similar to those described by PRÉAT *et al.* (2008) in the Devonian carbonates of Morocco. Pressure solution seams and microstylolites are common.

Microfacies type 7 (*sensu* the Givetian standard sequence of PRÉAT & MAMET, 1989) is not observed in the series. This point will be discussed later.

<u>Restricted environments with salinity fluctuations</u> (MF8 to 13)

Microfacies type 8 (or MF8)
Description: wackestones with centimetric pelecypod (disarticulated and joined shells) layers and issinellid (algae) packstones-bafflestones with abundant peloids and lumps. Small-sized gastropods, microbioclasts and ostracods are frequent in the bioclastic layers of the wackestones. Thin inframillimetric levels constituted by sponge spicules are also observed. Echinoderms and brachiopods are rare. *Umbella* and numerous cyanobacterial lumps are present in the issinellid packstones. The bioclasts (mainly pelecypods) are heavily micritized or encrusted by cyanobacteria and serpulids (Pl. 1, Fig. 8). Irregular pressure solution is abundant. Pyrite as small framboids (5-10 µm) and filaments (long up to 100 µm) are common in the wackestone matrix. Medium-sized calcitic microspar is present in the packstone matrix. This latter can be heavily burrowed.

Microfacies type 9 (or MF9)
Description: homogeneous mudstones and wackestones with peloids, pelecypods, gastropods, archaegastropods (BURCHETTE & RIDING, 1977), ostracods and *Umbella* (Pl. 2, Figs 1-2). The matrix contains abundant framboidal and 'filamentous' pyrite. This mineral encrusts as a very thin veneer numerous bioclasts, which are unrecognizable giving a 'bleb' aspect (*sensu* MAMET & PRÉAT, 2003) to the grain. Peloids constitute inframillimetric level including very small irregular cyanobacterial? tubes, some being dichotomous. Small ostracods form also thin interstratified levels.

Microfacies type 10 (or MF10)
Description: spongiostromid packstones and bindstones (Pl. 2, Fig. 3) with abundant ostracods displaying carapaces or stacked valves (Pl. 2, Fig. 4) and small-sized *Earlandia*. A few *Amphipora*, pelecypods, calcispheres and *Palaeomicrocodium* are present. Irregular fenestrae and thin desiccation cracks are observed. The spongiostromid structure is composed of a millimetric to plurimillimetric alternation of homogeneous, very fine-grained dolomudstone and peloidal-lumpy packstone, with abundant cyanobacterial filaments. Rare vertical or oblique burrows cross the laminar structure. Pyrite is common as small pyritospheres in the matrix or has been concentrated in the microstylolites.

Microfacies type 11 (or MF11)
Description: microsparitized peloidal packstones with abundant pelecypods, gastropods, ostracods, *Earlandia* and a few *Umbella*. *Bevocastria* is common in various subrounded to subangular poorly sorted lumps. The calcitic blocky microspar is whitish, medium- (10-50 µm) to coarse crystalline (up to 500 µm). It is present in large plurimillimetric acicular pseudomorphs after sulphate? (Pl. 2, Fig. 5) or included in irregular veins. It replaces progressively the micritic matrix 'isolating' numerous cyanobacterial (*Bevocastria*) chips giving to the sediment the appearance of a microconglomerate. A few cavities contain pelecypods surrounded by irregular lamellar calcitic cement probably associated with micritic meniscus cements. Pyrite is common as small pyritospheres in the matrix or has been concentrated in the irregular microstylolites.

Microfacies type 12 (or MF12)
Description: homogeneous mudstones with a few ostracods, mollusks and *Amphipora.* The microfauna and microflora are very poor and thin bioclastic levels with abundant mollusks are occasionally present (Pl. 2, Fig. 6). Pyritospheres and 'filamentous' pyrite is common.

Microfacies type 13 (or MF13)
Description: fine-grained dolomudstones and mudstones with large irregular geopetal cavities (3 cm in length and 1 cm deep) filled with subrounded lumps and various bioclasts (pelecypods, *Amphipora*, rare ostracods). The infilling sediment displays a normal grading and is slightly coarser than the matrix of the mudstone. Calcitic pseudomorphs are present and replace partly the matrix giving localized *in situ* 'puzzle-like' fragments (packstone-graintone appearance) in the mudstones (Pl. 2, Fig. 7). Irregular tubular curved cracks and bifurcating tubular structures (Pl. 2, Fig. 8) cross cut by irregular arcuate micritic septae forming an alveolar-septal structure (WRIGHT, 1983; MAMET & PRÉAT, 2005) are present. Very thin microparitized needles of unknown origin (?) are associated with the tubular structures. Calcite pseudomorphs of former large acicular minerals and microsparitized needles are also present and replace partly the matrix.

Microfacies and palaeoenvironmental interpretations

1. *Microfacies types 1 to 3:* the texture of the rocks (mudstones to packstones) associated with the characteristics of the bioclastic laminae record the relative paleobathymetry of the storm (SWB) and the fair-weather (FWWB) wave bases (EINSELE & SEILACHER, 1982; AIGNER, 1985; AHR, 1989). The laminar levels are rare and thin (< 1 mm) in MF1, common and of intermediate thickness in MF2 (mm) and thick (> 0.5 cm) and abundant in MF3. An open-marine fauna (echinoderms, brachiopods, bryozoa, styliolinids) occurs in all microfacies types. The size of the bioclasts increases with lamination thickness and with the complexity of the biotic assemblages. The laminations range from plane parallel to oblique from MF1 to MF3. They are relatively well preserved despite the bioturbation. These characteristics record distal to proximal changes and reflect the increasing effect of storms towards shallower offshore water from MF1 to MF3. The general depositional setting was probably that of a middle to outer mixed siliciclastic-carbonate shelf, with an inferred depth around 50-100 m for the deepest part (Nismes Fm) as suggested by the occurrences of MF1 distal tempestites *sensu* AIGNER (1985). Sedimentation is assumed to have been below the photic zone as indicated by the absence of algae. However, the depth estimation of this zone is difficult to determine due to the turbidity of these paleoenvironments with high clay and silt inputs (MAMET & PRÉAT, 2009). Dysaerobic and anaerobic conditions developed also in non-burrowed or slightly burrowed sediments, below the seawater-sediment interface, as indicated by the abundance of 'filamentous' pyrite, pyritospheres and 'blackened grains' related to probable sulphate-reducing bacteria (CASIER *et al.*, 2001; KONHAUSER, 2007). This process could also be partly responsible of the calcite microsparitization of the matrix (PRÉAT *et al.*, 2008).

2. *Microfacies 4 to 7*: these microfacies are interpreted as the barrier belt dominated by reworked stromatopores, corals and algae, following the scheme of PRÉAT & MAMET (1989). Among these facies, microfacies 6 is observed only in the Nismes section (Fromelennes Fm) and represents a peri-reefal environment. It contains reworked constructor macrofauna (stromatopores and corals with reciprocal encrustations) encrusted by cyanobacteria. Numerous geopetal cavities with internal peloidal sediment point to a shallow-water semi-restricted environment where cyanobacterial encrustments developed. The absence of true barrier facies (framestones, MF4) or fore-reef facies (MF5) suggests that the bioconstructions were limited to small patches along the shelf.

3. *Microfacies 8 to 13:* algae (issinellids) in the packstones (MF8), cyanobacteria or 'crytpalgae' and calcispheres in the bindstones (MF10) are the dominant organisms and point to a restricred lagoon. The previous open-marine fauna is absent and the environment is near emergence (MF 12) or semi-evaporitic (MF13). Salinity variations were the rule as indicated by the local abundance of *Earlandia*, *Umbella*, *Palaeomicrocodium* and hypersaline environments allowed sulphates to precipitate in the sediment (MF11 and MF13). The environment was very shallow, intertidal to supratidal as suggested by the archaegastropods (BURCHETTE & RIDING, 1977), the micritic meniscus cements associated with the geopetal cavities or the 'alveolar structures' which are similar to rootlets in Recent calcretes (KLAPPA, 1980).

Palaeoecology, sea-level fluctuations and sequence stratigraphy

The upper part of the Fromelennes Fm in the Nismes section is characterized by one moderate and two important relative sea-level fluctuations (SL1-SL3 in Fig. 3): SL1 is minor and records the transition from a semi-evaporitic lagoon (MF13) to a semi-restricted peri-reefal environment (MF6); SL2 and SL3 record larger sea-level rise from semi-restricted facies to open-marine facies below the fair-weather wave base in the distal part of the shelf ('distal tempestites' of MF1). The succession from the Fromelennes Fm to the Nismes Fm does not record a particular sea-level change: the open-marine facies are similar across the transition and show a weak shift from MF2-MF3 to MF1-MF2 which can be attributed to random energy fluctuations. The main change lies in the clay content and in the apparition of abundant carbonate nodules in the Nismes Fm, which becomes more and more shaly in its upper part. Brachiopods are very abundant at the base of this formation and this highlights a sharp contact with the underlying Fromelennes Fm. The evolution of the lithological curve across the Givetian / Frasnian boundary allows the recognition of 5 sequences (1 to 5, column 7 in Fig. 3) recording a drowning of the Givetian carbonate platform. This transgressive evolution proceeded in different steps, as mentioned above.

Ecological conditions are stressful in the lower part of the main section, the worst conditions occurring at the top of the first sequence (sequence 1) before the SL1 sea-level rise: salinity fluctuations are the rule, hypersaline and subaerial conditions with rootlets occur at the top of sequence 1. Endemic flora and fauna are present and dominated by cyanobacteria, mollusks or ostracods with a few *Amphipora* and *Umbella*. Open-marine fauna (corals, echinoderms, brachiopods, serpulids) appear in sequence 2 due to a slight relative sea-level rise (SL1) along with microbioclasts, archaegastropods, mollusks, various ostracods and peloids. *Umbella* are still present indicating the proximity of the littoral. This general semi-restricted environment is episodically stagnant as indicated by the 'blackened' or 'blebs' grains. True open-marine facies (sequence 3) follow the SL2 increase: echinoderms and brachiopods dominate and are frequently transported during storm activity. They constitute coarse- and medium-grained bioclastic packstone layers (proximal and distal tempestites), which are partly bioturbated. Ostracods could also be abundant. *Umbella* is now absent. Semi–restricted lagoonal conditions (sequence 4) cap this open-marine environment and abundant mollusks, micritized grains, peloids are observed. *Umbella* reappears and is common, because of a nearby shif-ting of the littoral. Issinellids (paleosiphonocladacean algae) are for the first time encountered pointing to a photic zone in a shallow lagoon. As the result of the second important sea-level rise (SL3) true open conditions appear in sequence 5. Abundant echinoderms (sea urchins, crinoids), brachiopods (with spines), mollusks and ostracods are present with a few bryozoans, encrusting serpulids and rare styliolinids. The facies is shaly and heavily burrowed. The bryozoans become more abundant in the carbonate beds interstratified in the Frasnian shaly part of the Nismes Fm.

The stacking pattern of the above-recognized sequences (fifth order? *sensu* VAN WAGOONER *et al.*, 1990) does not reveal a clear pattern. Sequences 1, 2 and 4 consist of meter–scale cycles recording a slight shallowing-upward evolution and sequences 3 and 5 do not present any significant evolution, their discrete facies shifts being probably related to energy variations in the open-marine environment. At a higher level (3rd order) the most important events are the two sea-level rises at the base of sequences 3 and 5. The second one seems more important since it coincides with the end of the carbonate factory and the colonization of the new environments by abundant brachiopods and echinoderms. Sequence 5 could highlight an early transgressive systems tract or a highstand systems tract and corresponds to the drowning of the Givetian carbonate platform, which lasted several millions of years. This drastic change is accompanied by a high detrital input (clays, silts) at the top of the Fromelennes and at the base of the Nismes Formations. Further detailed studies are needed to understand the exact processes related to the drowning of the Givetian platform, but it seems that at the end of the Givetian, sea level was unstable as recorded by the three fluctuations present in the Nismes section. The absence of microfacies 4, 5 and 7 indicate that no effective barrier system were present at that time suggesting that the Givetian carbonate platform was already dismantled prior to final drowning.

Ostracods of the Nismes sections (J.-G. CASIER)

Previous studies

The following ostracod taxa have been recorded by COEN (1982, 1985, 1987) in a sample collected 7 m under the top of the Fromelennes Fm: *Euglyphella* n. sp., *Uchtovia refrathensis* KRÖMMELBEIN, 1954, *Nodella faceta* ROZHDESTVENSKAJA, 1972, *Refrathella struvei* BECKER, 1967, *Coeloenellina* sp., *Cavellina rhenana* KRÖMMELBEIN, 1954, and *Roundyella patagiata* (BECKER, 1964).

In the Pont d'Avignon Mbr, COEN (*Ibid.*) recognized with the first conodont *Ancyrodella: Bairdia (R.) paffrathensis* KUMMEROW, 1953, *Uchtovia refrathensis* KRÖMMELBEIN, 1954, *Polyzygia beckmanni beckmanni*

KRÖMMELBEIN, 1954, *Jenningsina paffrathensis* KRÖMMELBEIN, 1954, and *Nodella hamata* BECKER, 1968. In the la Prée Mbr, COEN (*Ibid.*) recognized also: *Favulella lecomptei* BECKER, 1971, *Jenningsina lethiersi* BECKER, 1971, *Uchtovia materni* BECKER, 1971, *Amphissites* cf. *parvulus* (PAECKELMANN, 1913), *Ponderodictya* sp. C3 MAGNE, 1964 (= *Ponderodictya belliloci* CASIER, 1986 in the present paper), *Polyzygia neodevonica* (MATERN, 1929) and *Cryptophyllus* cf. *materni* (BASSLER & KELLETT, 1934). Finally, COEN (*Ibid.*) mentioned 11 taxa in the Moulin Liénaux Fm at Nismes but without any precision.

Material and methods

Ninety-four samples of approximately 500 g each were collected in the Nismes sections, 34 in the Fort Hulobiet Mbr (NI-100 to NI-130, NI-401 to NI-404), 11 in the Avignon Mbr (NI-405, NI-131 to NI-141), 13 in the Sourd d'Ave Mbr (NI-142 to NI-155), 11 in the La Prée Mbr (NI-156 to NI-161, NI-627 to NI-629, NI-1, NI-2,), and 25 in the Chalon Mbr (NI-3 to NI-21, NI-300 to 304, NI-307). All the samples were crushed by a hydraulic press and samples collected from shales were directly sieved on 250 µm and 1600 µm mesh screens. About 100 g of each of the other samples collected from limestones or from argillaceous limestones were attacked with 99.8% glacial acetic acid, at nearly 90°C, for four days at a rate of eight hours a day. This mode of extraction has been described by LETHIERS & CRASQUIN-SOLEAU (1988). The residues were sieved on the above-mentioned screens. For samples containing ostracods, after this first process, that part of the sample retained by the 1600 µm mesh screen was processed again. About 2,450 carapaces, valves and fragments of ostracods identifiable at any taxonomic level were thus extracted, 1,029 in the Fort Hulobiet Mbr, 171 in the Avignon Mbr, 420 in the Sourd d'Ave Mbr, 72 in the La Prée Mbr, and 759 in the Chalon Mbr.

The localisation of samples collected for the study of ostracods is reported on the Figures 3, 4 and 5, with the exception of the about 30 m thick shally La Prée Mbr cropping out in the main section, and of the shaly Chalon Mbr exposed in the section located under the ruin of the XVIIth century church. The position of these last samples is the following:
La Prée Mbr: NI-156 (0.1 m from the base of the Mbr.), NI-157 (1.5 m), NI-158 (7.5 m), NI-159 (17.5 m), NI-160 (19 m), NI-627 (20 m), NI-628 (23 m), NI-161 (24.5 m), NI-629 (25.5 m).

Chalon Mbr: NI-307 (0.1 m from the base of the section), NI-18 (0.8 m), NI-301 (1.4 m), NI-302 (1.8 m), NI-303 (2.0 m), NI-304 (2.2 m), NI-21 (2.3 m).

List of identified ostracod taxa

Suborder Palaeocopina HENNINGSMOEN, 1953
Superfamily Beyrichioidea MATTHEW, 1886
Family Beyrichiidae MATTHEW, 1886
Kozlowskiella plana (KUMMEROW, 1953)
Pl. 4, Fig. 1

Superfamily Kirkbyoidea ULRICH & BASSLER, 1906
Family Amphissitidae KNIGHT, 1928
Amphissites* cf. *tener BECKER, 1964
Pl. 4, Fig. 2

Amphissites* cf. *parvulus (PAECKELMANN, 1913)

Superfamily Nodelloidea BECKER, 1968
Family Nodellidae ZASPELOVA, 1952.
Nodella* cf. *hamata BECKER, 1968.
Pl. 4, Fig. 3

Family Scrobiculidae POSNER, 1951
Roundyella patagiata (BECKER, 1964)
Pl. 4, Fig. 4

Superfamily Hollinoidea SWARTZ, 1936
Hollinoidea sp. indet.
Pl. 4, Fig. 6.

Family Hollinellidae BLESS & JORDAN, 1971
Adelphobolbina europaea BECKER & BLESS, 1971?

Family Hollinidae SWARTZ, 1936
Parabolbinella vomis BECKER & BLESS, 1971
Pl. 4, Fig. 5

Superfamily Youngielloidea KELLETT, 1933
Family Youngiellidae KELLETT, 1933
Youngiella sp. F5 *in* MAGNE (1964)
Pl. 4, Figs 7-8

Superfamily Drepanelloidea ULRICH & BASSLER, 1923.
Family Aechminellidae SOHN, 1961
Balantoides minimus (LETHIERS, 1971)
Pl. 4, Figs 9-10

Balantoides sp. indet.

Family Bolliidae BOUCEK, 1936
Bolia belgica MATERN, 1929?
Pl. 4, Fig. 11

Superfamily unknown
Family Kirkbyellidae SOHN, 1961
Refrathella struvei BECKER, 1971
Pl. 4, Fig 12

Refrathella cf. ***struvei*** Becker, 1971
Pl. 4, Fig 13

Suborder Paraparchiticopina
Gramm *in* Gramm & Ivanov (1975)
Superfamily Paraparchitoidea Scott, 1959
Family Paraparchitidae Scott, 1959
Coeloenellina sp. A, **aff. *minima*** (Kummerow, 1953) *in* Casier (1991)
Pl. 4, Figs 14- 15

Coeloenellina sp. indet.

Suborder unknown
Superfamily unknown
Family Scrobiculidae Posner, 1951
Scobicula gracilis Casier & Olempska, 2008
Pl. 4, Fig. 16

Suborder Platycopina SARS, 1866
Superfamily Kloedenelloidea Ulrich & Bassler, 1908
Family Kloedenellidae Ulrich & Bassler, 1908
Evlanella mitis Adamczak, 1968
Pl. 4, Fig. 17

Evlanella sp. A, **aff. *mitis*** Adamczak, 1968
Pl. 4, Fig. 18

Uchtovia refrathensis (Krömmelbein, 1954)
Pl. 4, Fig. 19

Uchtovia sp. A, **aff. *refrathensis*** (Krömmelbein, 1954)
Pl. 4, Fig. 20

Uchtovia materni Becker, 1971.
Pl. 5, Fig. 1

Uchtovia? sp. indet.

Superfamily Cytherelloidea Sars, 1866
Family Cavellinidae Egorov, 1950
Cavellina macella Kummerow, 1953
Pl. 5, Fig. 2

Cavellina rhenana Krömmelbein, 1954
Pl. 5, Fig. 3

Cavellina devoniana Egorov, 1950
Pl. 5, Figs 4-5

Suborder Metacopina Sylvester-Bradley, 1961
Superfamily Healdioidea Harlton, 1933
Family Healdiidae Harlton, 1933
Cytherellina perlonga (Kummerow, 1953)
Pl. 5, Fig. 6

Superfamily Thlipsuroidea Ulrich, 1894
Family Thlipsuridae Ulrich, 1894
Polyzygia beckmanni beckmanni Krömmelbein, 1954
Pl. 5, Fig. 7

Polyzygia neodevonica (Matern, 1929)
Pl. 5, Fig. 8

Polyzygia neodevonica aragonensis Gozalo & Sanchez de Posada, 1986
Pl. 5, Fig. 9

Favulella lecomptei Becker, 1971
Pl. 5, Figs 10-11

Favulella sp. A, aff. ***lecomptei*** Becker, 1971

Favulella lecomptei spissa Żbikowska, 1983

Family Bufinidae Sohn & Stover, 1961
Punctomosea weyanti Becker, 1971
Pl. 5, Fig. 12

Family Quasillitidae Coryell & Malkin, 1936
Jenningsina paffrathensis Krömmelbein, 1954
Pl. 5, Fig. 13

Jenningsina lethiersi Becker, 1971
Pl. 5, Fig. 14

Svantovites magnei Becker, 1971
Pl. 5, Fig. 15

Ovatoquasillites nismesensis nov. sp.
Pl. 6, Fig. 2-4

Quasillites sp. A, **aff. *fromelennensis*** Milhau, 1983
Pl. 6, Fig. 1

Ponderodictya belliloci Casier, 1986
Pl. 6, Fig. 5

Ponderodictya **cf.** *belliloci* Casier, 1986
Pl. 6, Fig. 6

Family Ropolonellidae Coryell & Malkin, 1936
Plagionephrodes laqueus praelaqueus Casier & Olempska, 2008
Pl. 6, Fig. 7

Plagionephrodes sp. indet.
Pl. 6, Fig. 8

Superfamily Thlipsuroidea Ulrich, 1894?
Family unknown
Asturiella blessi Becker, 1971
Pl. 6, Fig. 9

Suborder Podocopina SARS,1866
Superfamily Bairdiocypridoidea SHAVER, 1961
Family Bairdiocyprididae SHAVER, 1961
Healdianella sp. A
Pl. 6, Fig. 10

Healdianella? sp. B
Pl. 6, Fig. 11

Healdianella? sp. C

Bairdiocypris corniger ROZHDESTVENSKAJA, 1962
Pl. 6, Fig. 12

Bairdiocypris sp. A, **aff.** ***rhenana*** KEGEL, 1932
Pl. 6, Fig. 13

Bairdiocypris sp. 5 *in* MAGNE (1964)
Pl. 6, Fig. 14

Family Bairdiocyprididae SHAVER, 1961?
Orthocypris kummerowi ZBIKOWSKA, 1983
Pl. 6, Fig. 15

Family Pachydomellidae BERDAN & SOHN, 1961
Tubulibairdia sp. A, **aff.** ***antecedens*** (KEGEL, 1932)
Pl. 6, Figs 16-17

Microcheilinella **cf.** ***archensis*** CASIER & OLEMPSKA, 2008
Pl. 7, Fig. 1

Microcheilinella sp. A *in* CASIER & OLEMPSKA (2008)
Pl. 7, Fig. 2

Microcheilinella sp. *in* COEN (1985)
Pl. 7, Fig. 3

Family Rectellidae NECKAJA, 1966
Rectella trapezoides ZASPELOVA, 1959? in COEN (1985)
Pl. 7, Fig. 4

Superfamily Bairdioidea SARS, 1888
Family Acratiidae GRÜNDEL, 1962
Acratia sp. indet.
Pl. 7, Fig. 5

Acratia? sp. indet.
Pl. 7, Fig. 6

Family Bairdiidae SARS, 1888
Bairdia paffrathensis KUMMEROW, 1953
Pl. 7, Fig. 7

Bairdia cf. ***paffrathensis*** KUMMEROW, 1953

Bairdia sp. *in* COEN (1985)
Pl. 7, Fig. 8

Bairdia (Rectobairdia) chalonensis
CASIER & OLEMPSKA, 2008

Bairdiacypris breuxensis CASIER & OLEMPSKA, 2008
Pl. 7, Fig. 9

Bairdiacypris sp. A.
Pl. 7, Fig. 10

Bairdiacypris sp. D

Bairdiacypris sp. E
Pl. 7, Fig. 11

Bairdiacypris sp. indet.

Schneideria? groosae BECKER, 1971
Pl. 7, Fig. 12

Order Eridostraca ADAMCZAK, 1961
Family Cryptophyllidae ADAMCZAK, 1961
Cryptophyllus sp. indet.
Pl. 7, Figs 13-14

Description of a new Ovatoquasillites LETHIERS, 1978

Ovatoquasilites nismesensis nov. sp.
Pl. 6, Figs 2-4

Derivatio nominis
From the Nismes village, close to Mariembourg.

Types
Holotype: Carapace (Pl. 6 Fig. 2a,b), NI-136. IRScNB n° b5144. L = 0.72 mm; H = 0.37 mm; W = 0.35 mm. Paratype A: Carapace (Pl. 6 Fig. 3), NI-136. IRScNB n° b5145. L = 0.72 mm; H = 0.38 mm; W = 0.32 mm. Paratype B: Carapace (Pl. 6 Fig. 4), NI-139. IRScNB n° b5146. L = 0.65 mm; H = 0.31 mm; W = 0.28 mm.

Locus-typicus
Nismes main section (N 50°04'26"; E 04°32'45") located approximately 250 m SW of the Nismes village centre, and above the resurgence of the Eau Noire River.

Stratum typicum
Late Givetian? - Early Frasnian (Devonian). Nismes Fm.

Material
21 valves and carapaces.

Diagnosis
Reticulated *Ovatoquasillites* with a straight hinge line in a narrow depression. Curvature of the right valve more regular than the left one in the antero-dorsal sector. Posterior border nearly straight in the postero-ventral sector. Regularly biconvex outline in dorsal view.

Description
Ovatoquasillites elongate and preplete. Greatest length at mid-height and position of the greatest height variable between the two-fifth and the fourth part of the great length. Dorsal border slightly convex to straight and posteriorly inclined, except in the anterior sector where it is more curved. Ventral border straight or slightly concave. Anterior border regularly curved with the extremity between the mid-height and the ventral third part of the height. Posterior border well rounded dorsaly and nearly straight ventraly with a posterior extremity at mid-height. Outline of the right valve similar to the outline of the left valve except in the antero-dorsal sector where the curvature of the right valve is more regular. In right lateral view, the left valve projects the right one all along the border and particularly in the antero-dorsal sector. Large muscle scar sometimes visible in the centre of the valves. In dorsal view, well rounded valves with the great width at the posterior third of the great length. Straight hinge line in a thin depression. Surface of valves finely reticulated.

Comparison
Ovatoquasillites nismesensis nov. sp. differs from several species belonging to the genus by the absence of spine in the postero-ventral sector. *O. nismesensis* nov. sp. differs from *Quasillites* sp. G 1 figured by MAGNE (1964, Pl. XVIII, Fig. 45a-c) from the Blacourt Limestone of Caffiers (Boulonnais, France) by its a greatest width. *O. nismesensis* nov. sp. differs also from *Quasillites fromelennensis* MILHAU, 1983, from the Fromelennes Fm at Fromelennes, by its bi-convex outline in dorsal view. *O. avesnellensis* LETHIERS, 1973, abundant in the base of the Famennian in the Synclinorium of Dinant posses the same outline and the same ornamentation but is distinguished by a hinge in a larger depression. *O. alveolatus* CASIER & DEVLEESCHOUWER, 1995, also abundant in the base of the Famennian, is distinguished by its rough pitted ornamentation.

Occurrence
Ovatoquasillites nismesensis nov. sp. is known from the Pont d'Avignon Mbr and the Sourd d'Ave Mbr belonging to the Nismes Fm (Late Givetian? - Frasnian).

Palaeoecology of ostracods

In the three sections investigated at Nismes, the ostracod fauna belongs to the Eifelian Mega-Assemblage generally characterised by a rich and diverse ostracod fauna indicative of shallow marine (neritic), semi-restricted or lagoonal environments. This mega-assemblage corresponds to the Eifelian ecotype defined by BECKER (*in* BANDEL & BECKER, 1975) (See: CASIER, 2004, and CASIER *et al.*, 2005).

1. In the 15 last meters of the Fort Hulobiet Mbr, which belong to the Fromelennes Fm (Fig. 3), ostracods are abundant and relatively diverse. Twenty-four taxa (Table 1) have been recognized, but the ostracod content is in reality very variable from one sample to the other. Ostracods are absent in six samples (NI-106, 108, 109, 110, 123, 125), unidentifiable in six others (NI-114, 116, 117, 124, 128, 403), and the monospecificity prevails frequently. We have also extracted numerous *Pumilio* brachiopods from sample NI-113.

The genus *Cavellina*, and especially the species *Cavellina devoniana* EGOROV, 1950, dominates largely the ostracod fauna from sample NI-100 to sample NI-105, displaying lagoonal conditions. The absence of ostracods in several samples of the overlying interval (upper part of sequence 1) is probably indicative of more stressfull lagoonal conditions. From sample NI-111 to sample NI-122, ostracods are anew present, with *Uchtovia refrathensis* (KRÖMMELBEIN, 1954) as dominating species now. The environment was semi-restricted with a pronounced marine influence attested by the presence of some podocopids in almost all these samples (CASIER, 2008). The richness in ostracods and their diversification in NI-118 (noteworthy the entry of several palaeocopid and metacopid species) display an open-marine environment below fair-weather wave base (CASIER, *ibid.*). The rarity or absence of ostracods in overlying samples NI-123 to NI-125 is anew indicative of more stressful lagoonal conditions as deduced from the sedimentological analysis. In NI-126 and above, the composition and rarity of the ostracod fauna, and the abundance of fragments of carapaces are probably related to an increase in energy levels of the environment. Only the last sample (NI-130) collected in the Fort Hulobiet Mbr displays a deeper open-marine environment below fair-weather wave base, as indicated by the entry of *Polyzygia beckmanni*

beckmanni KRÖMMELBEIN, 1954, *Plagionephrodes laqueus prolaqueus* CASIER & OLEMPSKA, 2008 and *Balantoides* sp.

2. Ostracods are frequently occurring in the Pont d'Avignon Mbr (Fig. 3, Table 2), except for sample NI-132, where they are absent and sample NI-138, only yielding unidentifiable specimens. Podocopids (4 species), metacopids (5 species) and palaeocopids (3 species) dominate the association. Platycopid ostracods, on the contrary, have not been identified, except for some *Uchtovia*. The environment remained open-marine, below fair-weather wave base.

3. The Sourd d'Ave Mbr (Fig. 3, Table 2) yield well-diversified ostracod associations, except for sample NI-152, which is barren and sample (NI-153) containing exclusively unidentifiable forms. Metacopids continue to increase in number of taxa and number of specimens, comparatively to the other groups of ostracods, attesting the deepening trend.

4. In the La Prée Mbr (Tables 2 & 3), ostracods are absent in 6 samples (NI-157, 158, 160, 161, 1, 2), and rare poorly diversified in all the others. The rarity of ostracods is certainly in part related to the difficulties to extract ostracods from these shales. Nevertheless the composition of the ostracod fauna is not indicative of an important change in water depth during the deposition of the La Prée Mbr.

5. In the Chalon Mbr (Fig. 5, Table 3), below the entry of *Palmatolepis punctata* (section in the underwood) the ostracod fauna is anew very rich and diversified. Metacopids, as well as podocopids and palaeocopids, are represented by a lot of species, indicating a better-oxygenated environment closer to fair-weather wave base.

6. Ostracods are present in all samples from the upper part of the Chalon Mbr, exposed in the section under the ruin of the XVIIth century church (Table 3, samples NI-18 and overlying suite). Several samples from that part of the Chalon Mbr, which belongs to the Middle Frasnian (*punctata* conodont Zone),

Fromelennes Fm - Fort Hulobiet Mbr	100	101	102	103	105	107	111	112	113	115	118	119	120	121	122	126	127	401	402	129	404	130
Kozlowskiella plana (KUMMEROW, 1953)	●	●	●	●																		
Acratia? sp. indet.	●								●													
Cryptophyllus sp. indet.	●					●			●													
Cavellina devoniana EGOROV, 1950	●	●	●	●	●			?		?			●									
Cavellina macella KUMMEROW, 1953	●	●	●													●						
Evlanella mitis ADAMCZAK, 1968			?				?				?			?	●							
Nodella cf. *hamata* BECKER, 1968							●															
Cavellina rhenana KRÖMMELBEIN, 1954							●															
Plagionephrodes sp. indet.							●	●	●	●	●				●							
Uchtovia refrathensis (KRÖMMELBEIN, 1954)							●	●	●	●	●	●	●	●	●			?		?	?	
Bairdia cf. *paffrathensis* KUMMEROW, 1953								●		●	●	●									?	?
Bairdiocypris sp. A, aff. *rhenana* KEGEL, 1932							●															●
Bairdia sp. *in* COEN (1985)									?	●	●											
Bairdiocypris corniger ROZHDESTVENSKAJA, 1962									●			●	●									
Cytherellina perlonga KUMMEROW, 1953										●					●							
Rectella trapezoides ZASPELOVA, 1959? *in* COEN (1985)											●		●									
Quasillites sp. A, aff. *fromelennensis* MILHAU, 1983											●				●							
Uchtovia sp. A, aff. *refrathensis* (KRÖMMELBEIN, 1954)											●		?	●				●				
Roundyella patagiata (BECKER, 1964)											●	●		●				?		?		
Schneideria? groosae BECKER, 1971											●										●	
Microcheilinella sp. *in* COEN (1985)													●									
Evlanella sp. A, aff. *mitis* ADAMCZAK, 1968															●							
Bairdiacypris sp. indet.															●							
Bairdiacypris sp. A																	●		●			
Jenningsina paffrathensis KRÖMMELBEIN, 1954																				●		
Polyzygia beckmanni beckmanni KRÖMMELBEIN, 1954																						●
Plagio. laqueus praelaqueus CASIER & OLEMPSKA, 2008																						●
Balantoides sp. indet.																						●
Acratia sp. indet.																						?

Table 1 — Distribution of ostracods in the Fort Hulobiet Mbr of the Fromelennes Fm (main section).

Nismes Fm	Pont d'Avignon Mbr.									Sourd d'Ave Mbr.										La Prée Mbr.				
	131	405	133	137	134	135	136	139	141	142	143	144	145	146	147	148	149	150	151	154	156	159	627	628	629
Orthocypris kummerowi ZBIKOWSKA, 1983	●																								
Bairdiocypris sp. A, aff. *rhenana* KEGEL, 1932	●				?	?	●	?																	
Plagio. laqueus praelaqueus CASIER & OLEMPSKA, 2008	●		?	●	●	●	●	●	●	●															
Jenningsina paffrathensis KRÖMMELBEIN, 1954	●			●			●	●				●													
Uchtovia refrathensis (KRÖMMELBEIN, 1954)	●				●	●	?	●		?							?								
Ovatoquasillites nismesensis nov. sp.	●			●			●	●			●		●			?			?						
Polyzygia beckmanni beckmanni KRÖMMELBEIN, 1954	●	●	●	●	●	●	●	●	●	●	●			?			●	●	●						
Bairdia paffrathensis KUMMEROW, 1953			?	●	●	?		●																	
Scobicula gracilis CASIER & OLEMPSKA, 2008				●			●	●		?															
Roundyella patagiata (BECKER, 1964)						●																			
Bairdiacypris sp. A							●																		
Ponderodictya belliloci CASIER, 1986						?	●		●	●	?	●	?					●					●		
Healdianella sp. A							●					●			?			?				?			?
Refrathella cf. *struvei* BECKER, 1967										●															
Rectella trapezoides ZASPELOVA, 1959? *in* COEN (1985)										●															
Ponderodictya cf. *belliloci* CASIER, 1986											●														
Balantoides sp. indet.											●														
Healdianella ? sp. B												●		●				●							
Cavellina devoniana EGOROV, 1950												●	?				?	?							
Favulella sp. A, aff. *lecomptei* BECKER, 1971												●							●						
Acratia sp. indet.																●									
Coeloenellina sp. indet.																	●								
Cryptophyllus sp. indet.																		●							
Favulella lecomptei BECKER, 1971																				●	●		●	●	●
Microcheili. cf. *archensis* CASIER & OLEMPSKA, 2008																						●			
Jenningsina lethiersi BECKER, 1971																						●	●	●	
Parabolbinella vomis BECKER & BLESS, 1971																								●	

Table 2 — Distribution of ostracods in the Pont d'Avignon, Sourd d'Ave and La Prée Members, all belonging to the Nismes Fm (main section).

contain a fauna exclusively composed of metacopids and palaeocopids, indicating a poorly oxygenated environment, deep below fair-weather wave base. The ostracod fauna from sample NI-304, however, contains numerous thick-shelled podocopid and Paraparchitidae, belonging to the genus *Coeloenellina*, which are in reality indicative of an oxygenated very shallow environment close to fair-weather wave base. Their presence is probably related to exceptional storms or to a tsunami. Noteworthy is the presence at the same level of the conodont genus *Icriodus* (VANDELAER *et al.*, 1989), also indicative of a shallow setting.

Biostratigraphy

The *Polyzygia beckmanni beckmanni* Zone and the *Favulella lecomptei* Zone based on metacopid ostracods are recognized at Nismes. The *P. beckmanni beckmanni* Zone begins some centimetres below the base of the Pont d'Avignon Mbr and extends to the top of the Sourd d'Ave Mbr. In reality the entry of that guide species is certainly facies-controlled and corresponds to the change of environment from shallow (above fair-weather wave base) marine agitated settings to deeper settings. Noteworthy is also that the guide-species is represented by numerous specimens in quasi all samples.

The *Favulella lecomptei* Zone starts in the top of the Sourd d'Ave Mbr, and extends all over the la Prée Mbr, the guide-species also being represented by numerous specimens in quasi all samples. However *F. lecomptei* has been found associated with *P. beckmanni beckmanni* in the uppermost sample of the Sourd d'Ave Mbr. Consequently, the definition of the *P. beckmanni beckmanni* Zone must be emended in "presence of *P. beckmanni beckmanni* before the first occurrence of *F. lecomptei*".

COEN (1987) has surmised that *P. beckmanni beckmanni* and *F. lecomptei* belong to the same phylogenetic succession. We agree with that hypothesis, which is not without consequences for the attribution of the species *lecomptei* to the genus *Favulella* SWARTZ & SWAIN, 1941. In reality, the species *lecomptei* might belong to the genus *Polyzygia* GÜRICH, 1896.

Nismes Fm & Moulin Liénaux Fm	La Prée Mbr.		Chalon Member																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	307	18	301	302	303	304	21
Bairdia sp. indet.	●			●																			
Healdianella? sp. C	●				●							●											
Jenningsina lethiersi BECKER, 1971	●			●		●		●				●	●	●			?						
Favulella lecomptei BECKER, 1971	●	●	●	●	●	●	●	●	●	●	●	●	●					●			●		●
Microcheilinella sp. A *in* CASIER & OLEMPSKA (2008)			●																				
Plagionephrodes laqueus praelaqueus CASIER & OLEMPSKA, 2008			●		●	●							●										
Refrathella struvei BECKER, 1967			●			●	●																
Youngiella sp. F5 *in* MAGNE (1964)			●			●		●	●	●	●	●				●			?				
Polyzygia neodevonica (MATERN, 1929)			●		●	●		●	●		●	●				●					●		
Asturiella blessi BECKER, 1971				●			?										●						
Amphissites cf. *parvulus* (PAECKELMANN, 1913)					●																		
Polyzygia neodevonica aragonensis G. & S. DE P., 1986					●							●											
Schneideria? groosae BECKER, 1971					●								●				?						
Uchtovia materni BECKER, 1971						●	●	●		●	?	?											
Scrobicula gracilis CASIER & OLEMPSKA, 2008						●	●				?	●	●				●				●	●	
Microcheilinella sp. indet.							●					●											
Bairdia (Rectobairdia) chalonensis CASIER & OLEMPSKA, 2008							●						?										
Balantoides minimus (LETHIERS, 1971)								●															
Uchtovia? sp. indet.								●															
Cryptophyllus sp. indet.								●													●		
Coeloenellina sp. indet.								●													?	●	
Healdianella sp. A								●														●	
Bairdiacypris breuxensis CASIER & OLEMPSKA, 2008									●														
Svantovites magnei BECKER, 1971												?											●
Bairdiacypris sp. D															●								
Punctomosea weyanti BECKER, 1971															●	●	●		●		●		
Favulella lecomptei spissa ŻBIKOWSKA, 1983																●							
Bolia belgica MATERN, 1929 ?																?							
Bairdiacypris sp. A																				?			
Adelphobolbina europaea BECKER & BLESS, 1971 ?																					●		
Tubulibairdia sp. A, aff. *antecedens* (KEGEL, 1932)																						●	
Amphissites cf. *tener* BECKER, 1964																						●	
Microcheilinella cf. *archensis* CASIER & OLEMPSKA, 2008																						●	
Hollinoidea sp. indet.																						●	
Bairdiacypris sp. E																						●	
Bairdiocypris sp. 5 *in* MAGNE (1964)																						●	

Table 3 — Distribution of ostracods in the top of the La Prée Mbr, belonging to the Nismes Fm, and in the Chalon Mbr, which is part of the Moulin-Liénaux Fm (section in the underwood and section under the ruin of a XVIIth century church).

Conclusions

Several ostracod assemblages belonging to the Eifelian Mega-Assemblage are recognized in the three sections investigated at Nismes. In the upper part of the Fromelennes Fm, they indicate lagoonal environments (= Ass. 0 *in* CASIER, 1987b, 2008; see also fig. 3 *in* CASIER *et al.*, 1995), semi-restricted environments (= Ass. I, *ibid.*), and marine environments above fair-weather wave base (= Ass. II, *ibid.*). The associations from the upper part of the Formation point to a marine environment below fair-weather wave base (= Ass. III, *ibid.*).

In the Nismes Fm and also in the main part of the Chalon Mbr, the ostracod fauna indicates environments below fair-weather wave-base (= Ass. III), but less deep for the Chalon Mbr exposed in the underwood. Finally, in the part of the Chalon Mbr exposed under the ruin of the XVIIth century church (*punctata* conodont Zone), the ostracod fauna is generally indicative of an open-marine poorly oxygenated environment below fair-weather wave base. Nevertheless, in one sample (NI-304) the composition of the ostracod fauna points to a very shallow well-oxygenated marine environment very close to fair-weather wave base. The presence of that fauna is intriguing and may be related to an abnormal event such an exceptional storm or a tsunami. A relation with the *punctata* isotopic Event (Yans *et. al.*, 2007) is possible. Yans and colleagues have demonstrated an abrupt and high-amplitude negative carbon isotopic excursion ($\delta^{13}C$ shift of -7‰) in the *punctata* conodont Zone, corresponding probably to a worldwide perturbation in the earth-ocean system. They suggested also that this isotopic event is related to a catastrophic release of oceanic methane hydrates and they estimated that among others an impact or a high-amplitude sea-level change may have contributed to that excursion. However the comparative study of ostracods present in the access path to the Arche quarry and these of the railway section in the Frasnian type region, has recently demonstrated that these organisms were not affected by a crisis during the *punctata* conodont Zone, close to the Early Frasnian / Middle Frasnian boundary (CASIER & OLEMPSKA, 2008a).

The only significant change in the ostracod fauna at Nismes is observed in the upper part of the Fromelennes Fm, several meters below the Givetian / Frasnian boundary, as officially designated by the Subcommission on Devonian Stratigraphy (SDS) in 1966. This change corresponds to the progressive passage from shallow lagoonal and semi-restricted environments to open-marine environments. The study of ostracods and the sedimentological analysis of the GSSP at Puech de la Suque in the Montagne Noire (France) showed that the Givetian / Frasnian boundary corresponds to the beginning of a sea-level rise (CASIER & PRÉAT, 2007). Consequently, it is suggested that this boundary should be fixed in the Nismes section more probably closer to the Givet Group / Frasnes Group boundary. This is also more in accordance with the results of the study of the Givetian / Frasnian GSSP by ABOUSSALAM (2009) and BECKER (oral commun., June, 2009).

The *Polyzygia beckmanni beckmanni* Zone and the *Favulella lecomptei* Zone of the Metacopina-based biozonation are recognized at Nismes, and the definition of the *P. beckmanni beckmanni* Zone must be revised in order to take into account the co-occurrence of both species during a very short time interval. The study shows that the entry of *P. beckmanni beckmanni* and of the conodont genus *Ancyrodella* is facies-controlled, and corresponds to the shift from agitated marine environment above fair-weather wave base to deeper marine environments, as also suggested by the sedimentological study. The latter has showed that the Givetian platform was unstable at the end of the Givetian, and progressive sea-level fluctuations led to the drowning of the carbonate platform.

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References

ABOUSSALAM, Z., 2009. New Conodont Faunas from around the Middle/Upper Devonian Boundary of the Montagne Noire (S. France). Abstract 9th North American Paleontological Convention, Cincinnati, Ohio. *Cincinnati Museum Center Scientific Contributions,* **3**: 226.

AHR, W. 1989. Sedimentary and tectonic controls on the development of an Early Mississippian carbonate ramp, Sacramento Mountains area, New Mexico. *In*: CREVELO, P., WILSON, J. & READ, J.F. eds. Controls on Carbonate Platform and Basin Development. *Society of Economic Palaeontologists and Mineralogists Special Publication*, **44**: 203-212.

AIGNER, T., 1985. Storm Depositional System. Dynamic stratigraphy on modern and ancient shallow-marine sequences. Lecture Notes in Earth Sciences, Springer Verlag, Berlin, Heidelberg, New York, 174 pp.

BANDEL, K. & BECKER, G., 1975. Ostracoden aus paläozoischen pelagischen Kalken der Karnischen Alpen (Silurium bis Unterkarbon). *Senckenbergiana lethaea*, **56,** 1: 1-83.

BOULVAIN , F., BULTYNCK, P., COEN, M., COEN-AUBERT, M., LACROIX, D., LALOUX, M., CASIER, J.-G., DEJONGHE, L., DUMOULIN, V., GHYSEL, P., GODEFROID, J., HELSEN, S., MOURAVIEFF, N., SARTENAER, P., TOURNEUR, F. & VANGUESTAINE, M., 1999. Les Formations du Frasnien de la Belgique. *Memoirs of the Geological Survey of Belgium,* **44**: 1-126.

BULTYNCK, P., 1982. Conodont succession and general faunal distribution across the Givetian-Frasnian boundary in the type area. *In:* F. BIGEY *et al.*: Papers on the Frasnian - Givetian boundary. Subcommission on Devonian Stratigraphy. Geological Survey of Belgium: 34-59.

BULTYNCK, P., CASIER, J.-G., COEN, M., COEN-AUBERT, M., GODEFROID, J., JACOBS, L., LOBOZIAK, S., SARTENAER, P. & STREEL, M., 1987. Pre-Congress excursion to the Devonian stratotypes in Belgium. *Bulletin de la Société belge de Géologie,* **95**, 3: 249-288.

BULTYNCK, P., CASIER, J.-G., COEN-AUBERT, M. & GODEFROID, J., 2001. Pre-conference field trip (VI): Couvin-Philippeville-Wellin area, Ardenne. *In:* JANSEN, U, KÖNIGSHOF, P., PLODOWSKI, G. & SCHINDLER, E (EDS):

Field trips guidebook 15th International Senckenberg Conference Mid-Palaeozoic Bio- and Geodynamics - The North Gondwana - Laurussia interaction, Frankfurt am Main, May 11-21: 1-44.

BULTYNCK , P., DREESEN, R., GROESSENS, E., STRUVE, W., WEDDIGE, K., WERNER, R. & ZIEGLER, W., 1988. Field Trip A (22-24 July, 1988), Ardennes (Belgium) and Eifel Hills (Federal Republic of Germany). *Courier Forschunginstitut Senckenberg*, **102**: 7-85.

BURCHETTE, T. & RIDING, R. 1977. Attached vermetiform gastropods in Carboniferous marginal marine stromatolites and biostromes. *Lethaia*, **10**: 17-28.

CASIER, J.-G., 1977. Contribution à la connaissance des ostracodes du Frasnien de la Belgique. *Professional Paper Administration des Mines - Service Géologique de Belgique*, **147,** 22 pp.

CASIER, J.-G., 1987a. Etude biostratigraphique et paléoécologique des ostracodes du sommet du Givétien et de la base du Frasnien à Ave-et-Auffe (Bord sud du Bassin de Dinant, Belgique). *Bulletin de la Société belge de Géologie*, **96**, 1: 23-34.

CASIER, J.-G., 1987b. Etude biostratigraphique et paléoécologique des ostracodes du récif de marbre rouge du Hautmont à Vodelée (partie supérieure du Frasnien, Bassin de Dinant, Belgique). *Revue de Paléobiologie*, **6**, 2: 193-204.

CASIER, J.-G., 2004. The mode of life of Devonian entomozoacean ostracods and the Myodocopid Mega-Assemblage proxy for hypoxic events. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **74 suppl**.: 73-80.

CASIER, J.-G., 2008. Guide de l'excursion: Les ostracodes du Dévonien Moyen et Supérieur du Synclinorium de Dinant. *In:* J.-G. CASIER (Ed): Résumés des communications et guide de l'excursion, 22ième Réunion des ostracodologistes de langue française, Bruxelles, 2-4 juin 2008: 25-79.

CASIER, J.-G. & DEVLEESCHOUWER, X., 1995. Arguments (Ostracodes) pour une régression culminant à proximité de la limite Frasnien - Famennien, à Sinsin. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **65:** 51-68.

CASIER, J.-G., KASIMI, R. & PRÉAT, A., 1995. Les ostracodes au passage Eifélien/Givétien à Glageon (Avesnois, France). *Geobios*, **28**, 4: 487-499.

CASIER, J.-G., LEBON, A., MAMET, B. & PRÉAT, A., 2005. Ostracods and lithofacies close to the Devonian-Carboniferous boundary in the Chanxhe and Rivage sections, northeastern part of the Dinant Synclinorium, Belgium. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **75:** 95-126.

CASIER, J.-G., LETHIERS, F. & PRÉAT, A., 2001. Ostracods and rock facies associated with the Devonian-Carboniferous boundary series in the Puech de la Suque section, Montagne Noire, France. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **71**: 31-52.

CASIER, J.-G., MAMET, B., SANDBERG, C. A. & PRÉAT, A., 2004. Ostracods and sedimentology of the D/C transition beds in the Anseremme railway bridge section, Dinant Basin, Belgium. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **74:** 45-68.

CASIER, J.-G. & OLEMPSKA, E., 2008a. Early Frasnian ostracods of the Eifelian Mega-Assemblage from the Arche quarry (Dinant Synclinorium, Belgium) and the *Palmatolepis punctata* Isotopic Event. *Acta Palaeontologica Polonica*, **54**, 4: 635-646.

CASIER, J.-G. & OLEMPSKA, E., 2008b. Middle Frasnian (Devonian) ostracods from the Frasnes railway section (Dinant Synclinorium, Belgium); taxonomy, biostratigraphy, paleoecology. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **78**: 51-66.

CASIER, J.-G. & PRÉAT, A., 2006. Ostracods and their environmental setting close to the Eifelian-Givetian boundary at Aisemont (Namur Synclinorium). *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **76**: 5-29.

CASIER, J.-G. & PRÉAT, A., 2007. Ostracods and lithofacies of the Middle/Upper Devonian boundary stratotype (Puech de la Suque, Montagne Noire, France). *Bulletin de la Société géologique de France*, **4**: 293-304.

COEN, M., 1982. Ostracod distribution in the Fromelennes Formation and the lower part of the "Assise de Frasnes" (Middle-Upper Devonian of the Ardennes). *In:* F. BIGEY *et. al.*: Papers on the Frasnian - Givetian boundary. Subcommission on Devonian Stratigraphy. Geological Survey of Belgium: 60-64.

COEN, M., 1985. Ostracodes givétiens de l'Ardenne. *Mémoires de l'Institut géologique de l'Université de Louvain*, **32**, 48 pp.

COEN, M., 1987. Ostracods of the Nismes section. *Bulletin de la Société belge de Géologie*, **95**, 3: 272.

EINSELE, G. & SEILACHER, A., 1982. Cyclic Event Stratification. Springer-Verlag, Berlin, Heidelberg, New York, 536 pp.

GODEFROID, J. & JACOBS, L., 1986. Atrypidae (Brachiopoda) de la Formation de Fromelennes (fin du Givétien) et de la partie inférieure de la Formation de Nismes (début du Frasnien) aux bords sud et sud-est du Synclinorium de Dinant, Belgique. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, **56**: 67-143.

KLAPPA, C.F. 1980. Rhizoliths in terrestrial carbonates: classification, recognition, genesis and significance. *Sedimentology*, **27:** 613-629.

KLAPPER, G., 2000. Species of Spathognathodontidae and

Polygnathidae (Conodonta) in the recognition of the Upper Devonian stages boundaries. *Courier Forschunginstitut Senckenberg,* **220**: 153-159.

KONHAUSER, K. 2007. Introduction to Geomicrobiology. Blackwell Publishing, 425 pp.

LETHIERS, F., 1973. Les ostracodes famenniens dans l'ouest du Bassin de Dinant (Ardenne). *Annales de la Société géologique du Nord,* **92** (1972): 155-169.

LETHIERS, F. & CRASQUIN-SOLEAU, S., 1988. Comment extraire les microfossiles à tests calcitiques des roches calcaires dures. *Revue de Micropaléontologie*, **31**, 1: 56-61.

MAMET, B. & PRÉAT, A., 2003. Sur l'origine bactérienne et fongique de la pigmentation de l'Ammonitico Rosso (Jurassique, région de Vérone, Italie du nord). *Revue de Micropaléontologie*, **46**: 35-46.

MAMET, B. & PRÉAT, A., 2005. Microfaciès d'une lentille biohermale à la limite Eifélien-Givétien (Wellin, bord sud du Synclinorium de Dinant). *Geologica Belgica*, **8,** 3: 85-111.

MAMET, B. & PRÉAT, A., 2009. Algues et microfossiles problématiques du Dévonien Moyen du 'Fondry des Chiens' (bord sud du Synclinorium de Dinant, Belgique): implications paléobathymétriques. *Revue de Micropaléontologie*, **52**, 3: 249-263.

MAGNE, F., 1964. Données micropaléontologiques et stratigraphiques dans le Dévonien du Boulonnais (France) et du Bassin de Namur (Belgique). *Thèse de 3ème cycle (inédite). Université de Paris, Société nationale des Pétroles d'Aquitaine, Direction Exploitation et Production, Centre de Recherches de Pau*, 172 pp.

MILHAU, B., 1983a. Valeur biostratigraphique et paléoécologique des ostracodes du Givétien supérieur de la région-type (Ardenne). *Geobios,* **16**, 3: 347-359.

MILHAU, B., 1983b. Ostracodes du Givétien supérieur du Boulonnais. Corrélations avec l'Ardenne. *Annales de la Société géologique du Nord,* **102**: 217-236.

PRÉAT, A. & MAMET , B. 1989. Sédimentation de la plate-forme carbonatée givétienne franco-belge. *Bulletin des Centres de recherche Exploration-Production Elf-Aquitaine*, **13**, 1: 47-86.

PRÉAT, A., EL HASSANI, A. & MAMET, 2008. Iron bacteria in Devonian carbonates (Tafilalt, Anti-Atlas, Morocco). *Facies*, **54**: 107-120.

VANDELAER, E., VANDORMAEL, C. & BULTYNCK, P., 1989. Biofacies and refinement of conodont succession in the Lower Frasnian (Upper Devonian) of the type area (Frasnes-Nismes, Belgium). *Courier Forschunginstitut Senckenberg,* **117**: 321-351.

VAN WAGOONER, J. C., MITCHUM, R. M., CAMPION, K. M. & RAHMANIAN, V. D., 1990. Siliciclastic Sequence Stratigraphy in Well Logs, Cores and Outcrops. American Association Petroleum Geologists, Methods in Exploration Series, 7, 55 pp.

WILSON, J. L. 1975. Carbonate Facies in Geological History. Springer Verlag, Berlin, Heidelberg, New York, 417 pp.

YANS, J., CORFIELD, R., RACKI, G. & PRÉAT, A., 2007. Evidence for perturbation of the carbon cycle in the Middle Frasnian *punctata* Zone (Late Devonian). *Geological Magazine,* **144**, 2: 263-370.

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Explanation of plates

The types are deposited in the collections of the Department of Paleontology (section Micropaleontology) of the Royal Belgian Institute of natural Sciences (IRScNB n° b…). The thin sections are deposited in the Department of Earth Sciences and Environment of the University of Brussels (ulb n° …). NI = sample number (see Fig. 3 and the text for the stratigraphic position).

Plate 1

Figs 1-2 — Burrowed (Fig. 1) and microsparitized (Fig. 2) bioclastic wackestone with an echinoderm plate, a styliolinid (Fig. 1) and a holothurian extraxial piece or extraxial abactinal part of a sea star (Fig. 2) (determined by Prof. B. David, Univ. of Bourgogne, Dijon). The calcite microspar is coarse-grained (20 to 30 µm, Fig. 2). Very fine-grained silty quartz grains (20 to 30 µm) are dispersed in the matrix (Fig. 1). Sample NI88, Ph. ulb n° 3688/08 and 3690/08, Microfacies 1, Frasnian, Scale bars = 390 µm.

Fig. 3 — Bioclastic wackestone with abundant pelecypods and gastropods. The micritic matrix is dense and contains small-sized pyritospheres (10 to 20 µm, black 'dots' on the picture). Pyrite is also present inside the molluscan shells. Sample NI61, Ph. ulb n° 3624/08, Microfacies 2, Givetian, Scale bar = 390 µm.

Fig. 4 — Bioclastic wackestone-packstone with pelecypods, echinoderms (crinoid ossicle and sea urchin spine) and brachiopods. A circular burrow is visible in the middle bottom of the picture. Sample NI62, Ph. ulb n° 3625/08, Microfacies 2, Givetian. Scale bar = 390 µm.

Fig. 5 — Bioclastic packstone with echinoderm plates, mollusks, brachiopods and ostracods. Bioclasts constitute a thin level with slight oblique stratification in a homogeneous wackestone. Sample NI35, Ph. ulb n° 3683/08, Microfacies 3, Givetian, Scale bar = 950 µm.

Fig. 6 — Coarse-grained packstone (coquina bed) with abundant brachiopod shells and crinoidal ossicles. The micritic matrix is microbioclastic, clayey and contains numerous irregular presure solution microseams. Sutured contacts are common between the larger bioclasts. Sample NI65, Ph. ulb n° 3636/08, Microfacies 3, Givetian, Scale bar = 950 µm.

Fig. 7 — Coral (transverse section through a tabulate) floatstone. The cavities are filled with a microbioclastic peloidal micrite (right border of the picture). The matrix is slightly microspartitized (upper letf corner of the picture). Sample NI6, Ph. ulb n° 3656/08, Microfacies 6, Givetian, Scale bar = 950 µm.

Fig. 8 — Well-stratified molluscan (pelecypod) wackestone. Pelecypod bioclasts are centimetric in length and encrusted by serpulids. The micritic matrix is microbioclastic (see lower part of the picture). Sample NI28, Ph. ulb n° 3574/08, Microfacies 8, Givetian, Scale bar = 390 µm.

Plate 2

Figs 1-2 — Thin (inframillimetric) packstone layer interstratified in a homogeneous mudstone visible in the upper part of Fig. 1. The packstone layer with abundant molluscan bioclasts and umbellids. Sample NI18, Ph. ulb n° 3557/08 and 3558/08, Microfacies 9, Givetian, Scale bars = 390 µm (Fig. 1) and 155 µm (Fig. 2).

Fig. 3 — Laminar peloidal packstone and microdolomudstone millimetric layers. The peloidal (peloids are very small-sized, between 10 and 50 µm) lamination is domal and contains small irregular tubules (microstromatolitic filaments), few ostracods (lower part of the picture) and *Earlandia* (between the two ostracods). Sample NI2, Ph. ulb n° 3571/08, Microfacies 10, Givetian, Scale bar = 950 µm.

Fig. 4 — Tightly stacked ostracod valves in a peloidal lumpy microsparitized packstone. Sample NI9, Ph. ulb n° 3529/08, Microfacies 10, Givetian, Scale bar = 155 µm.

Fig. 5 — Peloidal lumpy packstone related to the growth of a former evaporitic mineral (now calcite and dolomite after pseudomophism). Pelecypod bioclasts are visible at the right bottom of the picture. Sample NI6, Ph. ulb n° 3536/08, Microfacies 11, Givetian, Scale bar = 950 µm.

Fig. 6 — Bioclastic millimetric-thick layer with abundant pelecypods and gastropods in a homogeneous mudstone (see micritic matrix between bioclasts). An *Amphipora* bioclast is present in the layer at the upper right corner of the picture. Sample NI9, Ph. ulb n° 3541/08, Microfacies 12, Givetian, Scale bar = 950 µm.

Fig. 7 — Homogeneous mudstone with 'puzzle-like' texture presumably related to calcite pseudomorphs of sulfate minerals. The sediment has the apperance of a collapse breccia with 'in place' angular micritic blocks or chips. Sample NI12, Ph. ulb n° 3542/08, Microfacies 13, Givetian, Scale bar = 950 µm.

Fig. 8 — Network of of ramified and curved fissures filled with sparite in a dense micritic matrix. Sample NI14, Ph. ulb n° 3547/08, Microfacies 13, Givetian, Scale bar = 950 µm.

Plate 3

Fig. 1 — Coarse-grained equigranular (10 – 30 µm) and lamellar (up to 50 µm in length) calcitic microspar with microbioclasts (mainly mollusks fragments). Sample NI77, Ph. ulb n° 3659/08 Microfacies 1-2, Frasnian, Scale bar = 390µm.

Fig. 2 — Strongly bioperforated pelecypod shell in a bioclastic wackestone-packstone. The perforations are circular in transverse section and tubular in longitudinal section. They are filled with the micritic matrix of the sediment. This latter has been pyritized and partly calcitized as shown in the tubular perforation. Sample NI78, Ph. ulb n° 3671/08, Microfacies 2, Frasnian, Scale bar = 950 µm.

Figs 3-4 — Blackened-pyritized-coated pelecypods in a bioclastic (with crinoids) packstone. Massive pyritization is centripetal (Fig. 3) and reveals thin pyritic filaments (3 to 5 µm in diameter, Fig. 4). Outline of grains are thinly corroded and dissolved by pyrite. Sample NI83, Ph. ulb n° 3676/08 and 3683/08, Microfacies 3, Frasnian, Scale bars = 390 µm (Fig. 3) and 100 µm (Fig. 4).

Fig. 5 — Irregular calcite cavity partly replaced by medium-grained calcite microspar (in a fine-grained burrowed microparitized wackestone). Sample NI88, Ph. ulb n° 3691/08, Microfacies 1, Frasnian, Scale bar = 390 µm.

Fig. 6 — Dendritic pyritic microtufts partly broken by a small burrowed zone containing microbioclasts in a dense micritic matrix. Sample NI19, Ph. ulb n° 3561/08, Microfacies 6, Givetian, Scale bar = 390 µm.

Figs 7-8 — Fungal hyphae (filaments are straight, curved, dichotomous and have diameters ranging between 1 and 3 µm and lengths up to 200 µm) ending in a small-sized sphere (diameters of 5 to 10 µm) related to conodia and /or sporangia (fruiting bodies) infesting a brachiopod shell in a bioclastic packstone (not shown). Sample NI60, Ph. ulb n° 3615/08 and 3616/08, Microfacies 3, Givetian, Scale bars = 100 µm.

Plate 4

Fig. 1 — *Kozlowskiella plana* (Kummerow, 1953), NI-101, Fromelennes Fm, IRScNB n° b5108, carapace, a. right lateral view, b. dorsal view, x62.

Fig. 2 — *Amphissites* cf. *tener* Becker, 1964, NI-304, La Prée Mbr, IRScNB n° b5109, reworked? carapace, a. right lateral view, b. dorsal view, x58.

Fig. 3 — *Nodella* cf. *hamata* Becker, 1968, NI-111 IRScNB n° b5110, Fromelennes Fm, right lateral view of a broken carapace, x77.

Fig. 4 — *Roundyella patagiata* (Becker, 1964), NI-119, Fromelennes Fm, IRScNB n° b5111, right valve, x78.

Fig. 5 — *Parabolbinella vomis* Becker & Bless, 1971, NI-628, La Prée Mbr, IRScNB n° b5112, broken right valve, x42.

Fig. 6 — Hollinoidea indet, NI-304, Chalon Mbr, IRScNB n° b5113, reworked? carapace of a juvenile, a. right lateral view, b. dorsal view, x80.

Figs 7-8 — Y*oungiella* sp. F5 *in* Magne (1964), Chalon Mbr. 7 = NI-16, IRScNB n° b5114, right lateral view of a carapace, x115; 8 = NI-8, IRScNB n° b5115, dorsal view of a carapace, x119.

Figs 9-10 — *Balantoides minimus* (Lethiers, 1971), NI-8, Chalon Mbr. 9 = IRScNB n° b5116, right lateral view of a carapace, x116; 10 = IRScNB n° b5117, dorsal view of a carapace, x114.

Fig. 11 — *Bolia belgica* Matern, 1929? NI-16, Chalon Mbr, IRScNB n° b5118, broken right valve, x114.

Fig. 12 — *Refrathella struvei* Becker, 1967, NI-7, Chalon Mbr, IRScNB n° b5119, left valve, x80.

Fig. 13 — *Refrathella* cf. *struvei* Becker, 1967, NI-140, Sourd d'Ave Mbr, IRScNB n° b5120, left valve, x91.

Figs 14-15 — *Coeloenellina* sp. A, aff. *minima* (Kummerow, 1953) *in* Casier (1991), NI-304, Chalon Mbr. 14 = IRScNB n° b5121, right lateral view of a reworked? carapace, x48; 15 = IRScNB n° b5122, dorsal view of a reworked carapace, x50.

Fig. 16 — *Scobicula gracilis* Casier & Olempska, 2008, NI-12, Chalon Mbr, IRScNB n° b5123, carapace, a. right lateral view, b. dorsal view, x116.

Fig. 17 — *Evlanella mitis* Adamczak, 1968, NI-122, Fromelennes Fm, IRScNB n° b5124, broken carapace, a. left lateral view, b. dorsal view, x63 .

Fig. 18 — *Evlanella* sp. A, aff. *mitis* Adamczak, 1968, NI-122, Fromelennes Fm, IRScNB n° b5125, left valve, x48.

Fig. 19 — *Uchtovia refrathensis* (Krömmelbein, 1954), NI-122, Fromelennes Fm, IRScNB n° b5126, carapace, a. left lateral view, b. dorsal view, x50.

Fig. 20 — *Uchtovia* sp. A, aff. *refrathensis* (KRÖMMELBEIN, 1954), NI-121, Fromelennes Fm, IRScNB n° b5127, carapace, a. left lateral view, b. dorsal view, x75.

PLATE 5

Fig. 1 — *Uchtovia materni* BECKER, 1971, NI-7, Chalon Mbr, IRScNB n° b5128, carapace, a. right lateral view, b. dorsal view, x46.

Fig. 2 — *Cavellina macella* KUMMEROW, 1953, NI-101, Fromelennes Fm, IRScNB n° b5129, carapace, a. left lateral view, b. dorsal view, x65.

Fig. 3 — *Cavellina rhenana* KRÖMMELBEIN, 1954, NI-111, Fromelennes Fm, IRScNB n° b5130, carapace, a. left lateral view, b. dorsal view, x118.

Figs 4-5 — *Cavellina devoniana* EGOROV, 1950, Sourd d'Ave Mbr. 4 = NI-140, IRScNB n° b5131, left lateral view of a tecnomorph carapace, x67; 5 = NI-144, IRScNB n° b5132, dorsal view of a heteromorph carapace, x64.

Fig. 6 — *Cytherellina perlonga* (KUMMEROW, 1953), NI-115, Fromelennes Fm, IRScNB n° b5133, carapace, a. right lateral view, b. dorsal view, x47.

Fig. 7 — *Polyzygia beckmanni beckmanni* KRÖMMELBEIN, 1954, NI-135, Pont d'Avignon Mbr, IRScNB n° b5134, carapace, a. left lateral view, b. dorsal view, x61.

Fig. 8 — *Polyzygia neodevonica* (MATERN, 1929), NI-12, Chalon Mbr, IRScNB n° b5135, left valve, x58.

Fig. 9 — *Polyzygia neodevonica aragonensis* GOZALO & SANCHEZ DE POSADA, 1986, NI-5, Chalon Mbr, IRScNB n° b5136, left valve, x84.

Figs 10-11 — *Favulella lecomptei* BECKER, 1971, carapace. 10. NI-12, Chalon Mbr, IRScNB n° b5137, a. right lateral view, b. dorsal view, x75; 11. NI-144, Sourd d'Ave Mbr, IRScNB n° b5138, carapace, a. right lateral view, b. dorsal view, x85.

Fig. 12 — *Punctomosea weyanti* BECKER, 1971, NI-15, Chalon Mbr, IRScNB n° b5139, carapace, a. right lateral view, b. dorsal view, x60.

Fig. 13 — *Jenningsina paffrathensis* KRÖMMELBEIN, 1954, NI-131, Pont d'Avignon Mbr, IRScNB n° b5140, carapace, a. right lateral view, b. dorsal view, x72.

Fig. 14 — *Jenningsina lethiersi* BECKER, 1971, NI-627, La Prée Member, IRScNB n° b5141, left lateral view of a carapace, x64.

Fig. 15 — *Svantovites magnei* BECKER, 1971, NI-21, Chalon Mbr, IRScNB n° b5142, carapace, a. left lateral view, b. dorsal view, x70.

PLATE 6

Fig. 1 — *Quasillites* sp. A, aff. *fromelennensis* MILHAU, 1983, NI-118, Fromelennes Fm, IRSCNB n° b5143, carapace, a. right lateral view, b. dorsal view, X70.

Figs 2-4 — *Ovatoquasillites nismesensis* nov. sp. 2. NI-136, Pont d'Avignon Mbr, IRSCNB n° b5144, Holotype, a. right lateral view, b. dorsal view, x63; 3. NI-150, Sourd d'Ave Mbr, IRSCNB n° b5145, right lateral view of Paratype A, x62; 4. NI139, Pont d'Avignon Mbr, IRSCNB n° b5146, Right lateral view of Paratype B, x67.

Fig. 5 — *Ponderodictya belliloci* CASIER, 1986, NI-136, Pont d'Avignon Mbr, IRSCNB n° b5147, right lateral view of a carapace, X58.

Fig. 6 — *Ponderodictya* cf. *belliloci* CASIER, 1986, NI-143, Sourd d'Ave Mbr, IRScNB n° b5148, right lateral view of a broken valve, x49.

Fig. 7 — *Plagionephrodes laqueus praelaqueus* CASIER & OLEMPSKA, 2008, NI-135, Pont d'Avignon Mbr, IRScNB n° b5149, carapace, a. right lateral view, b. dorsal view, x55.

Fig. 8 — *Plagionephrodes* sp. indet., NI-122, Fromelennes Fm, IRScNB n° b5150, broken carapace, a. right lateral view, b. dorsal view, x59.

Fig. 9 — *Asturiella blessi* BECKER, 1971, NI-4, Chalon Mbr, IRScNB n° b5151, broken left valve, x75.

Fig. 10 — *Healdianella* sp. A, NI-144, Sourd d'Ave Mbr, IRScNB n° b5152, carapace, a. right lateral view, b. dorsal view, x56.

Fig. 11 — *Healdianella?* sp. B, NI-144, Sourd d'Ave Mbr, IRScNB n° b5153, carapace, a. right lateral view, b. dorsal view, x59.

Fig. 12 — *Bairdiocypris corniger* ROZHDESTVENSKAJA, 1962, NI-113, Fromelennes Fm, IRScNB n° b5154, poorly preserved carapace, a. right lateral view, b. dorsal view, x67.

Fig. 13 — *Bairdiocypris* sp. A, aff. *rhenana* KEGEL, 1932, NI-111, Fromelennes Fm, IRScNB n° b5155, carapace, a. right lateral view, b. dorsal view, x76.

Fig. 14 — *Bairdiocypris* sp. 5 *in* MAGNE (1964), NI-304, Chalon Mbr, IRScNB n° b5156, broken reworked? carapace, a. right lateral view, b. dorsal view, x30.

Fig. 15 — *Orthocypris kummerowi* ZBIKOWSKA, 1983, NI-131, Pont d'Avignon Mbr, IRScNB n° b5157, right lateral view of a poorly preserved carapace, x65.

Figs 16-17 — *Tubulibairdia* sp. A, aff. *antecedens* (KEGEL, 1932), NI-304, Chalon Mbr. 16. IRScNB n° b5158, right lateral view of a reworked? carapace, x34; 17. IRScNB n° b5159, reworked? carapace, a. right lateral view, b. dorsal view, x35.

PLATE 7

Fig. 1 — *Microcheilinella* cf. *archensis* CASIER & OLEMPSKA, 2008, NI-159, La Prée Mbr, IRScNB n° b5160, carapace, a. right lateral view, b. dorsal view, x54.

Fig. 2 — *Microcheilinella* sp. A *in* CASIER & OLEMPSKA (2008), NI-3, Chalon Mbr, IRScNB n° b5161, right lateral view of a carapace, x146.

Fig. 3 — *Microcheilinella* sp. *in* COEN (1985). NI-118, Fromelennes Fm, IRScNB n° b5162, carapace, a. right lateral view, b. dorsal view, x100.

Fig. 4 — *Rectella trapezoides* ZASPELOVA, 1959? in COEN (1985), NI-142, Sourd d'Ave Mbr, IRScNB n° b5163, carapace, a. right lateral view, b. dorsal view, x85.

Fig. 5 — *Acratia* sp. indet, NI-148, Sourd d'Ave Mbr, IRScNB n° b5164, poorly preserved carapace, a. right lateral view, b. dorsal view, x80.

Fig. 6 — *Acratia?* sp. indet., NI-100, Fromelennes Fm, IRScNB n° b5165, poorly preserved carapace, a. right lateral view, b. dorsal view, x57.

Fig. 7 — *Bairdia paffrathensis* KUMMEROW, 1953, NI-139, Pont d'Avignon Mbr, IRScNB n° b5166, carapace, a. right lateral view, b. dorsal view, x52.

Fig. 8 — *Bairdia* sp. *in* COEN (1985), NI-118, Fromelennes Fm, IRScNB n° b5167, broken carapace, a. right lateral view, b. dorsal view, x73.

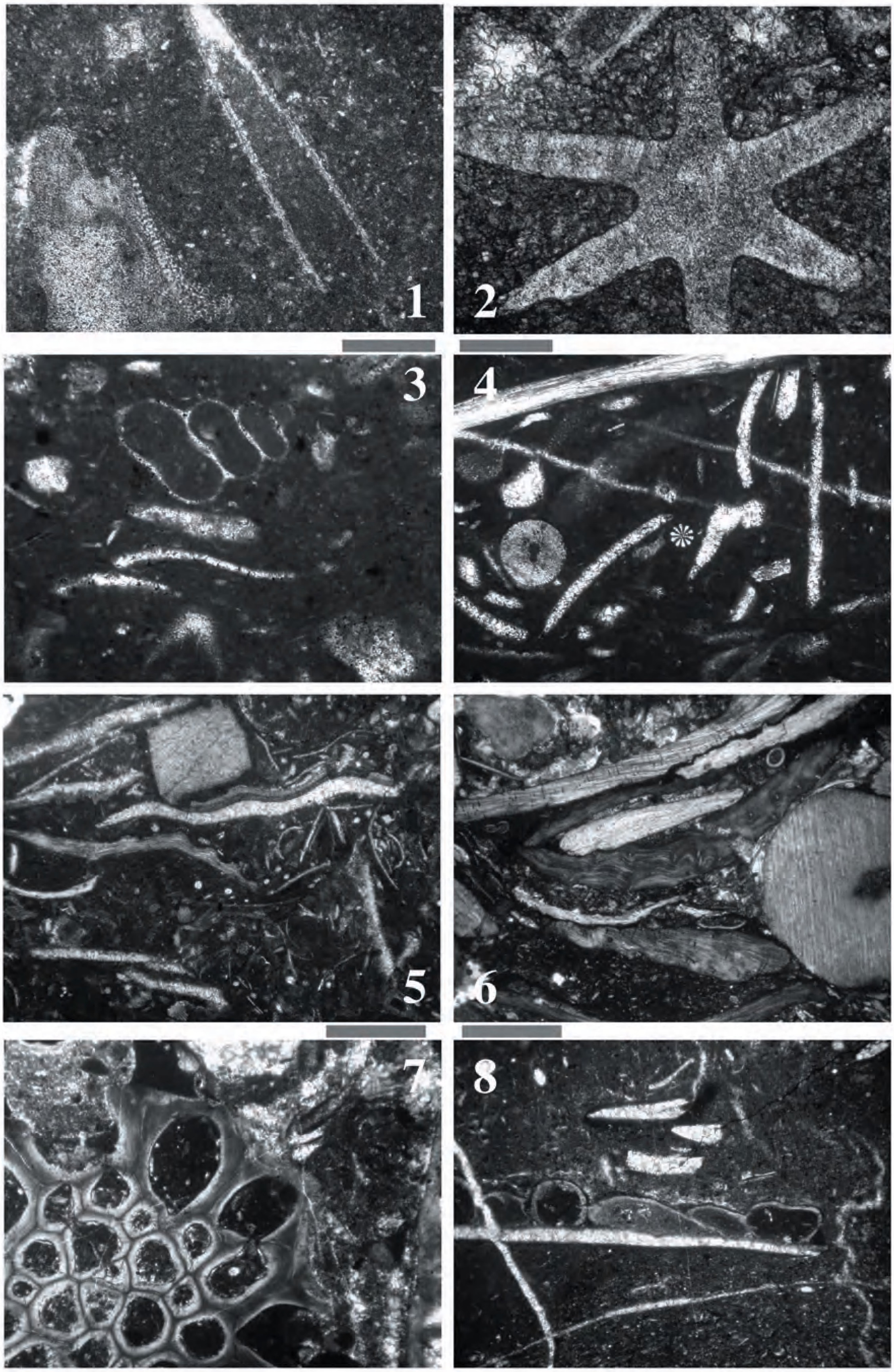
Fig. 9 — *Bairdiacypris breuxensis* CASIER & OLEMPSKA, 2008, NI-9, Chalon Mbr, IRScNB n° b5168, carapace, a. right lateral view, b. dorsal view, x59.

Fig. 10 — *Bairdiacypris* sp. A, NI-136, Pont d'Avignon Mbr, IRScNB n° b5169, carapace, a. right lateral view, b. dorsal view, x62.

Fig. 11 — *Bairdiacypris* sp. E, NI-304, Chalon Mbr, IRScNB n° b5170, reworked? carapace, a. left lateral view, b. dorsal view, x62.

Fig. 12 — *Schneideria? groosae* BECKER, 1971, NI-13, Chalon Mbr, IRScNB n° b5171, carapace, a. right lateral view, b. dorsal view, x92.

Figs 13-14 — *Cryptophyllus* sp. indet. 13. NI-19, Chalon Mbr, IRScNB n° b5172, poorly preserved carapace, a. left lateral view, b. dorsal view, x78; 14. NI-115, Fromelennes Fm, IRScNB n° b5173, poorly preserved valve, x66.



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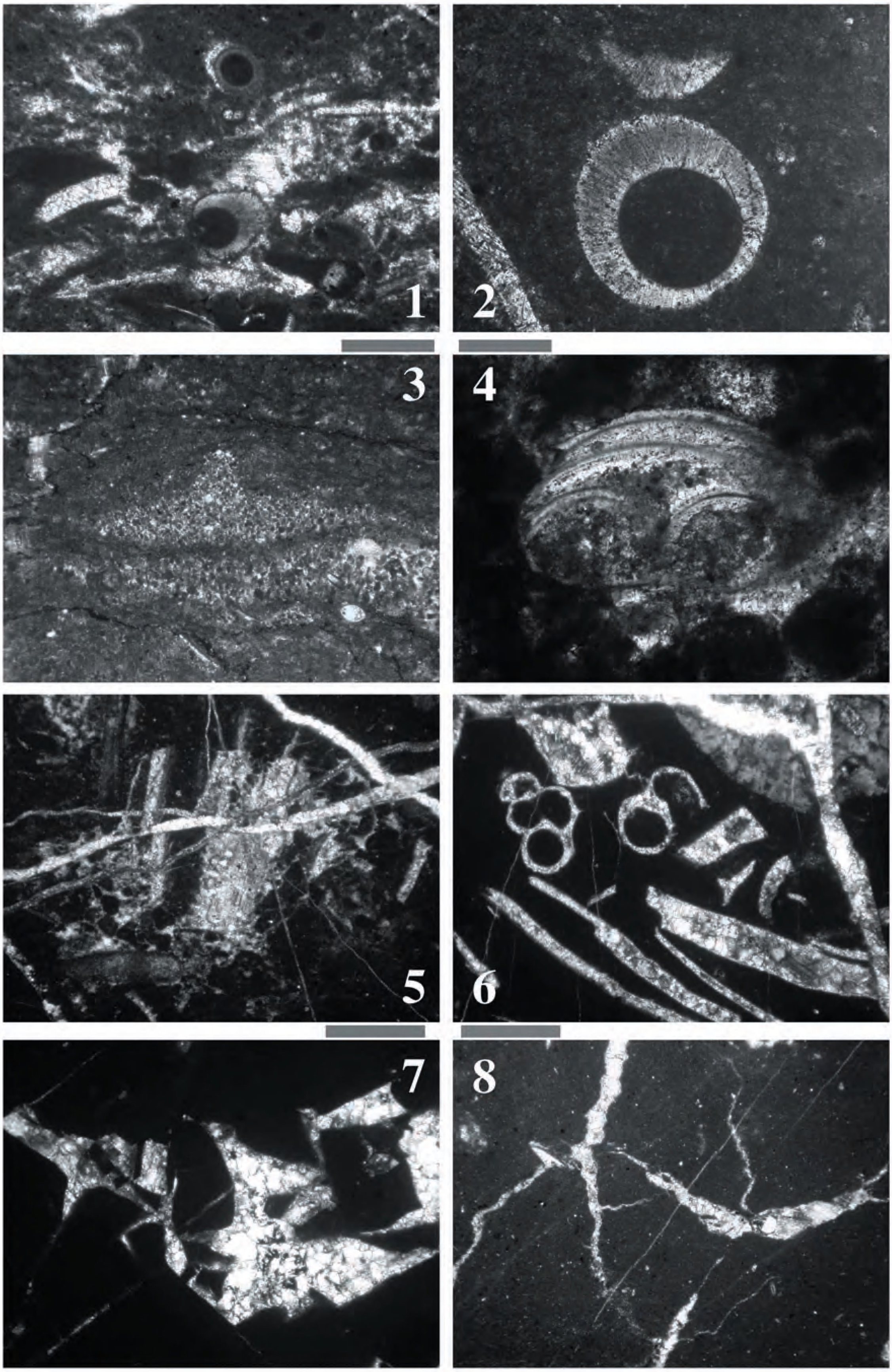

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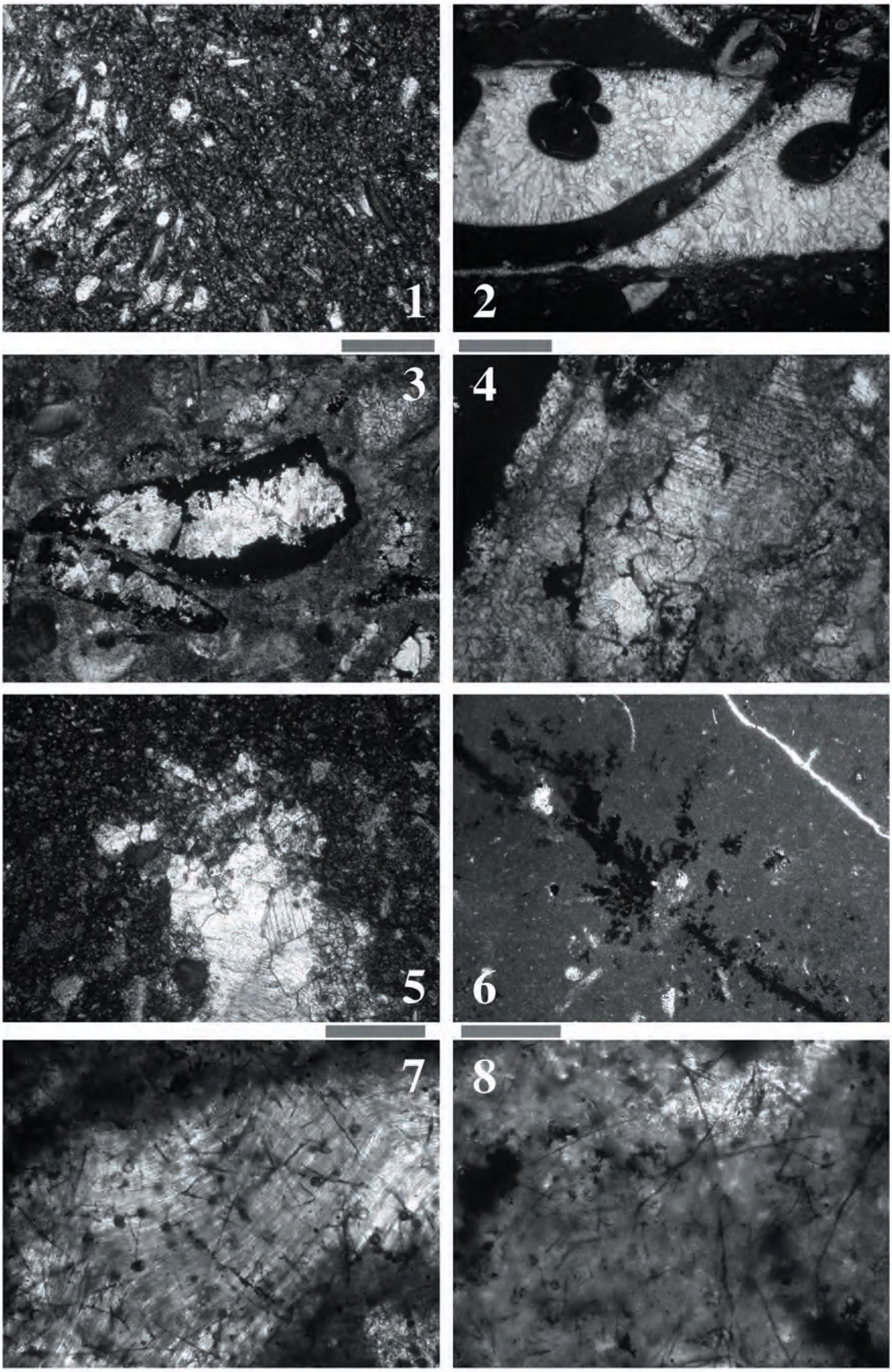

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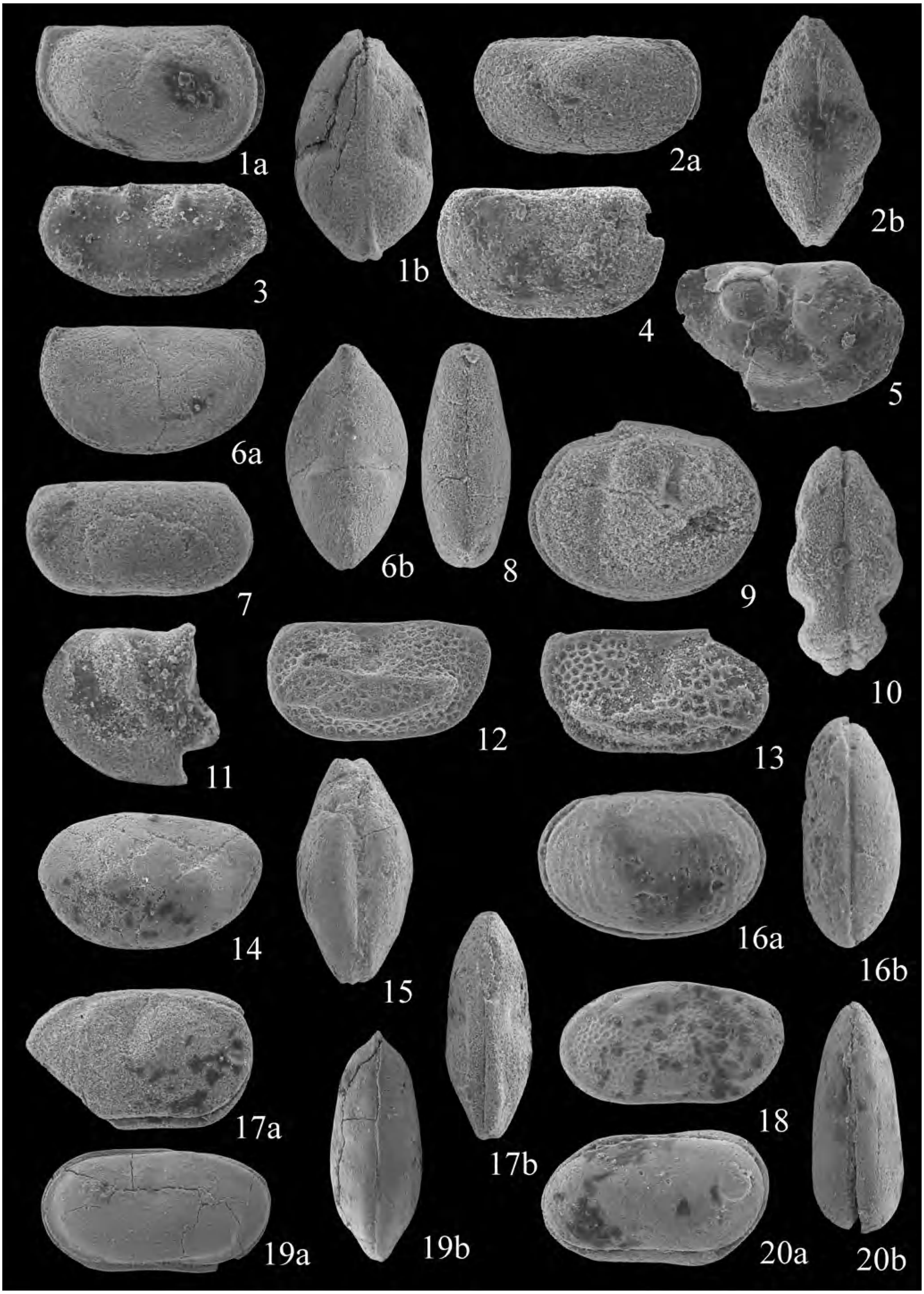
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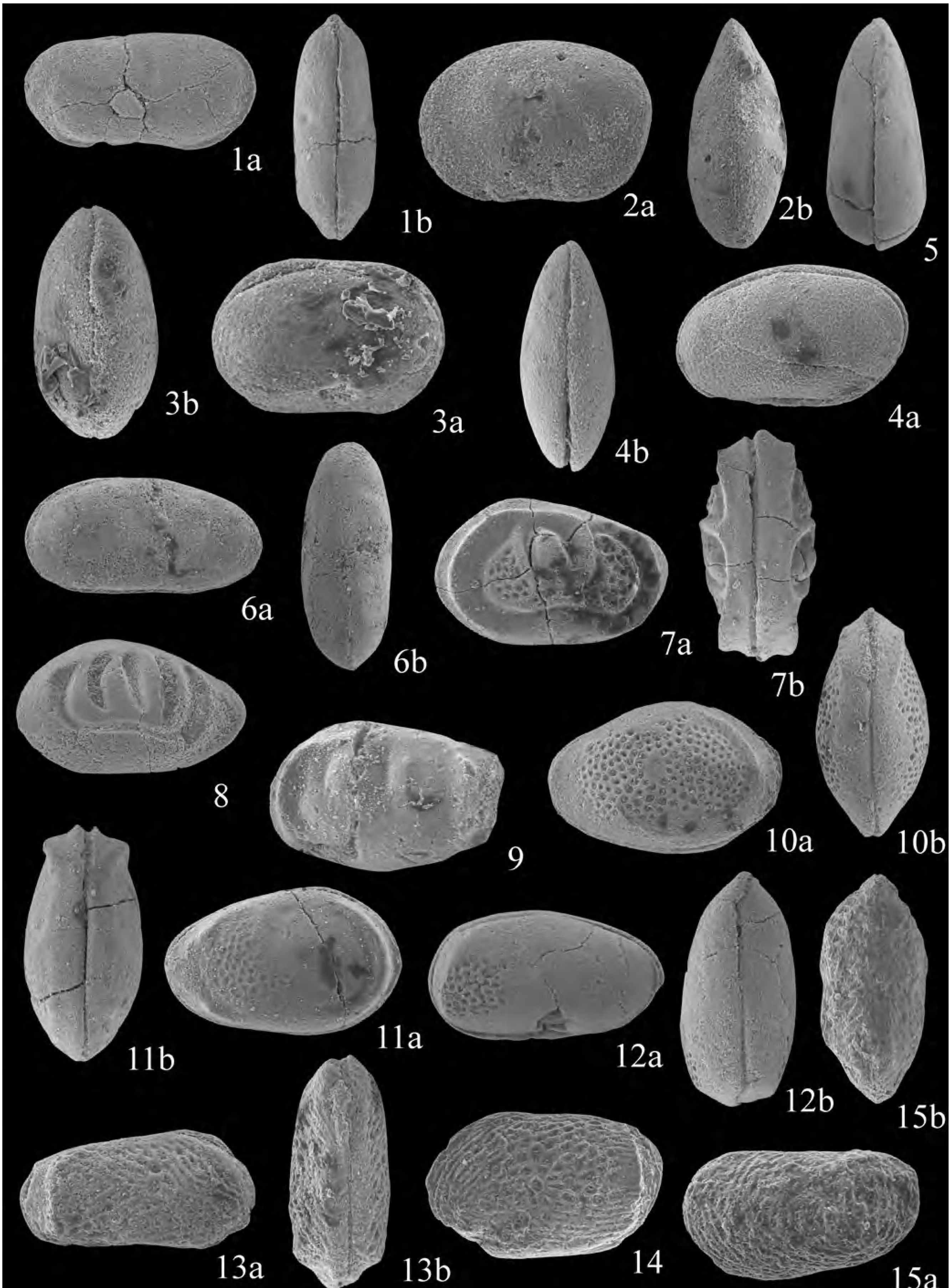
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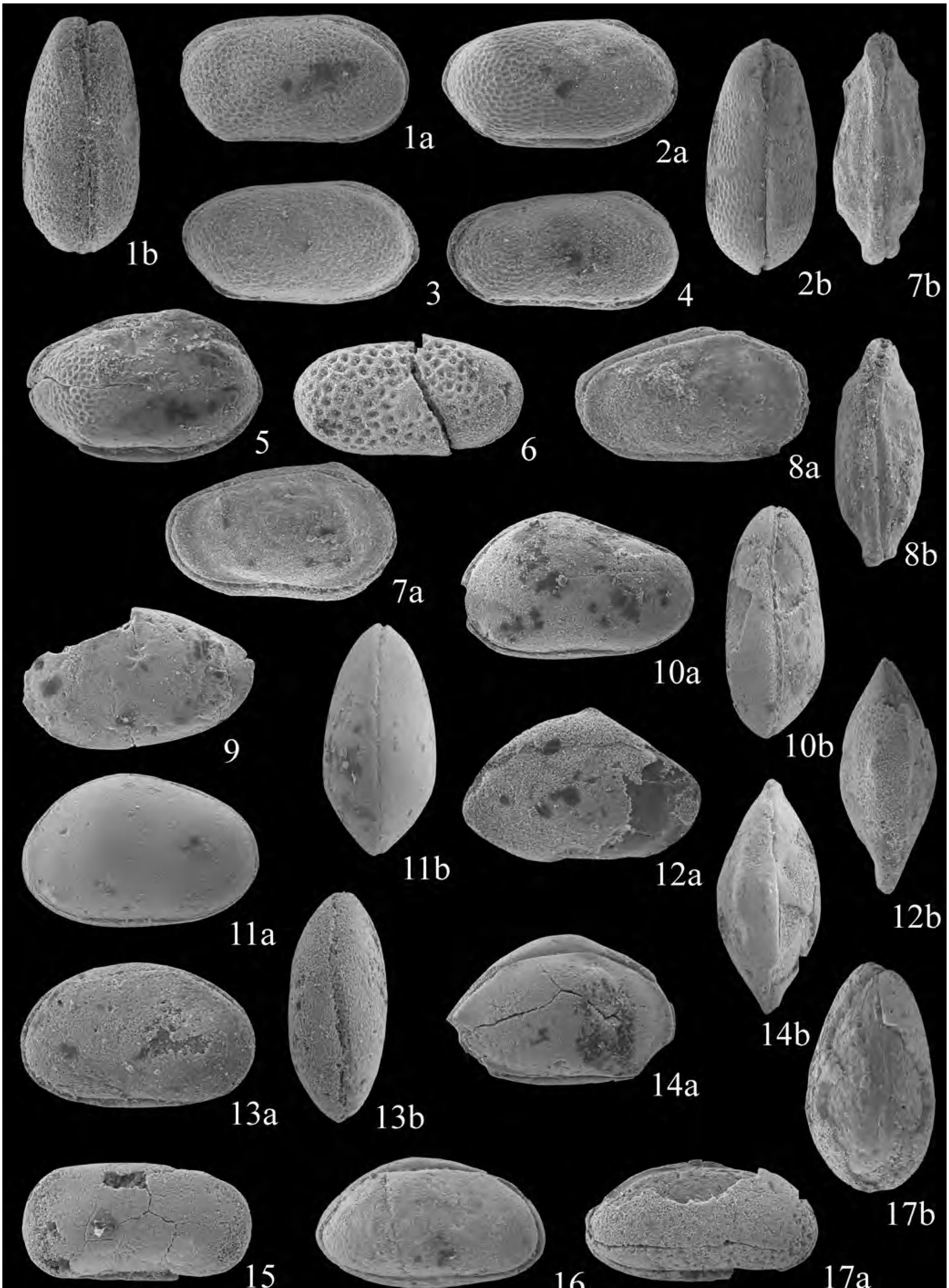
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PLATE 6

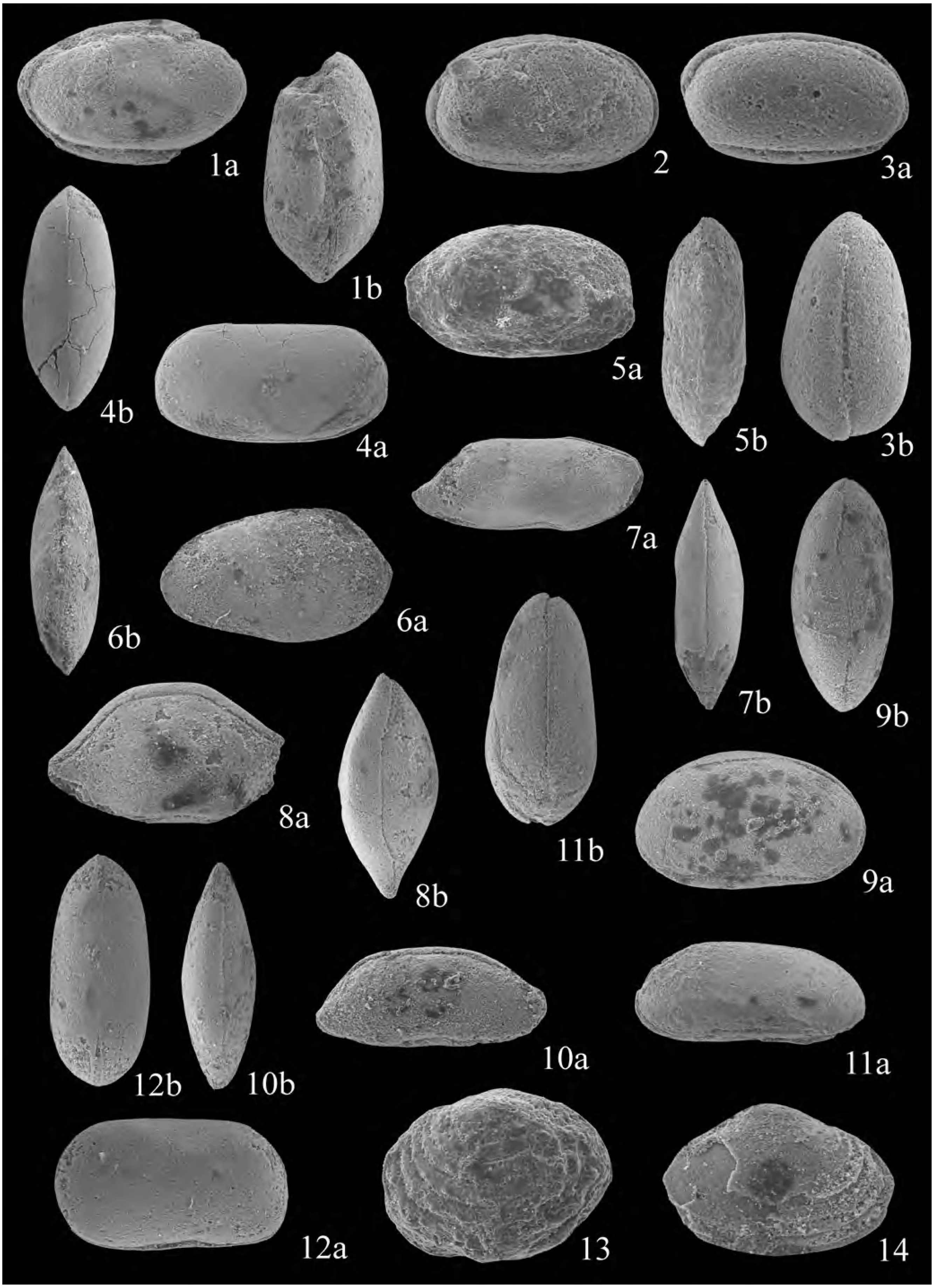
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PLATE 7