

# Ostracods and lithofacies close to the Devonian-Carboniferous boundary in the Chanxhe and Rivage sections, northeastern part of the Dinant Basin, Belgium

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## Abstract

The Chanxhe and Rivage sections along the Ourthe River are two important reference sections for the Devonian/Carboniferous (D/C) boundary in the northeastern part of the Dinant Basin. Seven major microfacies types are defined in the D/C strata (50 m) of these two sections. They permit recognition of several levels encompassing the Comblain-au-Pont and Hastière formations. These levels record shallow open-marine sedimentation oscillating between the storm and the fair-weather wave bases in the euphotic zone. The microfacies in the upper part of the sections (Hastière Formation) indicates strong salinity variations with evaporitic reflux and lagoonal influences. The environment is again open-marine in the uppermost part of the Hastière Formation. The general environment consists of small shoals which have partly isolated an offshore domain (MF1-MF4) from a semi-restricted area (MF6 and MF7) where salinity fluctuations were the predominant factor as indicated by monospecific fauna and flora (*Earlandia*, umbellinids, calcispheres, ...). Only ostracods and *Earlandia minima* (foraminifers) survived in these stressful environments. These organisms are related to cryptalgal bindstones or mats located at proximity and forming numerous "algal chips". The abundance of sulfate pseudomorphs in MF5, MF6 and MF7 indicate the importance of the diagenetic reflux of evaporitic brines in this general shallow marine environment. The main diagenetic overprint is the development of clear sparite cements replacing the original textures.

The foraminiferal zonation indicates hiatuses throughout the series.

Ostracods are moderately abundant in the Chanxhe and Rivage sections and sixty-two taxa, the majority of which are in open nomenclature, are recognized; nearly all are illustrated, and one new species (*Cavellina chanxhensis* nov. sp.) is established. They belong to the Eifelian Mega-Assemblage and practically all samples containing identifiable ostracods contain podocopid ostracods indicative of well-oxygenated water conditions with salinity normal or very close to the normal. The abundance of Platycopina and Eridostraca (*Cryptophyllus*) in the Comblain-au-Pont Formation indicates a deposition in a very shallow slight restricted environment. Due probably to the strong salinity variations pointed out by the sedimentological analysis, ostracods are missing, rare or poorly preserved in the top of the Comblain-au-Pont Formation and in the base and middle part of the Hastière Formation. However, no assemblage indicative of really semi-restricted water conditions was recorded in these levels probably because these variations of salinity were too strong and (or) too rapid. In the upper part of the Hastière Formation, ostracods are very abundant and indicative of marine environments between fair-weather and storm wave bases. The distribution of ostracods in the Chanxhe and Rivage sections is slightly different compared to sections investigated in the southwestern border of the Dinant Basin and in the Avesnes Basin. The

study of ostracods at Chanxhe and Rivage confirms also that the Hangenberg Event has probably no influence on their distribution in shallow settings.

Our conclusion is that the Chanxhe and Rivage sections are not reliably continuous successions for the study of the D/C boundary.

**Key-words:** Ostracods, Sedimentology, Paleocology, Devonian-Carboniferous boundary, Dinant Basin, Belgium

## Résumé

A Chanxhe et Rivage, dans la vallée de l'Ourthe, deux coupes de référence importantes pour la partie nord-est du Bassin de Dinant, exposent les couches de passage du Dévonien au Carbonifère (D/C). Sept microfaciès majeurs sont définis dans ces deux coupes (50 m) et permettent de reconnaître la succession de plusieurs niveaux dans les formations de Comblain-au-Pont et d'Hastière. Les faciès indiquent un milieu marin ouvert peu profond, situé dans la zone euphotique, entre la zone d'action des tempêtes et celle des vagues normales.

La partie supérieure des deux coupes (Formation d'Hastière) renferme principalement les microfaciès 6 et 7 indiquant de fortes variations de salinité avec évaporites de reflux et influences lagunaires prononcées. La partie supérieure de la Formation d'Hastière marque un retour aux conditions marines normales, qui prévalaient dans la Formation de Comblain-au-Pont. Le modèle sédimentaire général est celui d'une rampe mixte avec développement de petits "shoals" ou "dunes" bioclastiques isolant partiellement un domaine ouvert (MF1-MF4) d'un domaine semi-restreint (MF6 et MF7). Dans ce dernier les fluctuations de salinité sont importantes et se marquent par la prédominance de communautés fauniques ou de microflores monospécifiques (à *Earlandia*, Umbelles, Calcisphères). Les Ostracodes et *Earlandia minima* (Foraminifères) sont les seuls organismes à proliférer dans de tels environnements. Ils sont parfois associés à des bindstones ou tapis cryptalgaires et microbiens dont le démantèlement suite aux processus diagénetiques alimentent de nombreux "copeaux algaires" et "lumps" dans le milieu de sédimentation. Les nombreux pseudomorphes dans les MF5, MF6 et MF7 soulignent l'importance de la diagenèse de reflux de saumures évaporitiques dans cet environnement marin peu profond. Cette diagenèse se marque par un fort développement d'un ciment clair ou très blanchâtre de sparite en grands cristaux remplaçant les textures initiales. La zonation des Foraminifères met en évidence l'importance des hiatus ou discordances sédimentaires de la série D/C qui est loin de constituer une série continue. L'analyse de la courbe lithologique confirme également l'importance des hiatus. Les Foraminifères permettent également de corréliser entre eux les différents niveaux des deux coupes. L'analyse sédimentologique et biostratigraphique montre que les coupes de Chanxhe et de Rivage représentent de mauvaises sections pour l'étude de la transition D/C: en aucun cas elles ne représentent des séries continues. Enfin, l'altération diagénetique par reflux évaporitique rend particulièrement difficile la reconstitution et l'interprétation des paléoenvironnements de la Formation d'Hastière.

Les ostracodes sont relativement abondants dans les coupes de Chanxhe et Rivage, et soixante-deux taxa, la majorité en nomenclature



ouverte mais quasi tous figurés, sont reconnus, et une nouvelle espèce (*Cavellina chanxhensis* nov. sp.) est fondée. Ils appartiennent au Méga-Assemblage de l'Eifel et presque tous les échantillons contenant des ostracodes identifiables ont livré des Podocopina indiquant des eaux bien oxygénées à salinité normale ou très proche de la normale. L'abondance des Platycopina et des Eridostraca (*Cryptophyllus*) dans la Formation de Comblain-au-Pont dénote un milieu de dépôt devenant, mais plus rapidement à Rivage, très peu profond et très légèrement semi-restreint. Dans le sommet de la Formation de Comblain-au-Pont, dans la base et dans la partie moyenne de la Formation d'Hastière, les ostracodes sont parfois absents, indéterminables ou rares, et c'est probablement lié aux fortes variations de salinité mises en évidence par l'analyse sédimentologique. Néanmoins aucun assemblage d'ostracodes caractéristiques de milieux semi-restreints n'est mis en évidence dans ces niveaux. Les ostracodes présents dans le sommet de la Formation d'Hastière indiquent des milieux marins francs entre les niveaux d'action des vagues de beau temps et de tempêtes. La distribution des ostracodes diffère légèrement de celle observée dans la bordure sud-ouest du Bassin de Dinant, et dans le Bassin d'Avesnes. L'étude des ostracodes présents à Chanxhe et Rivage confirme que l'Événement Hangenberg n'a probablement aucune influence sur leur distribution en milieux peu profonds.

**Mots-clés:** Ostracodes, Sédimentologie, Paléocologie, Limite Dévo-nien-Carbonifère, Bassin de Dinant, Belgique

## Introduction

The study of ostracods and sedimentology from the Chanxhe and Rivage sections follows a series of studies focussed on the Devonian - Carboniferous (D/C) boundary. This series started in the Montagne Noire, southern France, with the Puech de la Suque section (CASIER *et al.*, 2001) and the new stratotype for the D/C boundary at La Serre (CASIER *et al.*, 2002). This series continued in the Avesnes Basin, North of France, with the Bocahut quarry (CASIER & PRÉAT, 2003), and in the southwestern border of the Dinant Basin, with the Anseremme railway bridge section (CASIER *et al.*, 2004). Ostracods are abundant and diverse throughout the D/C boundary in all these sections.

The goal of our paper is to complete the inventory of ostracods occurring close to the D/C boundary in the northeastern part of the Dinant Basin, and to see if the important sedimentological variations observed in the Avesnes Basin and in the southwestern part of the Dinant Basin are recognized in that region.

The D/C boundary has been recently placed at the first appearance of *Siphonodella sulcata* within the evolutionary lineage from *S. praesulcata* to *S. sulcata* (PAPROTH & STREEL, 1984). However due to shallow-marine settings and presence of hiatuses, pelagic conodont species are missing in the Chanxhe and Rivage sections. Consequently, the position of the D/C boundary cannot be fixed with precision at the base of the Hastière Formation.

The international Subcommittee of Devonian Stratigraphy (SDS) intends to subdivide the Famennian and a Strunian sub-stage has been proposed as last Famennian chronostratigraphic unit (SARTENAER, 1997; STREEL *et al.*, 1998, 2004; BRICE & MISTIAEN, 2003). MAMET *et al.* (1965) suggested to accept the first appearance of *Quasiendothyra kobeitusana* as the base of the Calcaire d'Étroeungt. Accordingly, our study of the Chanxhe and Rivage section starts close to the first appearance of this taxon.

## The Chanxhe and Rivage sections – General setting

The Chanxhe and Rivage sections are located in the northeastern part of the Dinant Basin, in the Ourthe Valley, approximately 20 km south of Liège, Belgium (Fig. 2).

The Chanxhe section (N 50°30'265; E 5°35'796) is located along the access road to the former quarry of Richopré, now used as a municipal dump (Fig. 1, point A). The investigated part of the section (Fig. 3) starts approximately 8 m below the bed in which CONIL (1964) found the first *Quasiendothyra kobeitusana*. It encompasses a great part of the Comblain-au-Pont Formation (Famennian), and the Hastière Formation (mainly Dinantian) separated by a tectonic fault responsible for a hiatus.

The Rivage section (N 50°29'026; E 5°35'247) begins along the railway (SNCB line 42), south of the Rivage

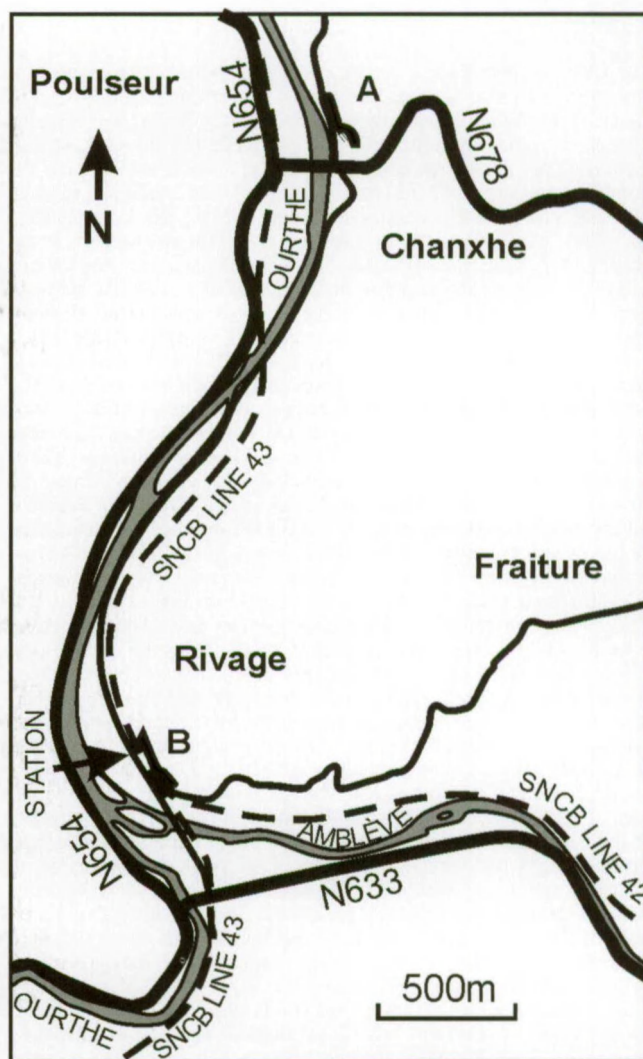


Fig. 1 — Geographic location of the Chanxhe and Rivage sections.



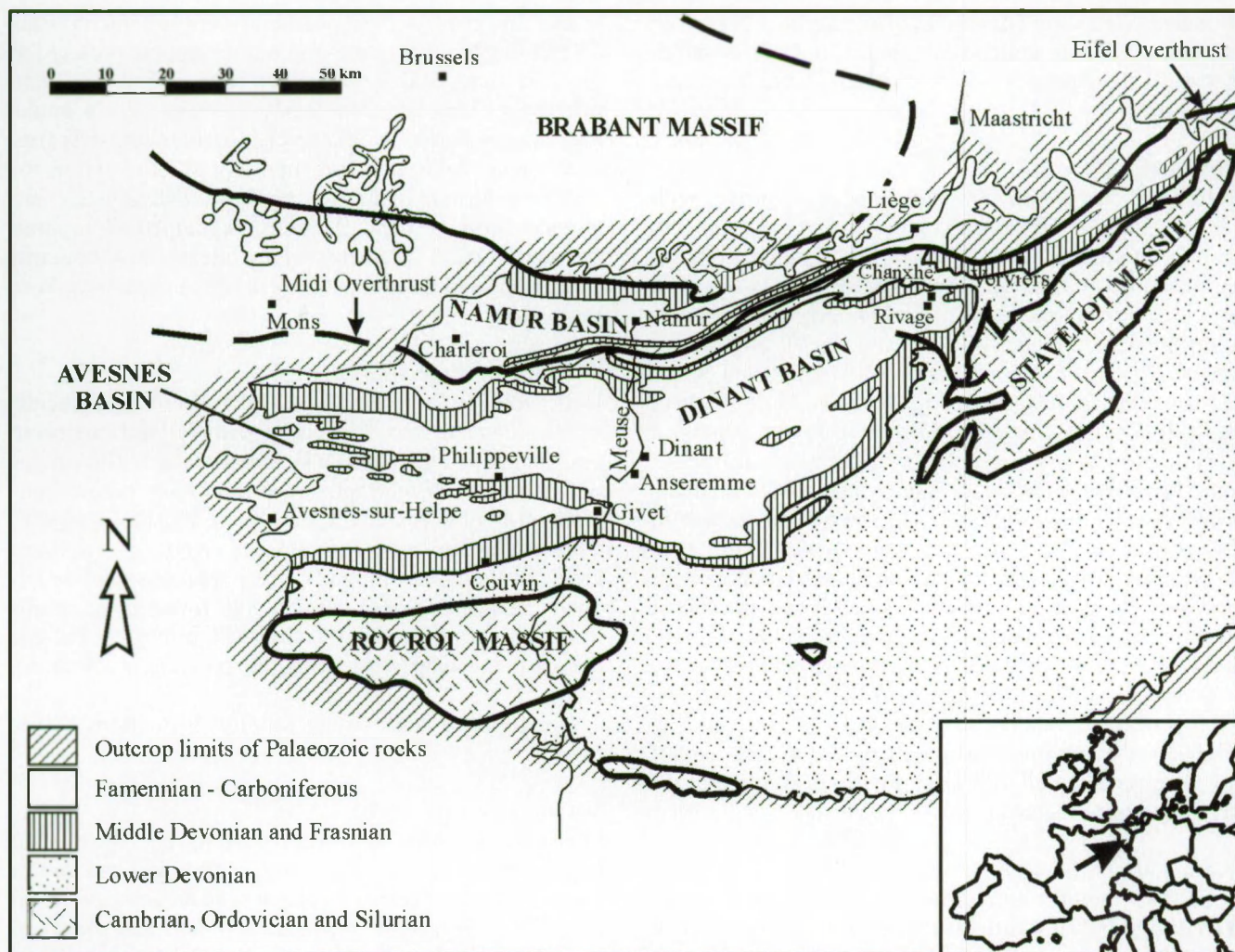


Fig. 2 — Location of the Bocahut quarry close to Avesnes-sur-Elpe, and of the Anseremme, Rivage and Chanxhe sections, on a geological map (Adapted from BULTYNCK *et al.*, 2001).

station, and continues after a bridge, along the road to Fraiture (Fig. 1, point B). The investigated part of the section (Fig. 4) starts with the bed in which CONIL (1964) reports the first *Quasiendothyra kobeitusana*. We found the species about 4 m above that level. A great part of the Comblain-au-Pont Formation (Famennian) and the Hastière Formation (mainly Dinantian) was investigated in this section. The contact between these two formations is also abnormal at Rivage.

The Chanxhe and Rivage sections are included in the classic geological field trip in the northeastern part of the Dinant Basin (DUSAR *in* ROBASYNSKI & DUPUIS, 1983). These two sections are also described in several other papers, *e.g.* MOURLON (1895), CONIL (1964), FRANSSON (1967), BOUCKAERT *et al.* (1968, 1970), BLESS *et al.* (excursion D *in* BOUCKAERT & STREEL eds., 1974), BECKER *et al.* (1974), CONIL *et al.* (1986) and VAN STEENWINKEL (1988). Ostracods from the Chanxhe and Rivage sections have been reported by ROME (1971), BECKER & BLESS (1974a,b), and BLESS *et al.* (excursion D *in* BOUCKAERT & STREEL eds., 1974).

#### Sedimentology and facies analysis (A. Pr at, B. Mamet & A. Lebon)

One hundred forty-two samples were collected for sedimentological analysis from the Chanxhe section and 101 from the Rivage section. Both sections are composed of thin- to medium, well-bedded shales, clayey limestones and limestones at the base and coarser and thicker limestones towards the top. Thin-sections permit recognition of the following seven microfacies types.

#### Microfacies description

Open marine near or within the storm wave base (MF1, MF2, MF3)

#### Microfacies 1 (or MF1)

Definition: micaceous siltstones, clayey and silty mudstones-wackestones containing thin levels of bioclastic packstones. Bioclasts consist of crinoids, brachiopods (some with spines), bryozoans, ostracods, trilobites and



abundant encrusting *Girvanella*. The matrix is burrowed and contains fine-grained fragments rich in organic matter. A few peloids are associated to the bioclastic packstones.

#### *Microfacies 2 (or MF2)*

Definition: clayey and silty burrowed wackestones with various bioclasts (abundant echinoderms, bryozoans, ostracods, molluscs, brachiopods, a few corals, stromatoporoids, foraminifers and algae (Pl. 5, Figs. 1-4)). The organisms are present as large partly micritized fragments in millimetric laminae (up to 2 mm thick), or as small lenses. *Girvanella* remain abundant as encrusted forms and irregular peloids (Pl. 5, Fig. 4). 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 fragments rich in organic matter (same type as those of MF1) and contain pyritized echinodermal bioclasts. Pyrite and pyritospheres can be abundant and display various morphotypes including filamentous ones. Some of these are dichotomic. Very-fine-grained pyrites (< 5 µm) are present inside the muddy grains (peloids, lumps), which are therefore blackened ("black grains"), and inside the micritic matrix. Pressure solution processes are more accentuated in the clayey facies giving a packstone texture to the sediment.

#### *Microfacies 3 (or MF3)*

Definition: laminar bioclastic and peloidal packstones-grainstones. Bioclasts are diversified and are coarser than in the previous microfacies types (Pl. 5, Fig. 5). The silt content is low, averaging a few percent (< 5%). In comparison with MF2, there is an increase of the number of foraminifers and a significant increase of the peloids consisting of micritised *Girvanella* debris. Small-sized pyrites, pyritospheres and "black grains" are as abundant as in MF2. The packstone matrix is often recrystallized in a homogeneous fine-grained calcitic microspar with abundant micronic pyritospheres.

Open marine near or within the fair-weather wave base (MF4, MF5)

#### *Microfacies 4 (or MF4)*

Definition: fine-grained laminar bioclastic-peloidal grainstones (Pl. 5, Figs. 6-8; Pl. 6, Fig. 1) and coarser cross-bedded and graded rudstones. Bioclasts are even coarser and rich in echinoderms. Plurilocular foraminifers (Endothyridae, Tournayellidae) are abundant (Pl. 5, Fig. 7). In comparison with previous microfacies types, laminations are thicker (up to 3 cm), frequent and display erosional contacts. Bioturbation processes and pressure solution figures are poorly developed. The silt content is very low (< 1%). As before, the *Girvanella* peloids consist of small-sized fragments. Larger fragments of *Girvanella* are also present. The cement is mainly syntaxial and well-developed in crinoidal grainstones-rudstones ("en-crinite", Pl. 5, Fig. 8). Rare asymmetrical calcite cement

is also observed. A clear sparite cement in large crystals (> 100 µm) replacing the original textures is present for the first time, and is associated with a coarse calcite microspar. This latter frequently contains pyrite grains and pyritospheres. A few calcite cavities (clear sparite and coarse microspar) are partially filled by tufts of idiotopic ferrous dolomite crystals. The crystals are aligned forming parallel bands developed along thin flexuous fungal filaments. This facies also contains stromatoporoid fragments (only in the Comblain-au-Pont Formation).

#### *Microfacies 5 (or MF5)*

Definition: Cross-bedded bioclastic rudstones with centimetric rounded microbreccia of peloidal and bioclastic grainstones (Pl. 6, Figs. 2-4). Bioclasts are still similar with stromatoporoid fragments present only in the Comblain-au-Pont Formation. Cements are also the same with a few asymmetrical ones in umbrella cavities or in intergranular pores (Pl. 6, Fig. 2). Clear sparite is well-developed, replaces original textures and forms large (pluri-millimetric) and irregular cavities (Pl. 6, Fig. 5). Peloids decrease in comparison with the previous microfacies types.

Open marine with strong salinity fluctuations (MF6, MF7)

#### *Microfacies 6 (or MF6)*

Definition: slightly bioturbated, fine to medium-grained laminar bioclastic and peloidal packstones and grainstones with abundant irregular lumps and angular algal chips (Pl. 6, Figs. 6,7). Algae are abundant and consist of issinellids, kamaenids, *Bevocastria*, calcipheres and umbellinids. Numerous bipyramidal quartz associated to the lumps containing nodular codiaceans (*Bevocastria*). A variety of this facies is represented by abundant foraminifers (*Earlandia minima*) and ostracods. The *incertae sedis Bisphaera* is common. Thin asymmetrical and irregular fibrous cements are occasionally present between the algal chips. Microbial filaments of various sizes are observed within the matrix of the packstones. They are similar to those described by PRÉAT *et al.* (2003) in the Viséan of the Avesnois. Small-sized idiotopic dolomite, sometimes dedolomitized, are also present. Large clear sparite cement crystals are well-developed and replace original textures (Pl. 6, Figs. 6, 7), as in MF5. They indicate sulfate pseudomorphs and can also be replaced by equigranular microspar. Macrofauna is still present and consist mainly of crinoids.

#### *Microfacies 7 (or MF7)*

Definition: packstones-grainstones with various millimetric- to centimetric-sized rounded to subangular algal chips (Pl. 6, Fig. 8). These poorly sorted fragments display small desiccation cracks and consist originally of codiaceans (*Bevocastria*) and *Girvanella* bindstones with a few sponge spicules. *Bisphaera* is still well-represented. Same macrofauna as previous microfacies types, and same clear sparitic cement replacing original textures.



### Microfacies and paleoenvironmental interpretations

The omnipresence of *Girvanella* throughout all sections indicates a depositional environment within the euphotic zone. The microbreccia and the angular algal chips with desiccation cracks point to very shallow environments. Faunal components (echinoderms, brachiopods, trilobites) indicate an open-marine domain in shallow waters for the seven microfacies types.

The textures of the rocks (mudstones to rudstones) associated with the different characteristics of the laminae indicate the relative paleobathymetry of the storm (SWB) and the fair-weather (FWWB) wave bases (EINSELE & SEILACHER, 1982; AHR, 1989). The laminar levels are rare in MF1, are thin and scarce in MF2, and of intermediate thickness in MF3, and are thick and abundant in MF4. These thicknesses are inferred despite the bioturbation processes which were not complete. Moreover these laminar levels contain the same bioclasts, their sizes increasing with lamination thickness as the complexity of the biotic assemblages. Cross-bedding is abundant in MF5 which contain large rounded microbreccia. The bioturbation figures disappear in MF5.

These characteristics suggest a mixed siliciclastic carbonate ramp system whose sedimentation is determined by the respective SWB and FWWB positions (WRIGHT & BURCHETTE, 1998). The microfacies type 1 with rare thin bioclastic levels is located near the base of the SWB and is related to decantation processes. The thin bioclastic laminae without erosive surfaces in MF1 are interpreted here as distal tempestites (d/SWB). Layers of moderate thickness in MF2 represent intermediate tempestites (i/SWB) and the thicker bioclastic levels of MF3 represent proximal tempestites (p/SWB). In this general context, the background sedimentation is decantation of clayey and carbonate muds in quiet environments (AIGNER, 1985). Bioturbation processes predominate and peter out progressively in microfacies 4 and 5, where energy is too high (erosional laminations, microbreccia or high sedimentation rates). In such conditions, crinoidal meadows and algal banks are destroyed and exported offshore or reworked in the FWWB. These microfacies are similar to those reported by PREAT & KASIMI (1995) in the Belgian-French Middle Devonian or by SEBBAR *et al.* (2000) in the Algerian Carboniferous (Tindouf Basin). Cross-bedding becomes systematic in MF4 and is the main characteristic of MF5 where the microbreccia are observed. These facies record environments of highest energy with periods of intense *in situ* reworking (microbreccia composed of facies of the same types), probably in the FWWB. Early cementation is revealed by the absence of mechanical compaction. This cementation was partly under vadose conditions (asymmetrical cements).

Small shoals have partly isolated an offshore domain (MF1-MF4) from a semi-restricted area (MF6 and MF7) where the salinity fluctuations were predominant as indicated by monospecific fauna and flora (*Earlandia*, *umbellinids*, *calcispheres*). Only ostracods and *Earlandia*

*minima* (foraminifers) survived in these stressful environments and are even very abundant in MF5 and MF6. These organisms are related to cryptalgal bindstones or mats located at proximity and delivering numerous "algal chips". The abundance of sulfate pseudomorphs in MF5, MF6 and MF7 also indicates the importance of diagenetic reflux of evaporitic brines in this overall shallow marine environment. The main diagenetic overprint is the development of the clear sparite cements replacing the original textures.

Normal marine conditions prevailed throughout the section, as the open marine macrofauna is periodically observed through all the standard microfacies sequence. MF4 and MF5 represented as a small bioclastic barrier or shoal, due to the accumulation by progradation of crinoidal and algal debris derived from proximal meadows. This shoal area temporarily isolated a "backshoal" zone from the open marine influence. During the periods of isolation, salinity fluctuations were important as suggested by specific microflora (codiaceans) and microfauna (monolocular foraminifers, ostracods). The salinity variations were frequent as the "barrier" was not effective through time. This leads to the tightened alternation or mixing of marine fauna with restricted or littoral flora and microfauna.

By comparison with the present-day average depths of the SWB and FWWB, MF1 to MF4 are interpreted to represent a mid-ramp below the FWWB (i.e. 25-30 m) and MF5, MF6 and MF7 a inner ramp setting in similar depths since the influence of fair-weather waves are still pronounced. Periods of shallower sedimentation were sporadically encountered as indicated by discrete vadose cementation (asymmetrical cements in MF4, MF5 and MF6) and algal chips with desiccation cracks (MF6 and MF7). The backshoal area was strongly influenced by a proximal? lagoonal domain which delivered floated *umbellinids* and *calcispheres*. Evaporitic conditions were probably present in this lagoon since reflux brines percolated through the whole backshoal area leading to abundant sulfate pseudomorphs in MF5, MF6 and MF7. Periods of shallower sedimentation associated with strong increase of the wave energy were also sporadically present and responsible for the formation of several micro-conglomeratic levels (microbreccia of peloidal and bioclastic grainstones-rudstones, MF5).

### Description of the levels (Fig. 3, 4)

Based on the interpretation of the lithologic curves, the sections analysed can be subdivided into several local levels (Fig. 3, 4):

#### Level 1

Collected on 9.5 m at Chanxhe and 4 m at Rivage, Comblain-au-Pont Formation. Thin-, medium- to thick-bedded siltstones, argillaceous mudstones, laminated sandy wackestones, bioclastic packstones interstratified with thick shales.



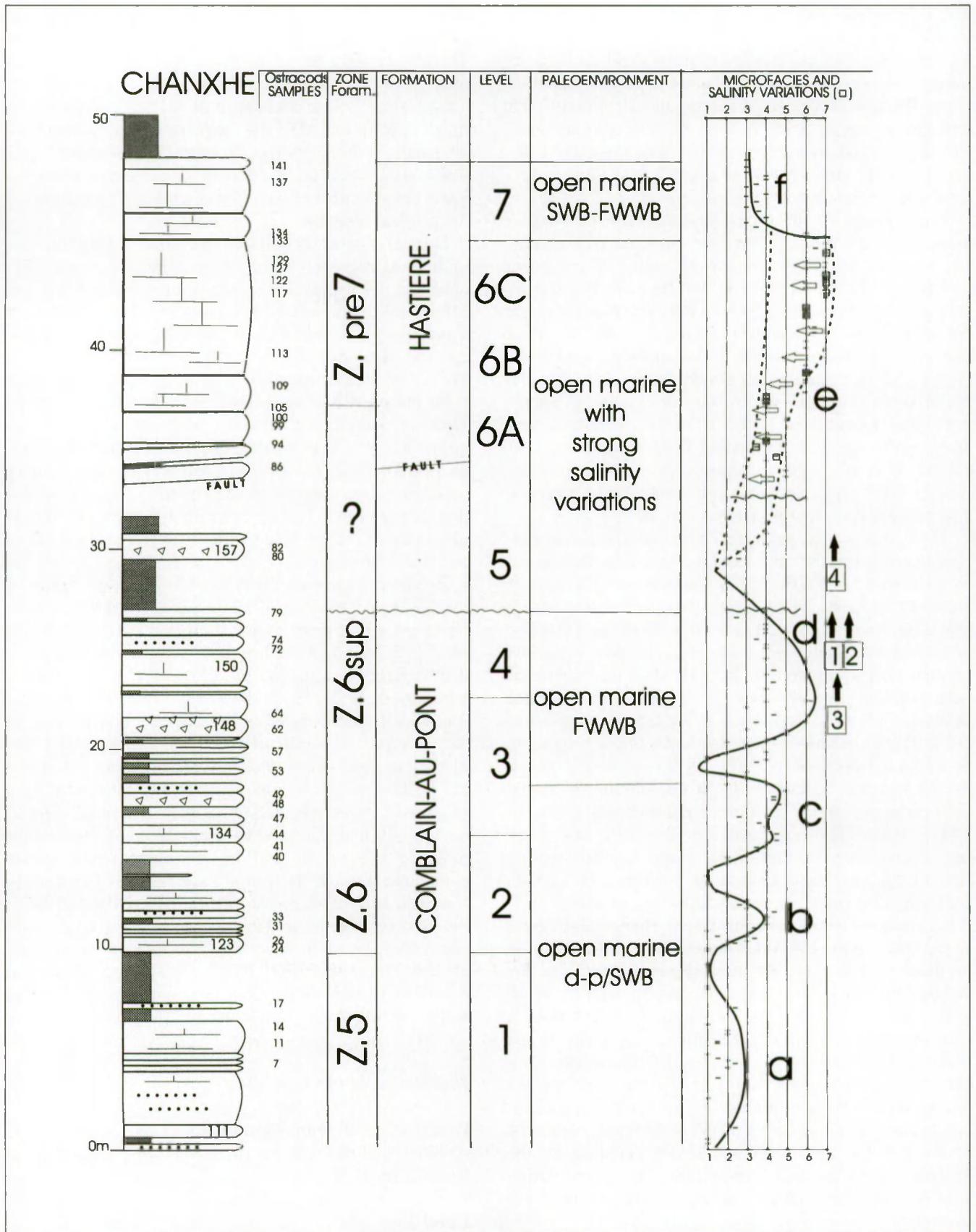


Fig. 3 — Lithological column of the Chanxhe section with some bed numbers of CONIL (1964). Other columns indicate positions of sedimentological and ostracod samples, foraminiferal zonation (MAMET, 1974), names of formations, level succession from 1 to 7 with the location of hiatuses, paleoenvironmental interpretation and microfacies/salinity evolutions. Abbreviations: d = distal, p = proximal, SWB = normal storm wave base, FWWB = normal of fair-weather wave base, Z = Zone. (See fig. 4 for the legend of symbols).



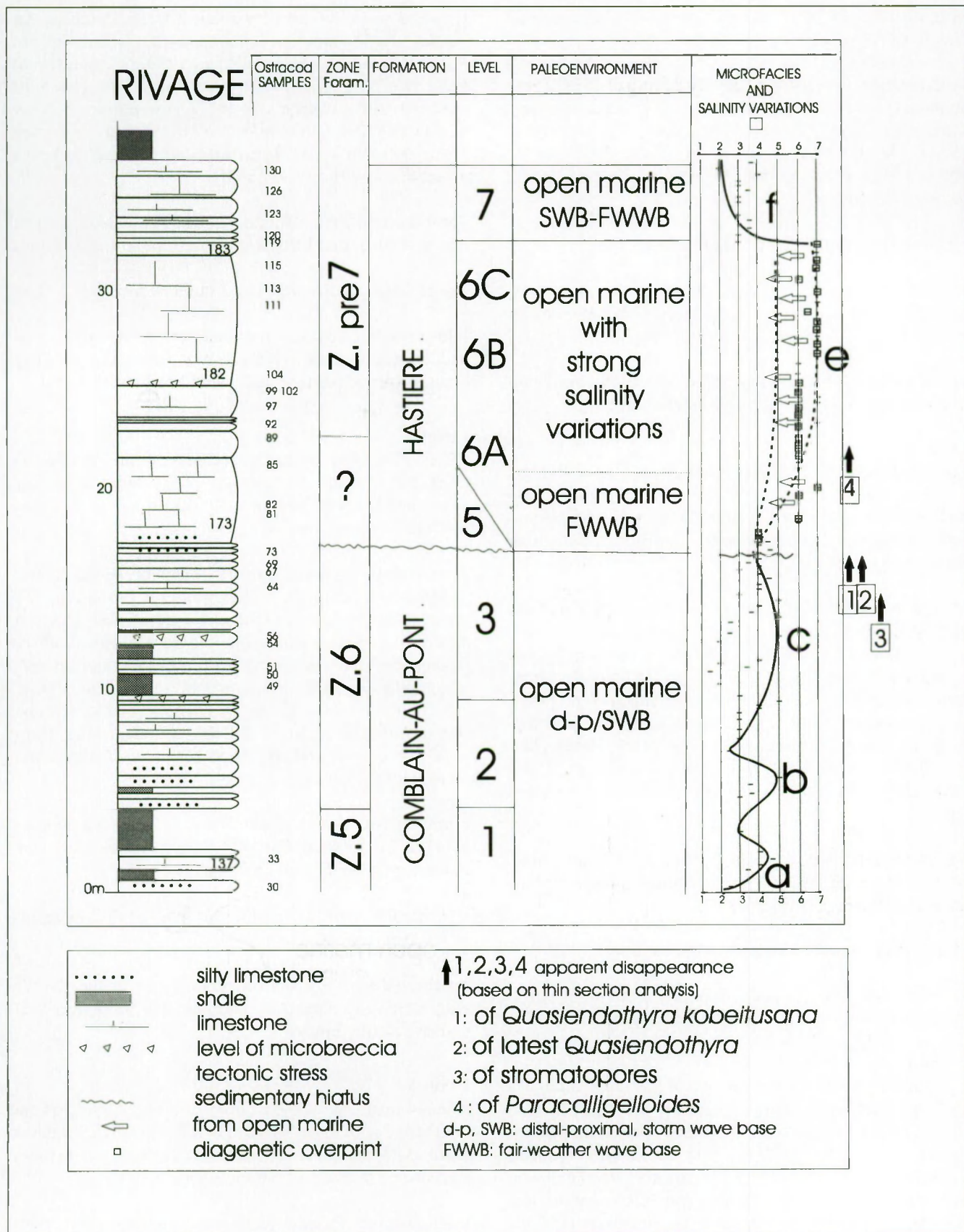


Fig. 4 — Lithological column of the Rivage section with some bed numbers of CONIL (1964). Other columns indicate position of sedimentological and ostracod samples, foraminiferal zonation (MAMET, 1974), names of formations, level succession from 1 to 7 with the location of hiatuses, paleoenvironmental interpretation and microfacies/salinity evolutions. Abbreviations: d = distal, p = proximal, SWB = normal storm wave base, FWWB = normal of fair-weather wave base, Z = Zone.



Microfossils: foraminifers are present. Algae consist mostly of *Girvanella*.

*Archaeosphaera*, *Bisphaera*, *Cryptophyllus*, *Girvanella problematica* NICHOLSON & ETHERIDGE, 1878 (very abundant as encrustations), *Kamaena*, *Latiendothyra*, *Paracaligelloides*, *Quasiendothyra bella* (CHENYSHEVA, 1952), *Quasiendothyra communis* (RAUZER-CHERNOUSSOVA, 1948), *Quasiendothyra regularis* (LIPINA 1955), *Septaglomospiranella*, *Septatournayella*.

Foraminiferal Zone: Zone 5, Late Famennian.

Macrofauna: mainly bioclasts. Brachiopods, bryozoans, crinoids, echinids, bivalves, sponges, stromatoporoids, trilobites.

Interpretation: Distal tempestites. Open marine outer ramp setting within the upper euphotic zone.

### Level 2

Collected on 4 m at Chanxhe and about 5 m at Rivage, Comblain-au-Pont Formation. Thin- to medium-, cross- and graded-bedded argillaceous mudstones/wackestones and peloidal bioclastic packstones/grainstones containing the first observed lumps.

Microfossils: foraminifers are present. Algae consist mostly of *Girvanella*.

*Bisphaera*, *Cryptophyllus*, *Earlandia*, *Girvanella problematica* NICHOLSON & ETHERIDGE, 1878 (very abundant), *Irregularina*, *Latiendothyra*, *Paracaligelloides*, *Quasiendothyra bella* (CHENYSHEVA, 1952), *Quasiendothyra communis* (RAUZER-CHERNOUSSOVA, 1948), *Quasiendothyra kobetusana* (RAUZER-CHERNOUSSOVA, 1948) (rare, about 600 µm), *Septaglomospiranella*, *Septatournayella*.

Foraminiferal Zone: base of Zone 6, latest Famennian, equivalent to the base of the Etroeungt Limestone (extended) in the Avesnois.

Macrofauna: mainly bioclasts, same as level 1.

Interpretation: Intermediate and proximal tempestites. Open marine mid-ramp setting. Upper euphotic zone.

### Level 3

Collected on 10 m at Chanxhe and at Rivage, Comblain-au-Pont Formation. Thin-, medium- to thick-bedded shales interstratified with bioclastic packstones/grainstones, grading to rudstones with centimetric rounded fragments. These reworked fragments are bioclastic grainstones. First occurrences of sporadic asymmetrical cement, clear sparite and idiotopic dolomite crystals. Common cross-bedding.

Microfossils: foraminifers abundant. Algae diversified.

*Archaeosphaera*, *Bisphaera* (abundant), *Cryptophyllus*, *Earlandia*, *Girvanella problematica* NICHOLSON &

ETHERIDGE, 1878 (still very abundant), *Irregularina*, *Kamaena*, *Lagenumbella*, *Latiendothyra*, *Laxoendothyra*, *Paracaligelloides obicus* BOGUSH 1970, *Quasiendothyra bella* (CHENYSHEVA, 1952), *Quasiendothyra communis* (RAUZER-CHERNOUSSOVA 1948), *Quasiendothyra kobetusana* (RAUZER-CHERNOUSSOVA, 1948) (very abundant, about 600-800 µm), *Septabrunsiina*, *Septaglomospiranella*, *Septatournayella*, *Uslonia*.

Foraminiferal Zone: Zone 6, Latest Famennian, equivalent to the original Etroeungt Limestone in the Avesnois.

Macrofauna: mainly bioclasts, same as level 1.

Interpretation: Sporadic proximal tempestites with cross-bedded grainstones (SWB). Initial beginning of diagenetic influence (vadose cement and reflux dolomite).

### Level 4

Observed on 4 m at Chanxhe (Comblain-au-Pont Formation), but overlain by hiatuses. Not present at Rivage. Thick-bedded peloidal bioclastic grainstones. First extensive clear cements replacing bioclasts.

Microfossils: foraminifers very abundant. Algae diverse.

*Bisphaera* (abundant), *Calcisphaera*, *Earlandia*, *Girvanella*, *Irregularina*, *Klubovella* (uncoiled *Quasiendothyra*), *Lagenumbella*, *Latiendothyra*, *Laxoendothyra*, *Paracaligelloides obicus* Bogush, *Quasiendothyra bella* (CHENYSHEVA, 1952), *Quasiendothyra communis* (RAUZER-CHERNOUSSOVA, 1978), *Quasiendothyra kobetusana* (RAUZER-CHERNOUSSOVA, 1948) (abundant, big forms >800 µm), *Quasiumbella*, *Septaglomospiranella*, *Septatournayella*, *Uslonia*.

Foraminiferal Zone: Upper Zone 6, latest Famennian, overlain by a hiatus. Partially incomplete as equivalent to the top of the Etroeungt Limestone.

Macrofauna: same as level 1, but level of disappearance of the stromatoporoids.

Interpretation: Cross-bedded grainstones in the FWB with increasing diagenetic and lagoonal influences (calopheres, umbellinids).

### Level 5

About 4 m at Chanxhe but cut by faulting. About 3 m and interbedded with facies of level 6 at Rivage. Thick-bedded shale with medium-bedded cross-bedded grainstones. Carbonates stressed in the fault zone.

Microfossils: foraminifers poor, algae very poor. Apparent disappearance of the quasiendothyrid lineage.

*Cryptophyllus*, *Earlandia*, *Girvanella* (rare), *Irregularina*, *Paracaligelloides* (still abundant but disappearance at top), *Septaglomospiranella*, *Septatournayella*, *Uslonia*.



Foraminiferal Zone: Undetermined, not diagnostic. Complete absence of Quasiendothyridae.

Macrofauna: same as level 1, with diverse molluscs (gastropods).

Absence of stromatopores.

Interpretation: return of same proximal tempestites as level 2.

#### Level 6A

Discontinuous levels cover most of the observed Hastière Formation and are interstratified with levels 5, 6B and 6C (at least 15 m). Thick-bedded packstones/grainstones with abundant peloids and lumps. Abundant clear sparite crystals replacing original sulfate crystals. Bipyramidal quartz crystals in lumps and algal tufts. Bacterial and fungal filaments omnipresent. Asymmetrical cement.

Microfossils: foraminifers poor. Algae abundant and diversified.

*Archaesphaera*, *Avesnella*, *Bevocastria*, *Bisphaera* (abundant), *Calcisphaera* (abundant), *Earlandia minima* (BIRINA 1948), *Girvanella*, *Issinella sainsii* (MAMET & ROUX, 1975), *Palaeoberesella* (abundant), *Polyderma* sp., *Quasiumbella* (abundant), *Septabrunsiina*, *Septaglomospiranella*, *Septatournayella*, *Uslonia*.

Foraminiferal Zone: Undetermined, no diagnostic foraminifers. Early Tournaisian at the base, when stratified with level 6C, Zone pre-7.

Macrofauna: same as level 5.

Interpretation: FWFB level with extensive diagenetic and lagoonal influences. Flora locally dominated by calciphores, palaeoberesellids and umbellinids. Euphotic zone.

#### Level 6B

Discontinuous levels through the base of the Hastière Formation, but cover most of its top. Mostly thick-bedded peloidal-lumpy packstones/grainstones. Abundant dolomitic microspar.

Microfossils: foraminifers with dominant monolocular *Earlandia*. Algae abundant and diversified.

*Bevocastria*, *Bisphaera* (abundant), *Calcisphaera*, *Earlandia minima* (BIRINA, 1948) (extremely abundant), *Girvanella*, *Issinella*, *Kamaena*, *Palaeoberesella*, *Polyderma* sp., *Quasiumbella*.

Foraminiferal Zone: characterized by the abundance of monolocular Earlandiidae and *Bisphaera*. No diagnostic plurilocular foraminifers but interstratified with level 6C that indicates Zone pre-7, Early Tournaisian.

Macrofauna: same as level 5 with reworked corals.

Interpretation: Extensive hypersaline conditions, superimposed on cryptalgal mats or normal marine saline fauna. Euphotic zone.

#### Level 6C

Discontinuous levels through the Hastière Formation, and often interstratified by level 6B. Thick-bedded cross-bedded peloidal bioclastic grainstones.

Microfossils: foraminifers, rather abundant. Algae, mostly *Girvanella*.

*Bisphaera*, *Calcisphaera*, *Earlandia clavatula* (HOWCHIN, 1888), *Earlandia elegans* (RAUZER-CHERNOUSSOVA & REITLINGER, 1937), *Earlandia minima* (BIRINA, 1948), *Eochernychinella* sp., *Latiendothyra*, *Salebra*, *Septabrunsiina*, *Septaglomospiranella*, *Septatournayella*, *Tournayella*.

Foraminiferal Zone: Zone pre-7, Early Tournaisian.

Macrofauna: same as level 5.

Interpretation: FWFB level, within the euphotic zone.

#### Level 7

Top of Hastière Formation. Peloidal bioclastic grainstones rich in cyanobacteria.

Microfossils: foraminifers abundant. Very abundant *Girvanella problematica* NICHOLSON & ETHERIDGE, 1878, *Earlandia clavatula* (HOWCHIN 1888), *Earlandia elegans* (RAUZER-CHERNOUSSOVA & REITLINGER, 1937), *Earlandia minima* (BIRINA, 1948), *Eochernychinella disputabilis* (DAIN, 1958), "*Granuliferella*", *Latiendothyra*, *Septabrunsiina*, *Septaglomospiranella* (abundant), *Septatournayella*.

Foraminiferal Zone: Zone pre-7, Early Tournaisian.

Interpretation: normal marine, within upper photic zone.

#### Discussion of the levels (Fig. 3, 4)

Analysis of the microfacies curves coupled with the foraminiferal zonation permits recognition of several hiatus and correlation between the two sections. Despite the presence of an evident tectonic fault in the Chanxhe profile, this section seems more complete than the Rivage one. However the presence of a sedimentary hiatus between levels 4 and 5 indicates that this profile is not complete. The Chanxhe microfacies curve can be subdivided into 6 parts ("a" to "f", Fig. 3) recording moderate variations of the wave energy in the open marine environment (parts "a" to "d"), followed by strong salinity fluctuations in part "e" and by a return to normal marine conditions (part "f"). The Rivage section (Fig. 4) shows an important sedimentary hiatus characterized by the complete absence of level 4 and by the partial absence of levels 3 and 5. The lithological



succession shows that part "d" is missing. The microfacies curve presents a trend similar to that of Chanxhe, and with the exception of the hiatuses, it is easy to correlate parts "f" from both sections which are distant of only 2.5 km.

### Ostracods of the Chanxhe and Rivage sections (J.-G. Casier & A. Lebon)

In his paper on ostracods from the lower Tournaisian of Belgium, ROME (1971) recorded five species in the Chanxhe section: *Beyrichiopsis annulata* n. sp., *Bairdia* aff. *kinderhookensis* MOREY, 1936, *Rectobairdia fusiformis* n. sp., *R. dilatata* n. sp. and *R. valdelata* n. sp. These last four species are probably synonyms and reported to *R. fusiformis* ROME, 1971, in CASIER & PRÉAT (2003).

BECKER & BLESS (1974a,b) reported 38 taxa from the parts of the Chanxhe and Rivage sections studied herein. Only three are in closed nomenclature. Twenty-eight of these taxa are figured in these two papers.

In the Comblain-au-Pont Formation (Famennian) of the Rivage section, BECKER & BLESS (1974a,b) recorded the presence of *Bairdiocypris* aff. *rudolphi* KUMMEROW, 1939, *Bairdiocypris* aff. *robusta* KUMMEROW, 1939, *Cryptophyllus* ssp., *Bairdia* ssp., *Shemonaella* ssp., *Uchtovia* aff. *gemina* (BUSCHMINA, 1968) and *Knoxiella* ssp. In the Hastière Formation (mainly Dinantian) of the Rivage section, they recorded the presence of *Bairdiocypris* aff. *rudolphi* KUMMEROW, 1939, *Bairdiocypris* aff. *robusta* KUMMEROW, 1939, "*Bernix*" *venulosa* KUMMEROW, 1939, *Knoxiella* ssp., *Shemonaella* ssp., *Uchtovia* aff. *gemina* (BUSCHMINA, 1968), *Shishaella* aff. *porecta* (ZANINA, 1956), *Acratia* aff. *rostrata* ZANINA, 1956, *Sulcocavellina* sp. 85, *Bairdia* (*Orthobairdia*?) cf. *granireticulata* HARLTON, 1929 *sensu* BUSCHMINA 1970 (=species 27 in BECKER & BLESS, 1974a), *Bairdia* sp. 26, *Bairdia* sp. 90 and *Bairdia* sp. 91.

In the Comblain-au-Pont Formation (Famennian) of the Chanxhe section, BECKER & BLESS (1974a,b) recorded the presence of Palaeocopid ostracode indet., Beyrichiacean? ostracode sp. 133 (= *Shemonaella* sp. 65 in BECKER & BLESS, 1974a), *Shemonaella*? sp. 66, *Ochscapha rara* (TSCHIGOVA, 1958) (= species 67 in BECKER & BLESS, 1974a), *Bairdia* sp. 26 and *Bairdia* indet. In the Hastière Formation (Mainly Dinantian) of the Chanxhe section, they recorded the presence of *Kummerowia* aff. *praetexta* (KUMMEROW, 1939) (= *Platychilina* aff. *praetexta* KUMMEROW, 1939 in BECKER & BLESS, 1974a), Palaeocopid? ostracode indet., "*Bernix*" *venulosa* KUMMEROW, 1939, *Shemonaella*? sp. 66, *Shemonaella*? sp. cf. 66, *Shishaella* aff. *porecta* (ZANINA, 1956), *Aparchites* sp. 126, *Microcheilinella* sp. cf. 38, *Bairdia* sp. 91, *Bairdia* sp. cf. 91, *Bairdia* (*Bairdia*) aff. *confragosa* SAMOILOVA & SMIRNOVA, 1960, *Bairdia* (*Bairdia*) sp. 26, *Bairdia* (*Bairdia*) sp. 126, *Bairdia* (*Orthobairdia*?) cf. *granireticulata* HARLTON, 1929 *sensu* BUSCHMINA 1970 (=species 27 in BECKER & BLESS, 1974a), *Bairdia* (*Rectobairdia*) sp. n. 127, *Bairdia* sp. cf. 127?, *Bairdia* indet., *Bairdiocypris* aff. *robusta* KUMMEROW, 1939, *Bairdiocy-*

*pris* aff. *rudolphi* KUMMEROW, 1939, *Acratia* aff. *rostrata* ZANINA, 1956 and *Acutiangulata* cf. *acutiangulata* (POZNER, 1960 in TSCHIGOVA, 1960) *sensu* BUSCHMINA, 1968.

In the guidebook of the International Symposium on Belgian Micropaleontological Limits held in Namur, BLESS (excursion C in BOUCKAERT & STREEL eds., 1974) reported several taxa recorded by BECKER & BLESS (1974b).

In 1977, TSCHIGOVA & BOUCKAERT indicated that *Uchtovia* aff. *gemina* (BUSCHMINA, 1968) *sensu* BECKER & BLESS (1974) would be a junior synonym of *Akidellina*? *lytvaensis* KOTSCHETKOVA & TKACHEVA, 1975. TSCHIGOVA (1977) and TSCHIGOVA & BLESS (1977) suggested also to place "*Bernix*" *venulosa* KUMMEROW, 1939, rather in the genus *Pseudoleperditia* SCHNEIDER, 1956. They considered also that *Ps. tuberculifera* SCHNEIDER, 1956, and *Ps. poolei* SOHN, 1969, are junior synonyms of *Ps. venulosa* (KUMMEROW, 1939).

COEN (1982) observed that *Shemonaella*? sp. 66 BECKER & BLESS, 1974, is a junior synonym of *Chamishaella kaisini* ROME, 1977.

Finally, COEN *et al.* (1988) noted that some *Acratia* aff. *rostrata* ZANINA, 1956, figured by BECKER & BLESS (1974a,b) belong to *Acratia obtusa* COOPER, 1941, and that *Bairdia* sp. 127 BECKER & BLESS, 1974, and *Bairdia dilecta* BUSCHMINA, 1975, are synonymous. They added that the *Bairdiocypris* aff. *robusta* KUMMEROW, 1939, figured by the same authors in 1974 belong more probably to the species *B. robusta*.

### Sampling and extraction of ostracods

Thirty-six samples of more or less 500 g each were collected for ostracods in the Chanxhe section (Fig. 3) and 27 in the Rivage section (Fig. 4). Ostracods were extracted by the hot acetolysis method (LETHIERS & CRASQUIN-SOLEAU, 1988). Each sample was crushed with a hydraulic press and dried. About 100 g of each sample was attacked with glacial acetic acid 99.8%, close to 90°C, for four days at the rate of eight hours a day. The residue was sieved with 100 µm, 250 µm and 1600 µm mesh sieves. For rich samples, the part of the sample held back by the 1600 µm mesh sieve was attacked once more and sieved with 250 µm and 1600 µm mesh sieves only.

About 1400 carapaces, valves and fragments of ostracods were extracted from the Chanxhe section, and about 1500 from the Rivage section.

### Systematic position of ostracod taxa observed in the Chanxhe and Rivage sections

Order Palaeocopida HENNINGSMOEN, 1953  
Suborder Palaeocopina HENNINGSMOEN, 1953

Superfamily Beyrichiacea MATTHEW, 1886

Family Beyrichiidae MATTHEW, 1886

– *Kozlowskiella*? sp. indet.

Family uncertain

– *Pseudoleperditia*? sp. A (Pl. 1, Fig. 1a,b).



## Superfamily Kirkbyacea ULRICH &amp; BASSLER, 1906

## Family Amphissitidae KNIGHT, 1928

– *Amphissites* sp. A *sensu* CASIER, 2003 (Pl. 1, Fig. 2a,b).

## Family Kirkbyidae ULRICH &amp; BASSLER, 1906

– *Villozona?* sp. A (Pl. 1, Fig. 3)

## Superfamily Youngiellacea KELLETT, 1933

## Family Youngiellidae KELLETT, 1933

– *Youngiella* cf. *calvata* (GREEN, 1963) (Pl. 1, Fig. 4).

– *Youngiella?* sp. A *sensu* CASIER, 2003 (Pl. 1, Fig. 5).

## Superfamily Primitiopsacea SWARTZ, 1936

## Family Graviidae POLENOVA, 1952

– *Coryellina* cf. *grandis* ROBINSON, 1978 (Pl., Fig. 6).

– *Coryellina?* sp. indet.

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

## Superfamily Paraparchitacea SCOTT, 1959

## Family Paraparchitidae SCOTT, 1959

– *Shishaella nana* ROME, 1977 (Pl. 1, Fig. 7a,b).  
(= *Shishaella* aff. *porrecta* (ZANINA, 1956) *in* BECKER & BLESS, 1974a).

– *Shishaella?* sp. indet (Pl. 1, Fig. 8a,b).

– *Chamishaella kaysini* ROME, 1977 (Pl. 1, Fig. 9a,b).  
(= *Chamishaella lysi* ROME, 1977; = *Shemonaella?*  
sp. 66 *in* BECKER & BLESS, 1974a).

– *Chamishaella* sp. A (Pl. 1, Fig. 11a,b)

– *Samarella* sp. A *sensu* CASIER, 2003 (Pl. 1, Fig. 12a,b).

## Family Coelonellidae SOHN, 1971

– *Coelonella* sp. A (Pl. 1, Fig. 13).

## Suborder Platycopina SARS, 1866

## Superfamily Cytherellacea SARS, 1866

## Family Cavellinidae EGOROV, 1950

– *Cavellina chanxhensis* nov. sp. (Pl. 1, Fig. 14a,b, 15).

– *Cavellina coela* (ROME, 1977) (Pl. 1, Fig. 16).

– *Cavellina sphenoides* ROME, 1977 (Pl. 1, Fig. 10).

– *Cavellina* sp. 36 *sensu* BECKER & BLESS, 1974.

## Superfamily Kloedenellacea ULRICH &amp; BASSLER, 1908

## Family Knoxitidae EGOROV, 1950

– *Barychilina gemina* (BUSCHMINA, 1968) (Pl. 1, Fig. 17a,b).

– *Barychilina* sp. A, aff. *gemina* (BUSCHMINA, 1968)  
(Pl. 2, Fig. 1a,b).

– *Barychilina?* sp. B (Pl. 2, Fig. 2).

– *Amicus complanatus* (KUMMEROW, 1939) (Pl. 2, Fig. 3).

– *Blessites feluyensis* TSCHIGOVA, 1977 (Pl. 2, Fig. 4).

– “*Knoxiella*” sp. A (Pl. 2, Fig. 5a,b).

## Order Podocopida SARS, 1866

## Suborder Podocopina SARS, 1866

## Superfamily Bairdiocypridacea SHAVER, 1961

## Family Bairdiocyprididae SHAVER, 1961

– *Healdianella lumbiformis* LETHIERS & FEIST, 1991  
(Pl. 2, Fig. 6a,b).

– *Healdianella dorsosulcata* CASIER, 2003 (Pl. 2, Fig. 7a,b).

– *Elliptocyprites lorangeri* LETHIERS, 1981 (Pl. 2, Fig. 8, 9).

– *Praepilatina* sp. A, aff. *adamczaki* OLEMPKA, 1979  
(Pl. 2, Fig. 15).

– *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939)  
(Pl. 2, Fig. 10-12).

– *Bairdiocypris* sp. B., aff. *rudolphi* (KUMMEROW, 1939)  
(Pl. 2, Fig. 13a,b). (= *pro parte* *B.* aff. *rudolphi* *in*  
BECKER & BLESS, 1974a; = *B.* sp. 31 BECKER & BLESS,  
1974 *in* CASIER & PRÉAT, 2003).

– *Bairdiocypris* sp. C (Pl. 2, Fig. 14).

– *Bairdiocypris?* sp. D (Pl. 2, Fig. 16a,b, 17a,b).

– *Microcheilinella* sp. A, aff. *buschminae* OLEMPKA,  
1981 (Pl. 2, Fig. 18a,b).

– *Microcheilinella* sp. B, aff. *buschminae* OLEMPKA,  
1981 (Pl. 3, Fig. 1a,b).

– *Microcheilinella* sp. C (Pl. 3, Fig. 2a,b).

– *Micronewsomites elatus* (LETHIERS, 1978) (Pl. 3,  
Fig. 3a,b).

## Family Rectonariidae GRÜNDEL, 1962.

– Rectonariidae? indet. (Pl. 3, Fig. 4).

## Superfamily Bairdiacea SARS, 1888

## Family Acratiidae GRÜNDEL, 1962

– *Famenella angulata perparva* LETHIERS & FEIST, 1991.  
(Pl. 3, Fig. 5).

– *Acratia bidecliva* LETHIERS & FEIST, 1991 (Pl. 3,  
Fig. 6a,b).

– *Acratia subobtusa* LETHIERS, 1974 (Pl. 3, Fig. 7a,b).

– *Acratia* sp. A, aff. *rostrata* ZANINA, 1956 (Pl. 3, Fig. 8,  
9a,b).

– *Acratia* sp. B (Pl. 3, Fig. 10).

– *Acratia* sp. F *sensu* CASIER, 2003 (Pl. 3, Fig. 11a,b).

– *Acutiangulata acutiangulata* (TSCHIGOVA, 1959) (Pl. 3,  
Fig. 12a,b).

## Family Bairdiidae SARS, 1888.

– *Bairdia hypsela* ROME, 1971 emend LETHIERS, 1975  
(Pl. 3, Fig. 13). (= *Bairdia* sp. 91 *in* BECKER & BLESS,  
1974a).

– *Bairdia irregularis* ROME, 1971 (Pl. 3, Fig. 14a,b).

– *Bairdia confragosa* SAMOILOVA & SMIRNOVA, 1960  
(Pl. 4, Fig. 1a,b).

– *Bairdia* sp. C, aff. *confragosa* SAMOILOVA & SMIRNOVA,  
1960 (Pl. 4, Fig. 2a,b).

– *Bairdia extenuata* NAZAROVA, 1951 (Pl. 4, Fig. 3).

– *Bairdia* sp. A, aff. *buschminae* CRASQUIN, 1985 (Pl. 4,  
Fig. 4a,b).

– *Bairdia* sp. B, aff. *buschminae* CRASQUIN, 1985 (Pl. 4,  
Fig. 5).

– *Bairdia* sp. D, aff. *philippovae* EGOROV, 1953 (Pl. 4,  
Fig. 6).

– *Bairdia* sp. E (Pl. 4, Fig. 9).

– *Bairdia cultrata* KUMMEROW, 1939 (Pl. 4, Fig. 8).

– *Bairdia* sp. 127 *sensu* BECKER & BLESS, 1974 (Pl. 4,  
Fig. 7).

– *Bairdianella* sp. A, aff. *cuspidis* BUSCHMINA, 1970 (Pl. 4,  
Fig. 10a,b).



- *Bairdiacypris robusta* KUMMEROW, 1939 (Pl. 4, Fig. 11, 12) (= *B. aff. robusta* in BECKER & BLESS, 1974a).
  - *Bairdiacypris* sp. A, aff. *nanbiancunensis* (WANG, 1988) (Pl. 4, Fig. 13a,b).
  - *Bairdiacypris* sp. B, aff. *nanbiancunensis* (WANG, 1988) (Pl. 4, Fig. 14, 15).
- Order Myodocipida SARS, 1866
- Myodocopida? sp. indet. (Pl. 4, Fig. 16).

Order Eridostraca ADAMCZAK, 1976

- *Cryptophyllus* sp. A (Pl. 4, Fig. 17).
- *Cryptophyllus* sp. indet. (Pl. 4, Fig. 18).

**Description of the new species *Cavellina chanxhensis***

The types are deposited in the collections of the Department of Palaeontology (Section Micropalaeontology) of the Belgian Royal Institute of Natural Sciences (IRScNB n°b...).

Genus *Cavellina* CORYELL, 1928

Type-species: *Cavellina pulchella* CORYELL, 1928.

***Cavellina chanxhensis* nov. sp.**  
(Pl. 1, Fig. 14a,b, 15)

? 1974a — *Sulcocavellina* sp. 85 - BECKER & BLESS, pl. 37, figs. 2, 3.

Derivation of the name – From the Chanxhe village, Ourthe Valley, Belgium.

Types - Holotype: Carapace. CH74. IRScNB n° b4441. L = 0.76 mm; H = 0.48 mm; W = 0.38 mm. (Pl. 1, Fig. 15).  
Paratype A: Carapace. CH74. IRScNB n° b4440. L = 0.84 mm; H = 0.52 mm; W = 0.40 mm. (Pl. 1, Fig. 14a,b).  
Paratype B: Carapace. CH72. IRScNB n° b4491. L = 0.87 mm; H = 0.55 mm; W = 0.41 mm.

Locus typicus – Chanxhe section (N 50°30'265; E 5°35'796) located along the access road to the former quarry of Richopré, Ourthe Valley, Belgium (Fig. 3).

Stratum typicum – Comblain-au-Pont Formation (samples CH72 and CH774).

Material – Ten carapaces.

Diagnosis – A species belonging to the genus *Cavellina* with a right valve overreaching strongly the left one all along the margin. Flange-like rib along the antero-dorsal, anterior and antero-ventral margins of the right valve. Presence possible of a pit or a slight sulcus at mid-length. Surface of valves finely punctuated.

Description – In lateral outline medium, amplete, elliptical carapace. Dorsal border regularly and slightly

rounded. Ventral border straight or very slightly concave in the middle part. Anterior margin regularly curved. Posterior margin more curved dorsally, and nearly straight postero-ventrally. Anterior extremity slightly below mid-height, and posterior extremity slightly above mid-height. Maximum length at mid-height, and maximum height at mid-length. Right valve overreaching strongly the left one all along the margin. Lateral outline of the left valve comparable to the right valve except posteriorly where the border is regularly curved. Flange-like rib along the antero-dorsal, anterior and antero-ventral margins of the right valve. A pit or a slight sulcus may be present at mid-length on each valve. In dorsal view, elliptic with the maximum wide at the posterior quarter of the length. Flange-like rib visible on the anterior side of the right valve. If present, sulci or pit slightly visible in dorsal view. Surface of carapace finely punctuated.

Comparison – In *Cavellina coela* (ROME, 1977) (Pl. 1, Fig. 16a,b), the flange-like rib on the right valve is more developed and extends along the dorsal border. This species also posses a flange-like rib along the anterior and ventral margins of the left valve. The lateral outline of *C. coela* is also different. The lateral and dorsal outlines of *Cavellina sphenoides* ROME, 1977 (Pl. 1, Fig. 10), also present in the same beds, are different and the overreaching of its left valve, no so important. These two species are smooth.

Occurrence – The new species is known from the Comblain-au-Pont Formation in the Chanxhe and Rivage sections. If the poorly preserved *Sulcocavellina* sp. 85 figured by BECKER & BLESS (1974a) belongs to *Cavellina chanxhensis* nov. sp., then the new species is accordingly present in the Hastière Formation at Rivage.

**Distribution of ostracods in the Chanxhe and Rivage sections** (Tables 1, 2)

In the Rivage and Chanxhe sections, ostracods are moderately abundant, except in the upper part of the Hastière Formation where they are very abundant. In the Chanxhe section, the samples CH127, CH129 and CH133 are rich, and the samples CH113, CH134, CH137 and CH141 are very rich. Ostracods are absent in samples CH11, CH33 and CH94, and unidentifiable in samples CH14, CH26, CH80, CH82, CH86, CH109, CH117 and CH122. In the Rivage section the samples RG49, RG64, RG67 are rich, and the samples RG120, RG123, RG126, RG130 are very rich. Ostracods are absent in samples RG97 and RG104, and unidentifiable in the sample RG115.

Sixty-two taxa, the majority of which are in open nomenclature, are recognized in the two sections investigated. Forty-five were found in the Chanxhe section and 52 in the Rivage section. In the Chanxhe section, 34 taxa are identified in the Comblain-au-Pont Formation, 27 in the Hastière Formation, and 14 (16?) are present in the two formations. In the Rivage section, 32 taxa are identified in the Comblain-au-Pont Formation, 38 in the



Hastière Formation, and 15 (18?) are present in the two formations. Twenty-four (26?) taxa out of 47 present in the Comblain-au-Pont Formation of the two sections investigated are recognized in the Hastière Formation.

The ostracod fauna is largely dominated by podocopid ostracods. The Podocopina are abundant, diverse, and the majority of taxa displaying long ranges, are present in the two formations. Sixty percent of taxa in the Comblain-au-Pont Formation belong to the podocopid, and 67 percent in the Hastière Formation.

Within the palaeocopid ostracods, the distribution and the diversification of the Palaeocopina, Paraparchiticopina and Platycopina are extremely different. The Palaeocopina are rare and moderately diversified. Eight and a half percent of taxa in the Comblain-au-Pont Formation, and 12 percent in the Hastière Formation belong to the Palaeocopina. They are more diversified in the Rivage section, and in the Chanxhe section they are present exclusively in the Comblain-au-Pont Formation. The Paraparchiticopina are more abundant in number of specimens but comparable in diversity. They are present in the two formations of both sections. Eight and a half percent of taxa belong to the Paraparchiticopina in the Comblain-au-Pont Formation, and 14 percent in the Hastière Formation. However, in the Comblain-au-Pont Formation, they are more diverse in the Chanxhe section. The Platycopina are relatively rich and diverse, and with the exception of a problematic carapace of *Barychilina*, and another of *Amicus complanatus*, they are exclusively present in the Comblain-au-Pont Formation. Nineteen percent of ostracod taxa belong to the Platycopina in the Comblain-au-Pont Formation, and 5 percent in the Hastière Formation.

The Eridostraca, represented by the genus *Cryptophylus*, are present exclusively in the Comblain-au-Pont Formation in the two sections investigated.

Finally the mydocopid ostracods are possibly represented by a very poorly preserved carapace in the Hastière Formation of the Chanxhe section.

#### **Remarks concerning the Eifelian Mega-Assemblage**

In 1975, BECKER (*in* BANDEL & BECKER, p. 61) instituted the Eifelian ecotype (= Eifeler Ökotyp) for high energy environments. This ecotype was characterized by highly ornamented palaeocopid, platycopid and metacopid ostracods (*Ibid.*). More recently, CASIER & LETHIERS (1998a, p. 86) emended the definition of this ecotype to take the occurrence of podocopid ostracods, **occasionally in abundance**, into account. For example, in the Etroeungt Formation cropping out in the Anseremme railway bridge section, 74 percent of ostracod taxa belong to the Podocopina (CASIER *et al.*, 2004). However, BECKER *et al.* (2004, p. 11) estimated that this emendation is a restriction and that such an assemblage clearly matches a distinct subecotype. For these authors, the emended ecotype does not refer to shallow water faunas *e.g.* rich in platycopines as known from the Eifel region and, in particular, from the Russian Platform, and Central

Canada (*Ibid.*). Such a remark is very astonishing: taking the occurrence of podocopids into account does not preclude other ostracod groups. It has never been the intention of CASIER & LETHIERS (1998) to restrict the definition of the Eifelian ecotype. Of course, the Eifelian ecotype is characterized by the presence of palaeocopids, platycopids and metacopids, but also of podocopids and even, but more rarely, of leperditicopids and Eridostraca. The relative proportion of these groups permits recognition of several assemblages from lagoonal environments to marine environments below storm wave base. However, these environments are not necessarily characterized by high energy contrary to BECKER's statement. Lagoonal environments and environments below storm wave-base are calm; marine environments between fair-weather and storm-wave bases, and semi-restricted environments are only occasionally disturbed. Only environments above fair-weather wave base represent a high energy environment where ostracods are generally broken. In fact, the salinity, the nature of the substrate, and more slightly the oxygenation of ground water, have also played a role in the Eifelian ecotype.

Recently, CASIER (2004) proposed to differentiate mega-assemblages, rather than ecotypes, for two reasons: 1. because the ecotype of BECKER (*in* BANDEL & BECKER, 1975) bring together taxa which have not necessarily shared the same environment (*e.g.* in the Entomozoid ecotype, entomozoid ostracods are considered by BECKER (1981, fig. 1) to have lived close to the surface and also on the sea-bottom); 2. because the term "ecotype" seems to be inappropriate since it describes a group of specimens belonging to one species, and adapted genetically to a particular habitat.

#### **Palaeoecology of ostracods (Tables 1, 2)**

Ostracods present in the Chanxhe and Rivage sections belong to the Eifelian Mega-Assemblage, and more precisely to the Assemblage III of CASIER (1987; see also CASIER & PRÉAT, 2003, Fig. 3). The Bairdiacean and Paraparchitacean ecozone of CRASQUIN (1984) forms part of this assemblage. Roughly, all the samples containing identifiable ostracods contain podocopid ostracods indicative of well-oxygenated water conditions, with a salinity normal or very close to the normal. Nevertheless, the abundance of Platycopina and Eridostraca in the Comblain-au-Pont Formation, denotes a deposition in a shallow environment becoming slightly semi-restricted. Assemblage I of CASIER (1987) indicative of semi-restricted water conditions was not recorded neither, in the Chanxhe, nor in the Rivage section.

In more detail, and first in the Chanxhe section, the podocopid ostracods are abundant and diversified in the investigated part of the Comblain-au-Pont Formation. In contrast, the Palaeocopina are rare and present only at the base of that level. The Paraparchiticopina and especially the Platycopina increase in number of taxa and specimens in the upper part of the Comblain-au-Pont Formation. The number of specimens belonging to the Eridostraca







HASTIERE FORMATION										Chanxhe
99	100	105	113	127	129	133	134	137	141	
										<i>Pseudoleperditia?</i> sp. A
										<i>Coryellina?</i> sp. indet.
										" <i>Knoxiella</i> " sp. A
										<i>Bairdiocypris?</i> sp. D
	?									<i>Shishaella nana</i>
			■		■					<i>Shishaella?</i> sp. indet.
			■					■		<i>Microcheilinella</i> sp. A, aff. <i>buschminae</i>
				■		■		■	■	<i>Bairdiocypris</i> sp. B, aff. <i>nanbiancunensis</i>
?					■		■	■		<i>Acratia subobtusa</i>
									■	<i>Chamishaella</i> sp. A
			■	■	■			■	■	<i>Bairdia extenuata</i>
■	?		■		■			■	?	<i>Acratia bidecliva</i>
										<i>Healdianella lumbiformis</i>
■						■	■	■	■	<i>Bairdia</i> sp. A, aff. <i>buschminae</i>
										<i>Cryptophyllus</i> sp. indet.
				■	?		■		■	<i>Bairdiocypris</i> sp. A, aff. <i>rudolphi</i>
			?	■	?					<i>Bairdia irregularis</i>
										<i>Acratia</i> sp. A, aff. <i>rostrata</i>
										<i>Bairdia</i> sp. E
										<i>Acratia</i> sp. B
										<i>Bairdiocypris</i> sp. B, aff. <i>rudolphi</i>
			?	■	■		■	■	■	<i>Bairdiocypris robusta</i>
										<i>Acratia</i> sp. F
										<i>Bairdia hypsela</i>
										<i>Barychilina gemina</i>
								■	■	<i>Chamishaella kaysini</i>
										<i>Youngiella</i> cf. <i>calvata</i>
										<i>Bairdia</i> sp. D, aff. <i>philippovae</i>
				■	?		■			<i>Bairdia confragosa</i>
								■		<i>Elliptocyprites lorangeri</i>
										<i>Cavellina</i> sp. 36
										<i>Cavellina chanxhensis</i>
				■						<i>Micronewsomites elatus</i>
										<i>Blessites feluyensis</i>
■										<i>Myodocopida?</i> sp. indet.
	?		?			■	■		■	<i>Bairdia</i> sp. C, aff. <i>confragosa</i>
		■								<i>Acratia</i> indet.
			■					■		<i>Samarella</i> sp. A
			■	■	■	■			■	<i>Bairdianella</i> sp. A, aff. <i>cuspis</i>
				■	?	■	■	■	■	<i>Healdianella dorsosulcata</i>
					?			?		<i>Bairdia</i> sp. B, aff. <i>buschminae</i>
							■		■	<i>Praepilatina</i> sp. A, aff. <i>adamczaki</i>
							■		■	<i>Microcheilinella</i> sp. B, aff. <i>buschminae</i>
								■		<i>Bairdiocypris</i> sp. A, aff. <i>nanbiancunensis</i>
								■		<i>Famenella angulata perparva</i>
									■	<i>Barychilina?</i> sp. B







HASTIERE FORMATION													Rivage	
81	82	85	89	92	99	102	111	113	119	120	123	126		130
									■	■		■		<i>Acratia</i> sp. A, aff. <i>rostrata</i>
										■		■		<i>Microcheilinella</i> sp. B, aff. <i>buschminae</i>
														<i>Bairdiocypris?</i> sp. D
														<i>Cryptophyllus</i> sp. A
														" <i>Knoxia</i> " sp. A
														<i>Barychilina</i> sp. A, aff. <i>gemina</i>
	■	■				■	■			■				<i>Acratia bidecliva</i>
							?	?		■		■		<i>Bairdia irregularis</i>
				■			?		■	■	■	■		<i>Bairdiocypris</i> sp. A, aff. <i>rudolphi</i>
														<i>Cavellina sphenoides</i>
														<i>Cavellina chanxhensis</i>
														<i>Barychilina gemina</i>
														<i>Cryptophyllus</i> indet.
?		?								■				<i>Bairdia hypsela</i>
														<i>Youngiella</i> cf. <i>calvata</i>
														<i>Cavellina coela</i>
														<i>Bairdiocypris</i> sp. C
														<i>Blessites feluyensis</i>
	■		■											<i>Shishaella nana</i>
		?	?		?		■				?			<i>Chamishaella kaysini</i>
														Rectonariidae? indet.
							?							<i>Micronewsomites elatus</i>
			■								■	■	■	<i>Acratia subobtusa</i>
		■	■	■					■	■	■	■	■	<i>Microcheilinella</i> sp. A, aff. <i>buschminae</i>
									■		■			<i>Bairdiocypris</i> sp. B, aff. <i>nanbiancunensis</i>
		?		■			?		■	■	■			<i>Bairdiocypris robusta</i>
			?	■					■		■	■		<i>Bairdia</i> sp. C, aff. <i>confragosa</i>
											■	■	■	<i>Healdianella lumbiformis</i>
		■							■	■	■		■	<i>Bairdia</i> sp. B, aff. <i>buschminae</i>
														<i>Microcheilinella</i> sp. C
									?					<i>Amicus complanatus</i>
													?	<i>Coryellina</i> cf. <i>grandis</i>
		■					■							<i>Samarella</i> sp. A
			■	■						■				<i>Bairdia</i> sp. A, aff. <i>buschminae</i>
				■										<i>Kozlowskiella?</i> sp. indet.
					■					■				<i>Bairdia extenuata</i>
						■				■	■	■		<i>Healdianella dorsosulcata</i>
							■							<i>Chamishaella</i> sp. A
							■							<i>Youngiella?</i> sp. A
							■				■			<i>Shishaella?</i> sp. indet.
										■				<i>Amphissites</i> sp. A
										■				<i>Bairdia</i> sp. D, aff. <i>philippovae</i>
										■	■			<i>Elliptocyprites lorangeri</i>
										■		■		<i>Baidianella</i> sp. A, aff. <i>cuspis</i>
										■	■	■		<i>Bairdia confragosa</i>
											■			<i>Bairdiocypris</i> sp. B, aff. <i>rudolphi</i>
											■	■		<i>Bairdiocypris</i> sp. A, aff. <i>nanbiancunensis</i>
												■		<i>Bairdia</i> sp. 127
												■		<i>Bairdia cultrata</i>
												■		<i>Acutiangulata acutiangulata</i>
													■	<i>Coelonella</i> sp. A
													■	<i>Villozona?</i> sp. A



(= *Cryptophyllus*) also increases. We can conclude that the environment was very shallow and generally well-oxygenated, and that the depth decreases in the upper part of the formation where the environment became slightly semi-restricted. Ostracods are rare at the top of the Comblain-au-Pont Formation (CH 79). They are absent (CH94), rare and generally unidentifiable (CH80, CH82, CH86, CH99, CH100, CH105, CH109, CH117, CH122) at the base and in the middle part of the Hastière Formation, and that certainly partly related to the strong salinity variations pointed out by the sedimentological analysis. In sample CH113 and also in the upper part of the Hastière Formation (samples CH127, CH129, CH133) ostracods are abundant; they are even very abundant and very diversified at the top of the formation (CH134, CH135 and CH141). In these samples, ostracods belong principally to the Podocopina, and except for a carapace at the top of the Hastière Formation, the Platycopina are absent. These ostracods are indicative of normal marine well-oxygenated environments between fair-weather and storm wave bases.

In the Rivage section, the distribution of Podocopida and Eridostraca is comparable to that observed in the Chanxhe section. Only the distribution of Palaeocopida differs. Except for a carapace of an enigmatic *Youngiella* cf. *calvata*, and a fragment of carapace of a *Coryellina* cf. *grandis*, the Palaeocopina are absent in the investigated part of the Comblain-au-Pont Formation. The Paraparchiticopina are present only in two samples, and the Platycopina are more abundant in the base of that level by comparison with the Chanxhe section. The environment was generally very shallow, well oxygenated and slightly semi-restricted.

In the Hastière Formation, the Palaeocopina are more abundant. However, the ostracod fauna is still largely dominated by podocopid ostracods. Ostracods are absent (CH97, CH94) or rare and poorly diversified (RG81, RG82, RG85, RG92, RG99, RG102, RG111, RG113) in the base and middle part of the Hastière Formation, indicating temporary semi-restricted water conditions. In the upper part of the Hastière Formation (sample RG119 and following), the great abundance and diversity of ostracods is indicative of an open marine environments between fair-weather and storm wave bases.

#### **Comparison with other regions**

Twenty-seven taxa present in the Chanxhe and Rivage sections are known from the Anseremme railway bridge section (CASIER & PRÉAT, 2003) in the southwestern border of the Dinant Basin, and from the Bocahut section (CASIER *et al.*, 2004) in the Avesnes Basin (Table 3). Fifty-five percent of taxa belonging to the Podocopina, 50 percent to the Palaeocopina and 50 percent to the Paraparchiticopina are recognized in the southwestern border of the Dinant Basin, in the Avesnes Basin, and in the northeastern border of the Dinant Basin. However, no platycopid species present in the Chanxhe and Rivage sections is known from the Anseremme or Bocahut sec-

tions. That can be explained by shallower water conditions prevailing during the deposition of the investigated part of the Comblain-au-Pont Formation, compared to the Etroengt Formation in the southwestern border of the Dinant Basin and in the Avesnes Basin. However, the platycopid ostracods *Amicus complanatus* (KUMMEROW, 1939), *Blessites feluyensis* TSCHIGOVA, 1977, *Cavellina coela* (ROME, 1977) and *Cavellina sphenoides* ROME, 1977, have been described from the Hastière Formation at Feluy, on the northern border of the Namur Basin (ROME, 1977; COEN, *et al.*, 1988; COEN, 1994). This could be explained by shallower, more stable, semi-restricted water conditions persisting during a longer period of time in that region.

*Famenella angulata perparva* LETHIERS & FEIST, 1991, *Acratia bidecliva* LETHIERS & FEIST, 1991, *Healdianella lumbiformis* LETHIERS & FEIST, 1991, *Micronewsomites elatus* (LETHIERS, 1978), *Bairdianella* aff. *cuspsis* BUSCHMINA, 1970, *Bairdia extenuata* NAZAROVA, 1951, and maybe *Youngiella calvata* (GREEN, 1963), are known from the Montagne Noire in southern France. The La Serre GSSP (CASIER *et al.*, 2001) and especially the Puech de la Suque section (CASIER *et al.*, 2002) were deposited in deeper settings, and this may explain the low number of species occurring at the same time in both regions.

The relations with the Russian platform are certainly more important than suggested by the number of Russian species recognized in the Chanxhe and Rivage sections. However, due to the poor determination criteria, and also to the existence of numerous convergent species in the Podocopina and the Paraparchiticopina that constitute the bulk of the ostracod fauna at Chanxhe and Rivage, synonymy lists are difficult to establish.

For the same reasons, and also because ostracods are very sensitive to environmental changes, no species of biostratigraphic value have been found in the Chanxhe and Rivage sections. Only the Metacopina, the Entomozoacea and the spiny ostracods of the Thuringian Megaassemblage (= Thuringian Ökotyp of BECKER *in* BANDEL & BECKER, 1975; see CASIER, 2004), have a biostratigraphic value during the Devonian and the Carboniferous.

#### **Ostracods and the Hangenberg Event**

We have reported that shallow environments were spared by the Hangenberg Event in the Anseremme railway bridge section (CASIER & PRÉAT, 2003), and in the Bocahut section (Avesnois, France) (CASIER *et al.*, 2004), while deeper environments were affected. For example, in the Puech de la Suque section, about 30 percent of ostracod species disappeared as a result of this event (CASIER *et al.*, 2001). In Thuringia and in the Rheinisches Schiefergebirge (Germany), and in the Holy Cross Mountains (Poland), the rate of extinction of ostracods is even higher (BECKER & BLUMENSTENGEL, 1995; OLEMPKA, 1997). In the Chanxhe and Rivage sections, the rate of extinction is not abnormal, or can be explained by changes in the environment. For example, almost all the



Table 3 — The 27 ostracod taxa present in both the southwestern and northeastern part of the Dinant Basin. Boc = carrière Bocahut (Avesnois); Ans. = Anseremme railway bridge section; Chan. = Chanxhe section; Riv. = Rivage section; D = Devonian; H = Hastière Formation (mainly Dinantian).

	Boc.		Ans.		Chan.		Riv.	
	D	H	D	H	D	H	D	H
<i>Amphissites</i> sp. A		■		■				■
<i>Youngiella</i> cf. <i>calvata</i>			■	■	?		?	
<i>Youngiella?</i> sp. A	?	■						■
<i>Coryellina</i> cf. <i>grandis</i>		■		■			?	
<i>Shishaella nana</i> ROME, 1977	■	■	■	■	■	?	■	■
<i>Chamishaella kaysini</i>			■	■	■	■	■	■
<i>Samarella</i> sp. A		■	■	■		■		■
<i>Healdianella lumbiformis</i>	■	■	■	■	■		■	■
<i>Healdianella dorsosulcata</i>		■		■		■		■
<i>Elliptocyprites lorangeri</i>		■	■	■	?	■		■
<i>Praepilatina</i> sp. A, aff. <i>adamczaki</i>	■	■		■		■		
<i>Bairdiocypris</i> sp. A, aff. <i>rudolphi</i>	■	■	■	■	■	■	■	■
<i>Bairdiocypris</i> sp. B, aff. <i>rudolphi</i>	■				■			■
<i>Microcheilinella</i> sp. A, aff. <i>buschminae</i>	■	■	■	■	■	■	■	■
<i>Microcheilinella</i> sp. B, aff. <i>buschminae</i>			■			■	■	■
<i>Micronewsomites elatus</i>	■	■			■	■		
<i>Famenella angulata perparva</i>	■	■	■	■		■		
<i>Acratia bidecliva</i>	■	■	■	■	■	■	■	■
<i>Acratia subobtusa</i>			■	■	■	■	■	■
<i>Acratia</i> sp. A, aff. <i>rostrata</i>	■	■	■	■	■		■	■
<i>Acratia</i> sp. F			■	?	■			
<i>Bairdia hypsela</i>	■	■	■	■	■		■	■
<i>Bairdia extenuata</i>	■	■	■	■	■	■		■
<i>Bairdia</i> sp. A, aff. <i>buschminae</i>			■	■	■	■		■
<i>Bairdianella</i> sp. A, aff. <i>cuspis</i>	■	■	■	■		■		■
<i>Bairdiocypris robusta</i>	■	■	■	■	■	■	■	■
<i>Bairdiocypris</i> sp. B, aff. <i>nanbiancunensis</i>	■		■	■	■	■	■	■

Platycopina indicative of very shallow slightly semi-restricted water conditions, disappeared in the Ourthe Valley close to the boundary between the Comblain-au-Pont and Hastière formations, whereas they survived on the northern border of the Namur Basin. Four species of Platycopina present in the Comblain-au-Pont Formation are recognized by ROME (1977) and COEN *et al.* (1988) in the Hastière Formation of the Feluy section. The Eridostraca (*Cryptophyllus*) also indicative of shallow semi-restricted environments, in the Comblain-au-Pont Formation of the Ourthe Valley, survived in the Hastière Formation at Onoz (ROME, 1977).

## Conclusions

Seven major microfacies types permit recognition of several levels encompassing the Comblain-au-Pont and Hastière formations in the Chanxhe and Rivage sections. Overall marine conditions prevailed during deposition, as

the open marine macrofauna is periodically observed through all the standard microfacies sequence (crinoids, bryozoans, brachiopods). MF4 and MF5 acted as a small bioclastic barrier or shoal, due to the accumulation by progradation of crinoidal and algal debris coming from proximal meadows. This shoal area temporarily isolated a "backshoal" zone from the open marine influence. During the periods of isolation, salinity fluctuations were important as suggested by specific microflora (codiaceans) and microfauna (monolocular foraminifers, ostracods). The salinity variations were frequent as the "barrier" was not effective through time. This leads to the tightened alternation or mixing of marine fauna with restricted or littoral flora and microfauna. These levels record shallow open marine sedimentation oscillating between the storm and the fair-weather wave bases in the euphotic zone (abundant *Girvanella* through all the series). The upper part of the sections (Hastière Formation) is mainly composed of microfacies 6 and 7 indicating strong salinity variations with evaporitic reflux and



lagoonal influences. The environment is again open marine in the upper part of the Hastière Formation. The abundance of sulfate pseudomorphs in MF5, MF6 and MF7 indicates also the importance of the diagenetic reflux of evaporitic brines in this general shallow marine environment. The main diagenetic overprint is the development of clear sparite cements replacing the original textures. This strong diagenetic alteration makes it more difficult to recognize and interpret the original paleoenvironment of the Hastière Formation in both sections. The foraminiferal zonation shows the importance of sedimentary hiatuses through the series, which are not continuous, as also indicated by the lithological curve.

Ostracods are moderately abundant in the Chanxhe and Rivage sections and belong to the Eifelian Mega-Assemblage. The association of ostracods present in the investigated part of the Comblain-au-Pont Formation in both sections, is indicative of a shallow marine environment becoming slightly semi-restricted, although more progressively in the Chanxhe section. In the upper part of the Comblain-au-Pont Formation and in the base of the Hastière Formation, ostracods are very rare and generally undeterminable; that is due probably to more restricted water conditions. In the rest of the Hastière Formation, ostracods are characteristic of normal marine environment between fair-weather and storm wave bases. However the absence or the rarity of ostracods in some samples collected in the middle part of the Hastière Formation is probably due to the strong salinity variations pointed out by the sedimentological analysis. Such strong and (or) rapid variations of salinity are not suitable for the

installation of an ostracod assemblage indicative of semi-restricted water conditions.

The distribution of ostracods in the northeastern part of the Dinant Basin is slightly different from the distribution observed in the Anseremme railway bridge section in the southwestern border of the Dinant Basin (CASIER *et al.*, 2004), and from the distribution observed in the Bocahut section in the Avesnes Basin (CASIER & PRÉAT, 2003).

The study of ostracods present in the Chanxhe and Rivage sections confirms that the Hangenberg Event had probably no influence on their distribution in shallow-water settings. The Hangenberg Event is, thus, not comparable to the Late Frasnian Upper Kellwasser Event (LETHIERS & CASIER, 1999; CASIER & LETHIERS, 2001).

The Chanxhe and Rivage sections are not reliable continuous successions for the study of the D/C boundary. All the studied successions from the Avesnois (MAMET & PRÉAT, 2003) to the Ourthe Valley, have discontinuous sedimentation. Most of the hiatuses occur at different levels. Such successions are not compatible with a continuous sequence required for the definition of the D/C boundary.

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## Explanation of Plates

The types are deposited in the collections of the Department of Palaeontology (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 (Préat n°...). CH... or RG... = sample number (see Fig. 3 and 4 for the stratigraphic position).

## PLATE 1

- Fig. 1a,b — *Pseudoleperditia?* sp. A. CH7. Comblain-au-Pont Formation. IRScNB n° b4427. Right lateral view of an internal mould. x70.
- Fig. 2a,b — *Amphissites* sp. A *sensu* CASIER, 2003. RG120. Hastière Formation. IRScNB n° b4428. Carapace. a. Right lateral view. b. Dorsal view. x90.
- Fig. 3 — *Villozona?* sp. A. RG130. Hastière Formation. IRScNB n° 4429. Left valve. x102.5.
- Fig. 4 — *Youngiella cf. calvata* (GREEN, 1963). CH48. Comblain-au-Pont Formation. IRScNB n° b4430. Right valve. x127.5.
- Fig. 5 — *Youngiella?* sp. A *sensu* CASIER, 2003. RG111. Comblain-au-Pont Formation. IRScNB n° b4431. Right lateral view of a fragment of carapace. x92.5.
- Fig. 6 — *Coryellina cf. grandis* ROBINSON, 1978. RG69. Comblain-au-Pont Formation. IRScNB n° b4432. Right lateral view of a fragment of carapace. x70.
- Fig. 7a,b — *Shishaella nana* ROME, 1977. CH7. Comblain-au-Pont Formation. IRScNB n° b4433. Carapace. a. Left lateral view. b. Dorsal view. x70.
- Fig. 8a,b — *Shishaella?* sp. indet. CH48. Comblain-au-Pont Formation. IRScNB n° b4434. Carapace. a. Left lateral view. b. Dorsal view. x70.
- Fig. 9a,b — *Chamishaella kaysini* ROME, 1977. CH137. Hastière Formation. IRScNB n° b4435. Carapace. a. Left lateral view. b. Dorsal view. x30.
- Fig. 10 — *Cavellina sphenoides* ROME, 1977. RG49. Comblain-au-Pont Formation. IRScNB n° b4436. Left lateral view of a carapace. x70.
- Fig. 11a,b — *Chamishaella* sp. A. CH48. Comblain-au-Pont Formation. IRScNB n° b4437. Carapace. a. Left lateral view. b. Dorsal view. x55.
- Fig. 12a,b — *Samarella* sp. A *sensu* CASIER, 2003. CH113. Hastière Formation. IRScNB n° b4438. Carapace. a. Left lateral view. b. Dorsal view. x60.
- Fig. 13 — *Coelonella* sp. A. RG130. Hastière Formation. IRScNB n° b4439. Left lateral view of a carapace. x137.5.
- Fig. 14a,b — *Cavellina chanxhensis* nov. sp. CH74. Comblain-au-Pont Formation. IRScNB n° b4440. Paratype A. a. Left lateral view. b. Dorsal view. x55.
- Fig. 15 — *Cavellina chanxhensis* nov. sp. CH74. Comblain-au-Pont Formation. IRScNB n° b4441. Holotype. a. Left lateral view. b. Dorsal view. x57.5.
- Fig. 16 — *Cavellina coela* (ROME, 1977). RG54. Comblain-au-Pont Formation. Carapace. IRScNB n° b4442. a. Left lateral view. b. Dorsal view. x70.
- Fig. 17a,b — *Barychilina gemina* (BUSCHMINA, 1968). CH74. Comblain-au-Pont Formation. IRScNB n° b4443. Carapace. a. Left lateral view. b. Dorsal view. x45.

## PLATE 2

- Fig. 1a,b — *Barychilina* sp. A, aff. *gemina* (BUSCHMINA, 1968). RG33. Comblain-au-Pont Formation. IRScNB n° b4444. Carapace. a. Left lateral view. b. Dorsal view. x60.
- Fig. 2 — *Barychilina?* sp. B. CH141. Hastière Formation. IRScNB n° b4445. Left lateral view of a carapace. x70.
- Fig. 3 — *Amicus complanatus* (KUMMEROW, 1939). RG69. Comblain-au-Pont Formation. IRScNB n° b4446. Right valve. x45.
- Fig. 4 — *Blessites feluyensis* TSCHIGOVA, 1977. RG56. Comblain-au-Pont Formation. IRScNB n° b4447. Right valve. x80.
- Fig. 5a,b — “*Knoxiella*” sp. A. RG46. Comblain-au-Pont Formation. IRScNB n° b4448. Carapace. a. Left lateral view. b. Dorsal view. x80.
- Fig. 6a,b — *Healdianella lumbiformis* LETHIERS & FEIST, 1991. CH49. Comblain-au-Pont Formation. IRScNB n° b4449. Carapace. a. Right lateral view. b. Dorsal view. x115.
- Fig. 7a,b — *Healdianella dorsosulcata* CASIER, 2003. RG120. Hastière Formation. IRScNB n° b4450. Carapace. a. Right lateral view. b. Dorsal view. x75.
- Fig. 8 — *Elliptocyprites lorangeri* LETHIERS, 1981. RG120. Hastière Formation. IRScNB n° b4451. Right lateral view of a carapace. x80.
- Fig. 9 — *Elliptocyprites lorangeri* LETHIERS, 1981. RG123. Hastière Formation. IRScNB n° b4452. Dorsal view of a carapace. x92.5.



- Fig. 10 — *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939). CH47. Comblain-au-Pont Formation. IRScNB n° b4453. Right lateral view of a carapace. x32.5.
- Fig. 11 — *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939). CH49. Comblain-au-Pont Formation. IRScNB n° b4454. Dorsal view of a carapace. x35.
- Fig. 12 — *Bairdiocypris* sp. A, aff. *rudolphi* (KUMMEROW, 1939). CH141. Hastière Formation. IRScNB n° b4455. Right lateral view of the carapace of a juvenile. x60.
- Fig. 13a,b — *Bairdiocypris* sp. B., aff. *rudolphi* (KUMMEROW, 1939). CH44. Comblain-au-Pont Formation. IRScNB n° b4456. Carapace. a. Right lateral view. b. Dorsal view. x47.5.
- Fig. 14 — *Bairdiocypris* sp. C. RG54. Comblain-au-Pont Formation. IRScNB n° b4457. Right lateral view of a carapace showing the postero-ventral spine. x80.
- Fig. 15 — *Praepilatina* sp. A, aff. *adamczaki* OLEMPKA, 1979. CH134. Hastière Formation. IRScNB n° b4458. Right lateral view of a carapace. x80.
- Fig. 16a,b — *Bairdiocypris?* sp. D. CH7. Comblain-au-Pont Formation. IRScNB n° b4459. Carapace. a. Right lateral view. b. Dorsal view. x65.
- Fig. 17a,b — *Bairdiocypris?* sp. D. CH72. Comblain-au-Pont Formation. IRScNB n° b4460. Carapace. a. Right lateral view. x45. b. Detail of the postero-ventral sector. x142.5.
- Fig. 18a,b — *Microcheilinella* sp. A, aff. *buschminae* OLEMPKA, 1981. RG123. Hastière Formation. IRScNB n° b4461. Carapace. a. Right lateral view. b. Dorsal view. x97.5.

## PLATE 3

- Fig. 1a,b — *Microcheilinella* sp. B, aff. *buschminae* OLEMPKA, 1981. RG120. Hastière Formation. IRScNB n° b4462. Carapace. a. Right lateral view. b. Dorsal view. x57.5.
- Fig. 2a,b — *Microcheilinella* sp. C. RG69. Comblain-au-Pont Formation. IRScNB n° b4463. Carapace. a. Right lateral view. b. Dorsal view. x70.
- Fig. 3a,b — *Micronewsomites elatus* (LETHIERS, 1978). CH74. Comblain-au-Pont Formation. IRScNB n° 4464. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 4 — Rectonariidae? indet. RG64. Comblain-au-Pont Formation. IRScNB n° b4465. Broken right valve. x90.
- Fig. 5 — *Famenella angulata perparva* LETHIERS & FEIST, 1991. CH137. Hastière Formation. IRScNB n° b4466. Right lateral view of a carapace. x92.5.
- Fig. 6a,b — *Acratia bidecliva* LETHIERS & FEIST, 1991. CH48. Comblain-au-Pont Formation. IRScNB n° b4467. Carapace. a. Right lateral view. b. Dorsal view. x95.
- Fig. 7a,b — *Acratia subobtusa* LETHIERS, 1974. RG123. Hastière Formation. IRScNB n° b4468. Carapace. a. Right lateral view. b. Dorsal view. x45.
- Fig. 8 — *Acratia* sp. A, aff. *rostrata* ZANINA, 1956. RG30. Comblain-au-Pont Formation. IRScNB n° b4469. Left valve. x35.
- Fig. 9a,b — *Acratia* sp. A, aff. *rostrata* ZANINA, 1956. RG119. Hastière Formation. IRScNB n° b4470. Carapace. a. Right lateral view. b. Dorsal view. x60.
- Fig. 10 — *Acratia* sp. B. CH44. Comblain-au-Pont Formation. IRScNB n° b4471. Right broken valve showing a postero-dorsal spine. x57.5.
- Fig. 11a,b — *Acratia* sp. F *sensu* CASIER, 2003. CH47. Comblain-au-Pont Formation. IRScNB n° b4472. Carapace. a. Right lateral view. b. Dorsal view. x50.
- Fig. 12a,b — *Acutiangulata acutiangulata* (TSCHIGOVA, 1959). RG126. Hastière Formation. IRScNB n° b4473. Carapace. a. Right lateral view. b. Dorsal view. x47.5.
- Fig. 13 — *Bairdia hypsela* ROME, 1971 emend LETHIERS, 1975. RG54. Comblain-au-Pont Formation. IRScNB n° b4474. Right lateral view of a carapace. x67.5.
- Fig. 14a,b — *Bairdia irregularis* ROME, 1971. CH44. Comblain-au-Pont Formation. IRScNB n° b4475. Carapace. a. Right lateral view. b. Dorsal view. x35.

## PLATE 4

- Fig. 1a,b — *Bairdia confragosa* SAMOILOVA & SMIRNOVA, 1960. RG119. Hastière Formation. IRScNB n° b4476. Carapace. a. Right lateral view. b. Dorsal view. x57.5.
- Fig. 2a,b — *Bairdia* sp. C, aff. *confragosa* SAMOILOVA & SMIRNOVA, 1960. RG123. Hastière Formation. IRScNB n° b4477. Carapace. a. Right lateral view. b. Dorsal view. x35.
- Fig. 3 — *Bairdia extenuata* NAZAROVA, 1951. CH113. Hastière Formation. IRScNB n° b4478. Right lateral view of a carapace. x85.



- Fig. 4a,b — *Bairdia* sp. A, aff. *buschminae* CRASQUIN, 1985. CH137. Hastière Formation. IRScNB n° b4479. Carapace. a. Right lateral view. b. Dorsal view. x32.5.
- Fig. 5 — *Bairdia* sp. B, aff. *buschminae* CRASQUIN, 1985. RG85. Hastière Formation. IRScNB n° b4480. Right lateral view of a carapace. x45.
- Fig. 6 — *Bairdia* sp. D, aff. *philippovae* EGOROV, 1953. CH41. Comblain-au-Pont Formation. IRScNB n° b4481. Right lateral view of a carapace. x60.
- Fig. 7 — *Bairdia* sp. 127 *sensu* BECKER & BLESS, 1974. RG126. Hastière Formation. IRScNB n° b4482. Right lateral view of a carapace. x37.5.
- Fig. 8 — *Bairdia cultrata* KUMMEROW, 1939. RG126. Hastière Formation. IRScNB n° b4483. Carapace. Right lateral view of a carapace. x30.
- Fig. 9 — *Bairdia* sp. E. CH44. Comblain-au-Pont Formation. IRScNB n° b4484. Right lateral view of a broken carapace characterized by a hinge line in a long depression. x60.
- Fig. 10a,b — *Bairdianella* sp. A, aff. *cuspis* BUSCHMINA, 1970. RG120. Hastière Formation. IRScNB n° b4485. Carapace. a. Right lateral view. b. Dorsal view. x70.
- Fig. 11 — *Bairdiacypris robusta* KUMMEROW, 1939. CH137. Hastière Formation. IRScNB n° b4486. Right lateral view of a carapace. x32.5.
- Fig. 12 — *Bairdiacypris robusta* KUMMEROW, 1939. CH137. Hastière Formation. IRScNB n° b4487. Dorsal view of a carapace. x42.5.
- Fig. 13a,b — *Bairdiacypris* sp. A, aff. *nanbiancunensis* (WANG, 1988). RG123. Hastière Formation. IRScNB n° b4488. Carapace. a. Right lateral view. b. Dorsal view. x57.5.
- Fig. 14 — *Bairdiacypris* sp. B, aff. *nanbiancunensis* (WANG, 1988). CH62. Comblain-au-Pont Formation. IRScNB n° b4489. Right lateral view of a carapace. x50.
- Fig. 15 — *Bairdiacypris* sp. B, aff. *nanbiancunensis* (WANG, 1988). CH62. Comblain-au-Pont Formation. IRScNB n° b4490. Dorsal view of a carapace. x60.
- Fig. 16 — *Myodocopida?* sp. indet. CH100. Hastière Formation. Lost specimen. Left lateral view of a carapace? x107.5.
- Fig. 17 — *Cryptophyllus* sp. A. RG54. Comblain-au-Pont Formation. IRScNB n° b4492. Broken valve. x55.
- Fig. 18 — *Cryptophyllus* sp. indet. CH74. Comblain-au-Pont Formation. IRScNB n° b4493. Exfoliated valve. x40.

## PLATE 5

- Fig. 1 — Slightly bioturbated silty clayey mudstone-wackestone with disarticulated ostracod valves and small-sized crinoidal fragments. RG49, Préal n° 2412, microfacies 2, level 3, Comblain-au-Pont Formation, Rivage section, scale bar 390  $\mu$ m.
- Fig. 2 — Same as Fig. 1, displaying a thin wackestone-packstone lamina with echinodermal fragments (echinid spine) and microbioclasts. RG49, Préal n° 2411, microfacies 2, level 3, Comblain-au-Pont Formation, Rivage section, scale bar 390  $\mu$ m.
- Figs. 3, 4 — Bioclastic silty peloidal packstone laminae in a bioturbated silty clayey mudstone (not seen here). The bioclasts consist of whole ostracods, micritized crinoids (Fig. 3), micritized grains and relatively large *Girvanella* fragments in the centre of the photograph (Fig. 4). The micritic matrix has recrystallized as fine-grained microspar. This latter is present inside the ostracod (Fig. 3). CH13, respectively Préal n° 2470 and n° 2168, microfacies 2, level 1, Comblain-au-Pont Formation, Chanxhe section, scale bar 390  $\mu$ m.
- Fig. 5 — Graded bioclastic packstone lamina in a clayey mudstone (not seen here). The lamina is centimetric and contains brachiopods, ostracods, a large trilobite (see the bottom of the photograph) and crinoidal fragments. The white arrow points to a small-sized rounded microbreccia consisting of a peloidal grainstone (of microfacies 4). To the right of the brachiopod fragment is a issinellid alga (small circle in the lower right corner). CH80, Préal n° 2290, microfacies 3, level 1, Hastière? Formation, Chanxhe section, scale bar 390  $\mu$ m.
- Fig. 6 — Medium-grained and poorly sorted bioclastic (trilobite, crinoids) peloidal grainstone. The large trilobite fragment forms a shelter cavity (bottom of the photograph) infilled by a fibrous radiaxial calcite cement and a drusy sparite. A few silty quartz grains are present (above the trilobite fragment). Crinoidal grains are partly micritized. CH60, Préal n° 2238, microfacies 4, level 3, Comblain-au-Pont Formation, Chanxhe section, scale bar 390  $\mu$ m.
- Fig. 7 — Microsparitized foraminiferal (Tournayellidae) and peloidal packstone with a few crinoids. The microspar is homogeneous and alters the former micritic texture. CH130, Préal n° 2268, microfacies 4, level 6, Hastière Formation, Chanxhe section, scale bar 390  $\mu$ m.
- Fig. 8 — Well-sorted crinoidal grainstone ("encrinite") with small irregular micritic grains (=foraminiferal sections). Syntaxial cement is well developed. CH135, Préal n° 2377, microfacies 4, level 7, Hastière Formation, Chanxhe section, scale bar 950  $\mu$ m.



## PLATE 6

- Fig. 1 — Medium-grained and well-sorted bioclastic grainstone with micritized grains and irregular *Girvanella* peloids. Bioclasts consist of disarticulated carapaces of *Cryptophyllus* ostracod and crinoids. Syntaxial calcite cement is well developed. CH42, Prémat n° 2188, microfacies 4, level 2, Comblain-au-Pont Formation, scale bar 390  $\mu\text{m}$ .
- Fig. 2 — Intergranular asymmetrical and meniscus cement around micritized crinoidal fragments (micritized grains) and peloids. The base of the photograph gives the normal stratigraphical position. The facies consist of a "bimodal" grainstone with micritized grains (see the figure) and large crinoids forming thin cross-bedded lamina (not seen here). CH55, Prémat n° 2225, microfacies 5, level 3, Comblain-au-Pont Formation, scale bar 155  $\mu\text{m}$ .
- Figs. 3, 4 — Centimetric-sized (up to 2 cm) rounded microbreccia in a microparitized silty grainstone. The microbreccia consists of a silty bioclastic peloidal packstone (a crinoidal fragment is visible on figure 4). RG55, respectively Prémat n° 2416 and n° 2417, microfacies 5, level 3, Comblain-au-Pont Formation, Rivage section, scale bar respectively 950 and 390  $\mu\text{m}$ .
- Fig. 5 — Coarse-grained peloidal and crinoidal grainstone. Peloids are irregular and abundant. Crinoids (and their thin syntaxial rim) are partly micritized and progressively replaced by large sparite crystals. These bioclasts are included in a plurimillimetric laminar grainstone interstratified in a cross-bedded and fine-grained peloidal grainstone (not seen here). Large irregular cavities filled by clear sparite are also observed (top of the picture). CH65, Prémat n° 2245, microfacies 5, level 3, Comblain-au-Pont Formation, scale bar 390  $\mu\text{m}$ .
- Fig. 6 — Crinoidal grainstone with abundant irregular lumps and algal chips. Clear large sparite crystals replace the crinoids and the lumps. As a result of this corrosion the grains display any sizes and any forms. CH100, Prémat n° 2319, microfacies 6, level 6, Hastière Formation, scale bar 390  $\mu\text{m}$ .
- Fig. 7 — Fine-grained peloidal and calcisphaerid microsparitized packstone. The sediment is a diagenetic grainstone due to the development of white sparite crystals replacing a former micritic texture. A fine grained greyish microspar is present between the small peloids CH112, Prémat n° 2328, microfacies 6, level 6, Hastière Formation, scale bar 390  $\mu\text{m}$ .
- Fig. 8 — Diagenetic grainstone (same process as figure 7) with large micritized grains (upper left corner), calcipheres and angular cryptalgal chip with thin orthogonal desiccation cracks. RG115, Prémat n° 2471, microfacies 7, level 6, Hastière Formation, scale bar 390  $\mu\text{m}$ .



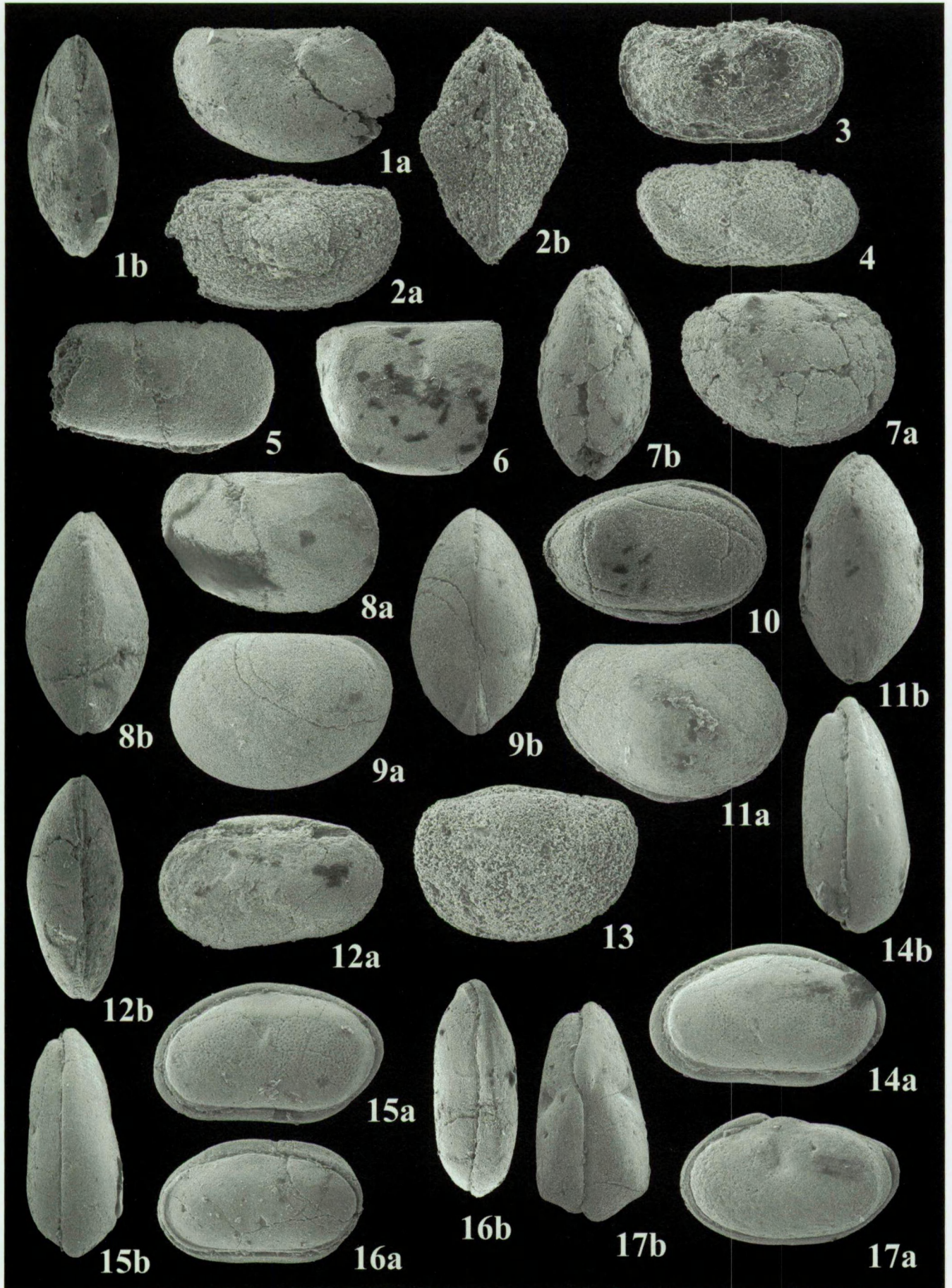


PLATE 1



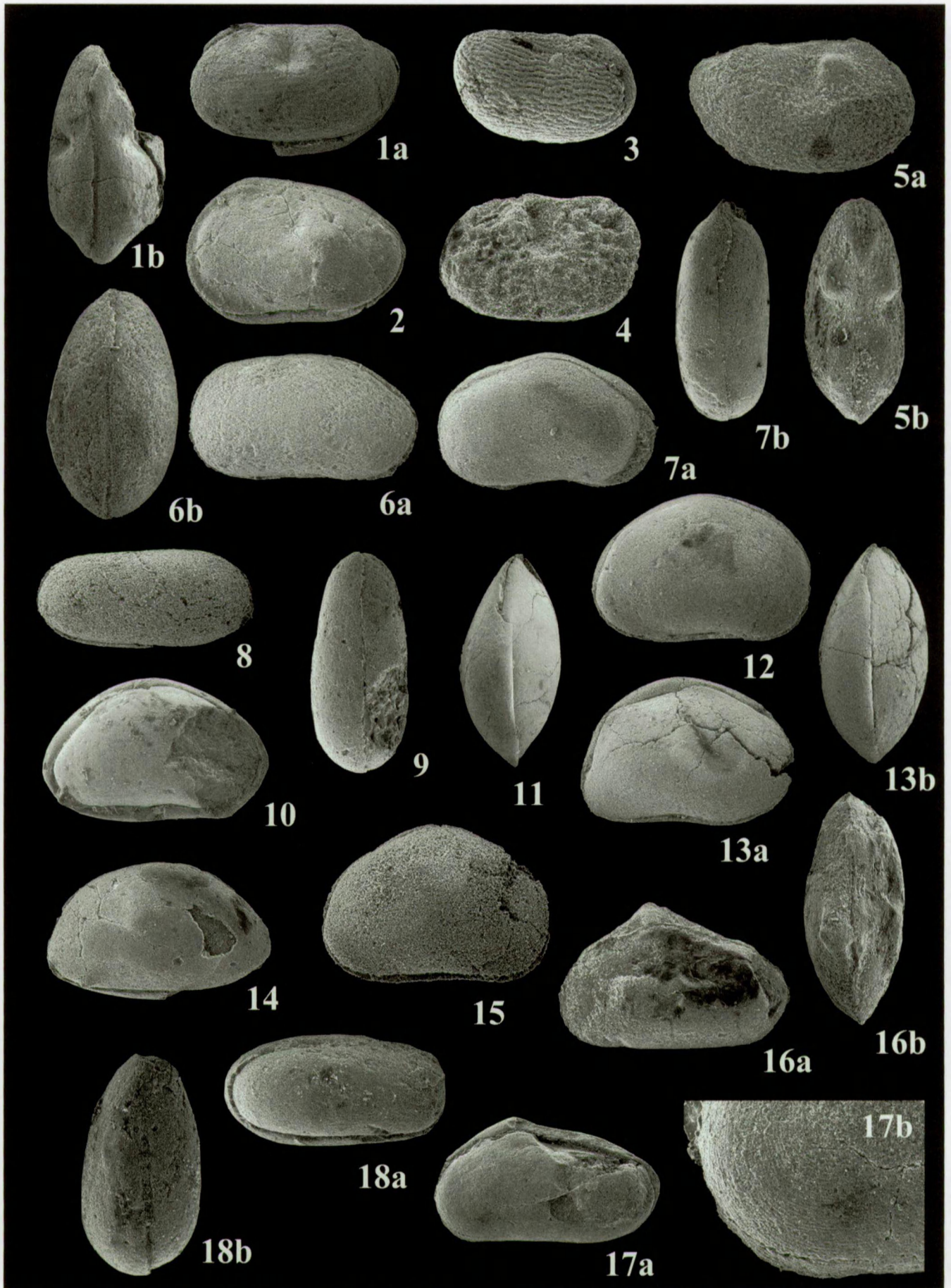


PLATE 2



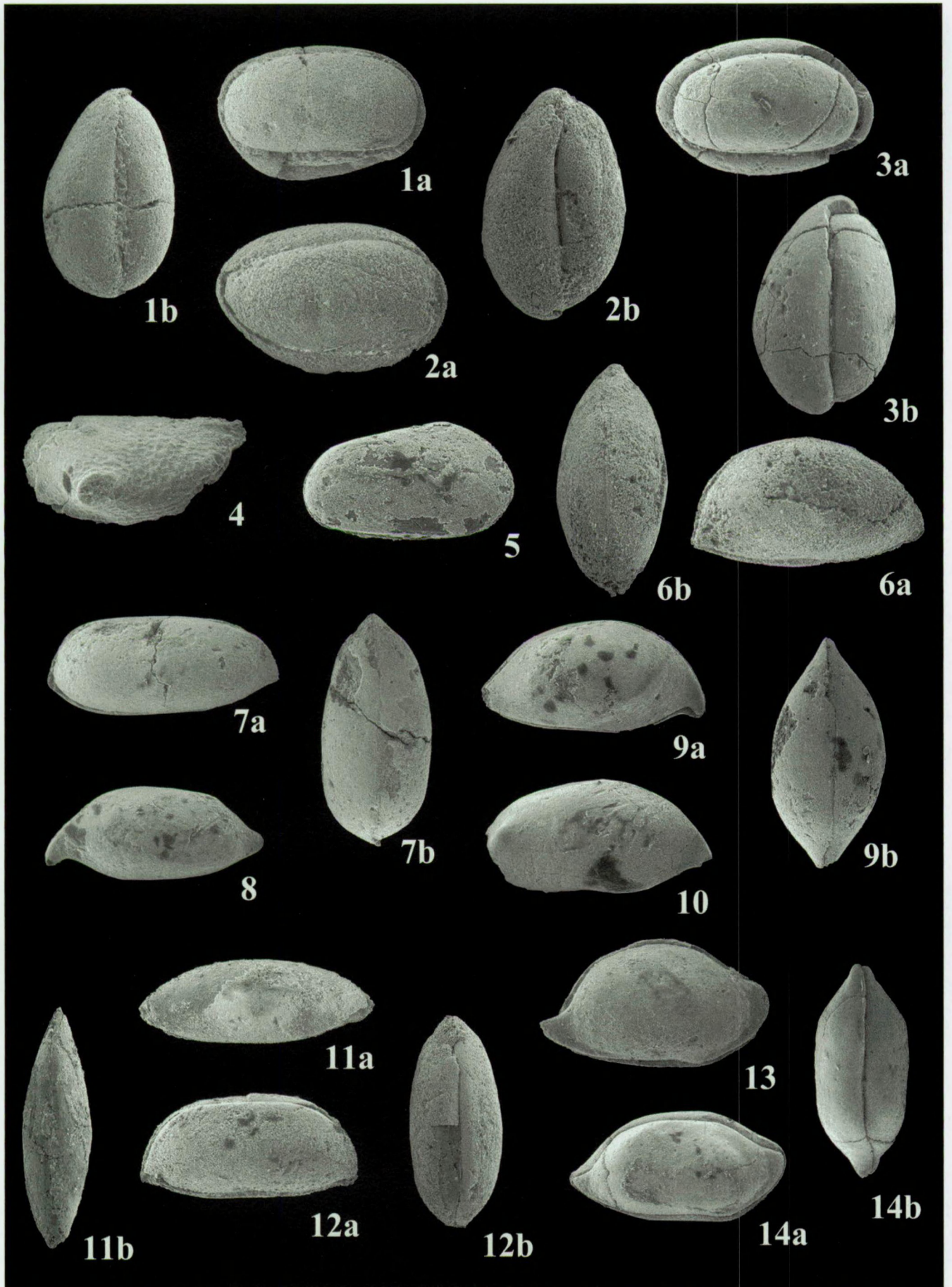


PLATE 3



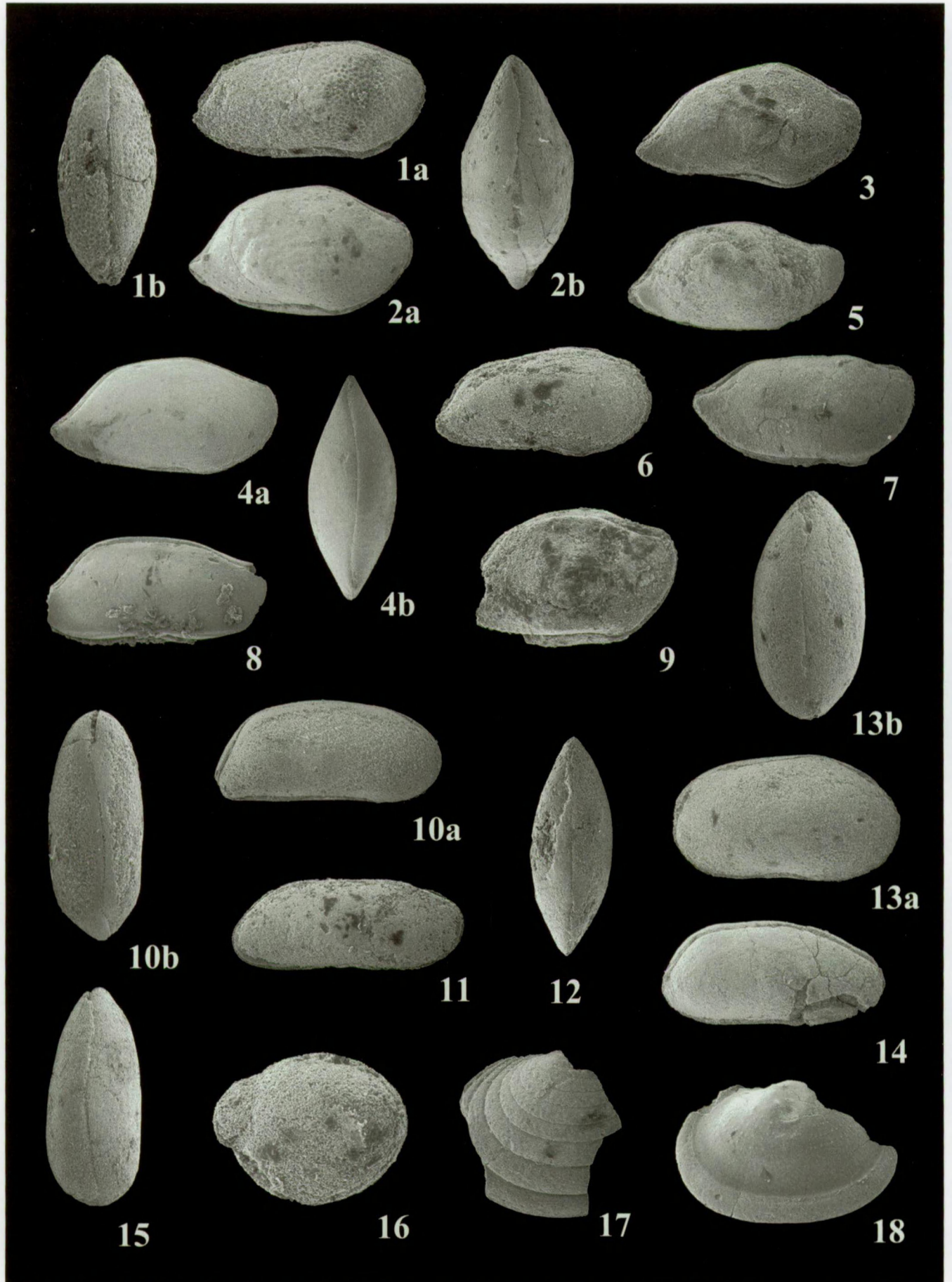


PLATE 4



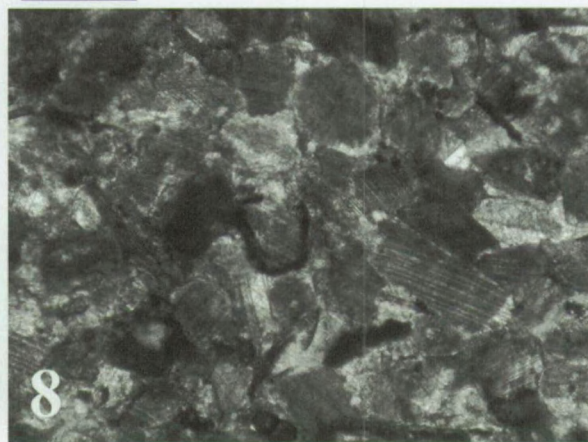
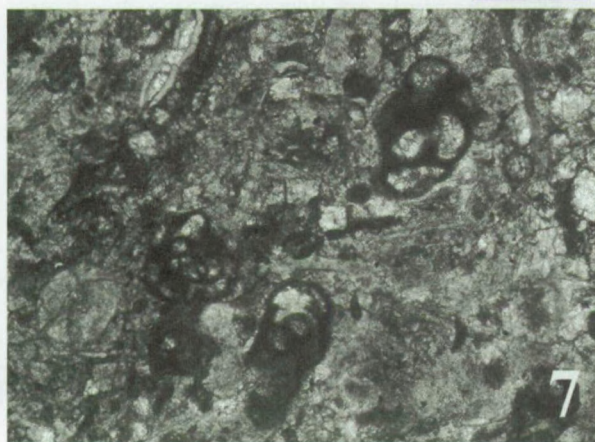
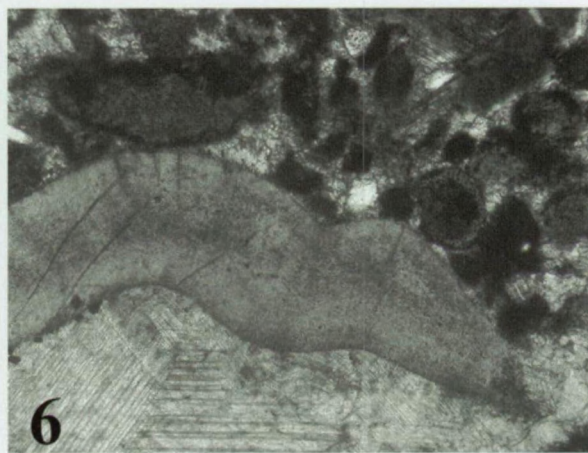
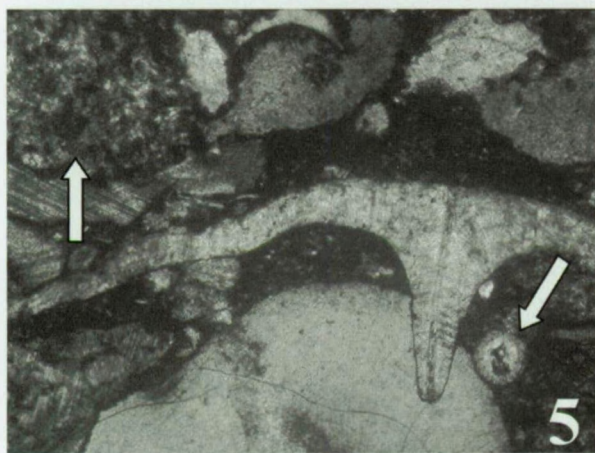
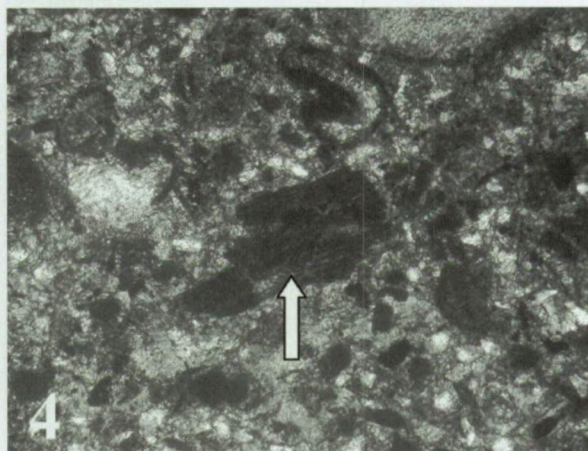
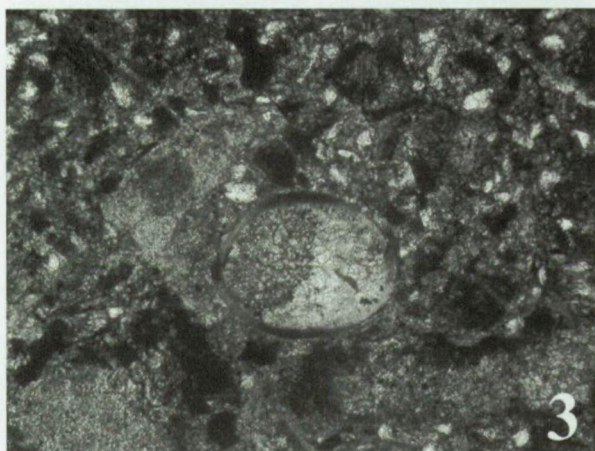
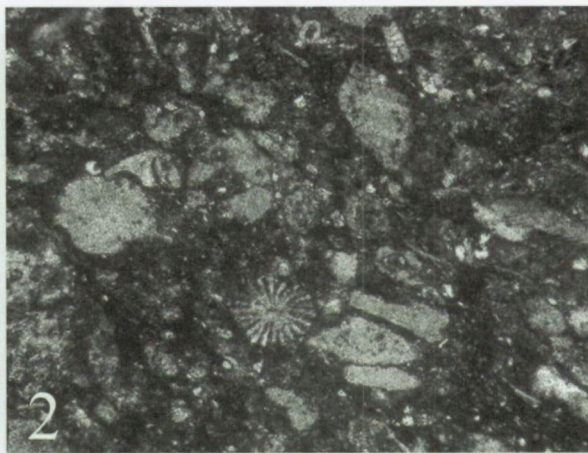
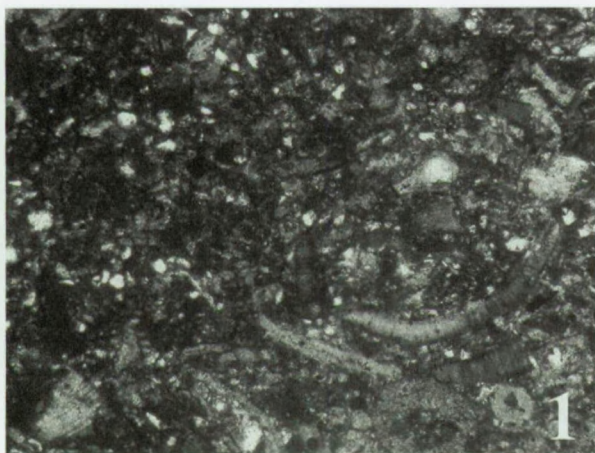


PLATE 5



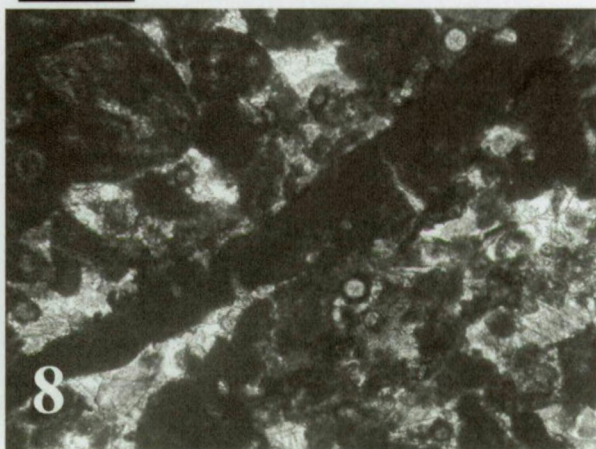
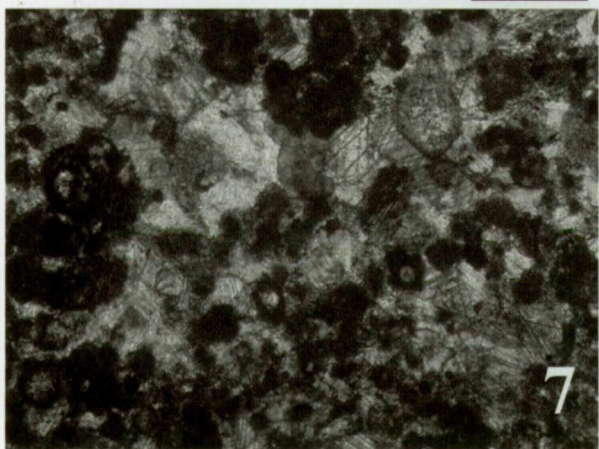
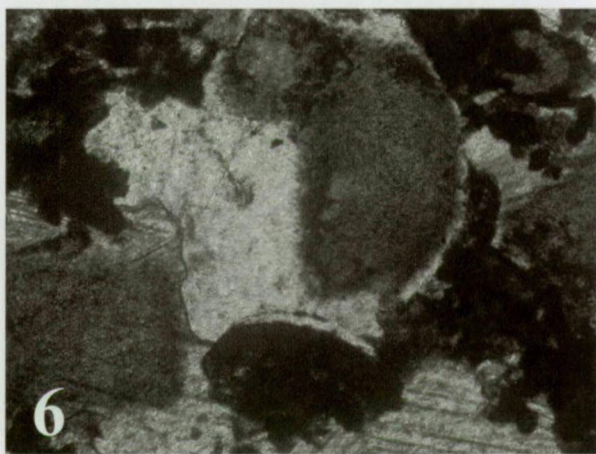
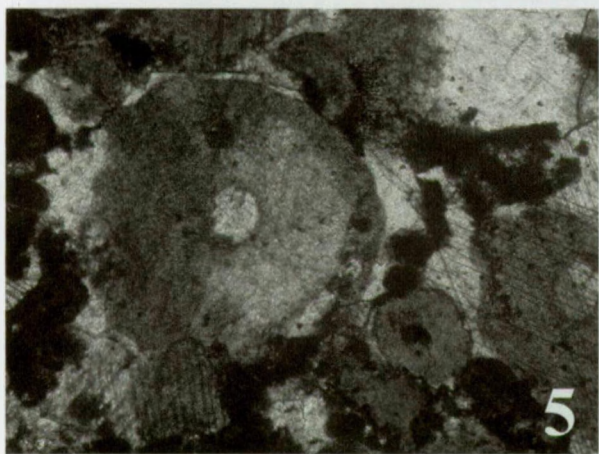
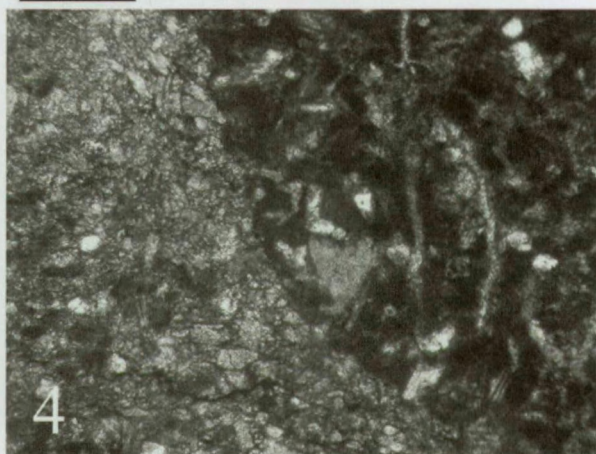
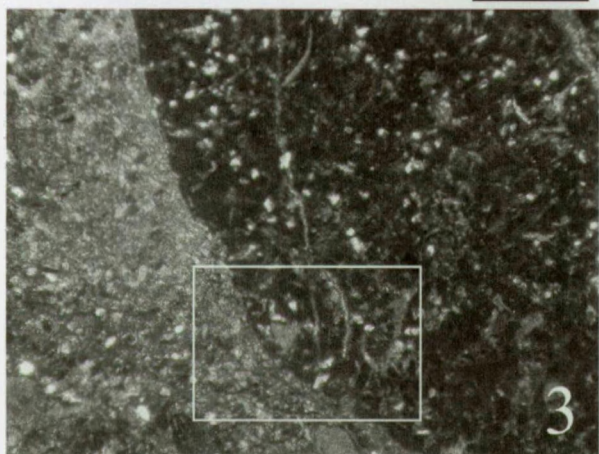
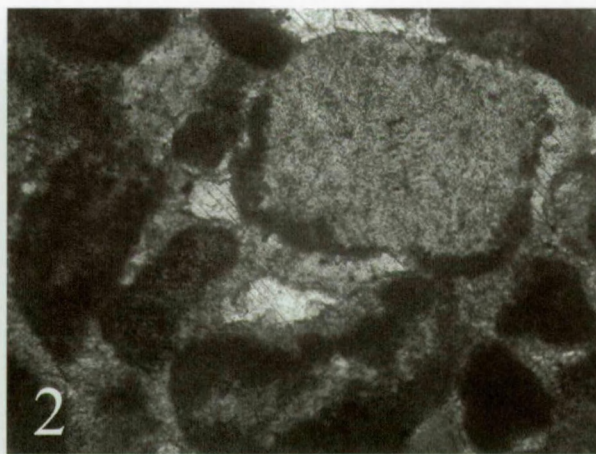
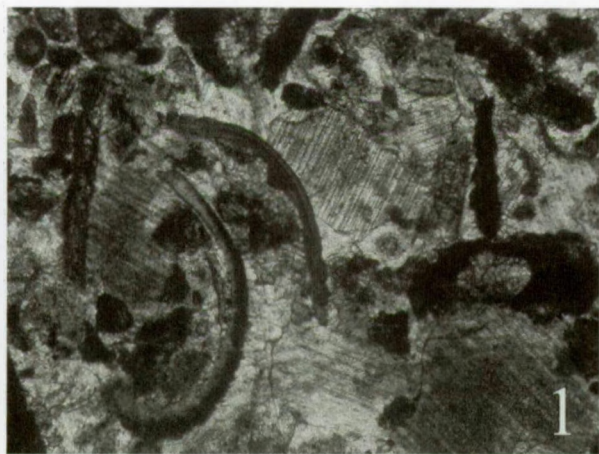


PLATE 6