

Ostracods and sedimentology of the Devonian-Carboniferous stratotype section (La Serre, Montagne Noire, France)

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Abstract

Despite their low abundance, ostracods are very diversified in the La Serre Devonian-Carboniferous (= D-C) Global Stratotype Section and Point (= GSSP). Seventy-one species are identified, 58 in the Devonian and 29 in the Carboniferous. The ostracod fauna is composed of ostracods belonging to the Eifelian ecotype alone or to a mixed assemblage of the Eifelian and Thuringian ecotypes. The relative abundance of these two ecotypes, the abnormal number of instars in some beds, the presence of ostracods in oolites and the occurrence of reworked specimens in elements of microbreccia give evidence for important changes in the conditions of the environment close to the D-C boundary. In the Late Devonian, ostracods display a regressive trend from deep environments below storm wave base to highly agitated environments above fair-weather wave base. But the sea level curve is not completely recorded in the La Serre section since two tectonic disturbed beds are present in the upper part of the profile. The number of ostracod species disappearing during the Hangenberg Event at La Serre seems to be less important in comparison with other sections investigated in Germany and Poland.

The sedimentological study displays a standard sequence composed of six carbonate microfacies (MF1 to MF6) and shows a quite abrupt transition from shallow hemipelagic environments (MF1) to shoreface-foreshore microbioclastic and ooidal shoals (MF2-MF5) reaching the upper beach foreshore (MF6). No evidence of subaerial emergence is found, nor any sedimentary structures indicating intertidal restricted environments. Microbreccias are abundant in MF5 and MF6; they are moderately to poorly sorted, subangular to subrounded, and show mixing of different eroded microfacies. All this supports strong and brief erosional phases within the transitional zone around 10 m water depth.

The sea level trend points to a general regression starting near the Hangenberg Horizon *sensu* FEIST et al. (2000), from our sample 37 (Fig. 2), to the top of the section (sample 64) as showed by the shift of microfacies 1 to microfacies 6 and the quite abrupt appearance of proximal coquina layers, interpreted tempestites, toward the upper part of the section. The energy level was very high as indicated by the broken oolites, the microbreccias and the lamination patterns. Finally a sea level increase (transgression) seems to have occurred in the uppermost part of the profile. Sea-level fluctuations were probably about ten of meters or more, as indicated by the erosion of microfacies 1 whose fragments form part of the microbreccias of microfacies 6.

The study of ostracods and the sedimentology confirm that the La Serre section is far from being an ideal GSSP.

Key-words: Ostracods, Sedimentology, Devonian-Carboniferous boundary, GSSP, Montagne Noire.

Résumé

Malgré leur faible abondance, les ostracodes sont extrêmement diversifiés dans le stratotype de la limite D-C de La Serre. Soixante et onze espèces sont identifiées, 58 dans le Dévonien et 29 dans le Carbonifère. La faune est composée d'ostracodes appartenant soit à l'écotype de l'Eifel seul, soit à un mélange des écotypes de l'Eifel et de Thuringe. L'abondance relative des ostracodes appartenant à ces deux écotypes, le nombre anormal de formes larvaires dans certains niveaux, la présence d'ostracodes au sein d'oolites et l'existence d'ostracodes remaniés dans des éléments de microbrèches attestent d'importants changements des conditions environnementales près de la limite D-C. Dans le Dévonien final, les ostracodes témoignent d'une tendance régressive à partir d'environnements profonds, sous le niveau d'action des vagues de tempêtes, à des milieux très agités, dans la zone d'action des vagues de beau temps. La variation du niveau marin n'est cependant pas enregistrée de manière complète car deux bancs à contact tectonique anormal sont présents dans la partie supérieure du profil. Le nombre d'espèces d'ostracodes disparaissant pendant l'Événement Hangenberg à La Serre, semble moins important que celui observé dans d'autres coupes étudiées en Pologne et en Allemagne.

L'analyse sédimentologique de la coupe de La Serre permet de définir une séquence standard composée de 6 microfaciès carbonatés. Leur succession (de MF1 à MF6) enregistre une diminution assez brutale de la profondeur d'eau depuis des milieux hémipélagiques situés sous la zone d'action des tempêtes majeures (MF1) jusqu'aux milieux d'avant-plage peu profonds soumis à de violents courants (MF6). Ces processus de remaniements sont à l'origine de l'érosion et de la bréchification des environnements littoraux (barres tidales bioclastiques et oolitiques...) ou hémipélagiques peu profonds. Le domaine littoral est situé à une dizaine de mètres de profondeur d'eau dans la zone photique. Aucun milieu restreint, ni émergé, n'a pu être mis en évidence.

La courbe lithologique établie à partir de la succession des microfaciès met en évidence une évolution régressive du niveau marin depuis la base de la section jusqu'à son sommet. Le niveau marin semble augmenter (évolution transgressive) ensuite dans l'extrême sommet de l'affleurement. Le contexte énergétique général est très élevé comme l'indique l'abondance des microbrèches formées à partir de l'érosion des MF1-5, des fragments anguleux d'oolites et les niveaux coquilliers représentant des tempestites proximales. Les structures laminaires planes parallèles ou entrecroisées et les granuloclasses soulignent également les fortes variations d'intensité et de direction des courants.

Les études ostracodologique et sédimentologique confirment que la coupe de La Serre est loin de fournir un stratotype de limite idéal.

Mots-clés: Ostracodes, Sédimentologie, Limite Dévonien-Carbonifère, Stratotype de limite, Montagne Noire.

Introduction

The Late Devonian and the Early Carboniferous are well exposed on the southern flank of the La Serre Hill, in the

Montagne Noire, southern France. For the study of the Devonian and of the Devonian-Carboniferous (=D-C) transition, several trenches were dug there under the direction of R. Feist during the 70's and 80's. The description and the precise location of these trenches were published by FEIST *et al.* (1990).

Recently we have reported the ostracods occurring from across the Frasnian-Famennian boundary in the La Serre trench C of R. Feist (LETHIERS *et al.*, 1998). In this section, 34 ostracod species have been identified in dark and bituminous limestones and shales related to hemipelagic sedimentation in dysoxic or anoxic bottom-water conditions.

The first goal of this second paper on ostracods from La Serre is to present the ostracods occurring in trench E'. This one has been proposed recently as Global Stratotype Section and Point (= GSSP) for the D-C boundary by the Working Group on the Devonian-Carboniferous Boundary established by the International Commission on Stratigraphy. This proposition was accepted in 1990 by the

International Union of Geological Sciences (PAPROTH *et al.*, 1991), principally because the La Serre trench E' was the only section known in that time that revealed the "evolutionary lineage of *Siphonodella praesulcata* to *Siphonodella sulcata*" (*Ibid.*).

The second goal of this paper is to go further in the study of the Hangenberg Event in the Montagne Noire. This event, also called the Final Devonian event or the D-C boundary event, corresponds to the deposition of the Hangenberg Shale in the Middle *praesulcata* Zone, the penultimate conodont zone in the Famennian (WALLISER, 1984, 1996). The Hangenberg Event is responsible for the disappearance of ammonoids (HOUSE, 1993; BECKER, 1993), conodonts (GIRARD, 1996), and trilobites (FEIST, 1991) and is frequently related to anoxic water conditions (HOUSE, 1985; BECKER & BLUMENSTENGEL, 1995), to sea-level changes (BLESS *et al.*, 1993), to a climatic cooling (CAPLAN & BUSTIN, 1999; STREEL *et al.*, 2000), or even to abnormal salinity conditions (FEIST & FLAIS, 1987).

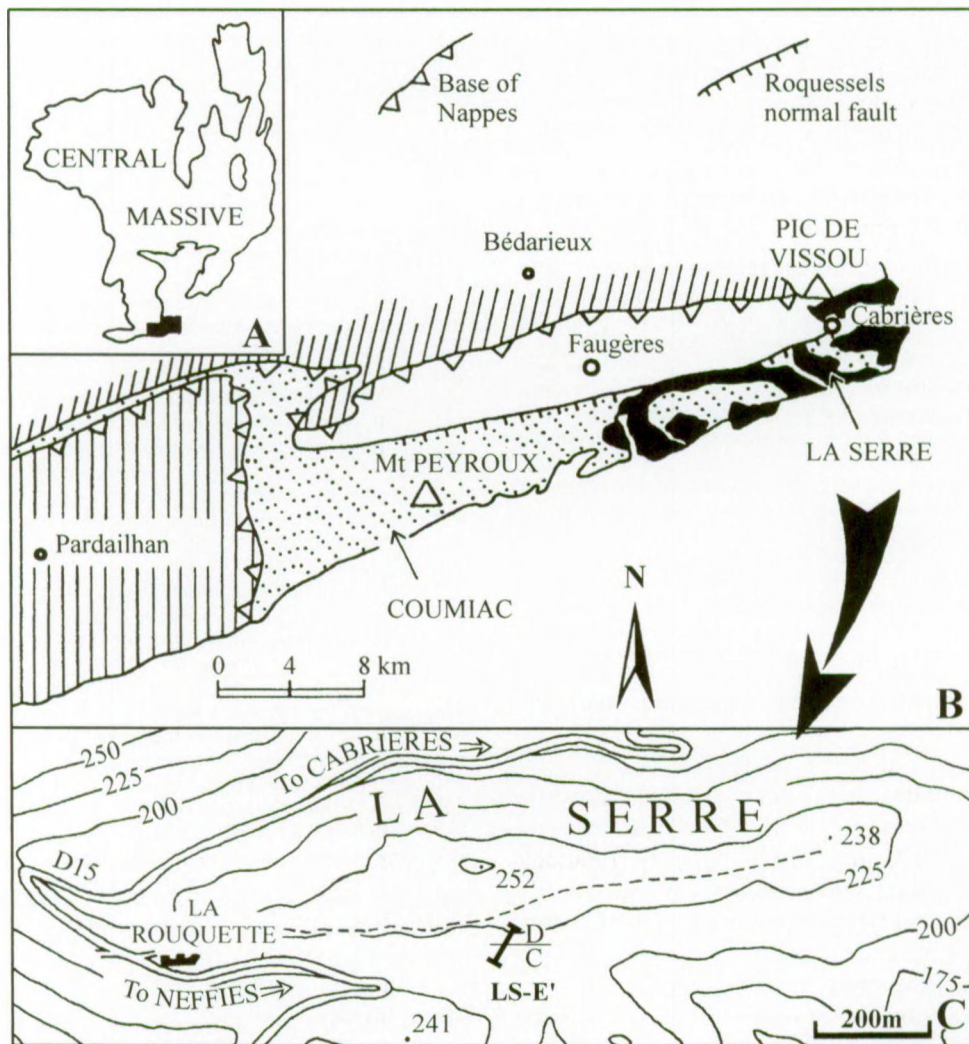


Fig. 1 — Geographic location of the La Serre Global Stratotype Section and Point: A. Montagne Noire in the Central Massif. B. Structural geology of this region. C. Locations of La Serre Hill and of the GSSP = LS-E' trench.

The La Serre D-C GSSP

The new D-C GSSP (GPS: N 43°33'324; E 3°21'531) is located on the southern flank of the La Serre Hill, 2.4 km south of Cabrières, in the Montagne Noire (Fig. 1). Trench E' exposes about 7.5 m of limestones beds (Fig. 2) pertaining to the Cabrières klippen area, and the D-C boundary has been fixed at the base of the bed in which we have collected the sample LSDC 62 (= bed 89 of FLAJS & FEIST, 1988) in a sequence of predominantly bio-detrital oolitic limestone within a pelagic matrix of shale and cephalopod bearing calcilitites (FEIST *et al.*, 1990).

The La Serre D-C GSSP has been studied by FEIST & FLAJS (1987), FLAJS & FEIST (1988), and FEIST *et al.* (2000). Brachiopods from this section have been reported by LEGRAND-BLAIN & MARTINEZ CHACON (1988); corals by SEMENOFF-TIAN-CHANSKY (1988); foraminifera, algae and microproblematica by VACHARD (1988); conodonts by GIRARD (1994), and trilobites by FLAJS & FEIST (1988).

Rock and facies analysis (A. Pr at)

From a thickness of nearly 7.5 m, 69 samples for thin sections were collected in the La Serre section for sedimentological analysis. The section is composed of a series of thin, well-bedded, fine-grained limestones at the base and coarser and thicker limestones toward the top where several conglomeratic beds are present. A particular point is the presence of an abnormal contact of several beds about 1.5 m below the D-C boundary. The beds associated with this tectonic contact may be due to sliding or faulting, are strongly different from the beds above and below: they are fine grained and homogeneous. The sedimentological analysis allowed recognition of a standard sequence of 6 microfacies recording an asymmetrical shallowing-upward trend of the relative sea level.

Microfacies description

Open marine below the storm wave base

Microfacies 1 (or MF1) (Pl. 6, Figs. 1-3)

Definition: silty burrowed mudstones and wackestones with a few microbioclasts composed of crinoids, ostracods (disarticulated or attached carapaces, Pl. 6, Fig. 3), mollusks, brachiopods (with spines) and trilobites. These latter are sometimes highly perforated and corroded (Pl. 6, Figs. 1-2). Crinoids have sponge perforations and pitting patterns. Rare sponge spicules are associated with a discrete fenestral fabric (see a reworked fragment, Pl. 9, Fig. 4). Rare phosphatic grains, perhaps bioclasts, are also observed. The matrix is completely or partly microsparitized, as are the burrows. These latter can concentrate the microbioclasts or the quartzose silty grains (Pl. 6, Figs. 1, 4). Small hematitized bacterial microtufts, black and reddish spheroids (Pl. 6, Fig. 3),

and curved filaments are disseminated in the matrix; they are similar to those described in the D-C series of the Puech de la Suque section (CASIER *et al.*, 2001) or in the Frasnian-Famennian series (PR AT *et al.*, 1999) in the same area of the Montagne Noire. Pressure solution microseams contain idiotopic dolomite crystals and bitumen.

Open marine near the storm wave base

Microfacies 2 (or MF2) (Pl. 6, Figs. 3-6)

Definition: laminated silty packstones rich in microbioclasts (< 100 µm, Pl. 6, Fig. 5) of ostracods, mollusks, crinoids, brachiopods, and rare kamaenid algae or small-sized phosphatic shells. The laminations are thin (< 1 mm, Pl. 6, Fig. 4) and related to the abundance of the microbioclasts. They are also disturbed by vertical burrows (Pl. 6, Fig. 4). Irregular peloids or perhaps micritized grains, are sporadically present. The matrix is completely or partly microsparitized (Pl. 6, Fig. 6). Pressure solution seams are present, and, as in MF1, they contain idiotopic dolomite crystals. They strengthen the laminar structure. This latter is sometimes due to increase of clays forming small regular ripples. Abundant flattened, black organic-matter fragments strengthen the laminar structure. Microbial? dichotomic tufts similar to those of MF1 are observed (Pl. 6, Fig. 6).

Open marine within the fair-weather wave base

Microfacies 3 (or MF3) (Pl. 7, Figs. 1-3)

Definition: fine- to medium-grained, well-sorted, and cross-bedded silty packstones rich in microbioclasts (± 100 µm) of mollusks, brachiopods, crinoids, bryozoan, ostracods (frequently with thick walls), trilobites, rare kamaenid algae, and small-sized shelly phosphatic fragments. Peloids are also present. The laminations (1 mm to 1 cm) are due to millimetre-thick layers of silty and flattened organic matter fragments. Microspar is similar to that of the previous microfacies and is distributed patchily in the matrix. Bioturbation is rare.

Microfacies 4 (or MF4) (Pl. 7, Figs. 4-6)

Definition: medium-grained, well-sorted and cross-bedded silty peloidal packstones with small sized (approximately 250 µm) subangular to subrounded microbreccias (Pl. 7, Fig. 5), oolites (Pl. 7, Fig. 6), angular broken oolite fragments (Pl. 7, Fig. 4), and bioclasts. The bioclasts are the same as in the previous facies but are larger, ranging from 100 to 500 µm, and contain numerous brachiopod spines. Fine-grained phosphatic grains or larger shells (Pl. 7, Fig. 5) are present. The microbreccias consist of mudstones and wackestones with a few mollusks and ostracods or of phosphatic microsparitized mudstones. The nuclei of the oolites are composed of bioclasts and sometimes of a microbreccia. Pressure solution seams are well developed. Laminations are of the same type as previous microfacies.

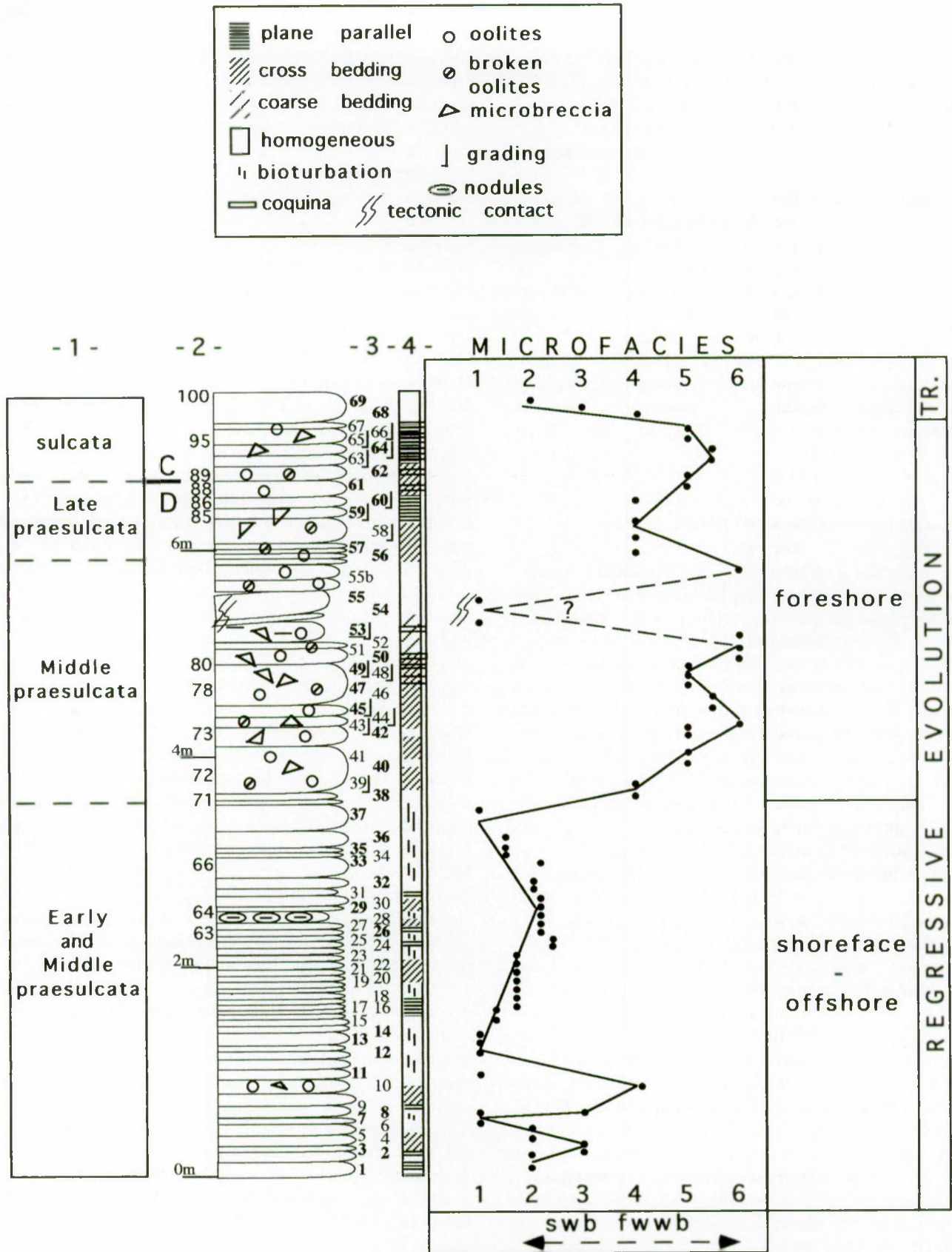


Fig. 2 — Lithological column of the La Serre Global Stratotype Section and Point (LS-E' trench) and position of sedimentological and ostracod samples (3). The ostracod samples are in bold characters. Conodont zonation (1) after GIRARD (1994) and number of beds (2) after FLAJS & FEIST (1988). Abbreviations: C = Carboniferous, D = Devonian, swb = normal storm wave base, fwwb = normal of fair-weather wave base, TR. = transgressive evolution, REG. = regressive evolution.

Microfacies 5 (or MF5) (Pl. 8, Figs. 1-3; Pl. 9, Figs. 4-6) Definition: medium- to coarse-grained, well-sorted and cross-bedded recrystallized (microspar) bioclastic packstones with abundant oolites (0.5-1 mm; Pl. 8, Fig. 1), angular broken oolite fragments, and angular to subangular microbreccias (Pl. 8, Fig. 3). Bioclasts are of the same composition as in previous microfacies; they are larger (1 mm to 1 cm, Pl. 8, Fig. 2) and embedded within the laminar structure. Rare algal (Codiaceae) fragments are present. A few quartz silt grains are dispersed in the matrix. The microbreccias are common and correspond probably to extraclasts reported in this profile by FLAJS & FEIST (1988). They are quite large (0.1 to 1 cm) and consist of reworked fragments of MF1, MF2, MF3 and MF4, the latter being composed of angular oolite packstone. Graded bedding is occasionally observed as bioturbation figures. Centimetric coquina levels (brachiopods, mollusks, crinoids) are interstratified within the microfacies.

Microfacies 6 (or MF6) (Pl. 8, Figs. 4-6; Pl. 9, Figs. 1-3) Definition: coarse to very coarse microconglomeratic bioclastic and oolitic packstone with angular to subangular centimetric microbreccias composed of the previous microfacies (Pl. 8, Figs. 4, 5; Pl. 9, Figs. 3-6; see also illustrations of bed 89 in FLAJS & FEIST, 1988). They are also composed of fenestral peloidal wackestone (Pl. 9, Fig. 4) not seen before as well as polygenic microbreccias (Pl. 8, Fig. 4). Numerous black to brown microsparitized mudstone microbreccias of MF1 (Pl. 8, Fig. 5; Pl. 9, Figs. 3, 5, 6) are associated particularly with this microfacies. A few microbreccias are oolitized. These moderately well-sorted fragments are broadly cross-bedded and moderately to poorly sorted. They are associated with oolites and angular broken oolite fragments of the same size as in previous MF5. Bioclasts are large (1 cm) and consist mainly of bryozoan, brachiopods, crinoids, trilobites, mollusks, and ostracods. Centimetre-sized coquina levels (brachiopods, mollusks, crinoids) are interstratified within the microfacies and display normal grading. The shell beds have an erosive, often irregularly scoured base, and the shells are sometimes imbricated. Codiacean algal fragments (*Hedstroemia*, Pl. 8, Fig. 6) are present. Bioclasts have ferruginous microspar filling sponge or fungal? perforations (Pl. 9, Figs. 1, 2) and microbreccias can contain numerous microbial ferruginous tufts or thin ferruginous coatings (Pl. 9, Fig. 3) similar to the ones illustrated by PRÉAT *et al.* (1999) from the Devonian of the Montagne Noire.

Microfacies and paleoenvironmental interpretation

The standard sequence (MF1 to MF6) has a quite abrupt transition from shallow hemipelagic environments (MF1) to shoreface-foreshore microbioclastic and ooidal shoals (MF2-MF5) reaching the upper beach foreshore (MF6). Weakly graded coquina levels up to several cm thick represent proximal tempestites (AIGNER, 1985) and are associated with MF5 and MF6. The oolites are clearly

high-energy deposits: the substrate was constantly and rapidly shifting, most of the energy being provided by tidal currents. No evidence of subaerial emergence was found, nor any sedimentary structures indicating intertidal restricted environments. Microbreccias are abundant in MF5 and MF6, they are moderately to poorly sorted, subangular to subrounded and show mixing of different eroded microfacies. All this supports strong and brief erosional phases.

These phases have also been supported by reworking of conodont associations representative of the entire Upper Devonian (FLAJS & FEIST, 1988).

Well-sorted MF2-M3-MF4 carbonate sands consist of parallel laminations that are often slightly inclined (low-angle laminations) and contain minor discordances. These minor truncation planes resulted from brief periods of erosion and separate the laminations into discrete sets. This type of stratification is similar to hummocky cross-stratification (HARMS *et al.*, 1975; BOURGEOIS, 1980). Small-scale hummocks and swales are visible on the field (beds containing samples 25-27, Fig. 2). They could indicate the transitional zone *sensu* AIGNER (1985), around 10 m water depth. The fine-grained burrowed sands (MF2-3) suggest the shoreface environment and the medium sandy and shelly beds (MF4-5-6) indicate the foreshore *sensu* COLLINSON *et al.* (1978). These fine- to medium-grained sands containing bioclasts and oolites were probably transported through tidal channels and finally spread over the shelf bottom.

Silty, burrowed mudstones and wackestones of MF1 represent the muddy background sediments and were inhabited by infaunal deposit feeders as suggested by burrowing. The environment inferred is that of quiet and deeper waters below the storm wave base and without evidence of turbidites and mudflows. Sedimentation is assumed to have been below the photic zone as suggested by the absence of algae. This facies is quite similar to the one described in the D-C series of Puech de la Suque section (CASIER *et al.*, 2001), and free oxygen was episodically low as suggested by the development near the seawater-sediment interface of possible iron-microbial filaments similar to those of the Lower Devonian of the Czech Republic (MAMET *et al.*, 1997), of the Devonian of the Montagne Noire (PRÉAT *et al.*, 1999), and of the mid-Jurassic of Normandy (PRÉAT *et al.*, 2000).

The sea level trend points to a general regression starting near the Hangenberg Horizon *sensu* FEIST *et al.* (2000), from our sample 37 (Fig. 2), to the top of the section (sample 64) as showed by the shift of microfacies 1 to microfacies 6 and the quite abrupt appearance of proximal coquina layers, interpreted tempestites, toward the upper part of the section. The energy level was very high as indicated by the broken oolites, the microbreccias, and the lamination patterns. Sea-level fluctuation was probably about ten meters or more as indicated by the erosion of microfacies 1 whose fragments form part of the microbreccias of microfacies 6. The uppermost part of the section is slightly transgressive.

Ostracods of the D-C GSSP (J.-G. Casier & F. Lethiers)**Introduction**

In the Montagne Noire, ostracods from the D-C transition have been studied in the Puech de la Suque section by LETHIERS & FEIST (1991) and CASIER & LETHIERS (*in CASIER et al.*, 2001). This section is located on the south-eastern slope of the Puech de la Suque Hill, 1.8 km southeast of St. Nazaire-de-Ladarez (Fig. 1). Altogether 4,750 ostracods were extracted on both sides of the D-C boundary in the Puech de la Suque section, and 71 species have been identified, half of which belong to the Thuringian ecotype. The study has shown that a maximum of 30 percent of species disappeared in the Puech de la Suque section during the Hangenberg Event, a low rate of extinction compared to that observed close to the Frasnian-Famennian (=F-F) boundary where 75 % of the ostracod species vanished. This study displayed also that the Hangenberg Event differs from the F-F boundary event by the absence of ostracod disaster species.

Thirty-eight samples were collected in the La Serre D-C GSSP for the study of ostracods, and about 1,000 carapaces and a few valves have been extracted by the hot acetolysis method (LETHIERS & CRASQUIN-SOLEAU, 1988). In six samples (LSDC 2, LSDC 14, LSDC 26, LSDC 35, LSDC 56 and LSDC 57) ostracods are absent, and only one fifth of the ostracods come from the base of the Carboniferous. In general, ostracods are poorly preserved; however, about two thirds could be identified.

Ostracods are very rare in the base of the section from sample LSDC 1 to sample LSDC 35. They are abundant from sample LSDC 36 to sample LSDC 42 and are rare in the rest of the section. Reworking is widespread. Oolites and microbreccia are abundant from sample LSDC 39 to

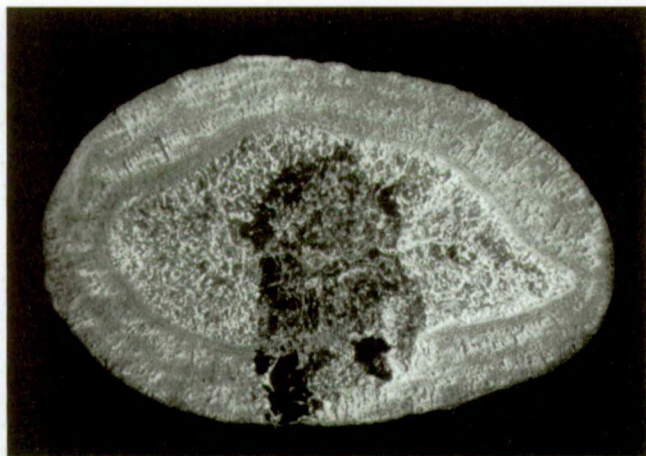


Fig. 3 — Oolite having grown by accretion around the ostracod species *Bairdia extenuata* NAZAROVA, 1951. IRScNB n° b3921. x 125.

the top of the section, and extremely abundant close to the D-C boundary. Several oolites have grown by accretion around ostracods (Fig. 3).

List and systematic placement of species occurring in the La Serre D-C GSSP

- Class OSTRACODA LATREILLE, 1802
 Order Palaeocopida HENNINGSMOEN, 1953
 Suborder Palaeocopina HENNINGSMOEN, 1953
 Superfamily Primitiopsacea SWARTZ, 1936
 Family Graviidae POLENOVA, 1952
 – *Coryellina* cf. *tenuisulcata* OLEMPKA, 1979 (Pl. 1, Fig. 2).
 – *Coryellina* sp. A, aff. *grandis* ROBINSON? 1978 *sensu* CASIER & LETHIERS (2001).
 Family Primitiopsidae SWARTZ, 1936
 – *Clavofabellina?* sp. indet. (Pl. 1, Fig. 3).
 Superfamily Kirkbyacea ULRICH & BASSLER, 1906
 Family Amphissitidae KNIGHT, 1928
 – *Amphissites* sp. A CASIER & LETHIERS, 2001.
 – *Amphissites* sp. indet.
 Family Arcyzonidae KESLING, 1961
 – *Reticestus* sp. OLEMPKA, 1979 (Pl. 1, Fig. 1a,b).
 Superfamily Youngiellacea KELLETT, 1933
 Family Youngiellidae KELLETT, 1933
 – *Youngiella calvata* (GREEN, 1963) (Pl. 1, Fig. 4a,b).
 Suborder Paraparchiticopina GRAMM, 1975
in GRAMM & IVANOV (1975)
 Superfamily Paraparchitacea SCOTT, 1959
 Family Paraparchitidae SCOTT, 1959
 – *Shivaella* sp. 1 OLEMPKA, 1981 (Pl. 1, Fig. 5a,b).
 – *Shivaella* sp. indet.
 – *Shemonaella* sp. *sensu* BUSCHMINA (1975) (Pl. 1, Fig. 6a,b).
 – *Shishaella lenica* (BUSCHMINA, 1970) (Pl. 1, Fig. 7a,b).
 – *Shishaella longiformis* (BUSCHMINA, 1970) (Pl. 1, Fig. 8a,b).
 Suborder Platycopina SARS, 1866
 Superfamily Kloedenellacea ULRICH & BASSLER, 1908
 Family Knoxitidae EGOROV, 1950
 – *Knoxiella* aff. *bastachica* (BUSCHMINA, 1970) (Pl. 1, Fig. 9a,b).
 – *Egorovina egorovi* (NAZAROVA, 1951)? (Pl. 1, Fig. 10).
 Superfamily Cytherellacea SARS, 1866
 Family Cavellinidae EGOROV, 1950
 – *Sulcella (Sulcella) jonesi* OLEMPKA, 1999 (Pl. 1, Fig. 11a,b).
 – *Sulcella (Postsulcella?)* nov. sp. A (Pl. 2, Fig. 1a,b).
 – *Sulcella (Sulcella)* sp. A.
 Order Podocopida SARS, 1866
 Suborder Metacopina SYLVESTER-BRADLEY, 1961
 Superfamily Quasillitacea CORYELL & MALKIN, 1936
 Family Quasillitidae CORYELL & MALKIN, 1936
 – *Ovatoquasillites slowikensis* (OLEMPKA, 1981).
 – *Ovatoquasillites?* sp. indet. (Pl. 2, Fig. 3).
 Superfamily Healdiaea HARLTON, 1933
 Family Healdiidae HARLTON, 1933
 – *Healdia thuringensis* GRÜNDEL, 1961 (Pl. 2, Fig. 4a,b).
 – *Timorhealdia ratra* GRÜNDEL, 1961 (Pl. 2, Fig. 5a,b).
 – *Timorhealdia* aff. *nitidula* (RICHTER, 1869) *sensu* OLEMPKA (1997) (Pl. 2, Fig. 6).

Suborder Podocopina Sars, 1866

Superfamily Bairdiocypridacea SHAVER, 1961

Family Bairdiocyprididae SHAVER, 1961

- *Healdianella lumbiformis* LETHIERS & FEIST, 1991? (Pl. 2, Fig. 7a,b).
- *Healdianella alba* LETHIERS, 1981 (Pl. 2, Fig. 2a,b, 8a,b).
- *Healdianella* cf. *insolita* (BUSCHMINA, 1977) (Pl. 2, Fig. 9a,b).
- *Healdianella* aff. *bispinosa* GRÜNDEL, 1961 *sensu* OLEMPKA (1979) (Pl. 2, Fig. 10a,b).
- *Bairdiocypris* cf. *arcuatus* (ROME, 1971) (Pl. 2, Fig. 11a,b).
- *Bairdiocypris* cf. *felix* ROZHDESTVENSKAJA 1972 (Pl. 2, Fig. 12b).
- *Bairdiocypris* sp. indet.

Family Pachydomellidae BERDAN & SOHN, 1961

- *Decoranewsomites blesii* (OLEMPKA, 1979) (Pl. 3, Fig. 1a,b, 2).
- *Micronewsomites* cf. *elatus* (LETHIERS, 1978) (Pl. 3, Fig. 3a,b).
- *Microcheilinella voronensis* SAMOILOVA, 1970 (Pl. 3, Fig. 4a,b).
- *Microcheilinella* nov. sp. A (Pl. 3, Fig. 5a,b).
- *Microcheilinella bushminae* OLEMPKA, 1981 (Pl. 3, Fig. 6a,b).
- *Microcheilinella* sp. *sensu* OLEMPKA (1979) (Pl. 3, Fig. 7a,b).
- *Microcheilinella* sp. indet.
- *Grammia* nov. sp. A CASIER & LETHIERS, 2001 (Pl. 3, Fig. 8).
- *Rectoplacera?* cf. sp. n. 1 OLEMPKA, 1997 (Pl. 3, Fig. 9a,b).

Family Gerodiidae GRÜNDEL, 1962

- *Gerodia warsteinia* BECKER, 1993 (Pl. 3, Fig. 10a,b).

Family Rectonariidae GRÜNDEL, 1962

- *Orthonaria rectagona* (GRÜNDEL, 1962) (Pl. 3, Fig. 11a,b).
- *Orthonaria* sp. A (Pl. 3, Fig. 12a,b).
- *Rectonaria inclinata* GRÜNDEL, 1961? (Pl. 3, Fig. 13).

Superfamily Bairdiacea Sars, 1888

Family Acratiidae GRÜNDEL, 1962

- *Famenella angulata perparva* LETHIERS & FEIST, 1991 (Pl. 3, Fig. 14a,b).
- *Famenella postkairovaensis* LETHIERS & CASIER, 1996 (Pl. 4, Fig. 1a,b).
- *Acratia* cf. *pskovensis* EGOROV, 1953 (Pl. 4, Fig. 2a,b).
- *Acratia bidecliva* LETHIERS & FEIST, 1991 (Pl. 4, Fig. 3a,b).
- *Acratia* cf. *gassanovae* EGOROV, 1953 *sensu* LETHIERS (1981) (Pl. 4, Fig. 4a,b).
- *Acratia sagittaeformis* LETHIERS & CASIER, 1999 subsp. (Pl. 4, Fig. 5a,b).
- *Acratia cooperi* GRÜNDEL, 1962 (Pl. 4, Fig. 6a,b).
- *Posneria* nov. sp. A, aff. *nasuta* ROZHDESTVENSKAJA, 1972 (Pl. 4, Fig. 7a,b).
- *Camdenidea?* sp. indet. (Pl. 4, Fig. 8a,b).
- *Clinacratia clinata* (BLUMENSTENGEL, 1965) (Pl. 4, Fig. 9).
- *Ceratacratia cerata* (BLUMENSTENGEL, 1965).

Family Bairdiidae Sars, 1888

- *Bairdianella* aff. *cuspis* BUSCHMINA, 1970 *sensu* KOTSCHETKOVA & JANBULATOVA (1987) (Pl. 4, Fig. 10a,b).
- *Bairdia* (*B.*) *feliumgibba* BECKER, 1982 (Pl. 4, Fig. 11a,b).
- *Bairdia* (*B.*) cf. *feliumgibba* BECKER, 1982 (Pl. 4, Fig. 12).
- *Bairdia* (*B.*) *extenuata* NAZAROVA, 1951 (Pl. 4, Fig. 13a,b).
- *Bairdia* (*B.*) *eleziana* EGOROV, 1953 (Pl. 5, Fig. 1a,b).
- *Bairdia* (*B.*) cf. *curta* M'COY, 1844 (Pl. 5, Fig. 2a,b).
- *Bairdia* (*B.*) sp. A. BECKER, 1993 (Pl. 5, Fig. 3a,b).
- *Bairdia* (*R.*) cf. *altiformis* BUSCHMINA, 1984 *sensu* WANG (1988) (Pl. 5, Fig. 4a,b).
- *Bairdia* (*R.*) *superba* LETHIERS, 1981 (Pl. 5, Fig. 5a,b).

- *Bairdia* (*C.*) cf. *strangulata* LETHIERS, 1981 (Pl. 5, Fig. 6).
- *Bairdia* sp. indet.
- *Processobairdia spinomarginata* BLUMENSTENGEL, 1965 (Pl. 5, Fig. 7a,b).
- *Processobairdia?* sp. indet.
- *Bairdiocypris subvirga* BUSCHMINA, 1979 (Pl. 5, Fig. 8).
- *Bairdiocypris* aff. *nabiancunensis* (WANG, 1988) (Pl. 5, Fig. 9a,b).
- *Bairdiocypris* cf. *quasielongata* BUSCHMINA, 1968 (Pl. 5, Fig. 10).

Order Myodocopida Sars, 1866

Suborder Myodocopina Sars, 1866

Superfamily Entomozoacea PRIBYL, 1951

Family Entomozoidae PRIBYL, 1951

- *Richterina* (*R.*) *striatula* (RICHTER, 1898)? (Pl. 5, Fig. 11).
- *Richterina* (*F.*) *semen* (JONES, 1895) (Pl. 5, Fig. 12).

Distribution of ostracods in the D-C GSSP (Table 1)

Despite the scarcity of specimens, especially close to the D-C boundary, and in the base of the Carboniferous, the ostracod fauna is very diversified in the La Serre D-C GSSP. Seventy-one species are identified, 58 in the Devonian and 29 in the Carboniferous. A maximum of 15 species occur on both sides of the boundary, but several species present in the Devonian of the La Serre D-C GSSP are known from the base of the Carboniferous in other sections. The Devonian species *Rectoplacera?* cf. sp. n. 1 OLEMPKA, 1997, *Acratia cooperi* GRÜNDEL, 1962, *Bairdiocypris* cf. *quasielongata* BUSCHMINA, 1968, *Youngiella calvata* (GREEN, 1963), *Healdia thuringensis* GRÜNDEL, 1961, *Ovatoquasillites slowikensis* (OLEMPKA, 1981) e.g., are known from the Carboniferous of Poland (OLEMPKA, 1997) or of the Puech de la Suque section in the Montagne Noire (CASIER *et al.*, 2001). On the other hand, the two Carboniferous species *Amphissites* sp. A and *Famenella angulata perparva* (LETHIERS & FEIST, 1991) are known from the Famennian of the Puech de la Suque section (CASIER *et al.*, 2001), and the species *Healdianella* aff. *bispinosa* GRÜNDEL, 1961 *sensu* OLEMPKA (1979) and the probable species *Rectonaria inclinata* GRÜNDEL, 1961 are known from the Famennian of the Holy Cross Mountains of Poland (OLEMPKA, 1979, 1997).

Paleoecology of ostracods

The three-fourths of ostracod species present in the La Serre section belong to the Eifelian ecotype of BECKER (*in* BANDEL & BECKER, 1975). This ecotype is generally indicative of well-oxygenated neritic conditions. Another fourth of the ostracod species present in the La Serre section belongs to the Thuringian ecotype of BECKER (*Ibid.*). The most characteristic belong to the genera *Orthonaria* BLUMENSTENGEL, 1965, *Rectonaria* GRÜNDEL, 1961, *Rectoplacera* BLUMENSTENGEL, 1965, *Grammia* KOTSCHETKOVA, 1980, *Clinacratia* BLUMENSTENGEL, 1979, *Healdia* ROUNDY, 1926, *Timorhealdia* BLESS, 1987, and *Gerodia* GRÜNDEL, 1962. They are indicative of

deeper-, calmer-, and maybe colder-water environments. Finally, the Myodocopid ecotype, indicative of calm and poorly oxygenated water conditions, is not present in the D-C GSSP. The occurrences of three valves of *Richterina (F.) semen* (JONES, 1895) and of a carapace of a possible *Richterina (R.) striatula* (RICHTER, 1898) in the Famennian part of the section are not significant.

The number of ostracods, the proportion of instars and adults ostracods, and the percentage of ostracod species belonging to the Eifelian and to the Thuringian ecotypes are highly variable in the D-C GSSP. This is indicative of important changes in the environment. From the sample 1 to the sample 35, ostracods are very rare and even absent in 4 samples (LSDC 2, LSDC 14, LSDC 26 and LSDC 35). One third belongs to the Thuringian ecotype, and most are instars found between the sieve fractions 100 µm and 250 µm. The inferred environment was moderately deep but just above storm wave base. In sample LSDC 36, ostracods are more abundant, the proportion between adults and instars is not abnormal, and 50% of the ostracod species belong to the Thuringian ecotype. The next sample (LSDC 37) is very rich in ostracods, which are very diverse and 40 percent of species belong to the Thuringian ecotype. These two last beds were deposited in a deeper and calmer environment below storm wave base. From sample LSDC 38 to sample LSDC 53, which are very rich in oolites and bioclasts, ostracods are relatively abundant; and Thuringian ecotype ostracods still present but in lower and variable proportion. The inferred environment was very agitated, again above storm wave base.

The samples LSDC 54 and LSDC 55 collected in the two beds associated with a tectonic contact, which may be due to sliding or faulting, contain an abnormal number of instars and one third of ostracods belong to the Thuringian ecotype. These ostracods indicate an environment close to storm wave base. In the two following samples (LSDC 56 and LSDC 57) ostracods are totally absent. The agitation of the environment is strong as displayed by the occurrence of numerous oolites.

From the sample LSDC 59 to the sample LSDC 64, and consequently from across the D-C boundary, ostracods belong mainly to the Eifelian ecotype indicative of a shallower marine environment. Only the sample LSDC 60, located some cm under the D-C boundary, is richer in ostracods and contains two species belonging to the Thuringian ecotype. This is indicative maybe of a brief return to deeper water conditions but always above storm wave base. Nevertheless, the presence of microbreccia in this bed and consequently of reworked ostracods is maybe responsible for misinterpretations. Finally the samples LSDC 68 and LSDC 69 which contain a greater number of ostracods belonging to the Thuringian ecotype, mark the rapid return to deeper water conditions below storm wave base.

The Hangenberg Event in the D-C GSSP

For GIRARD (1994), the bed 68 of FLAJS & FEIST (1988), rich in *Wocklumeria*, defines the time interval immedi-

ately preceding the period of global sedimentary change in relation to the Hangenberg Event. For the same author, the siliciclastic-calcareous unit of FLAJS & FEIST (1988), between our samples LSDC 53 and LSDC 59, may be equivalent to the Hangenberg Sandstone and the Seiler conglomerate in the Sauerland. Furthermore, in a recent description of the section, FEIST *et al.* (2000) stated that the Hangenberg black shale responsible for the Hangenberg Event might correlate precisely with the bed 69 of FLAJS & FEIST (1988). The abundance and the diversity of ostracods, obviously linked to the great energy of the environment, are very low above this bed. However from the 37 ostracod species recorded below the bed 69, only 12 are not recognized above but some carapaces found above the bed 69 were certainly reworked. The important local change in the sedimentation can at least explain in part this modification of the ostracod fauna.

Another change in the ostracod fauna would happen in relation to the beds in which we have collected samples LSDC 54 and LSDC 55. These are associated with a tectonic contact maybe due to sliding or faulting. From the 55 ostracod species recorded below these beds, only 20 are present above. Moreover ostracods are also absent in the two samples (LSDC 56 and LSDC 57) following these beds. Nevertheless several species, *e.g. Rectoplacera?* cf. sp. n. 1 OLEMPKA, 1997, *Acratia cooperi* GRÜNDEL, 1962, and *Bairdiocypris* cf. *quasielongata* BUSCHMINA, 1968, are known to survive in other sections.

In any case, we can estimate that the Hangenberg Event was not as catastrophic for the ostracod fauna in the La Serre GSSP, as it was in Thuringia (Germany) where 70% of ostracods of the Thuringian and Eifelian ecotypes disappeared (BLUMENSTENGEL, 1993) or in the Holy Cross Mountains of Poland where 60% of the ostracods of the Thuringian ecotype and all ostracods of the Myodocopid ecotype disappeared (OLEMPKA, 1997).

No ostracod assemblage indicative of dysaerobic water conditions have been found in the La Serre section. La Serre was probably not reached by hypoxic waters, or the event was too rapid to permit the installation of disaster species, conversely to what we have observed during the Kellwasser Event close to the F-F boundary in several sections.

Comparison with the Puech de la Suque section

Twenty-seven ostracod species at the maximum are common to the Puech de la Suque section and the La Serre section. These species are the following: *Amphissites* sp. A CASIER & LETHIERS in CASIER *et al.*, 2001, *Coryellina* cf. *tenuisulcata* OLEMPKA, 1979, *Ovatoquasilites slowikensis* (OLEMPKA, 1981), *Healdianella* cf. *insolita* (BUSCHMINA, 1977), *Bairdiocypris* cf. *felix* ROZHDESTVENSKAJA, 1972, *Decoranewsomites blessi* (OLEMPKA, 1979), *Microcheilinella voronensis* SAMOILOVA, 1970, *Grammia* nov. sp. A CASIER & LETHIERS in CASIER *et al.*, 2001, *Rectoplacera?* cf. sp. n. 1 OLEMPKA, 1997, *Orthonaria rectagona* (GRÜNDEL, 1962), *Rectonaria inclinata* GRÜNDEL, 1961?, *Famenella angulata perparva*

LETHIERS & FEIST, 1991, *Acratia bidecliva* LETHIERS & FEIST, 1991, *Acratia sagittaeformis* LETHIERS & CASIER, 1999 subsp., *Acratia cooperi* GRÜNDEL, 1962, *Clinacratia clinata* (BLUMENSTENGEL, 1965), *Ceratacratia cerata* BLUMENSTENGEL, 1965, *Bairdia (B.) feliumgibba* BECKER, 1982, *Bairdia (B.) extenuata* NAZAROVA, 1951, *Bairdia (B.)* sp. A BECKER, 1993, *Bairdia (R.)* cf. *altiformis* BUSCHMINA, 1984 *sensu* WANG (1988), *Bairdia (R.) superba* LETHIERS, 1981, *Processobairdia spinomarginata* BLUMENSTENGEL, 1965, *Bairdiacypris* cf. *quasielongata* BUSCHMINA, 1968, *Richterina (F.) semen* (JONES, 1895), and maybe *Healdianella lumbiformis* LETHIERS & FEIST, 1991, and *Richterina (R.) striatula* (RICHTER, 1898).

The differences of depth and in the energy of the environments explain why only one-third of ostracod species are common to the two sections. In the Puech de la Suque section, half of ostracod species belong to the Thuringian ecotype generally indicative of deeper very calm waters below storm wave base, whereas in the La Serre D-C GSSP only one-fourth of the ostracods belong to this ecotype. Furthermore and conversely to the Puech de la Suque section, mydocopid ostracods indicative of calm and poorly oxygenated water conditions when they are dominant are almost absent in the La Serre section.

Conclusions

The ostracod fauna recognized in the D-C GSSP belongs either to the Eifelian ecotype or to a mixed assemblage of the Eifelian and of the Thuringian ecotypes. The number of ostracods, the percentage of ostracod species belonging to these two ecotypes, and the ratio between adults and instars are highly variable and give evidence for important changes in the conditions of the environment. Ostracods in oolites and reworked ostracods in elements of microbreccia are also present in several samples and are indicative of an environment with strong energy close to the D-C boundary.

The ostracod fauna displays a regressive trend from deep environments below storm wave base to highly agitated environments in the latest Devonian. But the evolution of the sea level curve is not completely recorded since two disturbed beds are present in the upper part of the profile. The transgression in the early Carboniferous is more rapid and began about 60 cm above the D-C boundary.

The disappearance of ostracods species in the La Serre section is related to the paleoecological change induced

by the transgression. Nevertheless, the rarity of ostracods close to the D-C boundary and in the base of the Carboniferous and the importance of the reworking do not permit to precisely evaluate the percentage of species disappearing during the Hangenberg Event. Nevertheless, the number of disappearing species seems to be less important in comparison with other sections investigated in Germany (BLUMENSTENGEL, 1993) and in Poland (OLEMPKA, 1997) as it is the case for the Puech de la Suque section (CASIER *et al.*, 2001).

The standard sequence in the D-C GSSP is composed of six carbonate microfacies (MF1 to MF6) and is quite abrupt-transition, from shallow hemipelagic environments (MF1) to shoreface-foreshore microbioclastic and ooidal shoals (MF2-MF5) reaching the upper beach foreshore (MF6). No evidence of subaerial emergence occurs, nor do any sedimentary structures indicate intertidal restricted environments. The sea level trend points to a general regression starting near the Hangenberg Horizon *sensu* FEIST *et al.* (2000), from our sample 37 (Fig. 2), to the top of the section (sample 64) as showed by the shift of microfacies 1 to microfacies 6 and the quite abrupt appearance of proximal coquina layers (tempestites). The energy level was very high as indicated by the broken oolites, the microbreccias and the lamination patterns. Sea-level fluctuations were probably about ten meters or more as indicated by the erosion of microfacies 1, whose fragments form part of the microbreccias of microfacies 6. The sea level evolution is finally transgressive above the D-C boundary at the top of the section.

On the whole the D-C boundary is associated with several eustatic fluctuations of about ten meters, and as a consequence the energy level was very high and variable. Most of the fossils are reworked and mixed.

The study of ostracods and of the rock facies confirms the statement of PAPROTH *et al.* (1991) that, because the lack of important stratigraphic guides and the existence of reworking, the La Serre section is far from being an ideal GSSP.

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Explanation of Plates

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...). The thin sections are deposited in the Department of Earth Sciences and Environment of the University of Brussels (Préat...). LSDC = Sample number (see Fig. 2 for the stratigraphical position). Dev = Devonian. Carb. = Carboniferous.

PLATE 1

- Fig. 1 — *Reticestus* sp. OLEMPKA, 1979. LSDC 37. Dev. IRScNB n° b3859. Carapace. a. Left lateral view. b. Dorsal view. x100.
- Fig. 2 — *Coryellina* cf. *tenuisulcata* OLEMPKA, 1979. LSDC 47. Dev. IRScNB n° b3860. Right lateral view of a valve. x100.
- Fig. 3 — *Clavofabellina?* sp. indet. LSDC 60. Dev. IRScNB n° b3861. Right lateral view of a valve. x75.
- Fig. 4 — *Youngiella calvata* (GREEN, 1963). LSDC 37. Dev. IRScNB n° b3862. Carapace. a. Left lateral view. b. Dorsal view. x100.
- Fig. 5 — *Shivaella* sp. 1 OLEMPKA, 1981. LSDC 68. Carb. IRScNB n° b3863. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 6 — *Shemonaella* sp. *sensu* BUSCHMINA (1975). LSDC 62B. Carb. IRScNB n° b3864. Carapace. a. Right lateral view. x45. b. Dorsal view. x50.
- Fig. 7 — *Shishaella lenica* (BUSCHMINA, 1970). LSDC 38. Dev. IRScNB n° b3865. Carapace. a. Right lateral view. b. Dorsal view. x90.
- Fig. 8 — *Shishaella longaformis* (BUSCHMINA, 1970). LSDC 63A Carb. IRScNB n° b3866. Carapace. a. Right lateral view. b. Dorsal view. x70.
- Fig. 9 — *Knoxiella* aff. *bastachica* (BUSCHMINA, 1970). LSDC 40. Dev. IRScNB n° b3867. Carapace. a. Left lateral view. b. Dorsal view. x80.
- Fig. 10 — *Egorovina egorovi* (NAZAROVA, 1951)? LSDC 50. Dev. IRScNB n° b3868. Poorly preserved left valve. x80.
- Fig. 11 — *Sulcella* (*Sulcella*) *jonesi* OLEMPKA, 1999. LSDC 38. Dev. IRScNB n° b3869. Carapace. a. Right lateral view. b. Dorsal view. x100.

PLATE 2

- Fig. 1 — *Sulcella* (*Postsulcella?*) nov. sp. A. LSDC 37. Dev. IRScNB n° b3870. Carapace. a. Left lateral view. b. Dorsal view. x100.
- Fig. 2 — *Healdianella alba* LETHIERS, 1981? LSDC 61. Dev. IRScNB n° b3871. Carapace. a. Left lateral view. b. Dorsal view. x100.
- Fig. 3 — *Ovatoquasillites?* sp. indet. LSDC 69. Carb. IRScNB n° b3872. Left valve. x100.
- Fig. 4 — *Healdia thuringensis* GRÜNDEL, 1961. LSDC 60. Dev. IRScNB n° b3873. Carapace. a. Right lateral view. b. Dorsal view. x90.

- Fig. 5 — *Timorhealdia ratra* GRÜNDEL, 1961. LSDC 68. Carb. IRScNB n° b3874. Carapace. a. Right lateral view. X95. b. Dorsal view. x90.
- Fig. 6 — *Timorhealdia* aff. *nitidula* (RICHTER, 1869) *sensu* OLEMPKA (1997). LSDC 37. Dev. IRScNB n° b3875. Broken carapace in right lateral view. x100.
- Fig. 7 — *Healdianella lumbiformis* LETHIERS & FEIST, 1991? LSDC 68. Carb. IRScNB n° b3876. Carapace. a. Right lateral view. b. Dorsal view. x90.
- Fig. 8 — *Healdianella alba* LETHIERS, 1981. LSDC 40. Dev. IRScNB n° b3877. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 9 — *Healdianella* cf. *insolita* (BUSCHMINA, 1977). LSDC 37. Dev. IRScNB n° b3878. Carapace. a. Right lateral view. b. Dorsal view. x95.
- Fig. 10 — *Healdianella* aff. *bispinosa* GRÜNDEL, 1961 *sensu* OLEMPKA (1979). LSDC 68. Carb. IRScNB n° b3879. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 11 — *Bairdiocypris* cf. *arcuatus* (ROME, 1971). LSDC 62B. Carb. IRScNB n° b3880. Carapace. a. Right lateral view. b. Dorsal view. x70.
- Fig. 12 — *Bairdiocypris* cf. *felix* ROZHDESTVENSKAJA, 1972. LSDC 37. Dev. IRScNB n° b3881. Carapace. a. Right lateral view. b. Dorsal view. x100.

PLATE 3

- Fig. 1 — *Decoranewsomites blessi* (OLEMPKA, 1979). LSDC 37. Dev. IRScNB n° b3882. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 2 — *Decoranewsomites blessi* (OLEMPKA, 1979). LSDC 37. Dev. IRScNB n° b3883. Left valve. x90.
- Fig. 3 — *Micronewsomites* cf. *elatus* (LETHIERS, 1978). LSDC 37. Dev. IRScNB n° b3884. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 4 — *Microcheilinella voronensis* SAMOILOVA, 1970. LSDC 37. Dev. IRScNB n° b3885. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 5 — *Microcheilinella* nov. sp. A. LSDC 64. Carb. IRScNB n° b3886. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 6 — *Microcheilinella bushminae* OLEMPKA, 1981. LSDC 40. Dev. IRScNB n° b3887. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 7 — *Microcheilinella* sp. *sensu* OLEMPKA (1979), LSDC 38. Dev. IRScNB n° b3888. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 8 — *Grammia* nov. sp. A CASIER & LETHIERS, 2001. LSDC 37. Dev. IRScNB n° b3889. Carapace in right lateral view. x100.
- Fig. 9 — *Rectoplacera?* cf. sp. n. 1 OLEMPKA, 1997. LSDC 37. Dev. IRScNB n° b3890. Carapace. a. Right lateral view. b. Ventral view. x100.
- Fig. 10 — *Gerodia warsteinia* BECKER, 1993. LSDC 68. Carb. IRScNB n° b3891. Carapace. a. Right lateral view. b. x55. Dorsal view. x60.
- Fig. 11 — *Orthonaria rectagona* (GRÜNDEL, 1962). LSDC 37. Dev. IRScNB n° b3892. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 12 — *Orthonaria* sp. A. LSDC 37. Dev. IRScNB n° b3893. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 13 — *Rectonaria inclinata* GRÜNDEL, 1961? LSDC 69. Carb. IRScNB n° b3894. Right lateral view of a broken carapace. x100.
- Fig. 14 — *Famenella angulata perparva* LETHIERS & FEIST, 1991. LSDC 68. Carb. IRScNB n° b3895. Carapace. a. Right lateral view. b. Dorsal view. x100.

PLATE 4

- Fig. 1 — *Famenella postkairovaensis* LETHIERS & CASIER, 1996. LSDC 37. Dev. IRScNB n° b3896. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 2 — *Acratia* cf. *pskovensis* EGOROV, 1953. LSDC 62B Carb. IRScNB n° b3897. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 3 — *Acratia bidecliva* LETHIERS & FEIST, 1991. LSDC 69. Carb. IRScNB n° b3898. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 4 — *Acratia* cf. *gassanovae* EGOROV, 1953 *sensu* LETHIERS (1981). LSDC 63. Carb. IRScNB n° b3899. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 5 — *Acratia sagittaeformis* LETHIERS & CASIER, 1999 subsp. LSDC 33. Dev. IRScNB n° b3900. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 6 — *Acratia cooperi* GRÜNDEL, 1962. LSDC 37. Dev. IRScNB n° b3901. Carapace. a. Right lateral view. b. Dorsal view. x100.

- Fig. 7 — *Posneria* nov. sp. A, aff. *nasuta* ROZHDESTVENSKAJA, 1972. LSDC 37. Dev. IRScNB n°b3902. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 8 — *Camdenidea?* sp. indet. LSDC 37. Dev. IRScNB n°b3903. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 9 — *Clinacratia clinata* (BLUMENSTENGEL, 1965). LSDC 37. Dev. IRScNB n°b3904. Right lateral view of a poorly preserved carapace. x100.
- Fig. 10 — *Bairdianella* aff. *cuspis* BUSCHMINA, 1970 *sensu* KOTSCHETKOVA & JANBULATOVA (1987). LSDC 49. Dev. IRScNB n°b3905. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 11 — *Bairdia* (*B.*) *feliumgibba* BECKER, 1982. LSDC 37. Dev. IRScNB n°b3906. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 12 — *Bairdia* (*B.*) cf. *feliumgibba* BECKER, 1982. LSDC 47. Dev. IRScNB n°b3907. Right lateral view of a carapace. x100.
- Fig. 13 — *Bairdia* (*B.*) *extenuata* NAZAROVA, 1951. LSDC 37. Dev. IRScNB n°b3908. Carapace. a. Right lateral view. b. Dorsal view. x100.

PLATE 5

- Fig. 1 — *Bairdia* (*B.*) *eleziana* EGOROV, 1953. LSDC 37. Dev. IRScNB n°b3909. Carapace. a. Right lateral view. b. Dorsal view. x90.
- Fig. 2 — *Bairdia* (*B.*) cf. *curta* M'Coy, 1844. LSDC 33. Dev. IRScNB n°b3910. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 3 — *Bairdia* (*B.*) sp. A BECKER, 1993. LSDC 38. Dev. IRScNB n°b3911. Carapace. a. Right lateral view. b. Dorsal view. x70.
- Fig. 4 — *Bairdia* (*R.*) cf. *altiformis* BUSCHMINA, 1984 *sensu* WANG (1988). LSDC 47. Dev. IRScNB n°b3912. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 5 — *Bairdia* (*R.*) *superba* LETHIERS, 1981. LSDC 37. Dev. IRScNB n°b3913. Carapace. a. Right lateral view. b. Dorsal view. x100.
- Fig. 6 — *Bairdia* (*C.*) cf. *strangulata* LETHIERS, 1981. LSDC 45. Dev. IRScNB n°b3914. Right lateral view of a carapace. x80.
- Fig. 7 — *Processobairdia spinomarginata* BLUMENSTENGEL, 1965. LSDC 37. Dev. IRScNB n°b3915. Carapace. a. Right lateral view. b. Dorsal view. x80.
- Fig. 8 — *Bairdiacypris subvirga* BUSCHMINA, 1979. LSDC 63A. Carb. IRScNB n°b3916. Right lateral view of a carapace. x90.
- Fig. 9 — *Bairdiacypris* aff. *nanbiancunensis* (WANG, 1988). LSDC 37. Dev. IRScNB n°b3917. Carapace. a. Right lateral view. b. Dorsal view. x90.
- Fig. 10 — *Bairdiacypris* cf. *quasielongata* BUSCHMINA, 1968. LSDC 37. Dev. IRScNB n°b3918. Right lateral view of a carapace. x100.
- Fig. 11 — *Richterina* (*R.*) *striatula* (RICHTER, 1898)? LSDC 59. Dev. IRScNB n°b3919. Right lateral view of a carapace. x100.
- Fig. 12 — *Richterina* (*F.*) *semen* (JONES, 1895). LSDC 37. Dev. IRScNB n°b3920. Right lateral view of a fragment of carapace. x100.

PLATE 6

- Figs. 1, 2 — Silty (small white dots) burrowed bioclastic mudstone. The micrite matrix is slightly recrystallized in a very fine-grained calcite microspar. Presence of a corroded, perforated and encrusted trilobite fragment. The encrustations are of two types, one is due to a thin black-brownish hematitic coating related to the corrosion (see the upper left part of the shell, Fig. 1), the other is related to the perforation and has been replaced by a fine equigranular calcite containing black spheroids (see Fig. 2 for details). A crinoidal fragment is present (lower left part of Fig. 1). Fig. 2 shows also microbioclasts (ostracods) in the matrix. A dichotomic blackish microbial? microtuft is present on the upper left corner of Fig. 1. Pr at 82/20, sample LSDC 37, microfacies 1, scale bar 600 µm (Fig. 1) and 100 µm (Fig. 2).
- Fig. 3 — Silty (small white dots) burrowed mudstone with thin ostracod shells. The micrite matrix is slightly recrystallized in a very fine-grained calcite microspar. The matrix contains abundant ferruginous black spheroids similar to those described by CASIER *et al.* (2001) in the Puech de la Suque section. Pr at 82/6, sample LSDC 11, microfacies 1, scale bar 240 µm.
- Figs. 4, 5 — Heavily burrowed silty mudstone. The original thin laminar structure is partly preserved (see lower left part of Fig. 4, outside of the vertical burrow). The micrite matrix is slightly recrystallized in a very fine-grained calcite microspar and contains small idiotopic brownish dolomite crystals. Presence of molluscan (upper right corner of Fig. 4), trilobite, ostracod and bivalve (central part of Fig. 5) fragments. Pr at 82/12 and 82/15, sample LSDC 36,

- microfacies 2, scale bar 600 μm (Fig. 4) and 240 μm (Fig. 5).
- Fig. 6 — Burrowed silty mudstone with small-sized dichotomic hematitic brownish microbial? tufts and spheroids similar to those described by CASIER *et al.* (2001) in the Puech de la Suque section. The micrite matrix is slightly recrystallized in a very fine-grained calcite microspar and contains small idiotopic brownish dolomite crystals. Pr at 82/11 sample LSDC 34, microfacies 2, scale bar 240 μm .

PLATE 7

- Fig. 1 — Thin laminar silty microbioclastic packstone. The laminations display low angle cross-bedding and are composed of plurimillimetric alternations of microbioclastic (ostracods, crinoids, molluscs, brachiopods) packstone/grainstone (upper half of the figure) and silty peloidal microbioclastic packstone (lower half of the figure) layers. The bottom of the photograph is the stratigraphical base. Pr at 85/9, sample LSDC 3, microfacies 3, scale bar 240 μm .
- Figs. 2, 3 — Partly burrowed fine-grained silty laminar microbioclastic packstone. The laminations are composed of the alternation of thicker (plurimillimetric-centimetric) bioclastic (crinoids, ostracods, brachiopods, mollusks) grainstone (lower half of Fig. 2 and Fig. 3) and thinner (millimetric) silty peloidal microbioclastic packstone (upper half of the Fig. 2) layers. Pr at 85/13 and 85/15, sample LSDC 9, microfacies 3, scale bar 240 μm (Fig. 2) and 100 μm (Fig. 3).
- Fig. 5 — Laminated medium-grained shelly (brachiopods, pelecypods, rare ostracods) packstone with numerous greyish-blackish subrounded-subangular micritic microbreccias and a few crinoidal fragments (centre of the photograph). Irregular stylolites are present around the grains. Pr at 82/3, sample LSDC 10, microfacies 4, scale bar 240 μm .
- Figs. 4, 6 — Burrowed medium-grained cross-bedded silty bioclastic packstone with broken micritic oolites (Fig. 4) and well-rounded oolites (Fig. 6). Bioclasts consist of ostracods, brachiopods, bryozoans with abundant crinoids (Fig. 6). Small broken oolite fragments can be confused with "peloids" (Fig. 4). Pr at 85/22 and 85/23, sample LSDC 39, microfacies 4, scale bars 240 μm .

PLATE 8

- Fig. 1 — Medium- to coarse-grained oolitic and bioclastic (ostracods and crinoids) (dolo)packstone. Nuclei of oolites consist of bryozoan and pelecypod fragments. A few oolites are broken (small angular fragments with broken cortex and/or nucleus). An oolitic microbreccia is also present (upper right corner). Irregular stylolites are observed along the small dolomite crystals. Pr at 82/29, sample LSDC 41, microfacies 5, scale bar 240 μm .
- Fig. 2 — Medium- to coarse-grained oolitic and bioclastic (bryozoan, crinoids and brachiopods) (dolo)packstone. Oolites are broken. The nucleus of the broken oolite in the upper left corner is an ostracod. Irregular stylolites are observed along the small dolomite crystals. This "shelly" layer (see the large brachiopod fragment) belongs to a thin "coquina layer" interstratified in the oolitic packstone. It represents a proximal tempestite (see text). Pr at 83/17, sample LSDC 49, microfacies 5, scale bar 240 μm .
- Fig. 3 — Medium- to coarse-grained oolitic and bioclastic (dolo)packstone with an angular microbreccia containing an ostracod shell (see lower part of the breccia). The micrite of the microbreccia is slightly recrystallized in a fine calcite microspar. Oolites and broken. Irregular stylolites are observed along the small dolomite crystals. Pr at 82/27, sample LSDC 41, microfacies 5, scale bar 240 μm .
- Figs. 4, 5 — Coarse- to very coarse-grained microbrecciated (dolo)packstone with numerous oolites, broken oolites and bioclasts (Fig. 5). The subangular to subrounded microbreccias are polygenic (Fig. 4) and contain various bioclasts (mollusks, brachiopods or ostracods, Fig. 5). Micritized grains are also present (Fig. 5). Blackish microbreccias contain more fine-grained organic matter and could come from erosion of microfacies 1. Their matrix is a calcite microspar. See also Pl. 9, Figs. 4-6. Pr at 83/28 and 83/24, sample LSDC 51A, microfacies 6, scale bars 240 μm (Fig. 4) and 600 μm (Fig. 5).
- Fig. 6 — Coarse-grained oolite (dolo)packstone. The oolites are partly to completely micritized and very often broken in small angular pieces. An algal fragment (the Codiacean *Hedstroemia*) is present on the left lower corner. Shelly fragment and microbreccia are also present (see Pl. 9, Fig. 1 and 3). Pr at 83/10, sample LSDC 46, microfacies 6, scale bar 240 μm .

PLATE 9

- Fig. 1 — Coarse-grained oolite-bioclastic (dolo)packstone. The blackish zones are parts of broken micritized oolites. The photograph shows a molluscan fragment with ferruginous microspar filling sponge or fungal? perforations similar to the ones illustrated by Pr at *et al.* (1999) in the Devonian of the Montagne Noire. Pr at 83/9, sample LSDC 46, microfacies 6, scale bar 100 μm .
- Fig. 2 — Microbrecciated and bioclastic coarse-grained (dolo)packstone. Bioclasts consists of perforated brachiopods. Perforations are due to long microbial ferruginous filaments orthogonal to the wall of the brachiopod fragment. Pr at 83/36, sample LSDC 52, microfacies 6, scale bar 100 μm .

- Fig. 3 — Same coarse-grained oolite-bioclastic (dolo)packstone as figure 1 showing a large subrounded micritic microbreccia containing numerous microbial ferruginous tufts and a very thin ferruginous coating similar to the ones illustrated by Pr at *et al.* (1999) in the Devonian of the Montagne Noire. Pr at 83/6, sample LSDC 46, microfacies 5, scale bar 240 μm .
- Fig. 4 — Coarse- to very coarse-grained microbrecciated (dolo)packstone with numerous oolites, and angular broken oolite fragments. The microbreccias show a stromatactoidal cavity. Pr at 83/26, sample LSDC 41A, microfacies 6, scale bar 600 μm .
- Figs. 5, 6 — Very coarse-grained (dolo)packstone with large micritic microbreccias rich in ostracods. The micrite is slightly recrystallized in a very fine-grained calcite microspar. Pr at 83/21 and 83/22, sample LSDC 50, microfacies 5, scale bars 240 μm (Fig. 5) and 100 μm (Fig. 6).

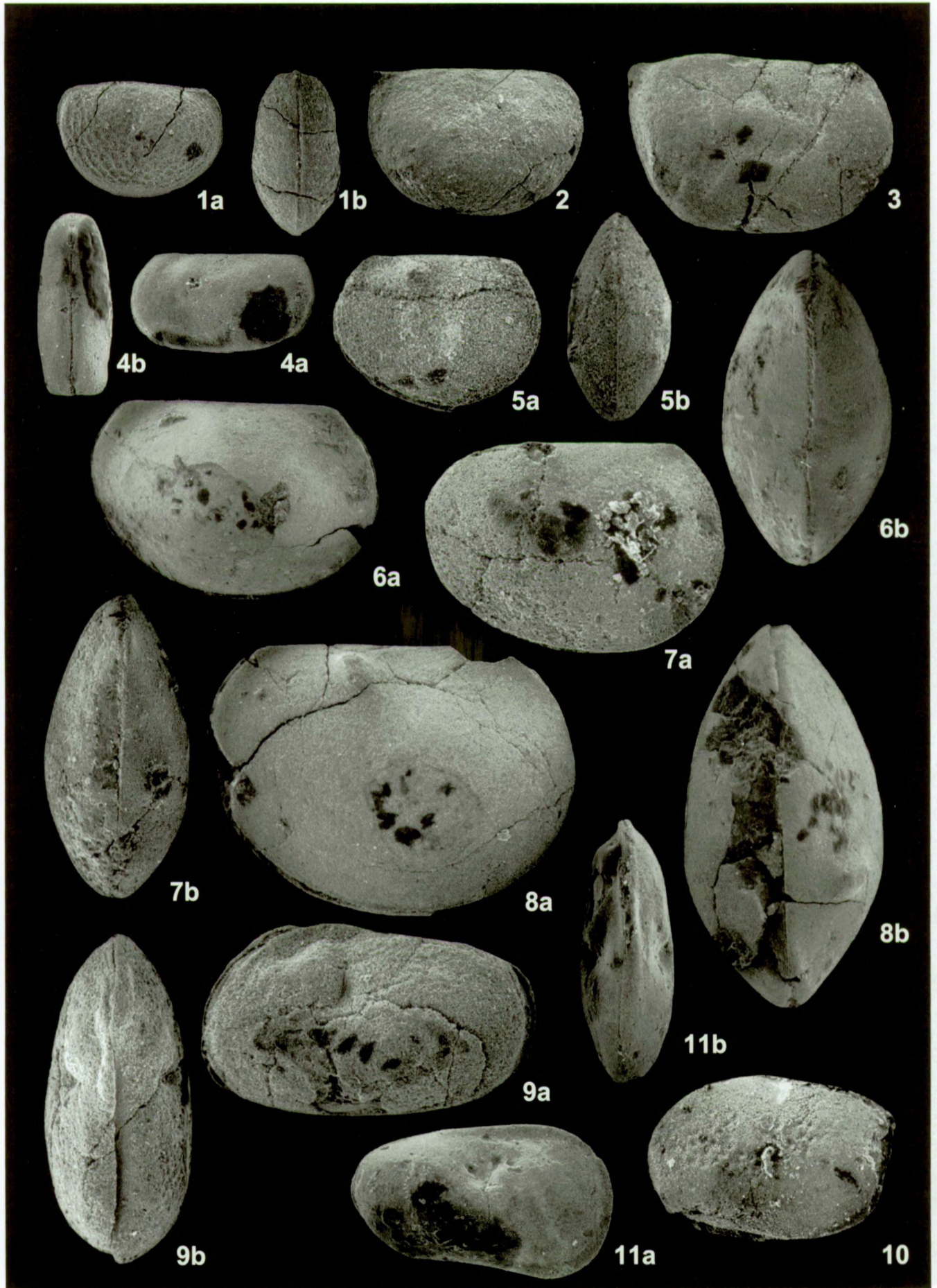


PLATE I

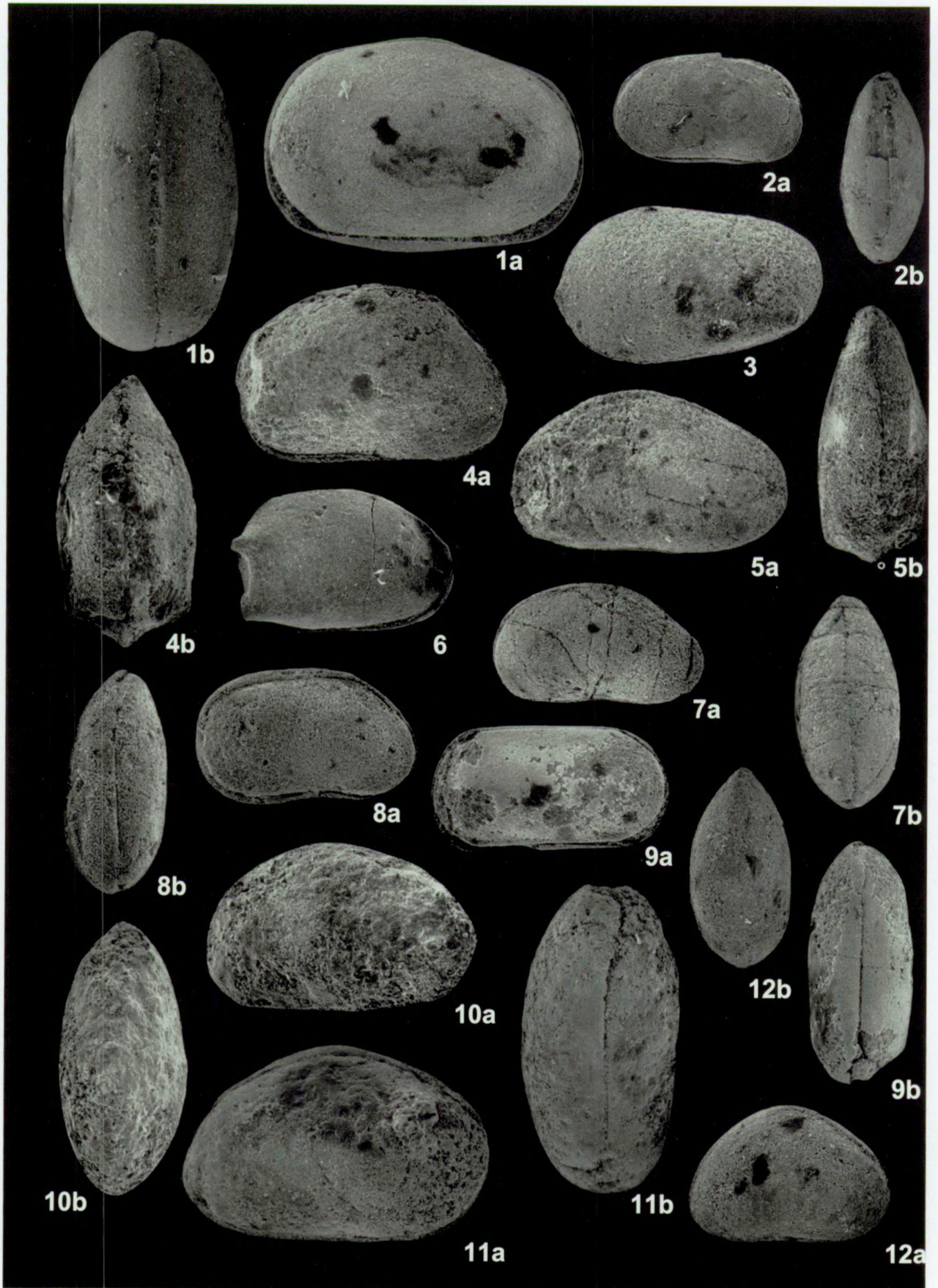


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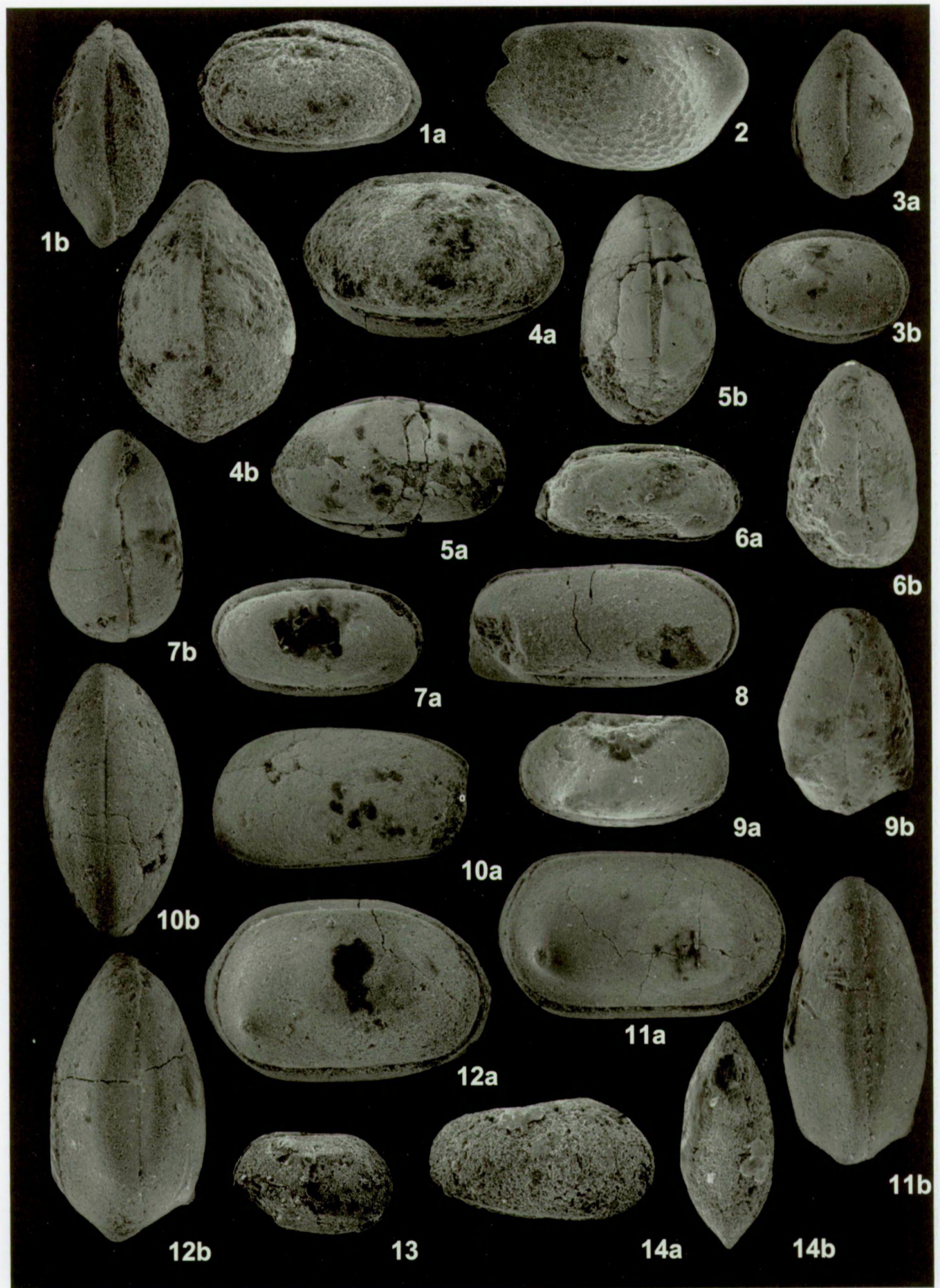


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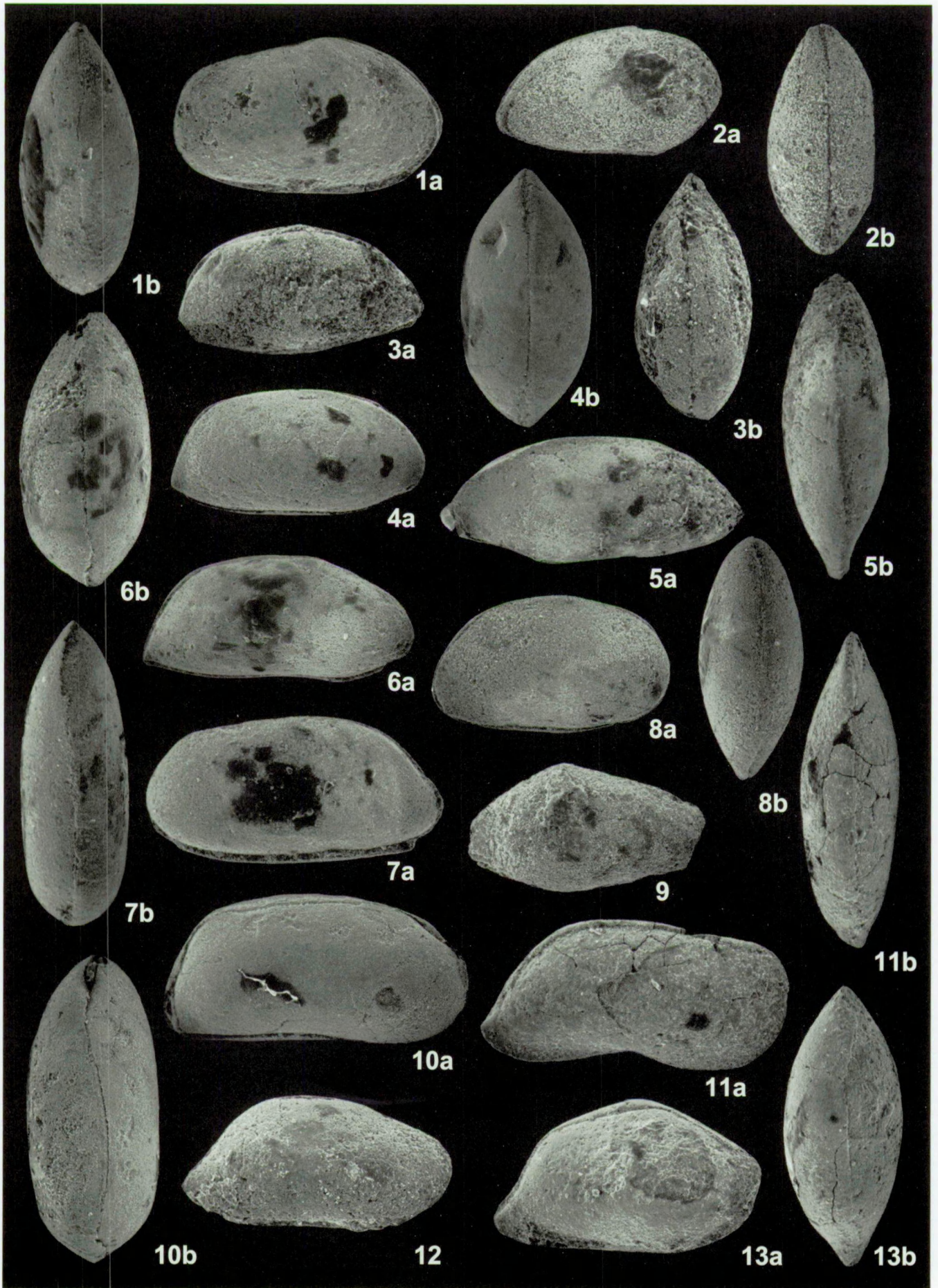


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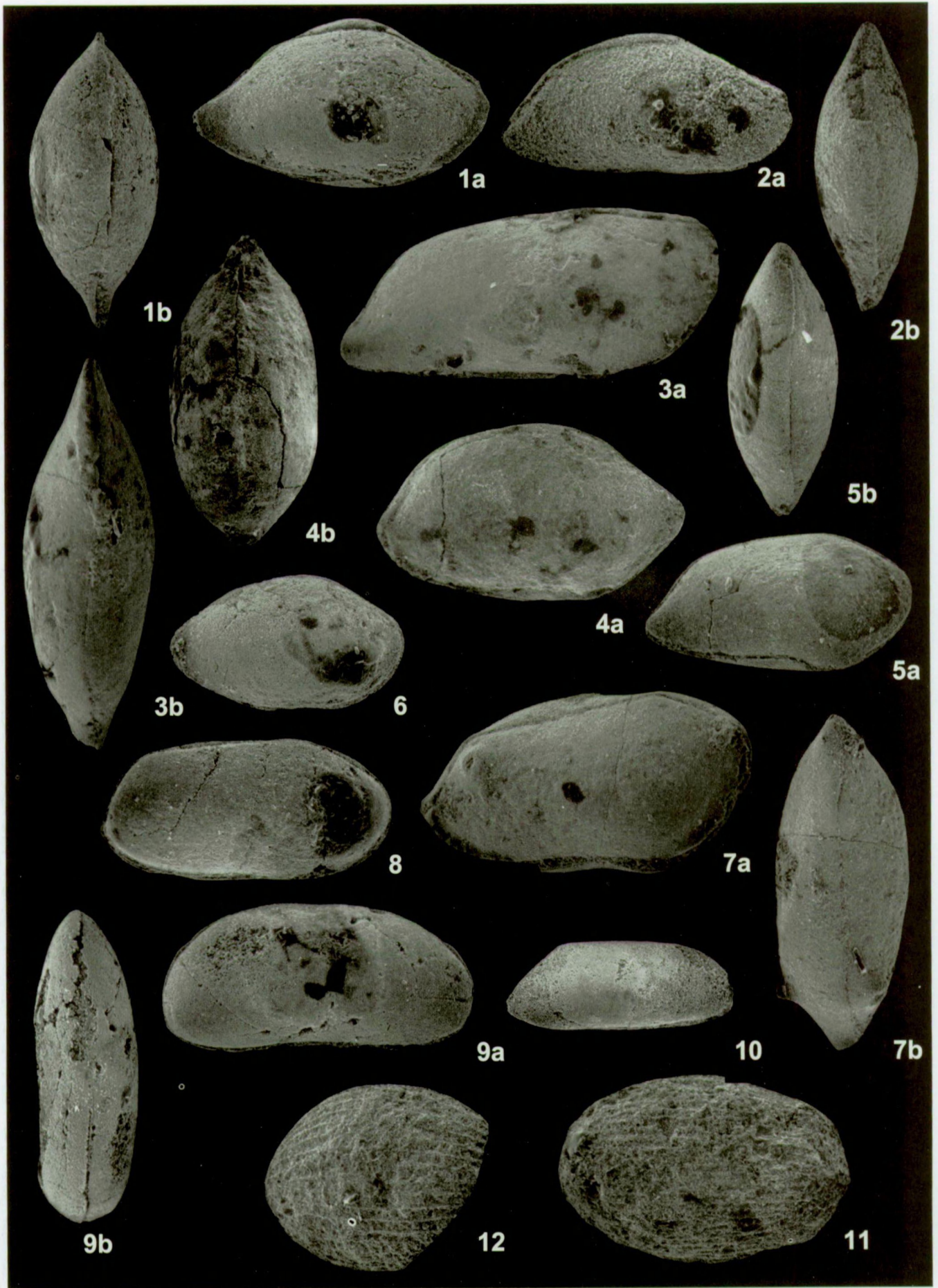


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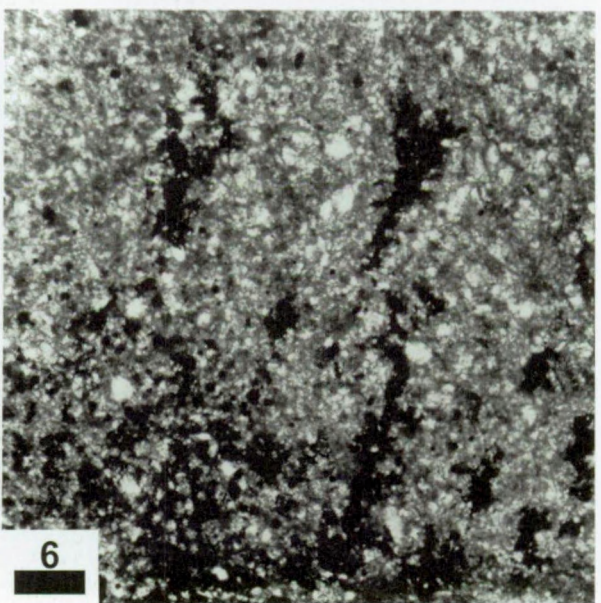
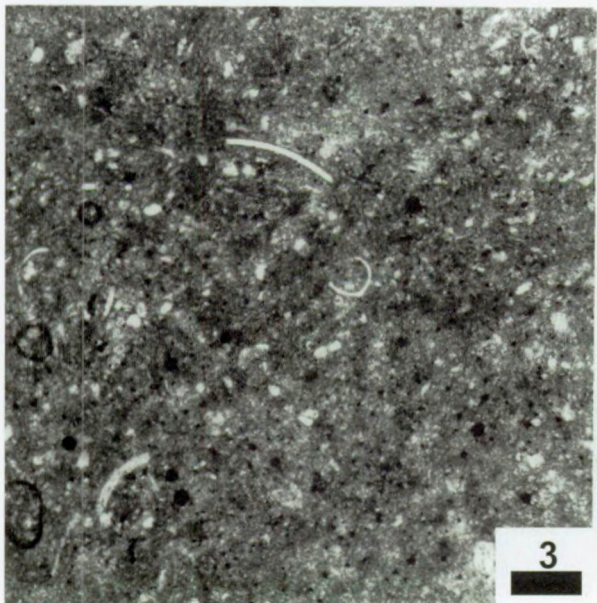
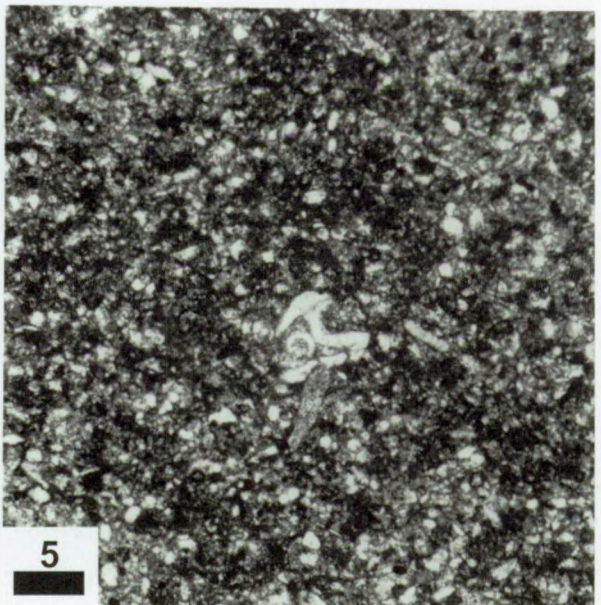
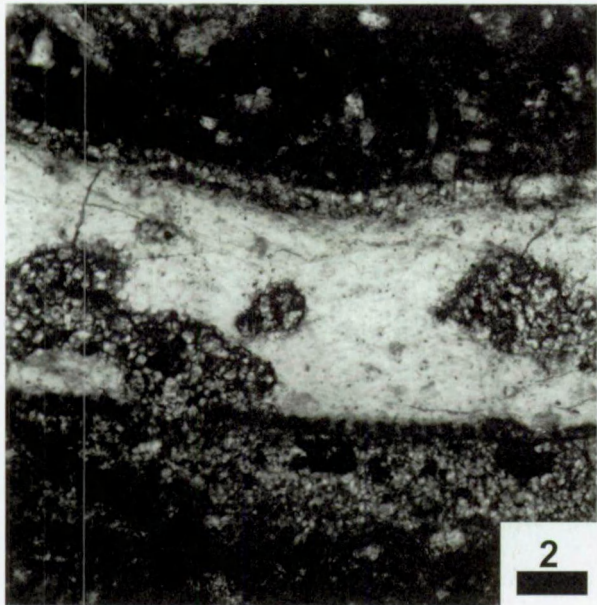
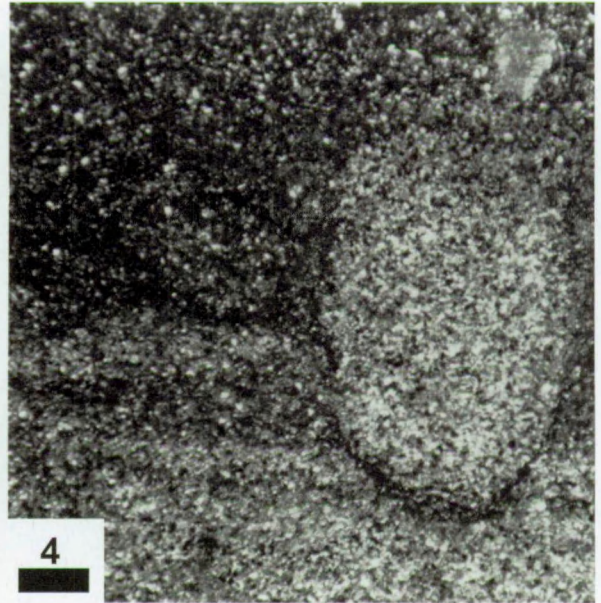
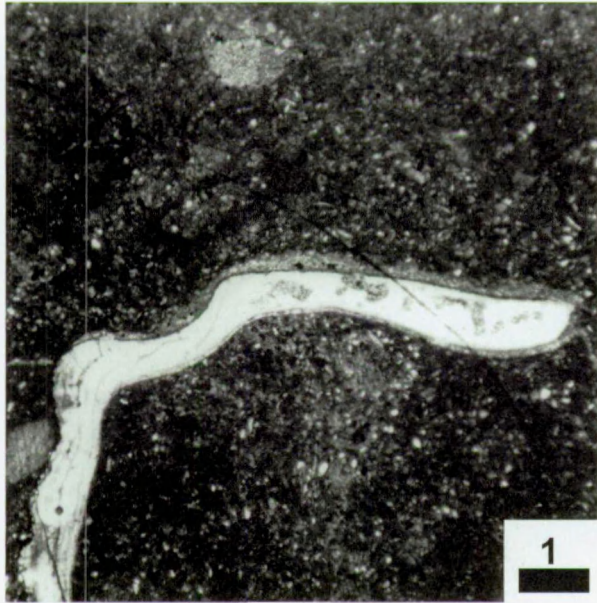


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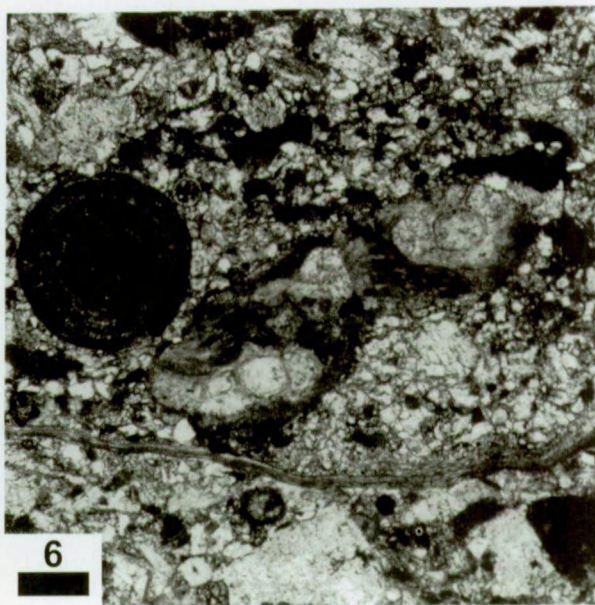
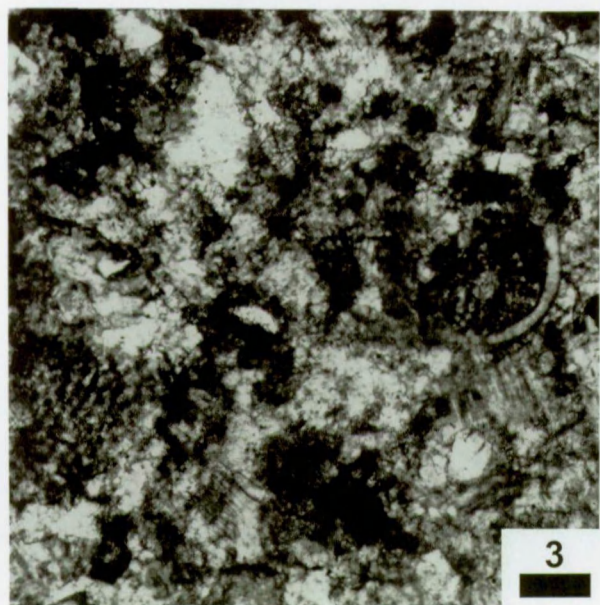
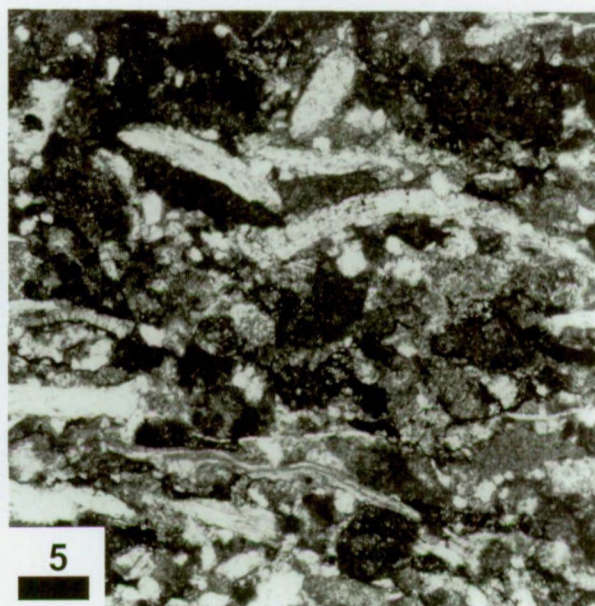
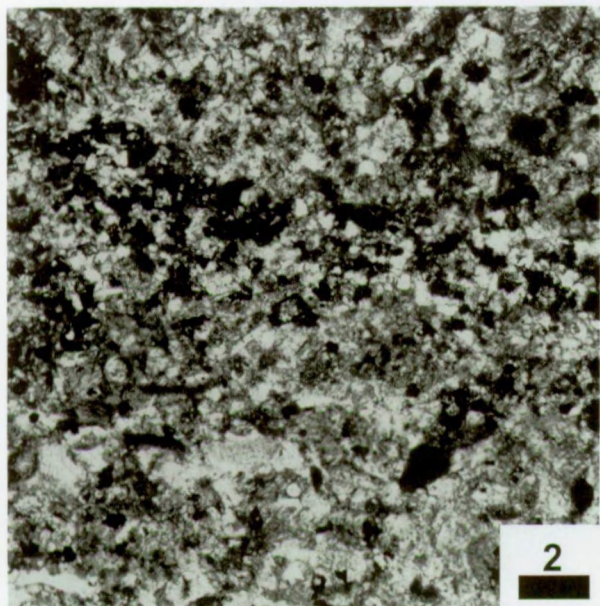
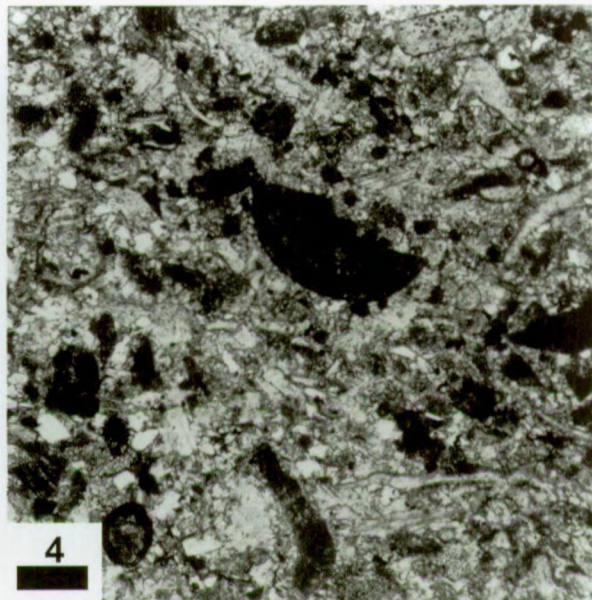
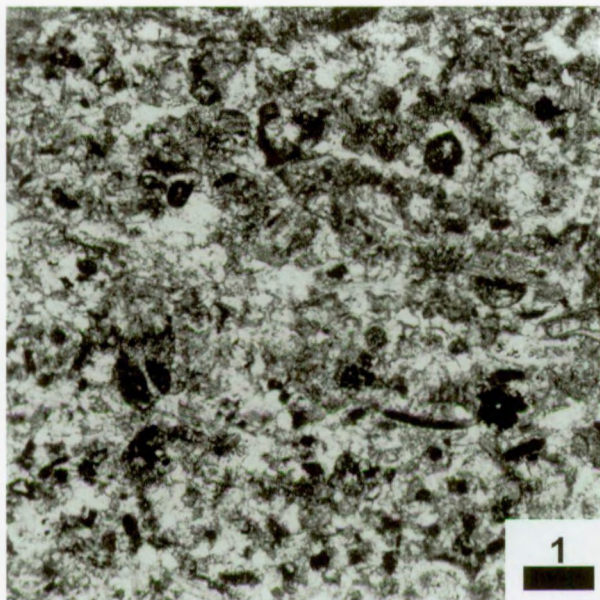


PLATE 7

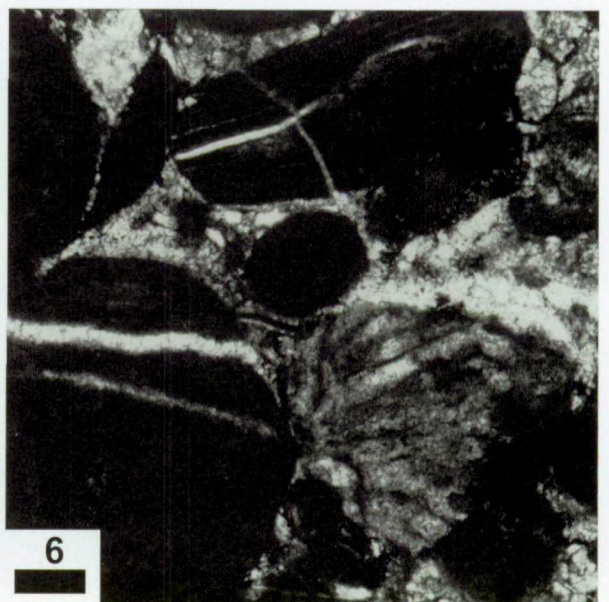
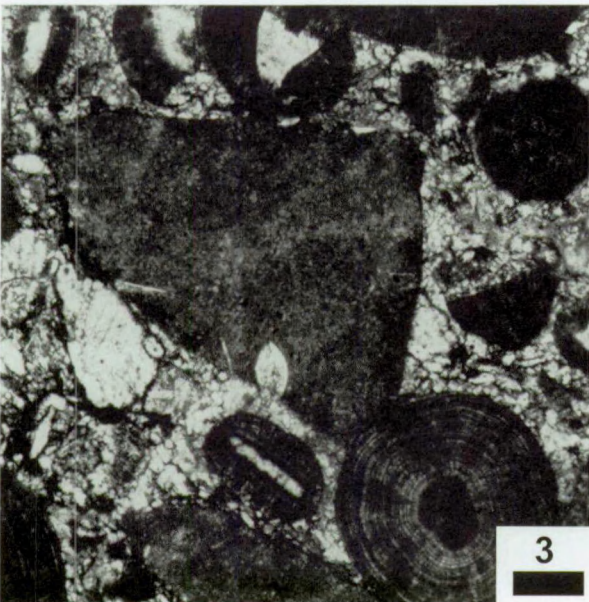
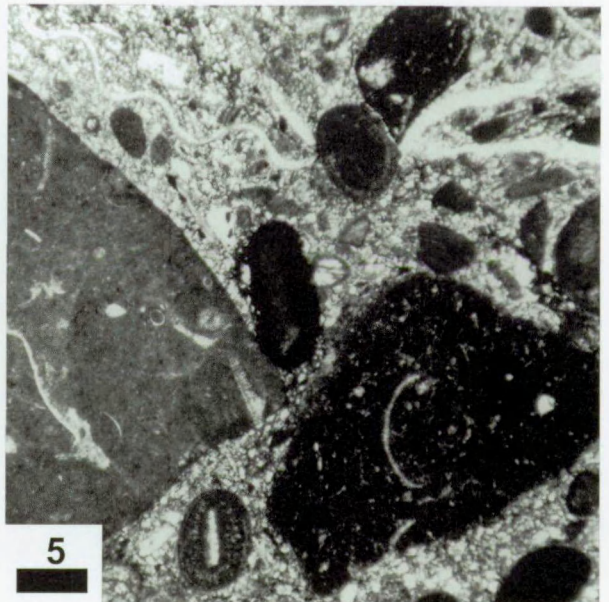
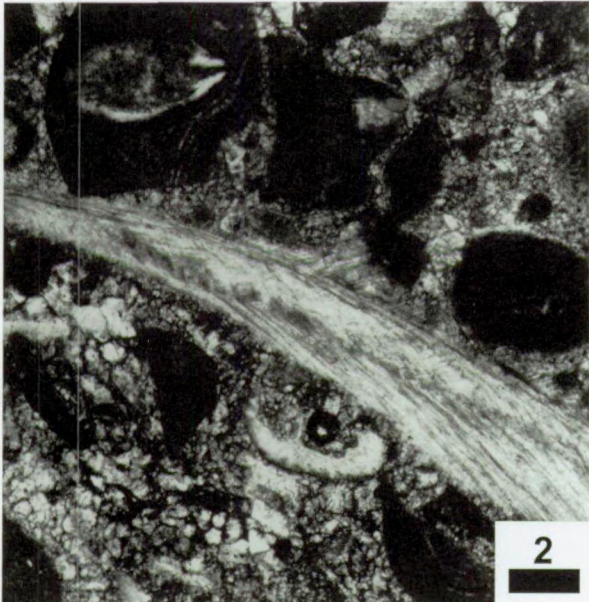
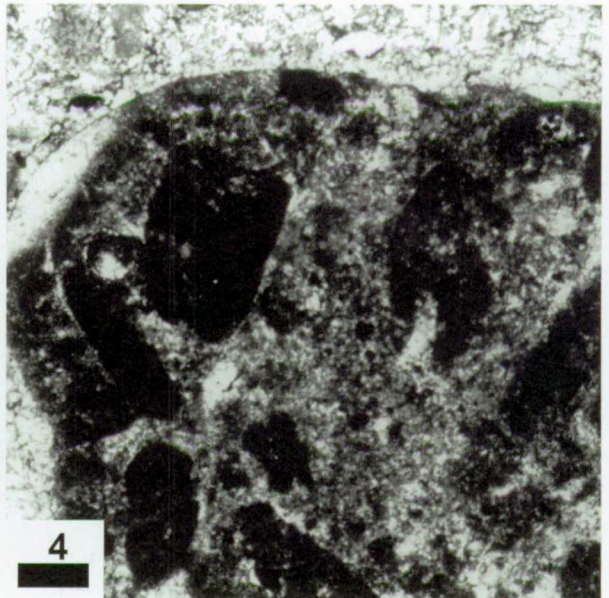


PLATE 8

