

Sedimentology, conodonts and ostracods of the Devonian - Carboniferous strata of the Anseremme railway bridge section, Dinant Basin, Belgium

by Jean-Georges CASIER, Bernard MAMET, Alain PRÉAT & Charles A. SANDBERG

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Abstract

Seven major carbonate microfacies are defined in the Devonian - Carboniferous (D/C) strata (50 m) of the Anseremme railway bridge section, south of Dinant. They permit recognition of several levels encompassing the Etroeungt and Hastière formations. "Bathymetric" sequences range from open marine, below the storm wave base, to semi-restricted lagoon. This sequence records a shallowing-upward trend of the relative sea level, from environments below the storm wave base to strongly eroded supratidal pre-evaporitic environments. Faunal components (echinoderms, brachiopods...) indicate open-marine domain for the first six microfacies located within the dysphotic-euphotic zone in relatively shallow waters. The textures of the rocks (mudstones to rudstones) associated with lamination characteristics indicate the position of the storm (SWB) and the fair-weather (FWWB) wave bases. Microfacies seven suggests a semi-restricted platform with salinity fluctuations from hypersaline brines to brackish waters. Thus, the boundary of the Etroeungt/Hastière formations is marked by an abrupt drop in sea level. Carbonate micro-conglomerates recording an important erosive phase and a sedimentary hiatus. The environment is again open marine in the upper part of the Hastière Formation. Our conclusion is that the Anseremme section is not a reliable continuous succession for the study of the D/C boundary. This confirms the VAN STEENWINKEL (1988, 1993) hypothesis based on other arguments.

Conodont faunas demonstrate that the Devonian sequence spans the five youngest conodont zones, but that two of these zones are not represented. The Epinette Formation is dated as the youngest part of the Middle *expansa* Zone. Thus, the boundary with the Late *praesulcata* Zone probably coincides with the sharp sedimentological change at the base of the Etroeungt Formation, which is interpreted to belong entirely to this zone. The disconformably overlying basal bed 159 of the Hastière Formation is dated as Late *praesulcata* Zone, with the Early and Middle *praesulcata* Zones unrepresented because of an hiatus or unconformity. Sparse conodont faunas suggest that only the two next-to-oldest Carboniferous *duplicata* and *sandbergi* Zones are represented in the higher part of the Hastière Formation. The oldest Carboniferous *sulcata* Zone and possibly part of the *duplicata* Zone are unrepresented because of an hiatus or unconformity above bed 159.

Ostracods are abundant and diversified at most levels in the Anseremme railway bridge section and sixty taxa, the majority in open nomenclature, have been identified and nearly all of them are figured. The ostracod fauna is indicative of shallow-marine environments between fair-weather and storm wave bases in the Etroeungt Formation, and to shallower water conditions periodically subjected to minor salinity variations in the base of the Hastière Formation. The upper part of the Hastière Formation is marked by a sea-level rise associated with a moderate decrease of the oxygenation of bottom waters. The intra-

Devonian hiatus at the Etroeungt-Hastière boundary shows no abnormal extinctions and no appearance of new taxa. Thus, the Hangenberg Event is not recognizable in the studied section.

Neither the sedimentological analysis nor the palaeontological study of the Bocahut quarry in the Avesnois and of the Anseremme railway bridge section confirm the hypothesis of a highstand for the Hastière Formation.

Key-words: Ostracods - Conodonts - Sedimentology - Devonian-Carboniferous boundary - Dinant Basin - Belgium

Résumé

La coupe du "pont-rail" d'Anseremme, au sud de Dinant, exposerait la limite Dévonien-Carbonifère (Formations d'Etroeungt et d'Hastière) et a été utilisée comme stratotype pour cette limite.

Sept familles majeures de microfaciès carbonatés (séquence standard MF1 à MF7) sont déterminées et leur succession enregistre une diminution progressive (MF1 à MF6) de la profondeur d'eau depuis des milieux de rampe externe silico-carbonatée situés par une soixantaine de mètres d'eau jusqu'aux environnements carbonatés de rampe interne de faible profondeur, parfois soumis à une diagenèse vadose. Le microfaciès 7 est érosif et traduit une diminution brutale de la tranche d'eau avec remaniement important de faciès lagunaires semi-restreints d'une plate-forme voisine. Les variations de salinité sont la règle depuis des saumures hypersalines de reflux jusqu'aux milieux saumâtres. Plusieurs séquences de microfaciès s'observent. Ces séquences bathymétriques vont des faciès de lagon semi-restreint jusqu'au marin ouvert franc situé sous la zone d'action des tempêtes. L'environnement général est oxygéné, de faible profondeur, et la distribution des organismes est principalement liée aux variations de l'énergie (vagues de tempêtes ou houle permanente) dans un système de rampe, ou aux fluctuations de salinité dans celui de plate-forme. Le passage des formations d'Etroeungt et d'Hastière est marqué par une brutale baisse eustatique. A cette évolution majeure correspond l'installation temporaire d'une plate-forme semi-restreinte. Un hiatus sédimentaire est donc associé à la limite D/C et s'étend jusqu'à la partie médiane du Calcaire d'Etroeungt. Aucun élément remanié de cette partie manquante n'a été observé dans le conglomérat de base du Calcaire d'Hastière, suggérant que cette partie ne se soit probablement jamais déposée, contrairement à Avesnes-sur-Helpe où elle a récemment été mise en évidence. Notre conclusion est que la section d'Anseremme n'est pas une succession continue susceptible d'apporter une solution au problème de la limite D/C. Ceci confirme l'hypothèse de VAN STEENWINKEL (1988, 1993) basée sur d'autres arguments.

La séquence couvre les cinq dernières zones de conodontes dévoniennes, mais deux parmi celles-ci ne sont pas représentées. La Formation d'Epinette correspond à la partie supérieure de la Zone à *expansa* moyenne. Par conséquent, sa limite avec la Zone à *praesulcata* supérieure coïncide probablement avec l'important changement sédimentologique observé à la base de la Formation d'Etroeungt qui est interprétée comme appartenant intégralement à la Zone à *praesulcata* supérieure. Le banc 159 de la base de la Formation d'Hastière appartient à la Zone à *praesulcata* supérieure. Les Zones à *praesulcata*

inférieure et moyenne ne sont pas représentées à cause d'un hiatus ou d'une discordance à ce niveau. De rares conodontes suggèrent que seules les Zones à *duplicata* et à *sandbergi* du Carbonifère soient représentées dans la partie supérieure de la Formation d'Hastière. La Zone à *sulcata* et probablement aussi une partie de la Zone à *duplicata* ne sont pas présentes à cause de l'hiatus ou de la discordance situé au-dessus du banc 159.

Les ostracodes sont abondants et diversifiés dans la coupe du "pont-rail" d'Anseremme. Soixante taxa, la majorité en nomenclature ouverte, sont recensés et presque tous sont figurés. Dans la Formation d'Etroeungt, la faune d'ostracodes indique des environnements marins peu profonds situés entre les niveaux d'action des vagues de beau temps et de tempêtes. Dans la base de la Formation d'Hastière, elle indique des environnements marins moins profonds, temporairement soumis à de légères variations de salinité. La partie supérieure de la Formation d'Hastière est marquée par une transgression à laquelle est associée une très légère diminution de l'oxygénation des eaux de fonds. Aucune extinction anormale ne peut être associée à l'hiatus observé au niveau de la limite des Formations d'Hastière et d'Etroeungt. L'événement Hangenberg n'est pas reconnu dans la coupe étudiée.

Ni l'analyse sédimentologique ni l'étude paléontologique de la carrière Bocahut dans l'Avesnois (France) et de la coupe du pont-rail d'Anseremme ne privilégient l'hypothèse d'un haut niveau marin pour la Formation d'Hastière.

Mots-clefs: Ostracodes - Conodontes - Sédimentologie - Limite Dévonien-Carbonifère - Bassin de Dinant - Belgique

Introduction

The Anseremme railway bridge section along the River Meuse is the best exposure of the Devonian-Carboniferous (D/C) boundary beds known in the Dinant Basin (CONIL, 1964). The section is included in the classic geological field trip in this area for the definition of the Dinantian (CONIL & GROESSENS in ROBASZYNSKI & DUPUIS, 1983).

Until now, only one ostracod species has been recorded by ROME & GOREUX (1964), and eight other ostracod taxa have been reported by BECKER & BLESS (1974; in BOUCKAERT & STREEL eds, 1974) in the Anseremme railway bridge section. However, the recent study of the Bocahut quarry close to Avesnes-sur-Elpe (France) has shown the occurrence of an abundant and diversified ostracod fauna, associated with important sedimentological variations, in the D/C transitional beds (CASIER & PRÉAT, 2003; MAMET & PRÉAT, 2003). Sixty-six ostracod taxa were identified in the D/C transitional strata and in the top of the Epinette Formation of the Bocahut quarry. Consequently, it was important to study in more detail the ostracods of the Anseremme railway bridge section. Moreover, the ostracods present in the western part of the Dinant Basin are poorly known compared to e.g. the ostracods described by TSCHIGOVA (1967, 1977) from the Russian Platform.

The Anseremme railway bridge section – General setting

The railway bridge section is located on the left bank of the River Meuse close to the Anseremme village (Fig. 1). More precisely, the section is located between the railway bridge and the N97 highway viaduct crossing the

River Meuse and on both sides of the 6.2 milestone of the 166 (Dinant-Jemelle) railway line (N 50°14'35"; E 4°54'30").

The section exposes the Epinette, Etroeungt, Hastière, Pont d'Arcole and Landelies formations, but only the Etroeungt and Hastière formations (about 40 m thick) were investigated in detail for the present study. The Anseremme railway bridge section has been studied by CONIL (1964, 1968), MAMET *et al.* (1965), VAN STEENWINKEL (1988, 1993) and more recently by MAMET & PRÉAT (2003).

The D/C boundary has been placed at the first appearance of the conodont *Siphonodella sulcata* within the evolutionary lineage from *S. praesulcata* to *S. sulcata* (PAPROTH & STREEL, 1984). However, due mainly to shallow-marine settings, and a probable unconformity, zonally diagnostic conodonts are scarce adjacent to the D/C boundary in the Anseremme railway bridge section, and neither *Siphonodella praesulcata* nor *S. sulcata* has been found (BOUCKAERT & GROESSENS, 1976). The oldest Carboniferous index conodont that has been recorded is *Siphonodella duplicata* in bed 174a (our samples AN85-87) at ± 8 m above the base of the Hastière Formation (VAN STEENWINKEL, 1980, 1984, 1993).

Rock and facies analysis (B. Mamet & A. Préat)

One-hundred-twenty-one samples for thin sections were collected for sedimentological analysis from the Anseremme railway bridge section. The section is composed of a series of thin- to medium-thick, well-bedded, clayey limestones at the base and coarser and thicker limestones toward the top, where several conglomeratic beds are present. Microfacies analysis (MAMET & PRÉAT, 2003) permits recognition of several sequences ranging through the Etroeungt and Hastière formations (see also VAN STEENWINKEL, 1988, 1993). The "bathymetric" sequences (eustacy, subsidence, salinity) range from open marine, below the storm wave base to semi-restricted lagoon. A standard sequence of 7 microfacies records a shallowing-upward trend of the relative sea level (MAMET & PRÉAT, 2003) from environments below the storm wave base to strongly eroded supratidal pre-evaporitic environments.

In their biostratigraphical (foraminifers) and sedimentological study, which compared the Anseremme D/C series with that of Avesnes-sur-Helpe (northern France, Avesnes basin), MAMET & PRÉAT (*Ibid.*) indicate that several sedimentary hiatuses are present within the Devonian sequence between the Etroeungt and Hastière formations.

Microfacies description

Open marine below the storm wave base

Microfacies 1 (or MF1)

Definition: clayey and silty mudstones with a few bio-

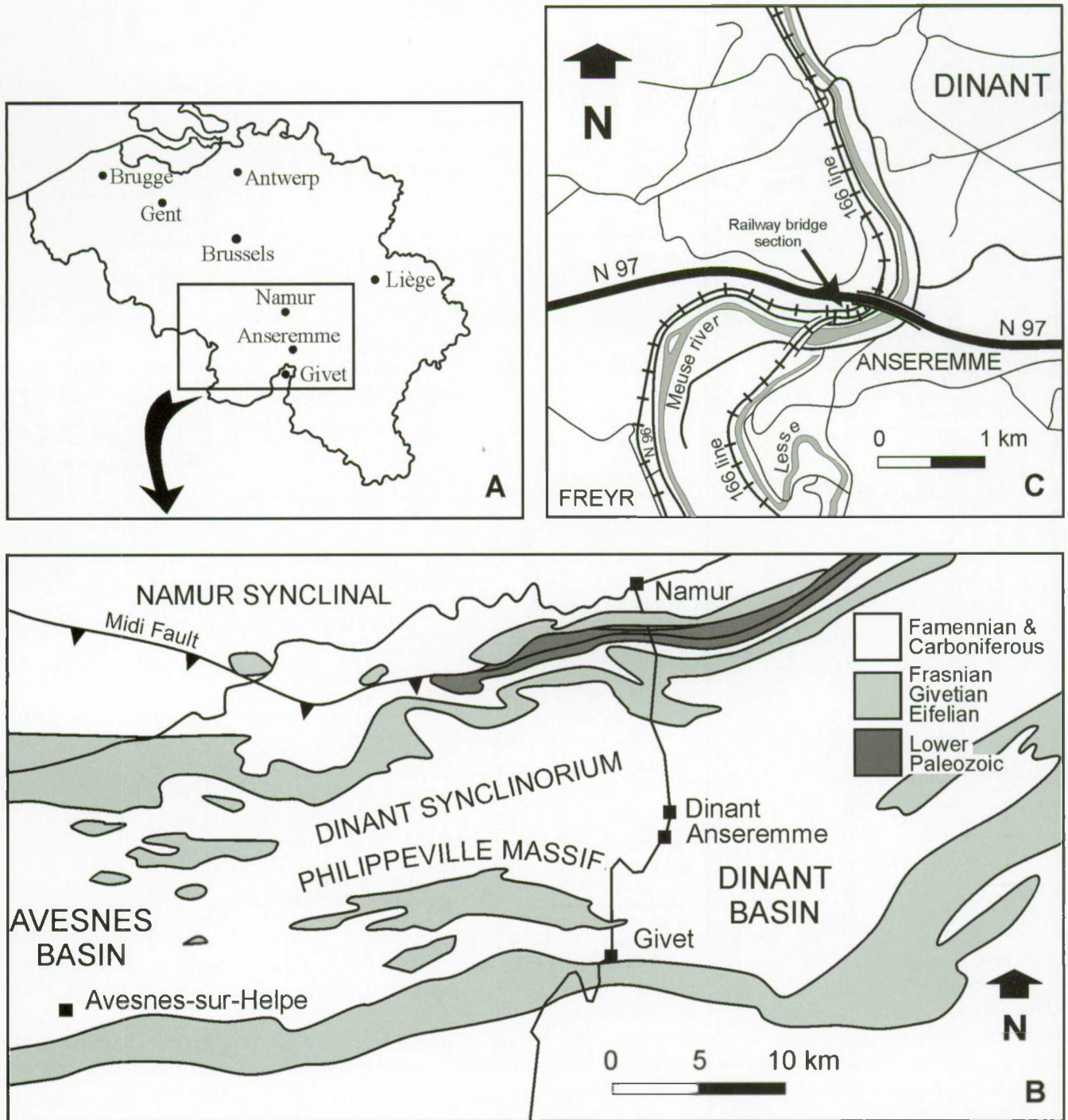


Fig. 1 — Geographic location of the Anseremme railway bridge section, south of Dinant, and of the Bocahut quarry close to Avesnes-sur-Helpe.

clasts composed of crinoids, brachiopods, bryozoa (Pl. 5, Fig. 1), ostracods, and various algae (*Girvanella*, kamaenids, issinellids). The matrix is burrowed and contains fine-grained organic-matter fragments. Compared to the Avesnes succession this MF1 is poorly represented at Anseremme (Fig. 2).

Open marine near the storm wave base

Microfacies 2 (or MF2)

Definition: clayey and silty burrowed wackestones (Pl. 5, Figs. 2-3) with various bioclasts (abundant echinoderms, bryozoans, ostracods, molluscs, brachiopods, a few for-

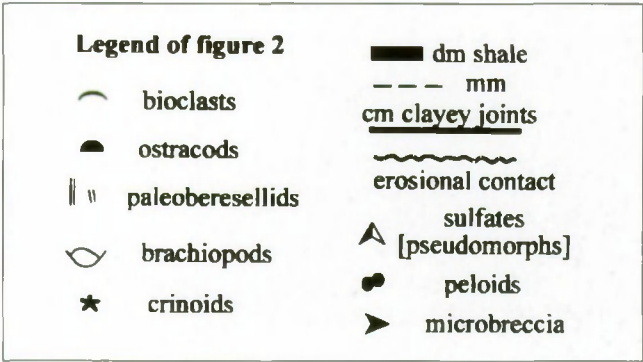
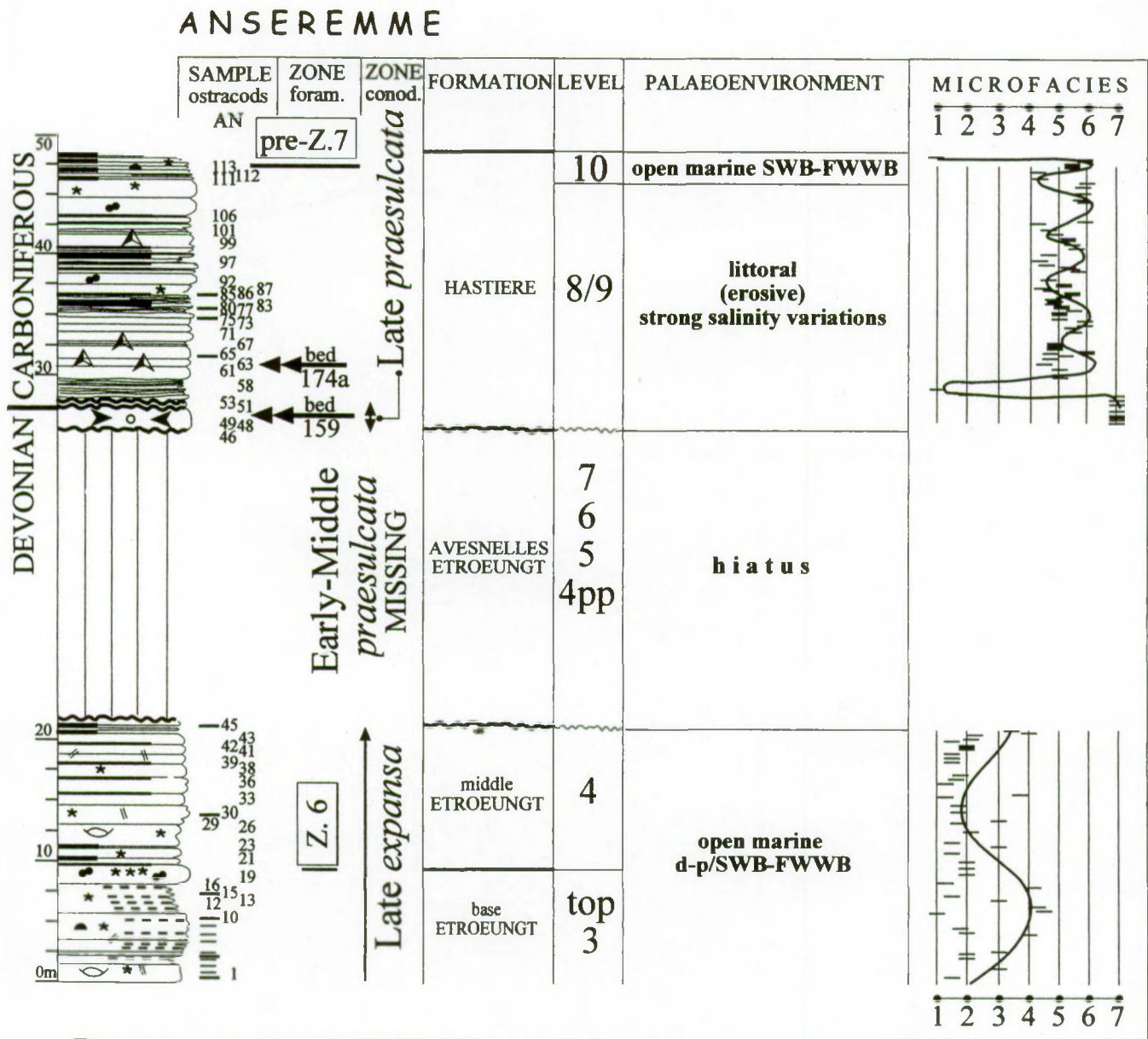


Fig. 2 — Lithological column of the Anseremme railway bridge section. Other columns indicate position of sedimentological and ostracod samples, foraminiferal zonation (MAMET, 1974), names of formations, level succession from 3 to 10 with the location of the hiatuses, palaeoenvironmental interpretation and microfacies evolution. Abbreviations: d = distal, p = proximal, SWB = normal storm wave base, FWWB = normal of fair-weather wave base, Z = Zone (From MAMET & PRÉAT, 2003).

aminifers and algae). These organisms are present as large fragments within millimetric laminae (up to 3 mm thick, Pl. 5, Fig. 4), or small lenses. Bioturbation figures are well developed at a centimetric scale and contain a recrystallized fine-grained homogeneous calcite microspar. In many cases these figures have obliterated the primary laminations. The micritic matrix can be rich in fine-grained organic matter fragments (same type as those of MF1) and echinodermal bioclasts are sometimes pyritized. Pressure solution processes are more accentuated in the clayey facies giving a packstone texture to the sediment.

Open marine within the storm wave base

Microfacies 3 (or MF3)

Definition: clayey and silty wackestones and packstones with diversified bioclasts (Pl. 5, Fig. 5, see previous facies). In comparison with MF2 there is an increase of the number of foraminifers and a significant development of algae (issinelids, kamaenids and *Girvanella*). Bioclasts display a bimodal distribution, one centred around 2-3 mm and the other around 0,5 mm.

Microfacies 4 (or MF4)

Definition: laminar bioclastic packstones. Bioclasts are the same as previously but are coarser and rich in echinoderms (Pl. 5, Fig. 6). Plurilocular foraminifers (Endothyridae, Tournayellidae) are abundant. Laminations are thicker and more frequent (Pl. 5, Figs. 6-7). They are centimetric (up to 3 cm), sometimes cross-bedded and display grading. Their lower parts are rich in millimetric brachiopod and echinodermal fragments, while their upper parts contain finer-grained bioclasts (100 to 200 µm) where foraminifers and algae are concentrated. Bioturbation processes and pressure solution figures are poorly developed. The silty fraction is absent. Rare *Incertae sedis* (*Bisphaera*) and a few micritized grains occur. The micritic matrix is sometimes recrystallized in a homogeneous fine-grained calcitic microspar.

Microfacies 5 (or MF5)

Definition: fine-grained silty peloidal and bioclastic packstones (Pl. 5, Fig. 8) and grainstones. Bioclasts are varied, composed of crinoids, bryozoans, brachiopods, ostracods, corals, trilobites and gastropods and form graded laminae a few millimetres thick. They are also mixed with abundant *Earlandia minima* (foraminifers), a few calcispheres and *Bisphaera* (*Incertae sedis*). Rare irregular lumps are present (Pl. 6, Fig. 1). The matrix contains abundant algae (issinelids and kamaenids). Bioturbation figures are rare and the micritic matrix of the packstones is commonly recrystallized in a homogeneous fine-grained calcitic microspar (Pl. 6, Fig. 1).

Open marine within the fair-weather wave base

Microfacies 6 (or MF6)

Definition: fine to medium-grained bioclastic and "lum-

py" grainstones. Algae are less abundant whereas the foraminifers (*Earlandia minima*) and ostracods proliferate. Peloids, micritized grains and umbellids are abundant. Bioclasts display various grading in steep cross-bedded laminations. Size variations between the laminations are variable. Discontinuities are plane without erosional figures. Alignments of mollusc shells highlight strong oblique stratifications (shell lag). Syntaxial cementations are well developed around the echinoderms. Matrix is partly or totally recrystallized in a homogeneous fine-grained calcitic "greyish" microspar or replaced by continuous or discontinuous large areas of coarse "white" calcite. The sediment is therefore transformed in a "false-grainstone" (Pl. 6, Figs. 2-3-4). Calcite fills irregular enterolithic-like cavities and calcitic microspar, and large calcite crystals replace the bioclasts (molluscs, echinoderms, corals, Pl. 6, Fig. 4). Such diagenetic alteration has never been observed on such a large scale (see microspar of microfacies 4 and 5) and highlights the "false-grainstone" texture. These replacements, which were observed at Avesnes-sur-Helpe (MAMET & PREAT, 2003), are more pronounced at Anseremme: they are clearly related to crystal growth (sulphates?) inside the microporous sediment and the micritic matrix of the packstones is cut into bits (Pl. 6, Figs. 2-3). A few bioclasts (crinoids, molluscs, issinelids...) are partly to completely dissolved. Bioturbation figures are exceptional and "true" stylolites appear for the first time.

Microfacies 7 (or MF7)

Definition: grainstones with various millimetric- to centimetric-sized rounded to subangular microbreccia (Pl. 6, Figs. 5-6), bioclasts (echinoderms, brachiopods, molluscs, foraminifers) and micro-conglomerates composed of polygenic microbreccia of different packstones and grainstones. These packstones and grainstones are oolitic (Pl. 6, Figs. 7-8), oncoidic, peloidal or contain micritized grains, bahamites and various lumps. The microbreccia are perforated and do not contain any previously recognized microfacies (MF1 to MF6). The grains frequently display cross-bedding and the shells (brachiopods, molluscs) form umbrella cavities. Cementation consists of a first isopaquous lamellar calcite phase followed by a drusy or syntaxial second calcitic phase. An asymmetric calcitic cement is sometimes present. Irregular fenestral and geopetal cavities infilled with vadose silt and peloid mudstones are observed.

Microfacies and palaeoenvironmental interpretations

Faunal components (echinoderms, brachiopods, trilobites...) indicate an open-marine domain within the dysphotic-euphotic zone in relatively shallow waters for the first six microfacies. The textures of the rocks (mudstones to grainstones) associated with the different characteristics of the laminae reveal the relative palaeobathymetry of the storm (SWB) and the fair-weather (FWWB) wave bases (EINSELE & SEILACHER, 1982, AHR, 1989). The

laminar levels, which are absent (MF1), thin and not abundant (MF2), of intermediate thickness despite the bioturbation processes (MF3), and finally thick and abundant (MF4), contain the same bioclasts. The size of the bioclasts increases with lamination thickness and with the complexity of the biotic assemblages. The bioturbation figures vary in the opposite trend becoming nonexistent in MF5 and MF6. Moreover, the lamination types vary along the microfacies standard sequence displaying erosional cross-bedding and amalgamation in MF5 and MF6, although plane in the other microfacies.

These characteristics suggest a mixed siliciclastic carbonate ramp system whose sedimentation is determined by the respective SWB and FWB positions (WRIGHT & BURCHETTE, 1998). Microfacies 1 without bioclastic levels is located below the SWB; sedimentation takes place in "deep" water at the base of the dysphotic zone and is related to decantation processes. Thin bioclastic laminae without erosive surfaces in MF2 are interbedded with clearly open-marine sediments (bioturbated micrites, open marine fauna) and interpreted here as distal tempestites (d/SWB). Layers of moderate thickness in MF3 represent intermediate tempestites (i/SWB) and the thicker bioclastic levels of MF4 represent proximal tempestites (p/SWB). In this general context, the background sedimentation is decantation of clayey and carbonate muds in quiet and "deep" environment (AIGNER, 1985). Bioturbation processes predominate and peter out progressively in microfacies 5 and 6, where energy is too high (erosional laminations or high sedimentation rates). In such conditions, crinoidal meadows, algal banks, stromatoporoid and coral bioconstructions are destroyed and exported in the offshore or reworked in the FWB. These microfacies are similar to the ones reported by PRÉAT & KASIMI (1995) in the Belgian-French Middle Devonian or by SEBBAR et al. (2000) in the Algerian Carboniferous (Tindouf basin).

By comparison with the present-day average depths of the SWB and FWB, MF1 and MF2 are interpreted to represent an outer-ramp setting at a depth of about 60 m, and MF3 and MF4, are interpreted to represent a mid-ramp below the FWB (i.e. deeper than 25–30 m). MF5 and MF6, stacked by progradation (?), filled the available space and represent an inner-ramp setting infiltrated by hypersaline brines ("false grainstone"). Only ostracods and *Earlandia minima* (foraminifer) survived in these highly stressful environments and are even abundant in MF5 and MF6. These facies display the strongest diagenetic alteration (repetitive dissolutions, microsparitisation, (de)dolomitization...). Finally MF7, only present in the lower part of the Hastière Limestone, indicates a littoral sedimentation reworking a carbonate platform (oolites, bahamites, oncoids...). These elements were not observed below. The Etroeungt/Hastière sequence indicates therefore a major evolution in the sedimentary system from an "open" ramp to a "restricted" platform system. The composition of the microbreccia in the Hastière Limestone suggests that the sea-level drop affected only the Hastière Limestone (an eroded unknown lower

part), despite the fact that the Avesnelles Formation and parts of the Etroeungt Formation are missing (MAMET & PRÉAT, 2003). The end-Devonian sea-level fall corresponds to the global eustatic fall shown in the Devonian curve by JOHNSON et al. (1985, 1986).

Sedimentary evolution

Based on the interpretation of the lithologic curve (MAMET & PRÉAT, 2003) the series can be subdivided in several local levels (Fig. 2):

L3: above basal bed of Etroeungt Limestone (9.8 m)

Open-marine (normal salinity) shelf facies within the storm wave base and the photic zone. Proximal tempestites are progressively more abundant toward the top where microfacies 4 dominates. Their bioclastic layers contain various foraminifers (*Quasiendothyra*, *Eoendothyra*, *Septabrunsiina*, *Latiendothyra*, *Septaglomospiranella*, *Septatournayella*) and ostracods (*Cryptophylus*...).

L4 pro parte (see MAMET & PRÉAT, 2003) – middle part of Etroeungt Limestone (11 m)

This level represents the continuation of the preceding ones with progressive increase of distal tempestites. MF1 and MF2 (mudstones and wackestones) are well represented with various brachiopods, crinoids and bryozoans. Foraminifers are less abundant but are similar to those in preceding level. Issinellids and *Girvanella* algae are episodically present as a few *Paracalligeloides* and *Bisphaera* (*Incertae sedis*). Despite the bioturbation, thin inframillimetric distal tempestites are well preserved. The matrix is often microsparitized.

L4 (pro parte), L5, L6 and L7 – Etroeungt and Avesnelles formations, base of Hastière Formation

According to the study of MAMET and PRÉAT (2003) these levels are missing.

L8 and L9 – Hastière Limestone (19.4 m)

These levels are discordant and composed in their lower part of polygenic micro-conglomerates reworking various shallow-water packstones-grainstones (with peloids, lumps, micritized grains, dolomitic burrows, bahamites, calcispheres...). The upper part of these sequences is composed of the same packstones-grainstones containing also brachiopods and crinoids. These facies are littoral and represent strong erosion of neighbouring semi-restricted lagoons. Packstones and grainstones contain abundant *Earlandia minima*, ostracod-rich layers (laminites) and display well-developed "false cement" related to sulphate dissolution.

L10 – Hastière Limestone (2 m)

Open-marine facies with normal salinities. The environment is the same as the one of levels 3 and 4 with various foraminifers (Tournayellidae), algae (*Girvanella*, *Aphralysia*...), *Sphaerinvia* and Salebriidae.

Conodonts of the Anseremme railway bridge section (C. A. Sandberg)

Introduction

A total of 22 conodont samples was collected in 1971 from the Upper Devonian sequence and from the Lower Carboniferous sequence above the basal bed of the Hastière Formation at the Anseremme railway bridge section. The samples were positioned according to bed numbers assigned in a columnar section by CONIL (1971, fig. 10b₂). The upper part of this section was shown in reduced format by BOUCKAERT & GROESSENS (1976), who identified new Devonian conodont species from CONIL's beds 146 and 159.

Devonian conodonts

The 10 samples collected from Devonian exposures permit precise zonal dating of the sequence according to the Late Devonian standard zonation (ZIEGLER & SANDBERG, 1990). The dates span the five youngest Devonian conodont zones. In ascending order, these are the: Middle *expansa* Zone, Late *expansa* Zone, Early *praesulcata* Zone, Middle *praesulcata* Zone, and Late *praesulcata* Zone. The original conodont determinations are revised herein according to conodont taxonomy and ranges for the youngest part of the Devonian presented by ZIEGLER, SANDBERG & AUSTIN (1974), SANDBERG & ZIEGLER (1979), ZIEGLER & SANDBERG (1984a, 1990), and SANDBERG & DRESEN (1984). Accordingly, the Epinette Formation is dated as Middle *expansa* Zone, but not the oldest part of this zone. The overlying Etroeungt Formation is dated as Late *expansa* Zone. The basal, massive, resistant ledge of the Hastière Formation is dated as Late *praesulcata* Zone. The faunas of some of the most productive and diagnostic conodont collections are listed and interpreted herein.

Middle *expansa* Zone

Two conodont samples, 71-BEL-9 and 71-BEL-79, were collected 0.4 m and 2.25 m, respectively, above the base of CONIL's (1971) bed 28, a 3-m-thick, thin-bedded, argillaceous limestone unit at the base of the Epinette Formation, which overlies the highest bed of the Condroz Group. Bed 28 also marks the lowest occurrence of the calcareous foraminifer *Quasiendothyra kobeitusana* (RAUSER, 1948). The identical combined conodont faunas of the two collections include these species: *Bispathodus spinulicostatus* (BRANSON, 1934), *Bi. aculeatus aculeatus* (BRANSON & MEHL, 1934), "*Icriodus*" *costatus* (THOMAS, 1949), "*I.*" *raymondi* SANDBERG & ZIEGLER, 1979, *Pandorinellina plumula plumula* RHODES, AUSTIN & DRUCE, 1969, *Pand. plumula nodosa* RHODES, AUSTIN & DRUCE, 1969, *Pand. plumula* tr. *Clydagnathus* sp., *Polygnathus communis* BRANSON & MEHL, 1934, *Pol. delicatulus* ULRICH & BASSLER, 1926, and *Pseudopolygnathus controversus* SANDBERG & ZIEGLER, 1979 tr. *Ps. graulichii* BOUCKAERT & GROES-

SENS, 1976. The start of the Middle *expansa* Zone is based on the first occurrence of *Bispathodus aculeatus aculeatus*. However, its descendant *Bi. spinulicostatus* first occurs later, well within the Middle *expansa* Zone. Additionally, "*Icriodus*" *raymondi* has its last occurrence at the end of this zone. Thus, the Epinette Formation is dated as being within, but not at the start of the Middle *expansa* Zone.

Late *expansa* Zone

Five conodont samples were collected from the Etroeungt Formation. Of these, the largest collection with the most diagnostic fauna was obtained in sample 71-BEL-11 from CONIL's (1971) bed 146, 3.6–3.8 m below the top of the formation. Ostracode samples AN 38 and AN 39 were probably collected from bed 146. The conodont fauna of 71-BEL-11 includes these species: *Apatognathus varians* BRANSON & MEHL, 1934, *Bispathodus aculeatus aculeatus*, *Bi. stabilis* (BRANSON & MEHL, 1934), *Bi. ultimus* (BISCHOFF, 1957), *Branmehla fissilis* (BRANSON & MEHL, 1934), *Br. praelonga* (COOPER, 1943), *Mehlina strigosa* (BRANSON & MEHL, 1934), *Polygnathus delicatulus*, *Pol. cf. Pol. inornatus* BRANSON, 1934, *Pseudopolygnathus cf. Ps. dentilineatus* BRANSON, 1934, and *Ps. graulichii*. This fauna is composed of mainly characteristic very late Devonian species. However, *Pseudopolygnathus graulichii* is an endemic species, first recorded from this bed by BOUCKAERT & GROESSENS (1976). Because of the shape of the basal cavity and the eversion of the basal cavity in some specimens, which are features similar to those of *Polygnathus longiposticus* BRANSON & MEHL, 1934, *Pseudopolygnathus graulichii* might be better assigned to *Polygnathus*. *Bispathodus ultimus* is the zonal indicator for the Late *expansa* Zone and thus conclusively dates this collection as well as the middle Etroeungt Formation.

Early and Middle *praesulcata* Zones

Deposits of the Early and Middle *praesulcata* Zones are not recorded in the Anseremme railway bridge section. Their absence is predictable because of the shallow-marine to peritidal very late Devonian palaeogeographic setting there and elsewhere in Belgium. The Devonian eustatic sea level curve for Euramerica records a drastic fall in sea level coinciding with the start of the Middle *praesulcata* Zone (JOHNSON et al., 1985, 1986). This eustatic fall was so severe (ZIEGLER & SANDBERG, 1984b) that during the entire Middle *praesulcata* Zone, *Siphonodella praesulcata* SANDBERG, 1971, a deeper water conodont species was forced to retreat from epicontinental seas to ocean basins (SANDBERG et al., 2002). This fall, which led to the Hangenberg Event, is represented, according to SANDBERG et al. (2002, p. 484): "by a hiatus or discontinuity or is masked within shallow-water deposits". Because of the sea level fall, erosion of near-coastal areas in Belgium undoubtedly removed any thin deposits that might have been laid down during the Early *praesulcata* Zone.

Late *praesulcata* Zone

Three conodont samples, 71-BEL-75, 71-BEL-74, and 71-BEL-73, were collected from the basal 12 cm, 30–45 cm above the base, and 115–135 cm above the base, respectively, of bed 159, the basal massive ledge of the Hastière Formation. The most significant fauna is from collection 71-BEL-73. This fauna includes: widely distributed latest Devonian species *Pelekysgnathus inclinatus* THOMAS, 1949, *Polygnathus communis*, *Pol. delicatulus*, *Pol. cf. Pol. inornatus*, and *Protognathodus kockeli* (BISCHOFF, 1957), as well as the endemic species *Pseudopolygnathus graulichii*. *Protognathodus kockeli* is the zonal indicator for the Late *praesulcata* Zone. A large specimen of this species from this bed was illustrated by BOUCKAERT & GROESSENS (1976, pl. 1, fig. 10). The occurrence of *Protognathodus kockeli* with Late Devonian taxa thus dates the basal ledge of the Hastière Formation as latest Famennian. Some authors (e.g., VAN STEENWINKEL, 1988) have suggested that bed 159, because of the abundance of conodonts, might be a “relict” deposit, that is, a reworked deposit. Collection 71-BEL-73, however, containing virtually the same fauna without *Protognathodus kockeli*, conclusively demonstrates that the conodont fauna of bed 159 is indigenous. Besides the I platform element of *Pelekysgnathus inclinatus*, its fauna includes four of the six coniform elements of the apparatus (see SANDBERG & DRESEN, 1984). Moreover, the complete apparatus of *Pseudopolygnathus graulichii* is present – the Pa, Pb, M, Sa, Sb, Sc, and Sd elements. Because of current sorting of different sizes and shapes of elements during reworking or redeposition, reworked conodont faunas would not be expected to contain complete or nearly complete apparatuses. The absence of *Siphonodella praesulcata* and presence of *Protognathodus kockeli* in these beds are in accord with the global distribution of these species in shallow-water settings.

Carboniferous conodonts

A total of 12 conodont samples were collected in the interval from beds 160 through 234 in the columnar section of CONIL (1971, fig. 10b₂) in the Carboniferous part of the Hastière Formation. However, only the lower five of these samples, from CONIL's beds 161, 163, 165, 169, and 174, which are critical to dating, have been processed as yet. These five samples yielded sparse faunas (only 1 to 11 conodonts/kilogram). The faunas consist almost entirely of long-ranging *Bispathodus aculeatus* and *Polygnathus communis*, which provide little useful information regarding precise zonal dating or the existence or magnitude of a hiatus above bed 159.

sulcata, *duplicata*, and *sandbergi* Zones

The eustatic fall in sea level continued across the Devonian–Carboniferous boundary with minor fluctuations until the start of the Lower *crenulata* Zone, when a major transgression began (SANDBERG, 2002). This accounts for the absence of *Siphonodella sulcata* in shallow-water beds of the

Hastière Formation above basal bed 159, and below bed 174a, where *Siphonodella duplicata* (BRANSON & MEHL, 1934) is recorded (VAN STEENWINKEL, 1988). Low sea level during these three oldest zones of the Carboniferous accounts for the rare occurrence of *Siphonodella* species throughout this shallow upper part of the Hastière Formation. The few specimens of *Siphonodella duplicata* and *S. quadruplicata* (BRANSON & MEHL, 1934) that are reported by VAN STEENWINKEL (1988) undoubtedly were transported onshore by storms from deeper water settings, where the two species lived. These two species demonstrate that the *duplicata* and *sandbergi* Zones must be represented in the upper part of the Hastière Formation, although the zonal boundary between them cannot be precisely located. Because of a lack of *S. sulcata*, however, it is uncertain, in the absence of other diagnostic taxa, whether *sulcata* Zone deposits were ever laid down or are unrecognisable.

Ostracods of the Anseremme railway bridge section (J.-G. Casier)

Introduction

In the literature, only a few ostracod taxa have been recorded in the Etroeungt and Hastière formations cropping out in the Anseremme railway bridge section. BECKER & BLESS (in BOUCKAERT & STREEL eds, 1974) mentioned the occurrence of the genera *Cryptophyllus*, *Bairdia*, *Knoxiella* and *Shemonaella*, of the species “*Bernix*” *venulosa*, and of two others ostracod taxa: *Bairdiocypris* aff. *rudolphi* and *Bairdiocypris* aff. *robusta*. The same year, BECKER & BLESS (1974) cited *Cryptophyllus* sp. 17, “*Bernix*” sp? 42, and figured *Knoxiella* sp. indet., *Knoxiella* sp. cf. 79, *Shemonaella* sp. cf. 65, and *Bairdia* sp. 26 from the same beds. Finally ROME & GOREUX (1964) mentioned *Cryptophyllus circularis* ROME & GOREUX, 1964 in the Etroeungt Formation.

Fifty-five samples (Fig. 2) were collected for ostracods in outcrops of the Etroeungt and Hastière formations, and about 3,500 carapaces, valves and fragments have been extracted by the hot acetolysis method (LETHIERS & CRASQUIN-SOLEAU, 1988). Ostracods are present in all the samples collected and they are generally well preserved.

Ostracods are scarce in samples AN5, AN6, AN8, AN51, AN71, AN106 and indeterminate in the sample AN5. They are abundant in samples AN4, AN7, AN10, AN38, AN41, AN42, AN86, AN92, AN111, AN113, and very abundant in samples AN83, AN85, AN87, AN97, AN101, AN112.

Systematic position of ostracod taxa observed in the Anseremme section

Order Palaeocopida HENNINGSMOEN, 1953
Suborder Palaeocopina HENNINGSMOEN, 1953

Superfamily Kirkbyacea ULRICH & BASSLER, 1906
Family Amphissitidae KNIGHT, 1928
– *Amphissites* sp. A (Pl. 1, Fig. 1a,b).

Superfamily Aparchitacea JONES, 1901

Family Aparchitidae JONES, 1901

- *Sacclatia? advena* CASIER, 2003 (Pl. 1, Fig. 2a,b).

Superfamily Youngiellacea KELLETT, 1933

Family Youngiellidae KELLETT, 1933

- *Youngiella calvata* (GREEN, 1963) (Pl. 1, Fig. 3a,b).

Superfamily Primitiopsacea SWARTZ, 1936

Family Graviidae POLENOVA, 1952

- *Coryellina grandis* ROBINSON, 1978 (Pl. 1, Fig. 4a,b).

Superfamily Hollinacea SWARTZ, 1936

- Hollinacea indet. CASIER, 2003 (Pl. 1, Fig. 5a,b).
- Hollinacea indet. A (Pl. 1, Fig. 7a,b).

Superfamily Beyrichiacea MATTHEW, 1986

Family Beyrichiidae MATTHEW, 1986

- *Kozlowskiella? sp. A* (Pl. 1, Fig. 6a,b, 8).

Suborder Paraparchiticopina GRAMM *in* GRAMM & IVANOV (1975)

Superfamily Paraparchitacea SCOTT, 1959

Family Paraparchitidae SCOTT, 1959

- *Shishaella nana* ROME, 1977 (Pl. 1, Fig. 9a,b).
- *Shishaella sp. A* (Pl. 1, Fig. 10a,b).
- *Shishaella? sp. B* (Pl. 1, Fig. 11).
- *Shemonaella sp. A* CASIER, 2003 (Pl. 1, Fig. 12a,b).
- *Shemonaella sp. B* (Pl. 1, Fig. 13a,b).
- *Shemonaella? sp. C* (Pl. 2, Fig. 1a,b).
- *Chamishaella kaysini* ROME, 1977 (Pl. 2, Fig. 2a,b).
- *Samarella sp. A* CASIER, 2003 (Pl. 2, Fig. 3a,b).
- *Samarella? sp. B*.

Suborder Platycopina SARS, 1866

Superfamily Kloedenellacea ULRICH & BASSLER, 1908

Family Knoxitidae EGOROV, 1950

- *Knoxiaella aff. bastachica* (BUSCHMINA, 1970) (Pl. 2, Fig. 4a,b).
- *Knoxites sp. A* (Pl. 2, Fig. 5).
- *Barychilina sp. A*, aff. *regia* JANBULATOVA, 1987. (Pl. 2, Fig. 6, 7).

Order Podocopida SARS, 1866

Suborder Podocopina SARS, 1866

Superfamily Bairdiocypridacea SHAVER, 1961

Family Bairdiocypridae SHAVER, 1961

- *Healdianella lumbiformis* LETHIERS & FEIST, 1991 (Pl. 2, Fig. 8a,b).
- *Healdianella dorsosulcata* CASIER, 2003 (Pl. 2, Fig. 9a,b).
- *Elliptocyprites lorangeri* LETHIERS, 1981 (Pl. 2, Fig. 10).
- *Praepilatina sp. A*, aff. *adamczaki* OLEMPKA, 1979 (Pl. 2, Fig. 11).
- *Bairdiocypris sp. A*, aff. *rudolphi* (KUMMEROW, 1939) (Pl. 2, Fig. 12, 13).
- *Bairdiocypris sp. B* (Pl. 2, Fig. 14).

- *Microcheilinella buschminae* OLEMPKA, 1981 sensu KOTCHETKOVA & JANBULATOVA, 1987 (Pl. 2, Fig. 15a,b).
- *Microcheilinella sp. A*, aff. *buschminae* OLEMPKA, 1981 (Pl. 2, Fig. 16).
- *Microcheilinella sp. B*, aff. *buschminae* OLEMPKA, 1981 (Pl. 3, Fig. 1a,b).

Family Pachydomellidae BERDAN & SOHN, 1961

- *Ampuloides sp. A*

Family Rectorariidae GRÜNDEL, 1962.

- *Rectoraria? sp. A*.

Superfamily Bairdiacea SARS, 1888

Family Acratiidae GRÜNDEL, 1962

- *Famenella angulata perparva* LETHIERS & FEIST, 1991 (Pl. 3, Fig. 2a,b).
- *Acratia bidecliva* LETHIERS & FEIST, 1991 (Pl. 3, Fig. 3a,b).
- *Acratia subobtusa* LETHIERS, 1974 (Pl. 3, Fig. 4a,b).
- *Acratia sp. A*, aff. *rostrata* ZANINA, 1956 (Pl. 3, Fig. 5a,b).
- *Acratia sp. B*, aff. *sagittaeformis* LETHIERS & CASIER, 1999 (Pl. 3, Fig. 6a,b).
- *Acratia sp. C*, aff. *subobtusa* LETHIERS, 1974 (Pl. 3, Fig. 7a,b).
- *Acratia sp. D* (Pl. 3, Fig. 8a,b).
- *Acratia sp. E* (Pl. 3, Fig. 9).
- *Acratia sp. F* (Pl. 3, Fig. 10).
- *Acratia? sp.* (Pl. 3, Fig. 11a,b).

Family Bairdiidae SARS, 1888.

- *Bairdia hypsela* ROME, 1971 emend LETHIERS, 1975 (Pl. 3, Fig. 12a,b).
- *Bairdia fusiformis* ROME, 1971 (Pl. 3, Fig. 13a,b).
- *Bairdia extenuata* NAZAROVA, 1951 (Pl. 3, Fig. 14, 15).
- *Bairdia mecyna* ROME, 1971 (Pl. 4, Fig. 1a,b).
- *Bairdia paranotoconstricta* LETHIERS, 1974.
- *Bairdia romei* LETHIERS, 1974?
- *Bairdia sp. A*, aff. *buschminae* CRASQUIN, 1985 (Pl. 4, Fig. 2a,b).
- *Bairdia sp. B*, aff. *feliumgibba* BECKER, 1982 (Pl. 4, Fig. 3a,b).
- *Bairdia sp. C*, aff. *extenuata* NAZAROVA, 1951 (Pl. 4, Fig. 4a,b).
- *Bairdia sp. D* (Pl. 4, Fig. 5a,b).
- *Bairdia sp. E* (Pl. 4, Fig. 6a,b).
- *Bairdia sp. F* (Pl. 4, Fig. 7a,b).
- *Bohlenatia? sp. A* CASIER, 2003 (Pl. 4, Fig. 8a,b).
- *Bairdianella sp. A*, aff. *cusps* BUSCHMINA, 1970 (Pl. 4, Fig. 9a,b).
- *Bairdianella sp. B*, aff. *cusps* BUSCHMINA, 1970 (Pl. 4, Fig. 10).
- *Bythocypris? sp. A* (Pl. 4, Fig. 11).
- *Bairdiacypris robusta* KUMMEROW, 1939 (Pl. 4, Fig. 12a,b).
- *Bairdiacypris sp. A* (Pl. 4, Fig. 13a,b).
- *Bairdiacypris sp. B*, aff. *nanbiancunensis* (WANG, 1988) (Pl. 4, Fig. 14).

HASTIERE FORMATION																									ANSEREMME		
46	48	49	51	53	58	61	63	65	67	71	73	75	77	80	83	85	86	87	92	97	99	101	106	111	112	113	
																											<i>Barvchilina</i> sp. A, aff. <i>regia</i>
																											<i>Samarella</i> sp. A
																											<i>Bairdia</i> sp. indet.
																											<i>Acratia</i> sp. B, aff. <i>sagittaeformis</i>
																											<i>Acratia bidecliva</i>
																											<i>Bairdianella</i> sp. A, aff. <i>cuspis</i>
																											<i>Bairdiocypris</i> sp. A
																											<i>Bairdia</i> sp. C, aff. <i>extenuata</i>
?																											<i>Bairdia hypsela</i>
																											<i>Healdianella lumbiformis</i>
																											<i>Microcheilinella buschminae</i>
																											<i>Shishaella</i> sp. A
																											<i>Shishaella?</i> sp. B
																											<i>Bairdia extenuata</i>
																											<i>Bairdia</i> sp. A, aff. <i>buschminae</i>
																											<i>Bairdiocypris</i> sp. A, aff. <i>rudolphi</i>
																											<i>Knoxella</i> aff. <i>bastachica</i>
																											<i>Kloedenellacea</i> indet.
																											<i>Acratia</i> sp. indet.
																											<i>Bairdiocypris</i> sp. indet.
																											<i>Bairdia paranotoconstricta</i>
																											<i>Acratia</i> sp. E
																											<i>Chamishaella kaysini</i>
																											<i>Cryptophyllus</i> sp. indet.
																											<i>Bairdia mecyna</i>
																											<i>Shemonaella</i> sp. B
																											<i>Bairdia fusiformis</i>
																											<i>Elliptocypris lorangeri</i>
																											<i>Bairdiocypris</i> sp. B, aff. <i>nanbiancunensis</i>
																											<i>Ampuloides</i> sp. A
																											<i>Bairdiocypris</i> sp. C
																											<i>Famenella</i> sp. indet.
																											<i>Bairdia</i> sp. B, aff. <i>feliumgibba</i>
																											<i>Bairdianella</i> sp. B, aff. <i>cuspis</i>
																											<i>Hollinacea</i> indet. CASIER, 2003
																											<i>Bairdia</i> sp. D
																											<i>Acratia</i> sp. A, aff. <i>rostrata</i>
																											<i>Acratia subobtusa</i>
																											<i>Kozłowskiella?</i> sp. A
																											<i>Acratia</i> sp. F
																											<i>Microcheilinella</i> sp. A, aff. <i>buschminae</i>
																											<i>Shemonaella?</i> sp. C
																											<i>Acratia</i> sp. D
																											<i>Microcheilinella</i> sp. B, aff. <i>buschminae</i>
																											<i>Famenella angulata perparva</i>
																											<i>Bairdia</i> sp. F
																											<i>Bohlenatia?</i> sp. A
																											<i>Bairdiocypris robusta</i>
																											<i>Bairdiocypris</i> sp. B
																											<i>Bythocypris?</i> sp. A
																											<i>Acratia</i> sp. C, aff. <i>subobtusa</i>
																											<i>Shishaella nana</i>
																											<i>Bairdiocypris</i> sp. indet.
																											<i>Youngiella calvata</i>
																											<i>Bairdia romei</i>
																											<i>Knoxites</i> sp. A
																											<i>Cryptophyllus</i> sp. C, aff. <i>ellipticus</i>
																											<i>Paraparchitacea</i> indet.
																											<i>Samarella</i> sp. indet.
																											<i>Bairdia</i> sp. E
																											<i>Microcheilinella</i> sp. indet.
																											<i>Hollinacea</i> indet. A
																											<i>Samarella?</i> sp. B
																											<i>Rectonaria?</i> sp. A
																											<i>Saccolatitia?</i> advena
																											<i>Healdianella dorsosulcata</i>
																											<i>Amphissites</i> sp. A
																											<i>Shemonaella</i> sp. indet.
																											<i>Shemonaella</i> sp. A
																											<i>Corvella grandis</i>
																											<i>Healdianella</i> sp. indet.
																											<i>Praepilatina</i> sp. A, aff. <i>adamczaki</i>

- *Bairdiacypris* sp. C (Pl. 4, Fig. 15a,b).

Order Eridostraca ADAMCZAK, 1976

- *Cryptophyllus* sp. C, aff. *ellipticus* ROME & GOREUX, 1964 (Pl. 4, Fig. 16).

Palaeoecology of ostracods

Sixty taxa, the majority of which are in open nomenclature, have been identified (Table 1). Fifty are present in the Etroeungt Formation and forty-seven in the Hastière Formation. In general the environment was favourable for a rich and diversified ostracod fauna except at the base of the Hastière Formation. The ostracod assemblages belong to the Eifelian ecotype of BECKER (in BANDEL & BECKER, 1975).

At the base of the Etroeungt Formation (level N3 of the sedimentological analysis; samples AN1 to AN19), and except in samples AN5, AN6 and AN8, ostracods are generally abundant. Thirty-eight (42?) taxa are recognized in this level. The ostracod assemblage is largely dominated by twenty-nine (32?) taxa of Podocopina, and the rest of the ostracod fauna is composed of four (6?) taxa of Paraparchiticipina (= Paraparchitacea), two of Palaeocopina, three of Platycopina (= Kloedenellacea), and of indeterminable Eridostraca (= *Cryptophyllus*). The assemblage is indicative of well-oxygenated water conditions in a shallow environment between fair-weather and storm-wave bases (= Assemblage III of CASIER, 1987; see also CASIER & PRÉAT, 2003, fig. 3). This ostracod assemblage is quite different from the assemblage present in the underlying Epinette Formation. Several samples collected in that formation, and not included in our study, are abnormally rich in larval ostracods, and are indicative of environments below storm wave base. The scarcity of ostracods in sample AN5, AN6 and AN8 may be explained by temporary sedimentation below storm wave base.

In the upper part of the Etroeungt Formation (level 4 of the sedimentological analysis; samples AN21 to AN45), ostracods are still abundant and diversified. Thirty-five (38?) ostracod taxa are recorded, and twenty-six (28?) are Podocopina. Two ostracod taxa belong to the Palaeocopina, three (4?) to the Paraparchiticipina, three other to the Platycopina, and one to the Eridostraca. The assemblage is still indicative of well-oxygenated water conditions in a shallow environment between fair-weather and storm-wave bases.

After an hiatus, the base of the Hastière Formation (= bed 159 of CONIL, 1964; samples AN46 to AN51) exposes a microconglomerate. Only two taxa of Podocopina, one of Platycopina and one other of Paraparchiticipina are recognized in this bed. These very rare ostracods are indicative of a marine environment. Sample AN51 contains a richer ostracod fauna, exclusively composed of indeterminable internal moulds.

Above the microconglomerate, the base of the Hastière

Formation (sample AN53 to AN80) is moderately rich and diversified. Twenty-three (27?) ostracod taxa are recorded. Eighteen belong to the Podocopina, four (5?) to the Platycopina, and one to the Paraparchiticipina. The Palaeocopina are missing at this level. The decrease of the number of ostracods, the absence of Palaeocopina, and the higher percentage of Platycopina (17 percent of the ostracods fauna belongs to the Kloedenellacea) are maybe linked to the variations of salinity observed during the sedimentological analysis. Consequently, this ostracod fauna belongs to the Assemblage I of CASIER (1987; see also CASIER & PRÉAT, 2003, fig. 3). However, the abundance of Podocopina indicates that these variations of salinity were weak.

The upper part of the Hastière Formation (sample AN83 to AN113) is again rich and diversified in ostracods, and forty (42?) ostracod taxa are recorded. Twenty-seven (29?) taxa belong to the Podocopina, seven to the Palaeocopina, six to the Paraparchiticipina and one to the Eridostraca. The Platycopina are missing in this level. The ostracod fauna belongs again to the Assemblage III of CASIER (*ibid.*), indicative of a marine environment below fair-weather wave base.

By comparison with the ostracod fauna present in the Etroeungt Formation, the Podocopina decreases from 74 percent to 67 percent, and the Platycopina from 9 percent to 0 percent in the upper part of the Hastière Formation. Conversely, the Palaeocopina increases from 5 percent to 17 percent, and the Paraparchiticipina from 9 percent to 15 percent. This change in the ostracod fauna can be explained by a moderate rise of sea level associated with a slight decrease of oxygenation.

Comparison with the Bocahut quarry

Ostracods are abundant and diversified throughout the Devonian-Carboniferous boundary beds in the Bocahut quarry close to Avesnes-sur-Helpe in the Avesnes "basin", North of France (CASIER & PRÉAT, 2003). Sixty-six ostracod taxa have been identified in this quarry and they belong to the Assemblage III of CASIER (1987), indicating oxygenated shallow-marine environments generally between storm and fair-weather wave bases. No assemblage indicative of semi-restricted water conditions has been found. In that section we have linked the absence of some platycopid ostracods in the Hastière Formation to the hiatus observed between the Avesnelles and the Hastière formations. However, the same change is observable in the middle part of the Hastière Formation (sample AN83) in the Anseremme railway bridge section. Moreover, at the same level we observe the entry of *Sacculatia? advena* CASIER, 2003, *Healdianella dorsosulcata* CASIER, 2003, *Coryellina grandis* ROBINSON, 1978 and *Samarella? sp. B*. This change in the fauna is perhaps the result of a diachronous sea level change.

If hiatuses observed in the two sections correspond to the Hangenberg Event, this event had little or no influence on the distribution of ostracods in shallow marine settings. Thirty-three (36?) taxa are present in both the

Etroeungt and Hastière formations in the Anseremme railway bridge section. The study of ostracods present in the Devonian-Carboniferous Global Stratotype Section and Point (GSSP) at La Serre trench E' and in the Puech de la Suque section, in the Montagne Noire, Southern France, have already demonstrated that the impact of the event on the bio-diversity has been largely overestimated (CASIER *et al.*, 2001, 2002).

Conclusions

Seven carbonate microfacies permit recognition of several marine settings ranging through the Etroeungt and Hastière formations in the Anseremme railway bridge section. The "bathymetric" sequences range from open-marine below the storm wave base to semi-restricted lagoon. Faunal components (echinoderms, brachiopods...) point to an open-marine domain for the first six microfacies. The textures of the rocks (mudstones to grainstones) associated with the different lamination characteristics indicate the relative palaeobathymetry of the storm (SWB) and the fair-weather (FWWB) wave bases in a major ramp. The series that contain these first six microfacies represent a mixed silico-carbonate ramp depositional system. The shallow-water facies are well developed, indicating a progressive decrease in accommodation space (reduced sea level rise or higher sedimentation rate). These conditions allowed the development of thin "back-barrier" sediments in the Hastière Formation (peritidal environments, microfacies seven). Microfacies seven suggests a semi-restricted platform where strong salinity fluctuations from hypersaline brines to brackish waters were the rule. The transition at the boundary of the Etroeungt and Hastière formations is marked by an abrupt sea level drop and sedimentation of carbonate microconglomerates recording an important erosive phase. The "true" thickness of the Hastière sedimentation is therefore unknown. Comparison with the same series in the Avesnes basin (MAMET & PREAT, 2003), shows that several formations (middle Etroeungt *pro parte*, upper Etroeungt, Avesnelles) are missing. Their lithologies were not observed in the microbreccia blocks of the microconglomerates of the Hastière Formation suggesting that they were never deposited. These two hiatuses (middle Etroeungt *pro parte* – upper Etroeungt – Avesnelles and lower part, or more?, of the Hastière Formation) indicate that this historical Anseremme profile is far from being a reliable section exposing the D/C boundary beds. The new Bocahut succession (MAMET & PREAT, 2003, CASIER & PREAT, 2003), although riddled by small non-sequences, is therefore one of best presently known outcrops exposing the D/C succession for northern

France (Avesnes basin) and southern Belgium (Dinant basin).

Abundant conodont faunas at the Anseremme railway bridge section demonstrate that the Devonian sequence spans the five youngest conodont zones, but that two of these zones are not represented. The Epinette Formation is dated as the youngest part of the Middle *expansa* Zone and the Etroeungt Formation is interpreted to belong entirely to the Late *expansa* Zone. The disconformably overlying basal bed 159 of the Hastière Formation is dated as Late *praesulcata* Zone, with the Early and Middle *praesulcata* Zones unrepresented because of an hiatus or unconformity produced by the sea-level fall associated with the Hangenberg Event. Sparse conodont faunas suggest that only the two next-to-oldest Carboniferous *duplicata* and *sandbergi* Zones are represented in the higher part of the Hastière Formation. The oldest Carboniferous *sulcata* Zone and possibly part of the *duplicata* Zone are unrepresented because of a hiatus or unconformity. Because the latest Devonian basal bed of the Hastière Formation is discontinuous with the Devonian sequence below and the Carboniferous sequence above, the Anseremme railway bridge section is not useful for locating the Devonian-Carboniferous boundary nor for describing a complete sequence of transitional beds.

Ostracods are abundant and diversified in the Anseremme railway bridge section and the assemblages recognized belong to the Eifelian ecotype. In the Etroeungt Formation, ostracods are indicative of shallow-marine environments between fair-weather and storm wave bases, except at the base of the formation where environments are periodically below storm wave bases. The ostracod fauna at the base of the Hastière Formation is indicative of shallower water conditions periodically submitted to minor salinity variations. Finally, the upper part of the Hastière Formation is marked by a sea level rise associated with a moderate decrease of oxygenation.

The intra-Devonian Etroeungt-Hastière boundary does not seem to have an important impact on the distribution of ostracods. This distribution is principally controlled by a sea level fall and minor salinity variations.

The sedimentological analysis and the palaeontological study of the Bocahut quarry in the Avesnois and of the Anseremme railway section does not match a continuous highstand hypothesis for the Hastière Formation as suggested by HANCE *et al.* (2001).

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- Jean-Georges CASIER
Département de Paléontologie
Section de Micropaléontologie-Paléobotanique
Institut royal des Sciences naturelles de Belgique
rue Vautier, 29, B-1000 Bruxelles, Belgique
E-mail: casier@naturalsciences.be
- Bernard MAMET and Alain PREAT
Département des Sciences de la Terre et de l'Environnement
Université libre de Bruxelles CP160
Av. F.D. Roosevelt, 50, B-1050 Bruxelles, Belgique
E-mail: apreat@ulb.ac.be
- Charles A. SANDBERG
U.S. Geological Survey
Box 25046, MS 939
Federal Center
Denver, CO 80225, U.S.A.
E-mail: sandberg@usgs.gov
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Explanation of Plates

The types are deposited in the collections of the Department of Palaeontology (section Micropalaeontology) 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 (Préat n°...). AN = sample number (see Fig. 2 for the stratigraphic position).

PLATE 1

- Fig. 1a,b — *Amphissites* sp. A. AN83. Hastière Formation. IRScNB n° b4258. Carapace. a. Right lateral view? b. Dorsal view. x105.
- Fig. 2a,b — *Sacculatia? advena* CASIER, 2003. AN97. Hastière Formation. IRScNB n° b4259. Carapace. a. Left lateral view. b. Dorsal view. x120.
- Fig. 3a,b — *Youngiella calvata* (GREEN, 1963). AN38. Etroeungt Formation. IRScNB n° b4260. Carapace. a. Left lateral view. b. Dorsal view. x145.
- Fig. 4a,b — *Coryellina grandis* ROBINSON, 1978. AN97. Hastière Formation. IRScNB n° b4261. Carapace. a. Left lateral view. b. Dorsal view. x60.
- Fig. 5a,b — Hollinacea indet. CASIER, 2003. AN99. Hastière Formation. IRScNB n° b4262. Carapace. a. Right lateral view. b. Dorsal view. x95.
- Fig. 6a,b — *Kozłowskiella?* sp. A. AN39. Etroeungt Formation. IRScNB n° b4263. Carapace. a. Left lateral view. b. Dorsal view. x125.
- Fig. 7a,b — Hollinacea indet. A. AN83. Hastière Formation. IRScNB n° b4264. Carapace. a. Left lateral view. b. Dorsal view. x85.
- Fig. 8 — *Kozłowskiella?* sp. A. AN29. Etroeungt Formation. IRScNB n° b4265. Left lateral view of a valve. x85.
- Fig. 9a,b — *Shishaella nana* ROME, 1977. AN83. Hastière Formation. IRScNB n° b4266. Carapace. a. Right lateral view. b. Dorsal view. x85.

- Fig. 10a,b — *Shishaella* sp. A. AN38. Etroeung Formation. IRScNB n° b4267. Carapace. a. Right lateral view. b. Dorsal view. x115.
 Fig. 11 — *Shishaella?* sp. B. AN67. Hastière Formation. IRScNB n° b4268. Right lateral view of a carapace. x60.
 Fig. 12a,b — *Shemonaella* sp. A CASIER, 2003. AN87. Hastière Formation. IRScNB n° b4269. Carapace. a. Right lateral view. b. Dorsal view. x55.
 Fig. 13a,b — *Shemonaella* sp. B. AN97. Hastière Formation. IRScNB n° b4270. Carapace. a. Right lateral view. b. Dorsal view. x95.

PLATE 2

- Fig. 1a,b — *Shemonaella?* sp. C. AN101. Hastière Formation. IRScNB n° b4271. Carapace. a. Left lateral view. b. Dorsal view. x105.
 Fig. 2a,b — *Chamishaella kaysini* ROME, 1977. AN4. Etroeung Formation. IRScNB n° b4272. Carapace. a. Right lateral view. b. Dorsal view. x35.
 Fig. 3a,b — *Samarella* sp. A CASIER, 2003. AN10. Etroeung Formation. IRScNB n° b4273. Carapace. a. Left lateral view. b. Dorsal view. x125.
 Fig. 4a,b — *Knoxiella* aff. *bastachica* (BUSCHMINA, 1970). AN3. Etroeung Formation. IRScNB n° b4274. Carapace. a. Left lateral view. b. Dorsal view. x55.
 Fig. 5 — *Knoxites* sp. A. AN43. Etroeung Formation. IRScNB n° b4275. Right lateral view of a carapace. x85.
 Fig. 6 — *Barychilina* sp. A, aff. *regia* JANBULATOVA, 1987. AN30. Etroeung Formation. IRScNB n° b4276. Right lateral view of a carapace. x70.
 Fig. 7 — *Barychilina* sp. A, aff. *regia* JANBULATOVA, 1987. AN1. Etroeung Formation. IRScNB n° b4277. Right lateral view of a valve. x60.
 Fig. 8a,b — *Healdianella lumbiformis* LETHIERS & FEIST, 1991. AN2. Etroeung Formation. IRScNB n° b4278. Carapace. a. Right lateral view. b. Dorsal view. x125.
 Fig. 9a,b — *Healdianella dorsosulcata* CASIER, 2003. AN83. Hastière Formation. IRScNB n° b4279. Carapace. a. Right lateral view. b. Dorsal view. x100.
 Fig. 10 — *Elliptocyprites lorangeri* LETHIERS, 1981. AN6. Etroeung Formation. IRScNB n° b4280. Right lateral view of a carapace. x110.
 Fig. 11 — *Praepilatina* sp. A, aff. *adamczaki* OLEMPKA, 1979. AN101. Hastière Formation. IRScNB n° b4281. Right lateral view of a carapace. x70.
 Fig. 12 — *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939). AN83. Hastière Formation. IRScNB n° b4282. Right lateral view of a carapace. x50.
 Fig. 13 — *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939). AN87. Hastière Formation. IRScNB n° b4283. Dorsal view of a carapace. x30.
 Fig. 14 — *Bairdiocypris* sp. B. AN21. Etroeung Formation. IRScNB n° b4284. Right lateral view of a carapace. x45.
 Fig. 15a,b — *Microcheilinella buschminae* OLEMPKA, 1981 sensu KOTCHETKOVA & JANBULATOVA, 1987. AN75. Hastière Formation. IRScNB n° b4285. Carapace. a. Right lateral view. b. Dorsal view. x110.
 Fig. 16 — *Microcheilinella* sp. A, aff. *buschminae* OLEMPKA, 1981. AN83. Hastière Formation. IRScNB n° b4286. Right lateral view of a carapace. x100.

PLATE 3

- Fig. 1a,b — *Microcheilinella* sp. B, aff. *buschminae* OLEMPKA, 1981. AN36. Etroeung Formation. IRScNB n° b4287. Carapace. a. Right lateral view. b. Dorsal view. x90.
 Fig. 2a,b — *Famenella angulata perparva* LETHIERS & FEIST, 1991. AN83. Hastière Formation. IRScNB n° b4288. Carapace. a. Right lateral view. b. Dorsal view. x130.
 Fig. 3a,b — *Acratia bidecliva* LETHIERS & FEIST, 1991. AN38. Etroeung Formation. IRScNB n° b4289. Carapace. a. Right lateral view. b. Dorsal view. x75.
 Fig. 4a,b — *Acratia subobtusata* LETHIERS, 1974. AN10. Etroeung Formation. IRScNB n° b4290. Carapace. a. Right lateral view. b. Dorsal view. x70.
 Fig. 5a,b — *Acratia* sp. A, aff. *rostrata* ZANINA, 1956. AN86. Hastière Formation. IRScNB n° b4291. Carapace. a. Right lateral view. b. Dorsal view. x50.
 Fig. 6a,b — *Acratia* sp. B, aff. *sagittaeformis* LETHIERS & CASIER, 1999. AN41. Etroeung Formation. IRScNB n° b4292. Carapace. a. Right lateral view. b. Dorsal view. x70.
 Fig. 7a,b — *Acratia* sp. C, aff. *subobtusata* LETHIERS, 1974. AN21. Etroeung Formation. IRScNB n° b4293. Carapace. a. Right lateral view. b. Dorsal view. x100.

- Fig. 8a,b — *Acratia* sp. D. AN13. Etroeungt Formation. IRScNB n° b4294. Carapace. a. Right lateral view. b. Dorsal view. x75.
 Fig. 9 — *Acratia* sp. E. AN4. Etroeungt Formation. IRScNB n° b4295. Right lateral view of a carapace. x125.
 Fig. 10 — *Acratia* sp. F. AN13. Etroeungt Formation. IRScNB n° b4296. Right lateral view of a carapace. x50.
 Fig. 11a,b — *Acratia?* sp. AN83. Hastière Formation. IRScNB n° b4297. Carapace. a. Right lateral view. b. Dorsal view. x65.
 Fig. 12a,b — *Bairdia hypsela* ROME, 1971 emend LETHIERS, 1975. AN4. Etroeungt Formation. IRScNB n° b4298. Carapace. a. Right lateral view. b. Dorsal view. x35.
 Fig. 13a,b — *Bairdia fusiformis* ROME, 1971. AN87. Hastière Formation. IRScNB n° b4299. Carapace. a. Right lateral view. b. Dorsal view. x50.
 Fig. 14 — *Bairdia extenuata* NAZAROVA, 1951. AN2. Etroeungt Formation. IRScNB n° b4300. Right lateral view of a carapace. x80.
 Fig. 15 — *Bairdia extenuata* NAZAROVA, 1951. AN38. Etroeungt Formation. IRScNB n° b4301. Dorsal view of a carapace. x95.

PLATE 4

- Fig. 1a,b — *Bairdia mecyna* ROME, 1971. AN4. Etroeungt Formation. IRScNB n° b4302. Carapace. a. Right lateral view. b. Dorsal view. x25.
 Fig. 2a,b — *Bairdia* sp. A, aff. *buschminae* CRASQUIN, 1985. AN83. Hastière Formation. IRScNB n° b4303. Carapace. a. Right lateral view. b. Dorsal view. x45.
 Fig. 3a,b — *Bairdia* sp. B, aff. *feliumgibba* BECKER, 1982. AN10. Etroeungt Formation. IRScNB n° b4304. Carapace. a. Right lateral view. b. Dorsal view. x95.
 Fig. 4a,b — *Bairdia* sp. C, aff. *extenuata* NAZAROVA, 1951. AN83. Hastière Formation. IRScNB n° b4305. Carapace. a. Right lateral view. b. Dorsal view. x65.
 Fig. 5a,b — *Bairdia* sp. D. AN83. Hastière Formation. IRScNB n° b4306. Carapace. a. Right lateral view. b. Dorsal view. x55.
 Fig. 6a,b — *Bairdia* sp. E. AN75. Hastière Formation. IRScNB n° b4307. Carapace. a. Right lateral view. b. Dorsal view. x50.
 Fig. 7a,b — *Bairdia* sp. F. AN21. Etroeungt Formation. IRScNB n° b4308. Carapace. a. Right lateral view. b. Dorsal view. x90.
 Fig. 8a,b — *Bohlenatia?* sp. A CASIER, 2003. AN67. Hastière Formation. IRScNB n° b4309. Carapace. a. Right lateral view. b. Dorsal view. x115.
 Fig. 9a,b — *Bairdianella* sp. A, aff. *cuspis* BUSCHMINA, 1970. AN29. Etroeungt Formation. IRScNB n° b4310. Carapace. a. Right lateral view. b. Dorsal view. x60.
 Fig. 10 — *Bairdianella* sp. B, aff. *cuspis* BUSCHMINA, 1970. AN10. Etroeungt Formation. IRScNB n° b4311. Right lateral view of a carapace. x100.
 Fig. 11 — *Bythocypris?* sp. A. AN21. Etroeungt Formation. IRScNB n° b4312. Right lateral view of a carapace. x100.
 Fig. 12a,b — *Bairdiacypris robusta* KUMMEROW, 1939. AN83. Hastière Formation. IRScNB n° b4313. Carapace. a. Right lateral view. b. Dorsal view. x45.
 Fig. 13a,b — *Bairdiacypris* sp. A. AN1. Etroeungt Formation. IRScNB n° b4314. Carapace. a. Right lateral view. b. Dorsal view. x90.
 Fig. 14 — *Bairdiacypris* sp. B, aff. *nanbiancunensis* (WANG, 1988). AN7. Etroeungt Formation. IRScNB n° b4315. Right lateral view of a carapace. x115.
 Fig. 15a,b — *Bairdiacypris* sp. C. AN85. Hastière Formation. IRScNB n° b4316. Carapace. a. Left lateral view. b. Dorsal view. x35.
 Fig. 16 — *Cryptophyllus* sp. C, aff. *ellipticus* ROME & GOREUX, 1964. AN45. Lateral view of a valve. Etroeungt Formation. IRScNB n° b4317. x60.

PLATE 5

- Fig. 1 — Silty mudstone with well-preserved delicate bryozoans. AN57. Préal n°1297. Microfacies 1. Levels 8/9. Hastière Formation. Scale bar 950 µm.
 Figs 2, 3 — Silty burrowed wackestone with crinoidal fragments, ostracods (Fig. 2), bryozoans (Fig. 3) and microbioclasts. The bioclasts are concentrated in small-sized lenses cut by a blackish pressure solution seam (Fig. 2). AN25, Préal n°1343 (Fig. 2) and n°1344 (Fig. 3), microfacies 2, level 4, Etroeungt Formation. Scale bar 950 µm.
 Fig. 4 — Clayey wackestone with an oblique millimetric laminae composed of a bioclastic (crinoids, ostracods) packstone. Bioturbation is weak. AN40, Préal n°1228, microfacies 2, level 4, Etroeungt Formation. Scale bar 390 µm.
 Fig. 5 — Medium-grained burrowed peloidal bioclastic packstone. Bioclasts are well sorted and consist of brachiopods, bryozoans, crinoids. They are embedded in a mudstone-wackestone and represent a former tempestite layer (see text). The micritic matrix contains a few silty quartzose grains. AN5, Préal n° 1333, microfacies 3, level 3, Etroeungt Formation. Scale bar 950 µm.

- Figs. 6, 7 — Abrupt contact between a fine-grained silty microbioclastic (mainly crinoids and ostracods) wackestone (upper part, Fig. 6) and an oblique medium-grained millimetric bioclastic laminae rich in subangular crinoidal fragments (lower part, Fig. 6), brachiopods and bryozoans (Fig. 7). The bioclasts display sutured contacts in the packstone layer (Figs. 6, 7). AN11, Pr  at n   1341 (Fig. 6) and n   1342 (Fig. 7), microfacies 4, level 3, Etroeung Formation, Scale bar 950 μ m.
- Fig. 8 — Fine-grained peloidal silty microbioclastic (crinoids) packstone. The sediment contains laminae with coarse bioclasts (here an echinodermal plate, with corals and bryozoans –not shown) representing proximal tempestites (see text). AN63, Pr  at n   1310, microfacies 5, levels 8/9, Hasti  re Formation, Scale bar 950 μ m.

PLATE 6

- Fig. 1 — Peloidal and lumpy silty packstone. “False cement” (see text) is partly replacing the micritic matrix. The figure shows two well-developed calcitic crystals (pseudomorphs after sulphates?) digesting the matrix and the peloids. Residues of these latter are trapped between the different crystals. The replacement gives also a fine-grained calcitic microspar (upper right corner). AN59, Pr  at n   1303, microfacies 5, levels 8/9, Hasti  re Formation, Scale bar 390 μ m.
- Fig. 2 — Fine-grained peloidal, “lumpy” and bioclastic (crinoids, ostracods and bryozoan) “false” grainstone (see text). The calcitic cement has replaced the original micritic matrix cutting this latter into bits and forming irregular lumps. Syntaxial cementation around a few crinoids (lower left corner). A few bioclasts are micritized. This sample contains calciphores and *Bisphaera* (not shown here). AN74, Pr  at n   1372, microfacies 6, levels 8/9, Hasti  re Formation, Scale bar 950 μ m.
- Fig. 3 — Fine-grained peloidal and lumpy “recrystallized” packstone. The “false cement” (see text) is slightly argillaceous and quite large englobing irregular residues (= “lumps”) of the former micritic matrix. At higher magnification the borders of the lumps are “geometric” following the crystal faces of the calcitic cement (see the large lump in the centre of the figure). The cement can also penetrate the former matrix isolating new (future) lumps (see the upper right corner). AN65, Pr  at n   1319, microfacies 6, levels 8/9, Hasti  re Formation, Scale bar 390 μ m.
- Fig. 4 — Completely recrystallized (homogeneous calcitic microspar) peloidal packstone with a well preserved *Bisphaera*. Larger “peloids” (to the left of the *Bisphaera*) are micritized microbioclasts. AN67, Pr  at n   1323, microfacies 6, levels 8/9, Hasti  re Formation, Scale bar 390 μ m.
- Fig. 5 — Bioclastic microconglomerate with plurimillimetric well rounded microbreccia composed of peloidal microbioclastic packstones. Bioclasts of the microconglomerate consist mainly of poorly sorted crinoids cemented by a syntaxial and equigranular calcite. A few micritized grains, peloids, ostracods and pelecypods are also present. AN46, Pr  at n   1259, microfacies 7, level 8, Hasti  re Formation. Base of bed 159 of CONIL (1964). Scale bar 950 μ m.
- Fig. 6 — Oolitic, lumpy and bioclastic poorly sorted grainstone-rudstone with a microbreccia composed of a peloidal microbioclastic packstone (bahamite?). Oolites are micritized. Bioclasts show crinoids partly in a syntaxial calcitic cement. Cementation in two phases: a first stubby lamellar and a second composed of equigranular calcite. AN48, Pr  at n   1243, microfacies 7, levels 8, Hasti  re Formation. Bed 159 of CONIL (1964), at 80 cm from its base. Scale bar 390 μ m.
- Fig. 7 — Medium-grained oolitic, peloidal and bioclastic grainstone-rudstone with microbreccia. Bioclasts are often micritized, form mud-coated grains and composed of crinoids and pelecypods. Microbreccia are subrounded, millimetric to centimetric (not illustrated here) and consist of oolitic and bioclastic wackestones-packstones. An umbrella cavity is present above the pelecypod shells (left side). Equigranular calcite cementation is well developed. AN52, Pr  at n   1286, microfacies 7, levels 8, Hasti  re Formation. Top of bed 159 of CONIL (1964).
- Fig. 8 — Fine-grained oolitic grainstone. Palissadic and equigranular calcite cementation is well developed. A few grains display slight sutured contacts. AN65, Pr  at n   1294, microfacies 7, levels 8, Hasti  re Formation, Scale bar 390 μ m.

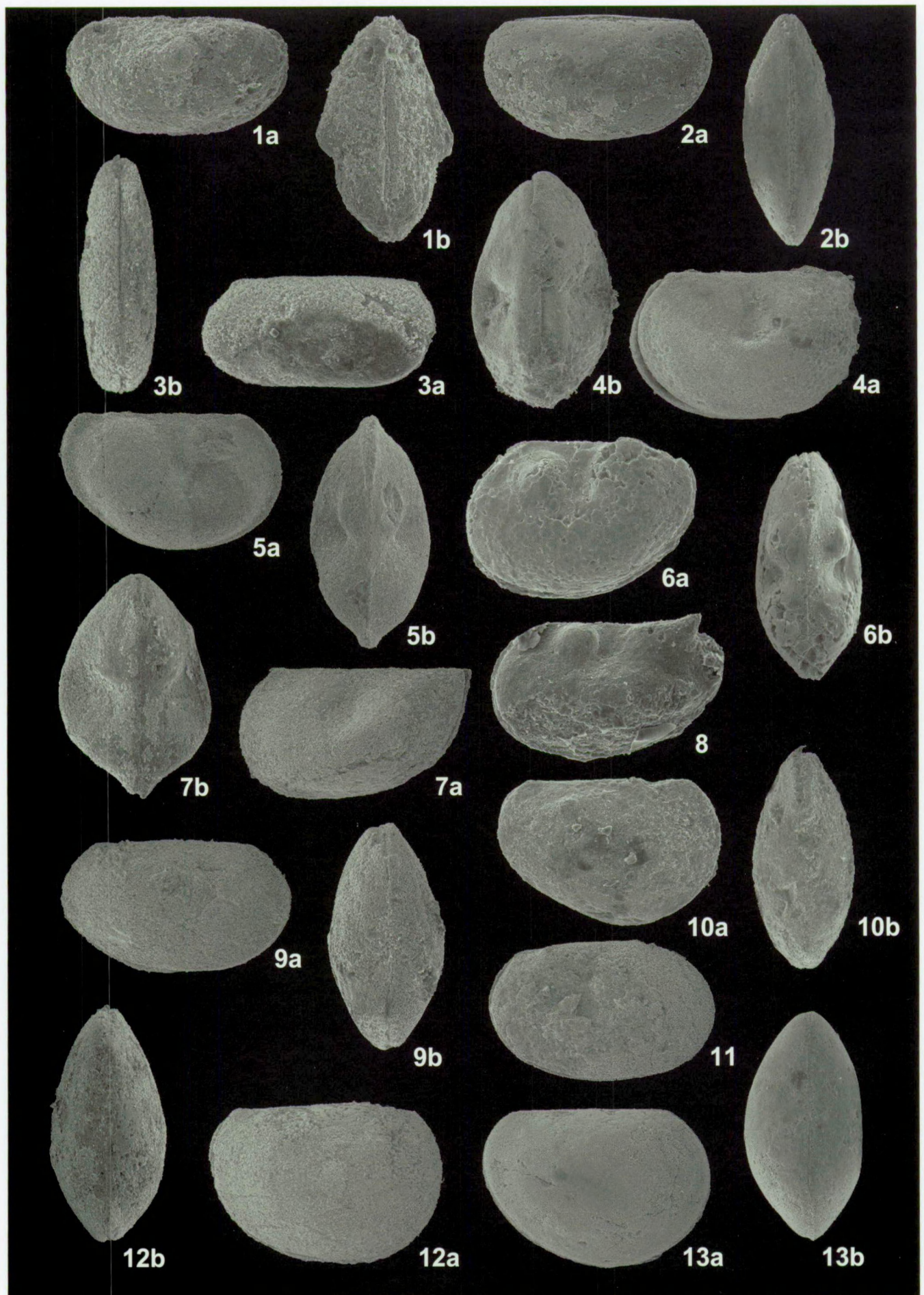


PLATE 1

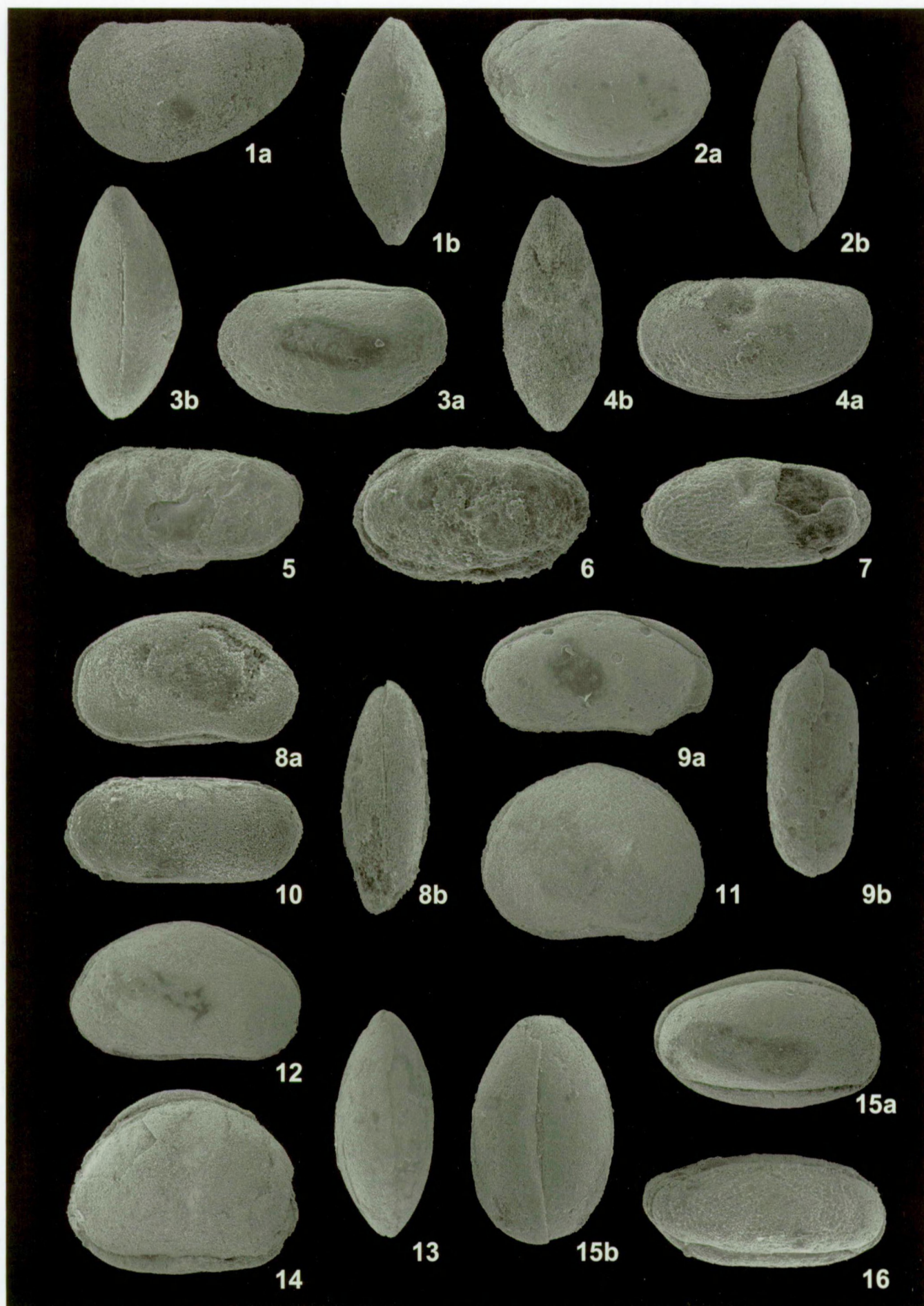


PLATE 2

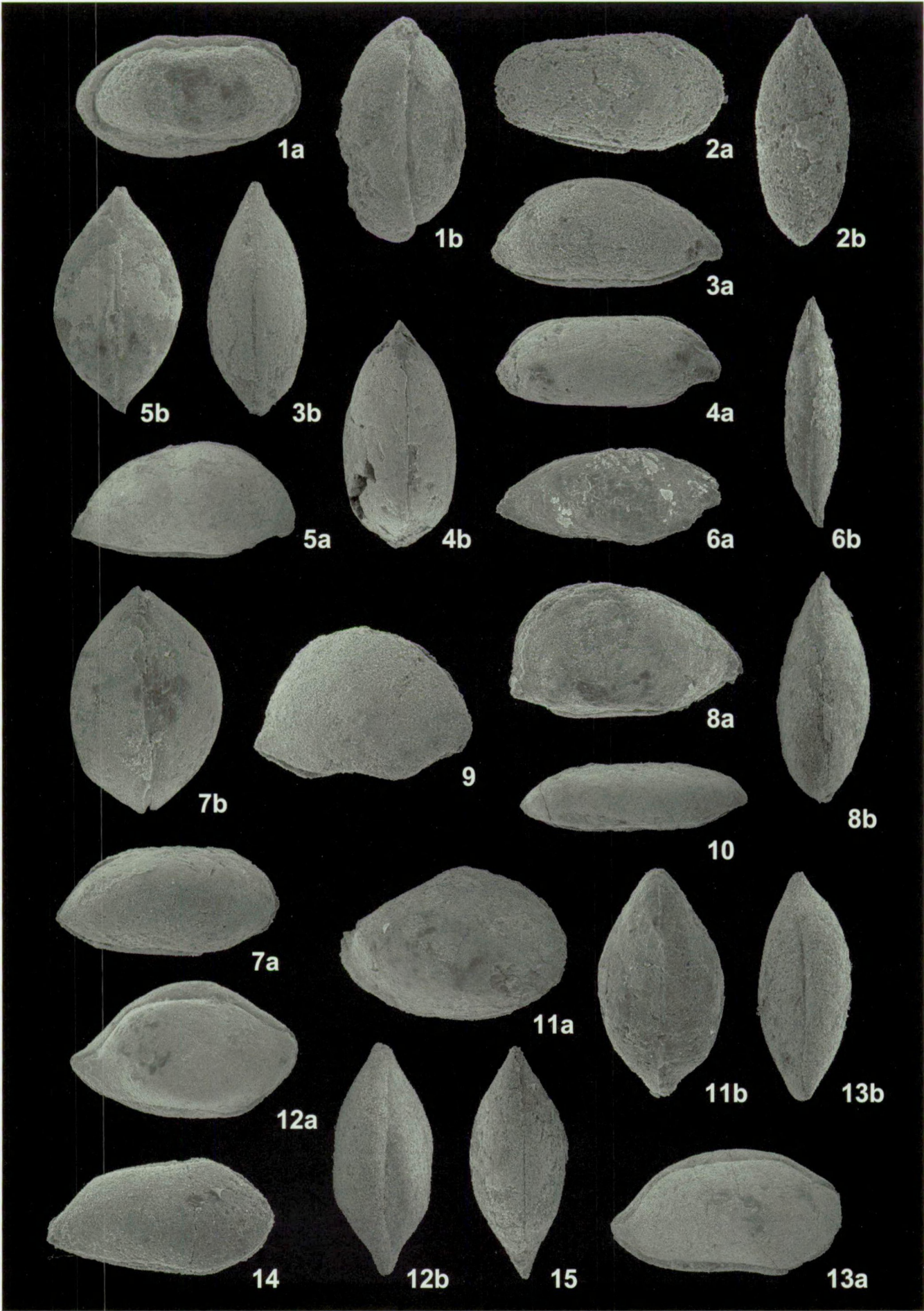


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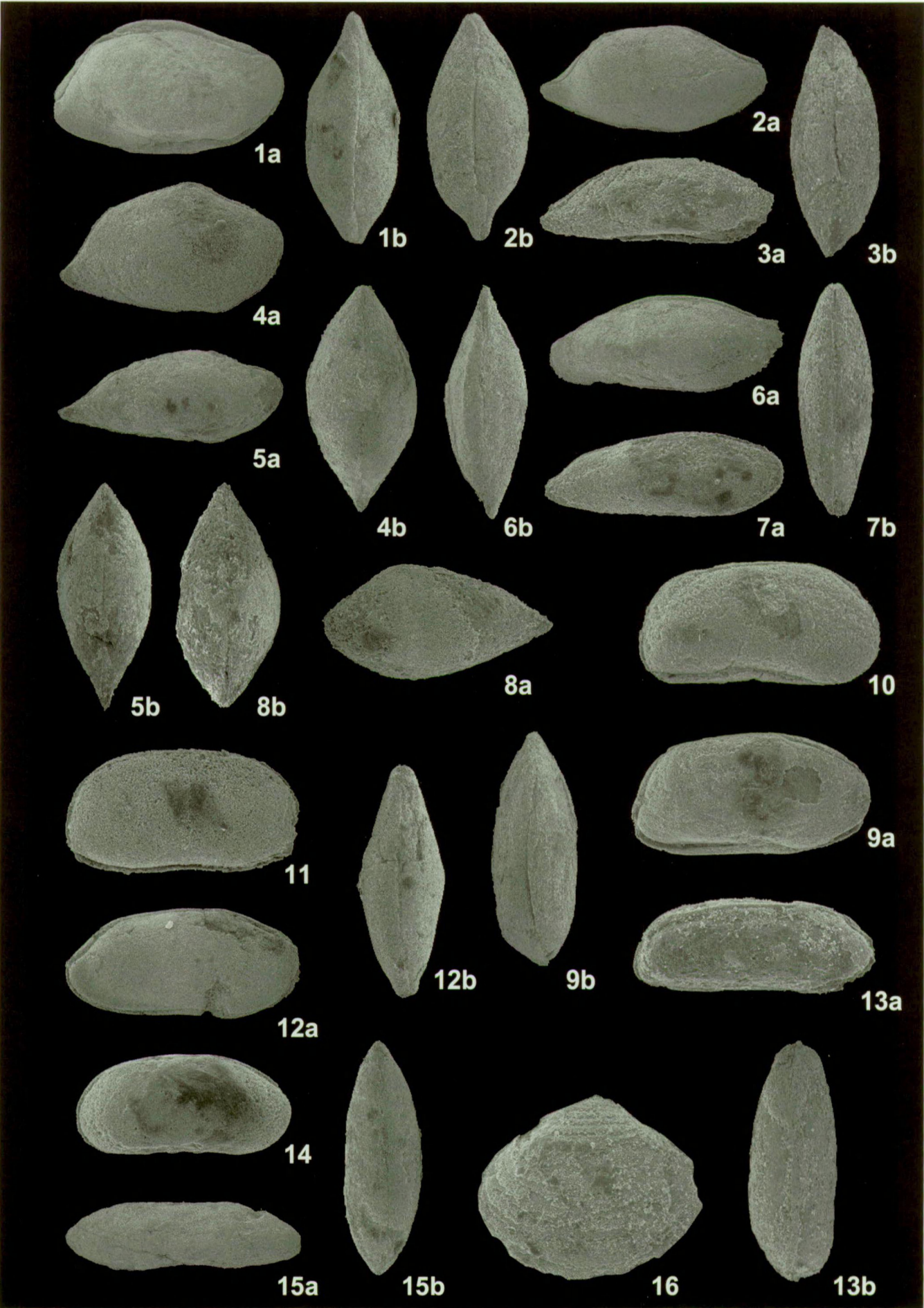


PLATE 4

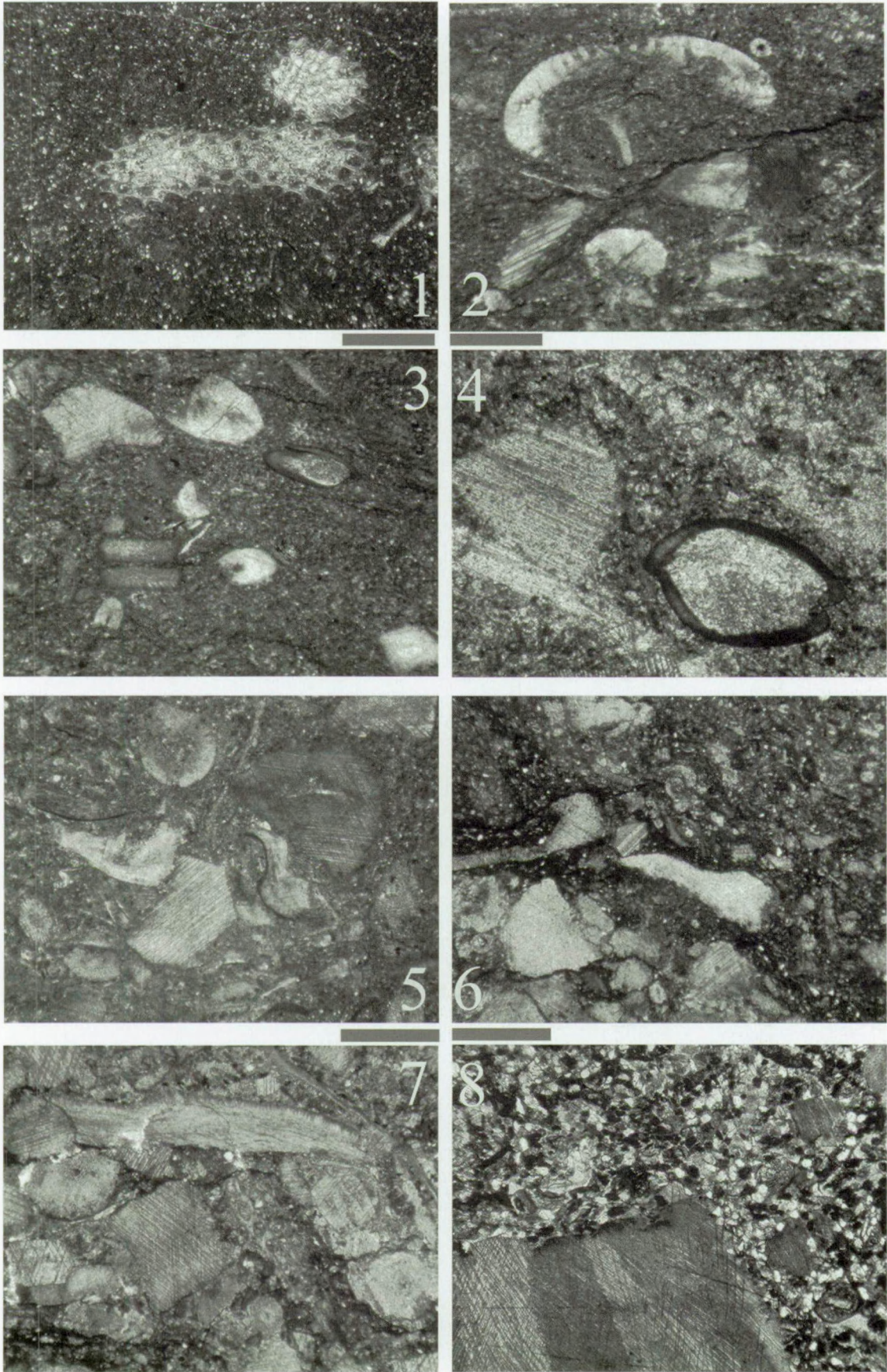


PLATE 5

