Ostracods and sedimentology of the Frasnian-Famennian boundary beds in the Kostomloty section (Holy Cross Mountains, Poland)

by Jean-Georges CASIER, Xavier DEVLEESCHOUWER, Francis LETHIERS, Alain PREAT & Grzegorz RACKI

Abstract

Sixty-eight ostracod species belonging to the Eifelian ecotype and the majority of which are figured, are recorded from across the Frasnian-Famennian boundary in the Kostomloty quarry, Holy Cross Mountains of Poland. In this 6.5 meter thick section, the ostracod fauna is rich and diverse in the Frasnian, but scarce and poorly diversified in the Famennian. Podocopids, with numerous Bairdiocypridacea and Bairdiacea, dominate in the Frasnian, and palaeocopids (with Kloedenellacea) prevail in the Famennian. Myodocopids are almost absent and metacopids are missing. The ostracods of the Kostomloty quarry indicate a regressive trend ranging from a marine environment below wave base in the late Frasnian, to semi-restricted water conditions in the early Famennian. No assemblage or lithology characteristic of hypoxic water conditions have been recorded from the Kostomloty section.

The disappearance of ostracods close to the Frasnian-Famennian boundary is pronounced in the Kostomloty section, and only 6 (8?) species out of 53 occurring in the late Frasnian cross the boundary. However, a total of 12 (14?) species survived the Frasnian-Famennian event if "wrongly disappearing species" and "wrongly new arriving species" are taken into account.

Sedimentological studies and sequence analyses also point to a regression associated with the Frasnian-Famennian boundary. The fall in sea level, starting at the boundary, has affected very shallow-water, semi-restricted back-shoal environments and has continued and included the erosion of the open-marine fore-shoal facies. This suggests a change of more than ten meters in sea level. After the regression, semi-restricted tidal flats and pre-evaporitic supratidal environments became widely established. On a broad scale, the microfacies curve shows a gradual shift from open-marine waters in the late Frasnian to restricted ones in the early Famennian. The 3rd order sequence boundary emphasizes this transition and the ostracod assemblages as well as those of other organisms (Algae) follow this general pattern.

Three new ostracod species are proposed: *Coelonella crassa* nov. sp., *Sulcella (Postsulcella) kostomlotyensis* nov. sp. and *Bairdia (Rectobairdia) sanctacrucensis* nov. sp.

Key-words: Ostracods - Sedimentology - Mass extinction - Late Devonian - Holy Cross Mountains - Poland

Résumé

Soixante-huit espèces d'ostracodes appartenant à l'écotype de l'Eifel, quasi toutes figurées, sont répertoriées au niveau de la limite des étages Frasnien et Famennien dans la carrière de Kostomloty située dans les Monts Sainte-Croix en Pologne. La faune d'ostracodes est très riche et diversifiée dans le Frasnien, mais par contre pauvre et peu diversifiée dans le Famennien. Les Podocopida, avec de nombreux Baidiocypridacea et Bairdiacea, prédominent dans le Frasnien alors que c'est le cas pour les Palaeocopida (Kloedenellacea compris) dans le Famennien. Les Myodocopida sont extrêmement rares et les Metacopida sont absents. L'étude des ostracodes de la carrière de Kostomloty montre une tendance régressive à partir d'environnements marins francs situés sous le niveau d'action des vagues à la fin du Frasnien, à d'autres milieux semi-restreints dans la base du Famennien. Ni lithologie ni assemblage caractéristiques d'eaux pauvres en oxygène dissous ne sont relevés dans la carrière de Kostomloty.

La disparition des ostracodes au niveau de la limite des étages Frasnien et Famennien est très importante dans la carrière de Kostomloty. Seules 6 (8?) espèces sur 53 présentes dans la partie supérieure du Frasnien passent la limite, mais 12 (14?) espèces survivent à l'événement si l'on tient compte des fausses disparitions et apparitions.

L'analyse sédimentologique et séquentielle montre l'importance de la baisse du niveau marin à la limite Frasnien-Famennien. Les environnements de mer ouverte (hauts-fonds et avant-hauts-fonds algaires) sont érodés et suggèrent une diminution d'au moins une dizaine de mètres. Plusieurs niveaux de conglomérats témoignent de cette érosion. Suite à la régression, des faciès confinés et littoraux dominent au Famennien dans la partie supérieure de la rampe interne et passent progressivement à des milieux pré-évaporitiques de type "sebkha". L'analyse séquentielle montre qu'une limite de séquence de 3ème ordre est associée à la limite Frasnien-Famennien et correspond à la chute du niveau marin. L'évolution générale tout au long du profil est celle d'une régression montrant la transition de faciès marins ouverts d'énergie modérée à forte (sommet du Frasnien) aux faciès confinés, parfois hypersalins, de faible à très faible énergie (base du Famennien). La distribution des ostracodes, de même que celle d'autres organismes (algues), suit cette évolution des environnements.

Trois nouvelles espèces d'ostracode sont fondées: *Coelonella crassa* nov. sp. , *Sulcella (Postsulcella) kostomlotyensis* nov. sp. and *Bairdia (Rectobairdia) sanctacrucensis* nov. sp.

Mots-clefs: Ostracodes - Sédimentologie - Extinction en masse - Dévonien Supérieur - Monts Sainte-Croix - Pologne

Introduction

The Late Devonian mass extinction is probably the second largest occurring during the Phanerozoic (CASIER & LETHIERS, 1998a; COPPER, 1998). The most extensive reef developments this planet has ever seen disappeared during this event (COPPER, 1994), followed by one of the longest periods of poor faunal diversity known after such a crisis. It is estimated that 21 percent of the families and 50 percent of all the animal genera were wiped out in the marine realm at this time of worldwide crisis (RAUP & SEPKOSKI, 1982; SEPKOSKI, 1990).

Ostracods are environmentally very sensitive crustaceans, and their study, therefore, provides valuable information about extinctions and other events. The study of ostracods of several sections worldwide shows that more than 70% of all benthic and nekto-benthic marine ostracod species disappeared abruptly and close to the Frasnian-Famennian boundary in lower latitudes (LETHIERS & CASIER, 1996; CASIER *et al.*, 1996; CASIER & LETHIERS, 1998a). The invasion of poorly oxygenated waters in shallow-marine environments of the Palaeotethys (CASIER, 1987; CASIER & LETHIERS, 1998a), and a rather abrupt fall in global sea level causing the reduction of shallow-marine habitats (CASIER & DEVLEESCHOUWER, 1995; CASIER & LETHIERS, 1998b), are considered important factors responsible for this extinction. A re-organization of global oceanic circulations has also been mentioned as a possible cause (COPPER, 1986; CASIER & LETHIERS, 1998c) and recently, RACKI (1998) emphasized the control the global late Devonian tectonic activity may have played.

Some late Frasnian and early Famennian ostracods have been described from the Holy Cross Mountains of southern Poland by OLEMPSKA (1979), and from north-western Poland by ZBIKOWSKA (1983). Until now, however, no ostracod study has focused on the Frasnian-Famennian boundary exclusively in that country. This is the first attempt to remedy this shortcoming.

The Kostomloty section (G. RACKI & X. DEVLEESCHOUWER)

Upper Devonian strata of the Kostomloty Hills, approximately 3 km NNE of Kielce (Fig. 1), represent the westernmost exposures of the Devonian series in the Holy Cross Mountains. The sequence forms part of the southern limb of the Miedziana Góra syncline, which itself is a minor segment of the complex central synclinorium of the Holy Cross Mountains (RACKI & SZULCZEWSKI *in* DVORAK *et al.*, 1995).

The bulk of the Frasnian sequence is formed largely of macrofossil-poor detrital limestones, partly oolitic (Kostomloty beds) and broadly varying from platy calcarenites (with encrinite intercalations) to poorly stratified intra-formational conglomerates and breccias (SZULCZEWSKI 1971, 1981; RACKI & SZULCZEWSKI *in* DVORAK *et al.*, 1995). Moreover, SZULCZEWSKI (1971) described, above the section investigated, a characteristic flat-pebble conglomerate (1m thick), consisting of limestones plates reaching 60 cm in length. In term, these Upper Devonian deposits were eroded and overlaid by a transgressive Zechstein conglomerate (SZULCZEWSKI, *Ibid.*) but these two last lithologies are hidden by rubble.

According to SZULCZEWSKI *et al.* (1993), the Frasnian-Famennian boundary interval is marked by: (1) transition from cherty, variously laminated and fine-grained deposits, rich in ooids and microbial grains, to flat-pebble conglomerates; (2) few bioclastic, crinoid-brachiopod intercalations; (3) significant condensation (breaks?) in the *triangularis* conodont Zone, combined with (4) stratigraphic mixing and conodont biofacies change.

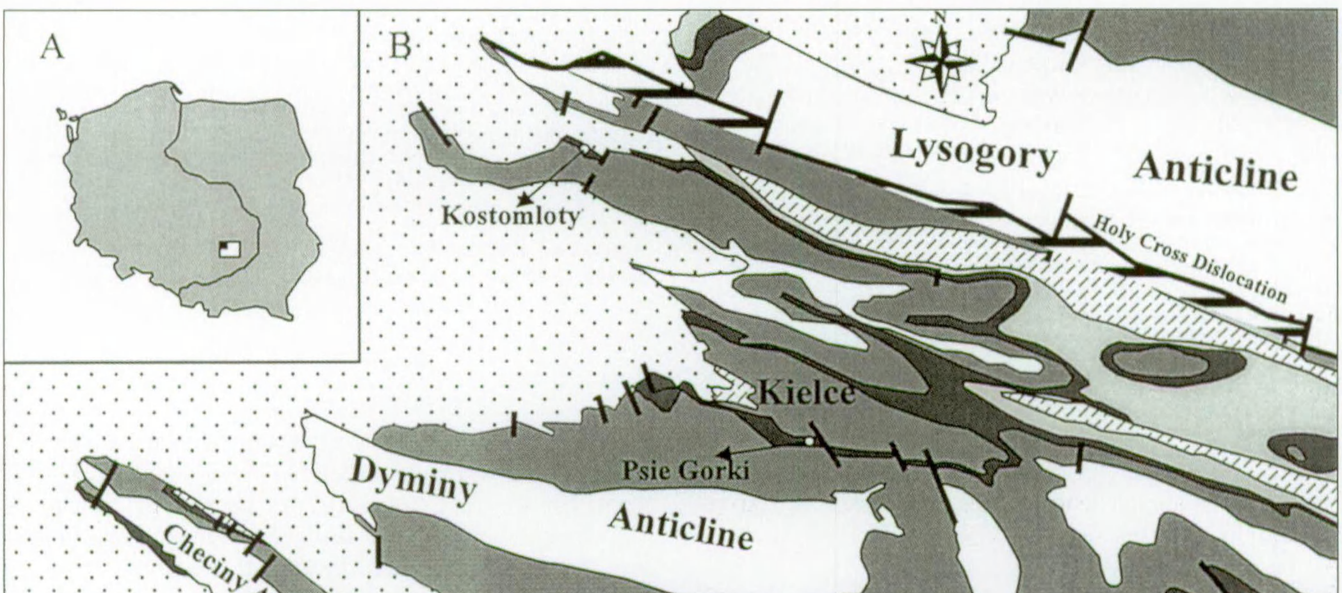


Fig. 1 — Locality map of the Kostomloty section and geological map of the Kielce area, Holy Cross Mountains (modified after SZULCZEWSKI, 1971). Legend: - 0: Cambrian to Silurian - 1: Lower and Middle Devonian - 2: Frasnian (Upper Devonian) - 3: Famennian (Upper Devonian) - 4: Lower Carboniferous - 5: Post-Variscan cover (Zechstein - Upper Cretaceous).

The F-F succession was previously thought to be conformable across the Frasnian-Famennian boundary (SZULCZEWSKI, 1971; RACKI, 1990; RACKI & SZULCZEWSKI *in* DVORAK *et al.*, 1995). The position of the boundary, however, has been recently traced in two small and abandoned quarries, located close to the crest of the eastern Kostomloty Hill. There, the thickness of the whole *triangularis* Zone is, at least locally, significantly reduced to approximately one meter, and the presence of the Early *triangularis* Zone can be only tentatively identified in the western locality (SZULCZEWSKI, unpubl. data). In the most easterly section under study, the Frasnian-Famennian boundary is placed at the top of bed 19. Numerous Foraminifera (*Eogeinitzina, Eonodosaria, Tickhinella* and *Nanicella*) indicate a Frasnian age for the lower part of the section (TOOMEY *et al.*, 1970; HLADIL & KALVODA, 1993).

The peculiar shallow-water carbonate complex indicates the persistence of the Frasnian Kostomloty shoal area in the northern part of the basin, probably at least as late as the *crepida* conodont Zone, and contemporaneous with a microbial build-up on the submerged Dyminy reef in the more southern (Kielce) segment of the Holy Cross carbonate shelf (SZULCZEWSKI, 1971; RACKI, 1990; SZULCZEWSKI *et al.*, 1993).

Sedimentology (X. DEVLEESCHOUWER & A. PREAT)

From a thickness of nearly 6.5 m, 97 samples for thin sections were collected in the Kostomloty quarry for the sedimentological part of the study. The section is composed of a series of thin, monotonous limestone beds with several marly horizons intercalated at the base, and several conglomeratic beds at the top. In a few of these, cherty nodules or lenticular silicified horizons are associated. The sedimentological analysis allowed to recognize a standard sequence of 11 microfacies recording a shallowing-upward trend of the relative sea level.

Microfacies Description

Open marine fore-shoal environments (Frasnian part)

Microfacies 1 (or MF1)

Wackestones and packstones rich in bioclasts. Numerous sponge spicules and small fragments of dasycladacean Algae (*Issinella* and *Kamaena*) as well as few Foraminifera (*Eogeinitzina, Eonodosaria and Tickhinella*), brachiopods, ostracods, tentaculids, crinoids, calcispheres, and scarce molluscs were observed. The rocks are finely laminated, and small fenestral structures (< mm) are present. Bioturbation is weakly developed.

Microfacies 2 (or MF2)

Micritic to microsparitic packstones enriched in tentaculids, ostracods and Foraminifera (same genera as in MF1). A few calcispheres (parathuramminids), brachiopods, crinoids and dasycladaceans Algae are present. The sediment is relatively well laminated and the matrix contains numerous peloids.

Microfacies 3 (or MF3)

Microsparitic packstones containing the same bioclasts as described for MF2 with abundant small-sized peloids. A few, several millimeter-deep, vertical burrows are also present and filled with MF2 sediments.

Algal shoal environments (Frasnian part)

Microfacies 4 (or MF4)

Dasycladacean packstones and grainstones enriched in fragments of *Issinella* with brachiopods, crinoids, calcispheres, trilobites, Foraminifera (*Eogeinitzina, Eonodosaria, Tickhinella* and *Nanicella*), ostracods, scarce tentaculids, molluscs, and peloids. Different lithotypes are distinguished based on type of lamination (planar, oblique, cross-stratified), on microbioclastic erosive layers, on size of issinellids, on abundance of peloids, and of open-marine bioclasts (tentaculids, brachiopods, crinoids and Foraminifera).

Microfacies 5 (or MF5)

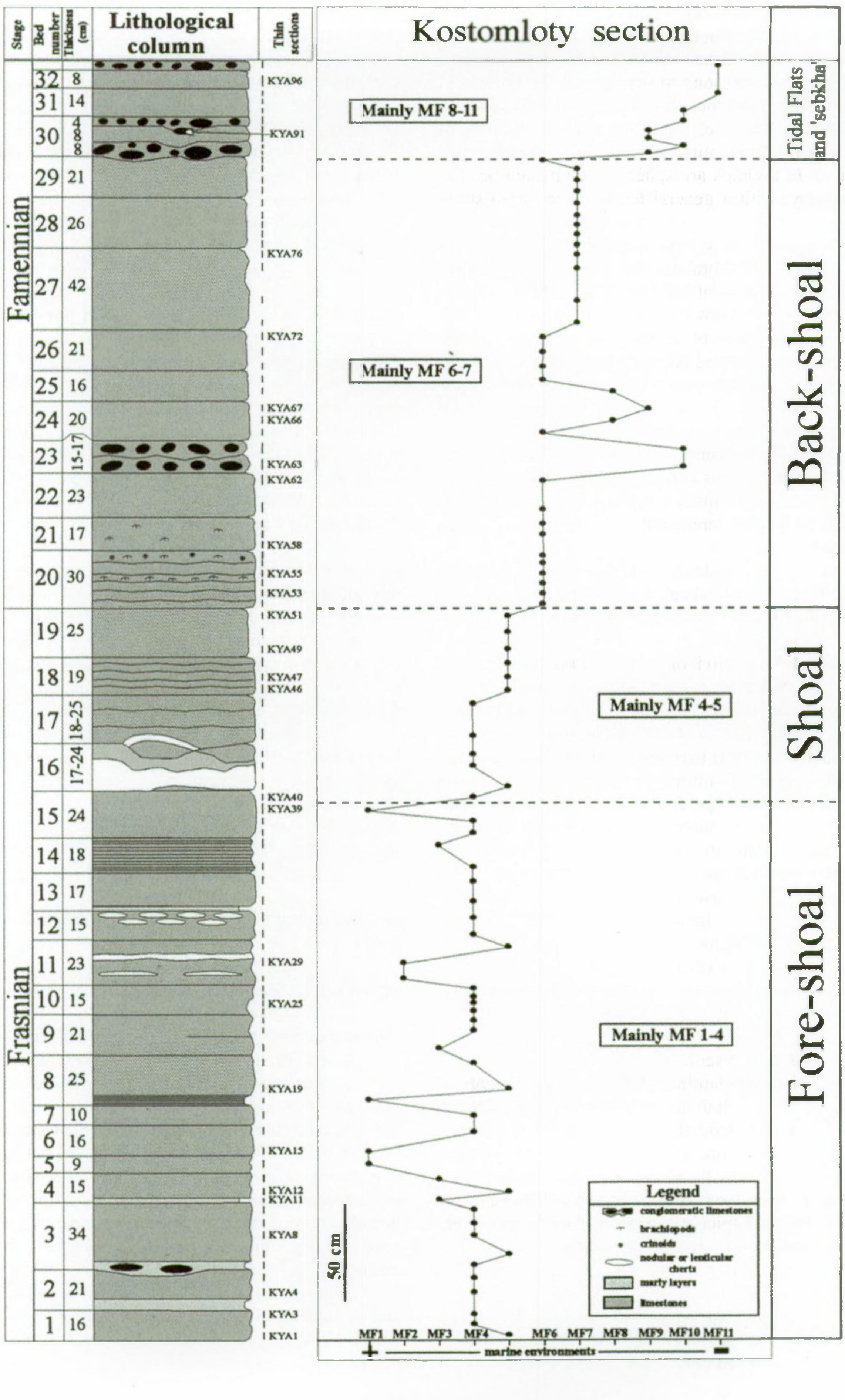
Coarse-grained dasycladacean grainstones and bafflestones divided into three lithotypes. Bioclasts dominated by algal fragments of *Issinella* (up to several mm in size) are the same as those of MF4. Sometimes, large, subangular nodules of wackestones and microsparitic packstones were observed. These nodules correspond to intraclasts of previous microfacies.

Semi-restricted back-shoal environments (Famennian part)

Microfacies 6 (or MF6)

Packstones and grainstones enriched in ooids, peloids, lumps, and intraclasts with brachiopods, crinoids, molluscs, ostracods, trilobites, green and red algal fragments (*Issinella*, *Girvanella*, *Solenopora* and *Parachaetetes*) and coated grains. The bioclasts (molluscs and crinoids) are micritized and perforated. Blocky spar- and syntaxial cements around echinodermal grains were observed. In some cases, a non-isopachous, equant, calcitic spar rim is present around the grains. Three lithotypes are recognized based on the abundance and types of ooids and intraclasts:

— MF6a contains many micritized superficial and radial ooids, algal or oolitic lumps and millimeter-sized intraclasts of MF 2 and MF4. The lithotype is poorly laminated;


Stage
Bed number
Thickness (cm)
Lithological column
Thin sections
Kostomloty section
Frasnian
Famennian
Mainly MF 8-11
Mainly MF 6-7
Mainly MF 4-5
Mainly MF 1-4
50 cm
Legend
conglomeratic limestones
brachiopods
crinoids
nodular or lenticular cherts
marly layers
limestones
MF1 MF2 MF3 MF4 MF6 MF7 MF8 MF9 MF10 MF11
+ marine environments -
Tidal Flats and 'sebkha'
Back-shoal
Shoal
Fore-shoal

— MF6b is enriched in three types of ooids: superficial, with entirely radial structure and fine radial-concentric structures. The size of these ooids never exceeds 1 mm. The radial ooids correspond to type 5 of STRASSER (1986) and shows a cortex composed of one thick lamina with an irregular radial structure. Radial-concentric ooids composed of several thin laminae correspond to the type 3 of STRASSER (*Ibid.*). Ooids are spherical, elongated or irregularly bumpy, with a general tendency to attain sphericity;

— MF6c contains many lumps and micritic microbreccias as well as many brachiopods, crinoids, ostracods, calcispheres and fragments of red Algae (*Solenopora* and *Parachaetetes*) with a few *Girvanella*. Ooids are scarcely represented. The sediment is weakly burrowed and contains numerous micritized Algae.

Microfacies 7 (or MF7)

Two lithotypes are present:

— MF7a are packstones enriched in recrystallized fragments of crinoids, molluscs and *Issinella*. The microfacies is relatively well laminated and contains numerous micropeloids;

— MF7b are fine peloidal grainstones with calcispheres and small lumps, ostracods and *Issinella* fragments.

Restricted tidal flat environments (Famennian part)

Microfacies 8 (or MF8)

This microfacies is well laminated and shows an alternation of thin peloidal laminae (peloids < 50 μm), and thicker laminae rich in peloids (< 150 μm), small ostracods, calcispheres and lumps (> 300 μm). Some of the thickest laminae contain numerous molds of molluscan shells. These laminae are sometimes interrupted by large fissures (several mm wide) filled with numerous molluscs, crinoids, peloids, lumps and coated grains, as well as angular breccia fragments of the same microfacies in all positions, including vertical ones.

Microfacies 9 (or MF9)

Two lithotypes are present:

— MF9a is distinctly laminated. Darker laminae correspond to packstones rich in micropeloids, sponge spicules, calcispheres, small corroded debris of *Issinella* and scarce ostracods. Lighter laminae are microsparitic packstones with ostracods, peloids, algal lumps and calcispheres;

— MF9b correspond to mudstones and wackestones with trilobites, connected spicule sponges and perforated echinoderms. This facies is strongly bioturbated and contains thin undulating laminae rich in quartz, sponge spicules, ostracods, microbioclasts and scarce *Kamaena*. Laminae correspond to small microstromatolitic domes.

←

Fig. 2 — Lithological column of the Kostomloty section, position of ostracod samples (KYA), and microfacies curve deduced from the sedimentological study.

Supratidal environments - "Sebkhas" (Famennian part)

Microfacies 10 (or MF10)

This microfacies corresponds to conglomeratic limestone layers in the outcrops. Angular to subnodular intraclasts (up to several cm in length) indicate the reworking of sediments of nearly all types of previous microfacies (polygenic conglomerate). These large clasts are embedded in a microsparitic to sparitic matrix with algal lumps, crinoids, brachiopods, dissolved molluscan shells, micritic microbreccia, red algal remains (up to 1 cm thick) and *Girvanella* nodules, Foraminifera (*Nanicella*) and few ooids.

Microfacies 11 (or MF11)

In this micro-conglomerate, clasts (up to several cm in length) are only those of mudstones (monogenic conglomerate) with few calcispheres and sponge spicules. Clasts are embedded in a spar cement which contains trilobites, crinoids and brachiopods. The morphology of the spar crystals indicates a sulphate origin.

Interpretation and discussion

The standard sequence (MF1 to MF11) shows a progression from open-marine "fore-shoal" environments (MF1-MF2), to restricted tidal flats or lagoons (MF9) finally reaching emersion (MF10-MF11). All sediments accumulated above the wave base level indicate an inner ramp setting. MF4-MF5 are enriched in Dasycladacea (green Algae) and represent a shoal environment in the photic zone. Moreover, dasycladacean Algae suggest a warm, shallow-water environment with variable salinities and a depth between 3 and 15 m (WILSON, 1975). The packstones and grainstones rich in Foraminifera, shells, and dasycladacean Algae are also typically found in bars and shoals heaped up by tidal currents in shallow lagoons and bays (WILSON, *Ibid.*).

The sea level trend points to a general regressive evolution at Kostomloty. The regression increased significantly at the Frasnian-Famennian boundary, and the last open marine environments are definitively abandoned. The fall in sea level was considerable as marked by abundant erosive microbreccias forming conglomeratic layers (MF10). Furthermore, the nature of the clasts indicates that at least part of the fore-shoal facies (MF3) had been eroded suggesting a sea level fall of more than 10 m. This interpretation is in agreement with the observations of SZULCZEWSKI (1971) who reported large, flat pebbles reaching 60 cm in the uppermost beds previously exposed. The final change involved the development of a "sebkha" environment (MF11).

The first conglomerate (bed 23) represents in the context of the eustatic fall, a third-order sequence boundary *sensu* VAN WAGONER *et al.* (1988). The importance of shoal environments is indicative of the highstands of sea-level as reported by BURCHETTE & WRIGHT (1992) in the ramp systems.

Ostracods (J.-G. CASIER & F. LETHIERS)

List and systematic placement of species occurring in the Kostomloty quarry

Subclass OSTRACODA LATREILLE, 1806
Order PALAEOCOPIDA HENNINGSMOEN, 1953
Suborder PALAEOCOPINA HENNINGSMOEN, 1953

Superfamily Kirkbyacea ULRICH & BASSLER, 1906
— Kirkbyacea indet. (Pl. 1, Fig. 1).
Family Amphissitidae KNIGHT, 1928
— *Amphissites* cf. *parvulus* (PAECKELMANN, 1913) (Pl. 1, Fig. 2a,b).
Superfamily Aparchitacea JONES, 1901
Family Aparchitidae JONES, 1901
— *Aparchites?* sp. 82 *sensu* BRAUN (1968) (Pl. 1, Fig. 3).
Superfamily Beyrichiacea MATTHEW, 1886
Family Welleriellidae ABUSHIK, 1971
— *Illativella* cf. *clivosa* ZANINA, 1960 (Pl. 1, Fig. 17).
Superfamily Primitiopsacea SWARTZ, 1936
Famille Graviidae POLENOVA, 1952
— *Selebratina* sp. LETHIERS & CASIER, 1996 (Pl. 1, Fig. 4, 5).

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

Superfamily Paraparchitacea SCOTT, 1959
Family Paraparchitidae SCOTT, 1959
— *Chamishaella?* sp. indet. (Pl. 1, Fig. 6a,b).
— *Shishaella?* sp. indet.
Family Coelonellidae SOHN, 1971
— *Coelonella crassa* nov. sp. (Pl. 1, Fig. 9a,b, 10, 11, 12a,b).
— *Coelonella?* sp. indet. *sensu* CASIER *et al.* (1999) (Pl. 1, Fig. 7a,b).
— *Coelonella* cf. sp. 220 BRAUN, 1968 (Pl. 1, Fig. 8a,b).

Suborder KLOEDENELLOCOPINA SCOTT, 1961 *sensu* LETHIERS (1981)

Superfamily Kloedenellacea ULRICH & BASSLER, 1908
Family Glyptopleuridae GIRTY, 1910
— *Blessites?* nov. sp. A (Pl. 1, Fig. 13).
Family Indivisiidae EGOROV, 1953
— *Indivisia variolata* ZANINA, 1960 (Pl. 1, Fig. 14).
— *Indivisia* cf. *indistincta* ZASPELOVA, 1953 (Pl. 1, Fig. 15).
Family Kloedenellidae ULRICH & BASSLER, 1908
— *Marginia* sp. A *sensu* CASIER & LETHIERS, 1998 (Pl. 1, Fig. 16).
— Kloedenellidae? sp. indet.

Suborder incertain

— Palaeocopida indet. A (Pl. 1, Fig. 18a,b).

Order PLATYCOPIDA SARS, 1866
Suborder PLATYCOPINA SARS, 1866

Superfamily Cytherellacea SARS, 1866
Family Cavellinidae EGOROV, 1950
— *"Cavellina"* sp. A, aff. *dushanensis* SHI, 1964 (Pl. 1, Fig. 19a,b).
— *Sulcella (Postsulcella) kostomlotyensis* nov. sp. (Pl. 1, Fig. 20, Pl. 2, Fig. 1a,b, 2a,b, 3, 4).
— *Sulcella (Postsulcella)* cf. *kostomlotyensis* nov. sp. (Pl. 2, Fig. 5a,b).

Order PODOCOPIDA MÜLLER, 1894
Suborder Podocopina SARS,1866

Superfamily Bairdiocypridacea SHAVER, 1961
Family Bairdiocyprididae SHAVER, 1961
— *Healdianella alba* LETHIERS, 1981 (Pl. 2, Fig. 6a,b).
— *Healdianella?* sp. B *sensu* BECKER, 1971 (Pl. 2, Fig. 7).
— *Healdianella?* sp. indet. (Pl. 2, Fig. 8a,b).
— *Bairdiocypris* nov. sp. A (Pl. 2, Fig. 9a,b).
— *Bairdiocypris* nov. sp. B, aff. *angulata* JAMBULOVA in litt. *sensu* KOTSCHETKOVA & JAMBULOVA, 1987 (Pl. 2, Fig. 10a,b).
— *Bairdiocypris* sp. C (Pl. 2, Fig. 11).
— *Bairdiohealdites gregalis* ROZHDESTVENSKAJA, 1972 (Pl. 2, Fig. 12).
— *Bairdiohealdites* sp. A, aff. *gregalis* ROZHDESTVENSKAJA, 1972 *sensu* CASIER *et al.* (1999) (Pl. 2, Fig. 13a,b).
— *Healdiacypris* sp. A (Pl. 2, Fig. 14a,b).
— *Orthocypris* cf. *exemplaris* ROZHDESTVENSKAJA, 1972 (Pl. 2, Fig. 15).
— *Orthocypris* sp. A *sensu* BECKER, 1971 (Pl. 2, Fig. 16a,b).
— *Orthocypris parilis* ROZHDESTVENSKAJA, 1972 (Pl. 2, Fig. 17).

Family Pachydomellidae BERDAN & SOHN, 1961.
— *Microcheilinella* sp. indet.
— *Decoranewsomites multicavus* (ROZHDESTVENSKAJA, 1972) (Pl. 2, Fig. 18a,b).
— *Micronewsomites natus* (ROZHDESTVENSKAJA, 1972) (Pl. 2, Fig. 19).
— *Ampuloides kellerwaldensis* CASIER & LETHIERS, 1999 (Pl. 3, Fig. 1).

Superfamily Bairdiacea SARS, 1888

Famille Acratiidae GRÜNDEL, 1962
— *Acratia badwildungensis* CASIER & LETHIERS, 1999 (Pl. 3, Fig. 2a,b).
— *Acratia evlanensis* EGOROV, 1953 (Pl. 3, Fig. 3a,b).
— *Acratia nevadaensis* CASIER & LETHIERS, 1997 (Pl. 3, Fig. 4a,b).
— *Acratia silincula* POLENOVA, 1953 (Pl. 3, Fig. 5a,b).
— *Acratia* nov. sp. A, aff. *silincula* POLENOVA, 1953 *sensu* CASIER & LETHIERS, 1998 (Pl. 3, Fig. 6a,b).
— *Acratia* nov. sp. B, aff. sp. 39 BRAUN, 1968 (Pl. 3, Fig. 7a,b).
— *Acratia* nov. sp. C, aff. *longa* ZASPELOVA, 1955 (Pl. 3, Fig. 8).
— *Acratia supina* POLENOVA, 1953 (Pl. 3, Fig. 9).
— *Acratia supinaeformis* LETHIERS, 1981 (Pl. 3, Fig. 10a,b).
— *Acratia* sp. A, aff. *bidecliva* LETHIERS & FEIST, 1991?
— *Acratia?* sp. *sensu* LETHIERS & CASIER, 1999.
— Acratiidae nov. sp. A (Pl. 3, Fig. 11a,b).

Family Acratiidae GRÜNDEL, 1962?
— *Famenella declivis* LETHIERS & CASIER, 1996 (Pl. 3, Fig. 12a,b).
— *Famenella?* nov. sp. A *sensu* CASIER & LETHIERS, 1998 (Pl. 3, Fig. 13a,b).

Family Bairdiidae SARS, 1888.
— *Bairdia (R.) sanctacrucensis* nov. sp. (Pl. 3, Fig. 14a,b, 15, 16).
— *Bairdia (R.) manifesta* ROZHDESTVENSKAJA & TSCHIGOVA, 1972 (Pl. 4, Fig. 1a,b).
— *Bairdia (R.) kelleri* EGOROV, 1953 (Pl. 4, Fig. 2a,b).
— *Bairdia (R.)* cf. *eleziana* EGOROV, 1953 *sensu* CASIER & LETHIERS, 1999 (Pl. 4, Fig. 3a,b).
— *Bairdia (R.)* sp. A, aff. *altodorsualis* CASIER & LETHIERS, 1998 (Pl. 4, Fig. 4a,b).
— *"Bairdia"* nov. sp. A (Pl. 4, Fig. 5a,b).
— *"Bairdia"* nov. sp. B (Pl. 4, Fig. 6).
— *"Bairdia"* nov. sp. C (Pl. 4, Fig. 7a,b).
— *Bairdiacypris anteroangulosa* CASIER & LETHIERS, 1997 (Pl. 4, Fig. 8a,b).
— *Bairdiacypris sobiekurowiensis* (OLEMPSKA, 1979) (Pl. 4, Fig. 9a,b).
— *Bairdiacypris martinae* CASIER & LETHIERS, 1987 (Pl. 4, Fig. 10a,b).
— *Bairdiacypris* cf. *vaga* BUSCHMINA, 1975 *sensu* KOTSCHETKOVA & JAMBULATOVA (1987) (Pl. 4, Fig. 11a,b).
— *Bairdiacypris* nov. sp. A, cf. *virga* BUSCHMINA, 1969 *sensu* KOTSCHETKOVA & JAMBULATOVA (1987) (Pl. 4, Fig. 12a,b).
— *Bairdiacypris* gr. *irregularis* (POLENOVA, 1953) (Pl. 4, Fig. 13a,b).
— *Bairdiacypris* cf. n. sp. B LETHIERS, 1981 (Pl. 4, Fig. 14a,b).
— *Bairdiacypris* nov. sp. C (Pl. 4, Fig. 15).

Order ERIDOSTRACA ADAMCZAK, 1961

Family Cryptophyllidae ADAMCZAK, 1961
— *Cryptophyllus* sp. indet. (Pl. 4, Fig. 16).

Order MYODOCOPIDA SARS, 1866
Suborder MYODOCOPINA SARS, 1866

Superfamily Entomozacea PRIBYL, 1951

Family Entomozoidae PRIBYL, 1950
— *Richterina (R.)* sp. A, aff. *striatula* (RICHTER, 1848)

Description of three new species

Types are deposited in the collections of the Department of Palaeontology (Section Micropaleontology) of the Belgian royal Institute of natural Sciences (IRScNB n° b...).

Genus *Coelonella* STEWART, 1936

Type-species: *Isochilina? scapha* (STEWART, 1930)

Coelonella crassa nov. sp.
(Pl. 1, Fig. 9a,b, 10, 11, 12a,b)

Derivatio nominis - The name is derived from Latin *crassus* = thick, massive, fat. Referring to the inflated width of the carapace.

Types - Holotype: Carapace. (Pl. 1, Fig. 9a,b). KYA11. IRScNB n° b3591. L = 0.46 mm; H = 0.32 mm; W = 0.29 mm.
Paratype A: Carapace. (Pl. 1, Fig. 10). KYA29. IRScNB n° b3592. L = 0.35 mm; H = 0.24 mm; W = 0.22 mm.
Paratype B: Carapace. (Pl. 1, Fig. 11). KYA29. IRScNB n° b3593. L = 0.27 mm; H = 0.21 mm; W = 0.18 mm.
Paratype C: Carapace. (Pl. 1, Fig. 12a,b). Psie Gorky section. PG8. IRScNB n° b3594. L = 0.46 mm; H = 0.34 mm; W = 0.33 mm.

Locus typicus - Kostomloty quarry in the Holy Cross Mountains, Poland.

Stratum typicum - Upper Frasnian.

Material - 10 carapaces and 12 valves.

Diagnosis - A very small species of the genus *Coelonella*, distinctly preplete, thick biconvex in dorsal view, with a slightly and regularly arched dorsal border.

Description - In lateral outline small, preplete and rounded carapace. Dorsal border slightly and regularly arched. Hinge line straight and depressed. Cardinal angles obtuse, the anterior somewhat larger than the posterior one. Posterior margin more curved and smaller than the anterior semi-circular margin, but both regularly curved. Ventral margin in continuity with anterior and posterior margins. Anterior extremity at half height, and posterior extremity close the dorsal third of height. Maximum lenght at mid-height and maximum height slightly before the median part of the carapace. Left valve overreaching the right all along the free border. Fine marginal ridge on both valves. In dorsal view, carapace regularly thick biconvex, without compressed anterior and posterior extremities, and with the maximum width at mid-lenght. Surface of valves smooth.

Remarks - In lateral outline, *Coelonella crassa* nov. sp. resembles *Coeloenellina optata* (POLENOVA, 1955) from the lower Frasnian of the Volga-Ural region, and *Coeloenellina* sp. cf. *C. fabiformis* (KESLING & KILGORE, 1952) *sensu* JONES (1968) from the Famennian of the Bonaparte Gulf Basin in Australia. It differs in being smaller, thicker, and in possessing a dorsal border not too convex at mid-lenght.

Occurrence - Upper Frasnian of the Kostomloty section (samples KYA4, KYA8, KYA11, KYA12, KYA19, KYA29, KYA39) and of the Psie Gorki section at Kielce (samples PG3, PG5, PG8).

Genus *Sulcella* CORYELL & SAMPLE, 1932

Type-species: *Sulcella (Sulcella) sulcata* CORYELL & SAMPLE, 1932

Subgenus *Postsulcella* ADAMCZAK, 1968

Type-species: *Sulcella (Postsulcella) testis* ADAMCZAK, 1968

Sulcella (Postsulcella) kostomlotyensis nov. sp.
(Pl. 1, Fig. 20, Pl. 2, Fig. 1a,b, 2a,b, 3, 4)

Derivatio nominis - From the Kostomloty quarry where this new species has been discovered.

Types - Holotype: Carapace tecnomorph. (Pl. 2, Fig. 1a,b). KYA76. IRScNB n° b3603. L = 0.59 mm; H = 0.36 mm; W = 0.24mm.
Paratype A: Carapace heteromorph. (Pl. 2, Fig. 2a,b). KYA76. IRScNB n° b3604. L = 0.64 mm; H = 0.38 mm; W = 0.31 mm.
Paratype B: Carapace tecnomorph. (Pl. 2, Fig. 3). KYA91. IRScNB n° b3605. L = 0.53 mm; H = 0.33 mm; W = 0.22 mm.
Paratype C: Carapace tecnomorph. (Pl. 2, Fig. 4). KYA76. IRScNB n° b3606. L = 0.52 mm; H = 0.31 mm; W = 0.22mm.

Locus typicus - Kostomloty quarry of the Holy Cross Mountains, Poland.

Stratum typicum - Upper Frasnian and Lower Famennian.

Material - 12 carapaces and 7 valves.

Diagnosis - A species belonging to the genus and subgenus *Sulcella (Postsulcella)*; preplete, with a vestigial stragulum which forms the short inclined anterior part of the dorsal border. Posterior border regularly rounded, and ventral border straight.

Description - Small unequivalve carapace with a preplete ovoidal outline in lateral view. Anterior part of the dorsal margin straight to slightly convex forming an angle of 155° with the straight and longer posterior part. Ventral margin straight. Anterior and posterior margins regularly rounded. Maximum height generally slightly before the median part of the carapace, and maximum length at half-height. Slight adductoral depression in the mid-dorsal part of the carapace and delicate flattening of the anterior and antero-ventral margins of the left valve. Right valve overreaching slightly the left along the ventral margin and along the dorsal margin, except where the height is at a maximum. Stragulum (= overreaching of the anterior part of the dorsal margin) slightly developed, short and inclined. Valves symmetric in dorsal view with flattened flanks converging forward. Maximum width at the posterior third of the carapace. Surface of valves smooth or finely reticulate. Dimorphism of domiciliar type.

Remarks - *Sulcella (P.) kostomlotyensis* nov. sp. is distinguished by its great variation of the lateral contour due to the position of the maximum height from slightly before the median part (Paratype A) to the anterior third of the carapace (Paratype C).

Differs from *Sulcella (P.) testis* ADAMCZAK, 1968 and from *Sulcella (P.) mutae* ADAMCZAK, 1968 from the Middle Devonian of Poland by its preplete outline and straight ventral margin. *Sulcella (P.) kotchoensis* LETHIERS, 1981 from the Famennian of Alberta and Northwest Territories (Canada) has a distinct stragulum and its ornamentation is strongly reticulate.

Occurrence - Only known from the Upper Frasnian and Lower Famennian strata (samples KYA39, KYA62, KYA76, KYA91, KYA96) of the Kostomloty quarry.

Genus *Bairdia* McCOY, 1944

Type-species: *Bairdia curta* McCOY, 1844

Bairdia (Rectobairdia) SOHN, 1960

Type-species: *Bairdia depressa* GEIS, 1932

Bairdia (Rectobairdia) sanctacrucensis nov. sp.
(Pl. 3, Fig. 14a,b, 15, 16)

Derivatio nominis - The name is derived from Latin *sanctus* = holy and *crux* = cross. Referring to the Holy Cross Mountains.

Types - Holotype: Carapace. (Pl. 3, Fig. 14a,b). KYA11. IRScNB n° b3635. L = 0.43 mm; H = 0.24 mm; W = 0.18 mm.
Paratype A: Carapace. (Pl. 3, Fig. 15). KYA29. IRScNB n° b3636. L = 0.59 mm; H = 0.31 mm; W = 0.24 mm.
Paratype B: Carapace. KYA29. IRScNB n° b3637. L = 0.41 mm; H = 0.24 mm; W = 0.18 mm.
Paratype C: Carapace. (Pl. 3, Fig. 16). KYA11. IRScNB n° b3638. L = 0.33 mm; H = 0.18 mm; W = 0.16 mm.

Locus typicus - Kostomloty quarry of the Holy Cross Mountains, Poland.

Stratum typicum - Upper Frasnian.

Material - 18 carapaces and 2 valves.

Diagnosis - A mid-sized, moderately elongate species of *Bairdia (Rectobairdia)* with a dorsal margin inclined backwards, and a long, nearly straight antero-dorsal margin. Ventral margin concave slightly behind mid-lenght. Low posterior non-acuminate extremity; weak overlap.

Description - Mid-sized and moderately elongate carapace. Almost straight dorsal margin inclined backwards. Antero-dorsal and postero-dorsal margins nearly straight, the last one smaller and more inclined. Ventral margin moderately concave slightly behind mid-lenght. Antero-ventral margin long and convex. Postero-ventral margin short and distinctly well rounded. Anterior extremity at mid-height, and posterior extremity low close to the ventral level. Ventral margin of the right valve more curved comparatively to the ventral margin of the left valve. Small overlap along the ventral margin. Left valve overreaching slightly the right valve along the free margin, except for the antero-ventral margin. Maximum height towards the anterior third of the carapace and maximum length at half-height. Carapace spindle-shaped in dorsal view, with maximum width at half-length and extremities very slightly compressed. Surface of valves smooth.

Remarks - As seen in lateral and dorsal views, the carapace outline in *Bairdia (R.) sanctacrucensis* nov. sp. resembles that of *Bairdia kynovensis* ROZHDESTVENSKAJA, 1959 from the Frasnian of Bashkiria and of *Bairdia ivanovae* EGOROV, 1953 from the Frasnian of the Russian Platform. But the posterior extremity is more acuminate and the ventral concavity at mid-lenght in *B. kynovensis*. In *Bairdia ivanovae*, the overlap is more pronounced and the ventral margin convex.

Occurrence - Only known from the Upper Frasnian (samples KYA1, KYA8?, KYA11, KYA29, KYA39) strata of the Kostomloty quarry.

Palaeoecology

Twenty-seven samples were selected for the study of the ostracods (Fig. 2) with 15 during the sedimentological analysis. More than 1000 carapaces and valves of ostracods have been extracted by the hot acetolysis method (LETHIERS & CRASQUIN, 1988). Twenty samples contained determinable ostracods (Tab. 1), but in 7 samples (KYA25, KYA40, KYA46, KYA49, KYA51, KYA63 and KYA67) ostracods are either absent or undeterminable, and all ostracods belong exclusively to the Eifelian ecotype of BECKER (*in* BANDEL & BECKER, 1975 *emend.* CASIER & LETHIERS, 1998c).

In the Frasnian and samples KYA3 to KYA39, the ostracod fauna is rich and diverse, and assemblages are indicative of a marine environment below the fair-weather wave base. Metacopid ostracods which are known to prefer calm environments and argillaceous substrates are missing. The relative proportion between deposit feeders (podocopids) and filter feeders (palaeocopids and platycopids) is indicative of well-oxygenated water conditions in these beds (LETHIERS & WHATLEY, 1994).

In the Famennian, ostracods are rare and poorly diversified. Comparatively to the Frasnian (Tab. 2), podocopids decrease in number of species from 77 percent to 37.5 percent; conversely palaeocopids, Kloedenellacea included, increase in number of species from 17 percent to 44 percent. This change is indicative of regressive influences confirmed by the apparition of species of *Cryptophyllus*, *Sulcella*, and several species of the Paraparchitacea and Kloedenellacea (*Indivisia*, *Marginia*) which are commonly found in euryhaline environments.

In samples KYA55, KYA66, KYA72, KYA96, ostracods are indicative of semi-restricted water conditions (= Assemblage I *in* CASIER, 1987). However, in samples KYA58, KYA62, KYA76, and KYA91 ostracods indicative of semi-restricted water conditions are found mixed together with ostracods belonging to the more open-marine Bairdiacea and Bairdiocypridacea. Variations of salinity are probably also responsible for the absence of ostracods in samples KYA63 and KYA67.

The extinction of the ostracods (Tabl. 1)

The disappearance of many ostracod species close to the Frasnian-Famennian boundary is evident and noteworthy in the Kostomloty section, and only 6 species out of 53 occurring in the Late Frasnian cross the boundary! These species are the following: *Selebratina* sp. *sensu* LETHIERS & CASIER, 1996, *Micronewsomites natus* (ROZHDESTVENSKAJA, 1972), *Indivisia variolata* ZANINA, 1960,

Table 1 — Distribution of ostracods in upper Frasnian and lower Famennian beds in the Kostomloty section.

	← FRASNIAN											FAMENNIAN →								
KOSTOMLOTY	**1**	**3**	**4**	**8**	**11**	**12**	**15**	**19**	**29**	**39**	**47**	**53**	**55**	**58**	**62**	**66**	**72**	**76**	**91**	**96**
Ampuloides kellerwaldensis CASIER & LETHIERS, 1999	●								●	?										
Bairdia (R.) sanctacrucensis nov. sp.	●			?	●				●	●										
Acratia supina POLENOVA, 1953	●				●	●			●	●	?									
"Bairdia" nov. sp. C		?			●			●												
Bairdiacypris sobiekurowiensis (OLEMPSKA, 1979)		●			●				●											
Acratia supinaeformis LETHIERS, 1981		?			●				●	●										
Bairdiacypris nov. sp. C		●					●	?		●		?								
Acratia nov. sp. B, aff. sp. 39 BRAUN, 1968			●	●																
Blessites? nov. sp. A			?						●											
Bairdiacypris cf. n. sp. B LETHIERS, 1981			●						●											
Coelonella crassa nov. sp.			●	●	●	●		●	●	●										
Bairdiohealdites gregalis ROZHDESTVENSKAJA, 1972			●							●										
Decoranewsomites multicavus (ROZHDESTVENSKAJA, 1972)			●				?	●	●	●										
Acratia evlanensis EGOROV, 1953			●	●	●			●	●	●										
Acratia silincula POLENOVA, 1953			?		●				●	●										
Selebratina sp. LETHIERS & CASIER, 1996			●		●	●	●		●	●					●	●				
Bairdiacypris cf. *vaga* BUSCHMINA, 1975				?			●		●											
Bairdiacypris nov. sp. A, cf. *virga* BUSCHMINA, 1969				●	●				●	●										
Aparchites? sp. 82 *sensu* BRAUN (1968)					●															
Healdianella? sp. indet.					●															
Bairdiocypris nov. sp. A					●															
Healdiacypris sp. A					●															
"Bairdia" nov. sp. B					●															
Healdianella? sp. B *sensu* BECKER, 1971					●	●														
Acratia nevadaensis CASIER & LETHIERS, 1997					●		?	●	●											
Bairdiacypris martinae CASIER & LETHIERS, 1987					●		●	●	●											
Acratia nov. sp. A, aff. *silincula* POLENOVA, 1953					?				●											
Acratia nov. sp. C, aff. *longa* ZASPELOVA, 1955					●					●										
Orthocypris parilis ROZHDESTVENSKAJA, 1972					●	●				●										
Healdianella alba LETHIERS, 1981					●				●	●										
"Bairdia" nov. sp. A					●	●				●										
Bairdiacypris gr. *irregularis* (POLENOVA, 1953)					●				●	●										
Micronewsomites natus (ROZHDESTVENSKAJA, 1972)					●														●	
Bairdiocypris nov. sp. B, aff. *angulata* JAMBULOVA in litt.						●		●	●											
Indivisia variolata ZANINA, 1960						●				●									●	
Bairdiocypris sp. C							●		●											
Orthocypris cf. *exemplaris* ROZHDESTVENSKAJA, 1972							●		●					●						
Famenella declivis LETHIERS & CASIER, 1996								●												
Bairdia (R.) sp. A, aff. *altodorsualis* CASIER & LETHIERS, 1998								●												
Coelonella cf. sp. 220 BRAUN, 1968									●											
Bairdiohealdites sp. A, aff. *gregalis* ROZHDESTVENSKAJA, 1972									●											
Acratia? sp. *sensu* LETHIERS & CASIER, 1999									●											
Acratiidae nov. sp. A									●											
Famenella? nov. sp. A *sensu* CASIER & LETHIERS, 1998									●											
Orthocypris sp. A *sensu* BECKER, 1971									●	●										
Amphissites cf. *parvulus* (PAECKELMANN, 1913)									●	●										
Bairdia (R.) kelleri EGOROV, 1953									●	●										
Bairdiacypris anteroangulosa CASIER & LETHIERS, 1997									●									?		
Kloedenellidae? sp. indet.										●										
"Cavellina" sp. A, aff. *dushanensis* SHI, 1964										●										
Sulcella (Postsulcella) kostomlotyensis nov. sp.										●						●		●	●	●
Richterina (R.) sp. aff. *striatula* (RICHTER, 1848)										●										
Coelonella? sp. indet. *sensu* CASIER *et al.* (1999)										●						●		●	●	
Microcheilinella sp. indet.												●	●		●					
Sulcella (Postsulcella) cf. *kostomlotyensis* nov. sp.													●							
Bairdia (R.) cf. *eleziana* EGOROV, 1953													●		●				●	
Illativella cf. *clivosa* ZANINA, 1960													?					●	●	
Chamishaella? sp. indet.														●	●			●		
Shishaella? sp. indet.														●						
Acratia badwildungensis CASIER & LETHIERS, 1999															●					
Bairdia (R.) manifesta ROZHDESTVENSKAJA & TSCHIGOVA, 1972															●			●	●	
Cryptophyllus sp. indet.																●				
Palaeocopida indet. A																	●	●		
Acratia sp. A, aff. *bidecliva* LETHIERS & FEIST, 1991?																		●		
Indivisia cf. *indistincta* ZASPELOVA, 1953																		●	●	
Marginia sp. A *sensu* CASIER & LETHIERS, 1999																		●	●	
Kirkbyacea indet.																			●	●

Table 2 — Distribution of ostracod species among orders in the Kostomloty section.

KOSTOMLOTY	FRASNIAN	FAMENNIAN
PALAEOCOPIDA (Kloedenellacea included)	17%	44%
PLATYCOPIDA	4%	12.5%
PODOCOPIDA	77%	37.5%
ERIDOSTRACA	0%	6%
MYODOCOPIDA	2%	0%

Orthocypris cf. *exemplaris* ROZHDESTVENSKAJA, 1972, *Sulcella (P.) kostomlotyensis* nov. sp., and *Coelonella?* sp. indet. *sensu* CASIER *et al.* (1999). *Indivisia variolata* was first described from the Frasnian and Famennian of the Russian Platform, and *Coelonella?* sp. indet. is known from the Frasnian and Famennian of the Schmidt Quarry, Germany.

Two other poorly preserved species, *Bairdiacypris* nov. sp. B and *Bairdiacypris anteroangulosa* CASIER & LETHIERS, 1997, survived probably also the Frasnian-Famennian event in the Kostomloty quarry. The survival of the latter species is not unexpected because it survived the Frasnian-Famennian event in Germany and Nevada.

"Wrongly disappearing species" and "wrongly new arriving species" are pointed out at the Frasnian-Famennian boundary in several sections (LETHIERS & CASIER, 1999). These are linked either to local paleoecological factors or to the mobility of species during the Frasnian-Famennian event (*Ibid.*). Some species surviving in one province might disappear or might be part of a new Famennian arriving species in another province.

Five "wrongly disappearing species" are numbered in the Kostomloty quarry. *Cavellina?* sp. A, aff. *dushanensis* SHI, 1964, for instance is known in the Famennian of Nevada; *Healdianella alba* LETHIERS, 1981, in the Frasnian and Famennian of Canada and France; *Bairdiohealdites gregalis* ROZHDESTVENSKAJA, 1972, in the Famennian of Bashkiria and, finally, *Acratia nevadaensis* CASIER & LETHIERS, 1997, in the Frasnian and Famennian of Nevada.

Only one species, *Acratia supinaeformis* LETHIERS, 1981, described first from the Frasnian and Famennian of Canada, is a "wrongly new arriving species" in the Famennian of the Kostomloty section.

In summary, a total of 12 (14?) out of 54 species occurring in the Kostomloty quarry cross the Frasnian-Famennian boundary. This percentage is similar to the one observed in the Coumiac Global Stratotype Section and Point for the Frasnian-Famennian boundary (southern France), in the Schmidt quarry parastratotype (Germany), and in the Devils Gate Pass section (Nevada) (CASIER & LETHIERS, 1998a). All together this confirms that more than 70% of all benthic and necto-benthic ostracods did not survive the Frasnian-Famennian event in the lower latitudes.

Conclusions

The development of the ostracods in the Kostomloty quarry is indicative of a regressive trend starting from marine environments below wave base in the late Frasnian, to semi-restricted water conditions in the early Famennian. Sediments at the lowermost part of the section **(beds 1-15)** still indicate a fore-shoal environment, and contain a rich and diverse ostracod fauna pointing to open-marine environments in settings of moderate energy. Shoal environments as represented by **beds 16-19** were higher energetic ones and no ostracods or only poorly preserved specimens were observed. In the early Famennian **(beds 20-32)**, the eustatic fall reached its maximum as indicated by erosional features. As a consequence of the continuing regression, restricted environments (*e.g.* algal mats) with poorly diversified faunas (calcispheres, sponges and ostracods) developed. These environments were not suitable for proliferation of the ostracods, and which were confined, therefore, to poorly diversified assemblages dominated by palaeocopids (Kloedenellacea included). For the uppermost part of the section, evaporitic conditions are indicated and no ostracods were found for this reason.

A regression in earliest Famennian time has been demonstrated in several Belgian sections (CASIER & DEVLEESCHOUWER, 1995), in Nevada (CASIER & LETHIERS, 1998b), and in China (CASIER *et al.*, 1997). At Senzeille, Sinsin, Hony and Lambermont (Belgium), very abundant but poorly diversified ostracod faunas occur in the lowermost Famennian strata, and nested valves are abundant at Sinsin, Hony and Lambermont. In the lower Famennian section of Devils Gate Pass (Nevada), reworked upper Frasnian "deep-water" conodonts (SANDBERG *et al.*, 1988) are mixed with shallow-marine ostracods which also indicates an abrupt sea level fall. In China, a poorly diversified shallow marine ostracod fauna has also been found in the lower Famennian strata of the Lijiaping section (CASIER *et al.*, 1997). Thus the study of ostracods associated with the Frasnian-Famennian boundary in the Kostomloty section conforms to the other findings and points to the same fall in sea level associated with the Frasnian-Famennian boundary as postulated by JOHNSON *et al.* (1985).

The disappearance of ostracods at the Frasnian-Famennian boundary in the Kostomloty section is drastic and linked with the worldwide change of the sea-level. Their disappearance at Kostomloty is comparable to the disappearance of ostracods in several sections in Belgium, the type region for the definition of the Frasnian and Famennian stages. Nevertheless no assemblage or lithology characteristic of hypoxic water conditions have been recorded from the Kostomloty section.

The sedimentological and sequence analyses also allow to reconstruct the regression associated with the Frasnian-Famennian boundary. The fall in sea-level, culminating at the boundary, has eventually produced very shallow-water semi-restricted back-shoals, and obviously continued to the point involving the erosion of the open-marine fore-shoal sediments. These observations suggest an eustatic fall of more than ten meters. The semi-restricted tidal flats and pre-evaporitic supratidal environments of the early Famennian are followed by the sudden apparition of littoral facies colonized by various red Algae. The regressive tendency in these studied series is well documented over the southern Polish shelf (NARKIEWICZ, 1988).

The sequential evolution of the lithological series shows a clear regressive trend continuing from the upper Frasnian to the lower Famennian. On a broad scale, this evolution means a progressive shift from open marine waters to restricted ones across the boundary. The 3rd order sequence boundary emphasizes this transition and the ostracod assemblages as well as those of other organisms (Algae) follow this general pattern.

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Jean-Georges CASIER
Département de Paléontologie
Section de Micropaléontologie-Paléobotanique
Institut royal des Sciences naturelles de Belgique
rue Vautier, 29, B-1000 Bruxelles,
Belgique
E-mail: casier.pal@kbinirsnb.be

Xavier DEVLEESCHOUWER & Alain PREAT
Département des Sciences de la Terre et
de l'Environnement
Université libre de Bruxelles
Av. F.D. Roosevelt, 50, B-1050 Bruxelles,
Belgique
E-mail: apreat@ulb.ac.be
xdevlees@ulb.ac.be

Francis LETHIERS
Université Paris VI
Département de Géologie sédimentaire
Laboratoire de Micropaléontologie
4, place Jussieu, F-75252 Paris Cedex 05,
France
E-mail: lethiers@ccr.jussieu.fr

Grzegorz RACKI
Department of Earth Sciences
Silesian University
Bedzinska Str., 60, PL-41-200 Sosnowiec,
Poland
E-mail: racki@us.edu.pl

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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...). KYA = Sample number. Fr = Frasnian. Fa = Famennian.

PLATE 1

Fig. 1 — Kirkbyacea indet. KYA91. Fa. IRScNB n° b3583. Left valve. x50.
Fig. 2 — *Amphissites* cf. *parvulus* (PAECKELMANN, 1913). KYA39. Fr. IRScNB n° b3584. Carapace. a. Right lateral view. b. Dorsal view. x105.
Fig. 3 — *Aparchites?* sp. 82 *sensu* BRAUN (1968). KYA11. Fr. IRScNB n° b3585. Right lateral view of a carapace. x100.
Fig. 4 — *Selebratina* sp. LETHIERS & CASIER, 1996. KYA66. Fa. IRScNB n° b3586. Left lateral view of a carapace. x100.
Fig. 5 — *Selebratina* sp. LETHIERS & CASIER, 1996. KYA29. Fr. IRScNB n° b3587. Dorsal view. x100.
Fig. 6 — *Chamishaella?* sp. indet. KYA76. Fa. IRScNB n° b3588. Carapace. a. Right lateral view. b. Dorsal view. x80.
Fig. 7 — *Coelonella?* sp. indet. *sensu* CASIER *et al.* (1999). KYA39. Fr. IRScNB n° b3589. Carapace. a. Right lateral view. x85. b. Dorsal view. x90.
Fig. 8 — *Coelonella* cf. sp. 220 BRAUN, 1968. KYA29. Fr. IRScNB n° b3590. Carapace. a. Left lateral view. b. Dorsal view. x90.
Fig. 9 — *Coelonella crassa* nov. sp. Holotype. KYA11. Fr. IRScNB n° b3591. Carapace. a. Right lateral view. b. Dorsal view. x80.
Fig. 10 — *Coelonella crassa* nov. sp. Paratype A. KYA29. Fr. IRScNB n° b3592. Right lateral view of the carapace. x100.
Fig. 11 — *Coelonella crassa* nov. sp. Paratype B. KYA29. Fr. IRScNB n° b3593. Left lateral view of the carapace. x110.
Fig. 12 — *Coelonella crassa* nov. sp. Paratype C. Psie Gorki. PG8. Fr. IRScNB n° b3594. Carapace. a. Right lateral view. b. Dorsal view. x80.
Fig. 13 — *Blessites?* nov. sp. A. KYA29. Fr. IRScNB n° b3595. Fragment of a valve. x60.
Fig. 14 — *Indivisia variolata* ZANINA, 1960. KYA39. Fr. IRScNB n° b3596. Right valve. x60.
Fig. 15 — *Indivisia* cf. *indistincta* ZASPELOVA, 1953. KYA91. Fa. IRScNB n° b3597. Right valve. x70.
Fig. 16 — *Marginia* sp. A *sensu* CASIER & LETHIERS, 1998. KYA76. Fa. IRScNB n° b3598. Fragment of a left valve. x80.
Fig. 17 — *Illativella* cf. *clivosa* ZANINA, 1960. KYA91. Fa. IRScNB n° b3599. Left valve. x80.
Fig. 18 — Palaeocopida indet. A. KYA76. Fa. IRScNB n° b3600. Carapace. a. Right lateral view. b. Dorsal view. x80.
Fig. 19 — *Cavellina?* sp. A, aff. *dushanensis* SHI, 1964. KYA39. Fr. IRScNB n° b3601. Carapace. a. Right lateral view. b. Dorsal view. x80.
Fig. 20 — *Sulcella (Postsulcella) kostomlotyensis* nov. sp. KYA39. Fr. IRScNB n° b3602. Left lateral view of a carapace. x100.

PLATE 2

Fig. 1 — *Sulcella (Postsulcella) kostomlotyensis* nov. sp. Holotype. KYA76. Fa. IRScNB n° b3603. Carapace. a. Left lateral view. b. Dorsal view. x80.
Fig. 2 — *Sulcella (P.) kostomlotyensis* nov. sp. Paratype A. KYA76. Fa. IRScNB n° b3604. Carapace. a. Left lateral view. b. Dorsal view. x80.
Fig. 3 — *Sulcella (P.) kostomlotyensis* nov. sp. Paratype B. KYA91. Fa. IRScNB n° b3605. Left lateral view of the carapace. x75.
Fig. 4 — *Sulcella (P.) kostomlotyensis* nov. sp. Paratype C. KYA76. Fa. IRScNB n° b3606. Left lateral view of the carapace. x75.
Fig. 5 — *Sulcella (Postsulcella)* cf. *kostomlotyensis* nov. sp. KYA55. Fa. IRScNB n° b3607. Carapace. a. Left lateral view. b. Dorsal view. x70.
Fig. 6 — *Healdianella alba* LETHIERS, 1981. KYA11. Fr. IRScNB n° b3608. Carapace. a. Right lateral view. x110. b. Dorsal view. x120.
Fig. 7 — *Healdianella?* sp. B *sensu* BECKER, 1971. KYA11. Fr. IRScNB n° b3609. Left lateral view of a carapace. x115.
Fig. 8 — *Healdianella?* sp. indet. KYA11. Fr. IRScNB n° b3610. Carapace. a. Right lateral view. b. Dorsal view. x90.
Fig. 9 — *Bairdiocypris* nov. sp. A. KYA11. Fr. IRScNB n° b3611. Carapace. a. Right lateral view. x100. b. Dorsal view. x110.
Fig. 10 — *Bairdiocypris* nov. sp. B, aff. *angulata* JAMBULOVA in litt. *sensu* KOTSCHETKOVA & JAMBULOVA, 1987. KYA29. Fr. IRScNB n° b3612. Carapace. a. Right lateral view. b. Ventral view. x80.
Fig. 11 — *Bairdiocypris* sp. C. KYA29. Fr. IRScNB n° b3613. Right lateral view of a broken carapace. x70.
Fig. 12 — *Bairdiohealdites gregalis* ROZHDESTVENSKAJA, 1972. KYA4. Fr. IRScNB n° b3614. Right valve. x50.
Fig. 13 — *Bairdiohealdites* sp. A, aff. *gregalis* ROZHDESTVENSKAJA, 1972 *sensu* CASIER *et al.* (1999). KYA29. Fr. IRScNB n° b3615. Carapace. a. Right lateral view. b. Dorsal view. x60.
Fig. 14 — *Healdiacypris* sp. A. KYA11. Fr. IRScNB n° b3616. Carapace. a. Right lateral view. x110. b. Dorsal view. x120.
Fig. 15 — *Orthocypris* cf. *exemplaris* ROZHDESTVENSKAJA, 1972. KYA39. Fr. IRScNB n° b3617. Left lateral view of a carapace. x70.

Fig. 16 — *Orthocypris* sp. A *sensu* BECKER, 1971. KYA29. Fr. IRScNB n° b3618. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 17 — *Orthocypris parilis* ROZHDESTVENSKAJA, 1972. KYA12. Fr. IRScNB n° b3619. Fragment of right valve. x60.

Fig. 18 — *Decoranewsomites multicavus* (ROZHDESTVENSKAJA, 1972). KYA29. Fr. IRScNB n° b3620. Carapace. a. Right lateral view. b. Dorsal view. x75.

Fig. 19 — *Micronewsomites natus* (ROZHDESTVENSKAJA, 1972). KYA11. Fr. IRScNB n° b3621. Right lateral view of a carapace. x145.

PLATE 3

Fig. 1 — *Ampuloides kellerwaldensis* CASIER & LETHIERS, 1999. KYA29. Fr. IRScNB n° b3622. Right lateral view of a carapace. x105.

Fig. 2 — *Acratia badwildungensis* CASIER & LETHIERS, 1999. KYA62. Fa. IRScNB n° b3623. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 3 — *Acratia evlanensis* EGOROV, 1953. KYA4. Fr. IRScNB n° b3624. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 4 — *Acratia nevadaensis* CASIER & LETHIERS, 1997. KYA29. Fr. IRScNB n° b3625. Carapace. a. Right lateral view. b. Dorsal view. x60.

Fig. 5 — *Acratia silincula* POLENOVA, 1953. KYA29. Fr. IRScNB n° b3626. Carapace. a. Right lateral view. b. Dorsal view. x90.

Fig. 6 — *Acratia* nov. sp. A, aff. *silincula* POLENOVA, 1953 *sensu* CASIER & LETHIERS, 1998. KYA39. Fr. IRScNB n° b3627. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 7 — *Acratia* nov. sp. B, aff. sp. 39 BRAUN, 1968. KYA8. Fr. IRScNB n° b3628. Carapace. a. Right lateral view. b. Dorsal view. x50.

Fig. 8 — *Acratia* nov. sp. C, aff. *longa* ZASPELOVA, 1955. KYA11. Fr. IRScNB n° b3629. Right lateral view of a carapace. x90.

Fig. 9 — *Acratia supina* POLENOVA, 1953. KYA11. Fr. IRScNB n° b3630. Right lateral view of a carapace. x80.

Fig. 10 — *Acratia supinaeformis* LETHIERS, 1981. KYA29. Fr. IRScNB n° b3631. Carapace. a. Right lateral view. b. Dorsal view. x60.

Fig. 11 — Acratiidae nov. sp. A. KYA29. Fr. IRScNB n° b3632. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 12 — *Famenella declivis* LETHIERS & CASIER, 1996. KYA19. Fr. IRScNB n° b3633. Carapace. a. Left lateral view. x105. b. Ventral view. x100.

Fig. 13 — *Famenella?* nov. sp. A *sensu* CASIER & LETHIERS, 1998. KYA29. Fr. IRScNB n° b3634. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 14 — *Bairdia (R.) sanctacrucensis* nov. sp. Holotype. KYA29. Fr. IRScNB n° b3635. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 15 — *Bairdia (R.) sanctacrucensis* nov. sp. Paratype A. KYA11. Fr. IRScNB n° b3636. Right lateral view of the carapace. x95.

Fig. 16 — *Bairdia (R.) sanctacrucensis* nov. sp. Paratype C. KYA11. Fr. IRScNB n° b3638. Right lateral view of the carapace. x105.

PLATE 4

Fig. 1 — *Bairdia (R.) manifesta* ROZHDESTVENSKAJA & TSCHIGOVA, 1972. KYA62. Fa. IRScNB n° b3639. Carapace. a. Right lateral view. b. Dorsal view. x50.

Fig. 2 — *Bairdia (R.) kelleri* EGOROV, 1953. KYA29. Fr. IRScNB n° b3640. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 3 — *Bairdia (R.)* cf. *eleziana* EGOROV, 1953 *sensu* CASIER & LETHIERS, 1999. KYA91. Fa. IRScNB n° b3641. Carapace. a. Right lateral view. b. Dorsal view. x60.

Fig. 4 — *Bairdia (R.)* sp. A, aff. *altodorsualis* CASIER & LETHIERS, 1998. KYA19. Fr. IRScNB n° b3642. Carapace. a. Right lateral view. b. Dorsal view. x80.

Fig. 5 — "*Bairdia*" nov. sp. A. KYA11. Fr. IRScNB n° b3643. Carapace. a. Right lateral view. x105. b. Dorsal view. x115.

Fig. 6 — "*Bairdia*" nov. sp. B. KYA11. Fr. IRScNB n° b3644. Right lateral view of a carapace. x115.

Fig. 7 — "*Bairdia*" nov. sp. C. KYA11. Fr. IRScNB n° b3645. Carapace. a. Right lateral view. b. Dorsal view. x105.

Fig. 8 — *Bairdiacypris anteroangulosa* CASIER & LETHIERS, 1997. KYA29. Fr. IRScNB n° b3646. Carapace. a. Right lateral view. b. Dorsal view. x70.

Fig. 9 — *Bairdiacypris sobiekurowiensis* (OLEMPSKA, 1979). KYA11. Fr. IRScNB n° b3647. Carapace. a. Right lateral view. b. Dorsal view. x80.

Fig. 10 — *Bairdiacypris martinae* CASIER & LETHIERS, 1987. KYA29. Fr. IRScNB n° b3648. Carapace. a. Right lateral view. b. Dorsal view. x90.

Fig. 11 — *Bairdiacypris* cf. *vaga* BUSCHMINA, 1975 *sensu* KOTSCHETKOVA & JAMBULATOVA (1987). KYA29. Fr. IRScNB n° b3649. Carapace. a. Right lateral view. x65. b. Dorsal view. x75.

Fig. 12 — *Bairdiacypris* nov. sp. A, cf. *virga* BUSCHMINA, 1969 *sensu* KOTSCHETKOVA & JAMBULATOVA (1987). KYA29. Fr. IRScNB n° b3650. Carapace. a. Right lateral view. b. Dorsal view. x75.
Fig. 13 — *Bairdiacypris* gr. *irregularis* (POLENOVA, 1953). KYA39. Fr. IRScNB n° b3651. Carapace. a. Left lateral view. b. Dorsal view. x80.
Fig. 14 — *Bairdiacypris* cf. n. sp. B LETHIERS, 1981. KYA29. Fr. IRScNB n° b3652. Carapace. a. Right lateral view. x60. b. Dorsal view. x70.
Fig. 15 — *Bairdiacypris* nov. sp. C. KYA15. Fr. IRScNB n° b3653. Left valve. x50.
Fig. 16 — *Cryptophyllus* sp. indet. KYA66. Fa. IRScNB n° b3654. Fragment of a valve. x65.

PLATE 5

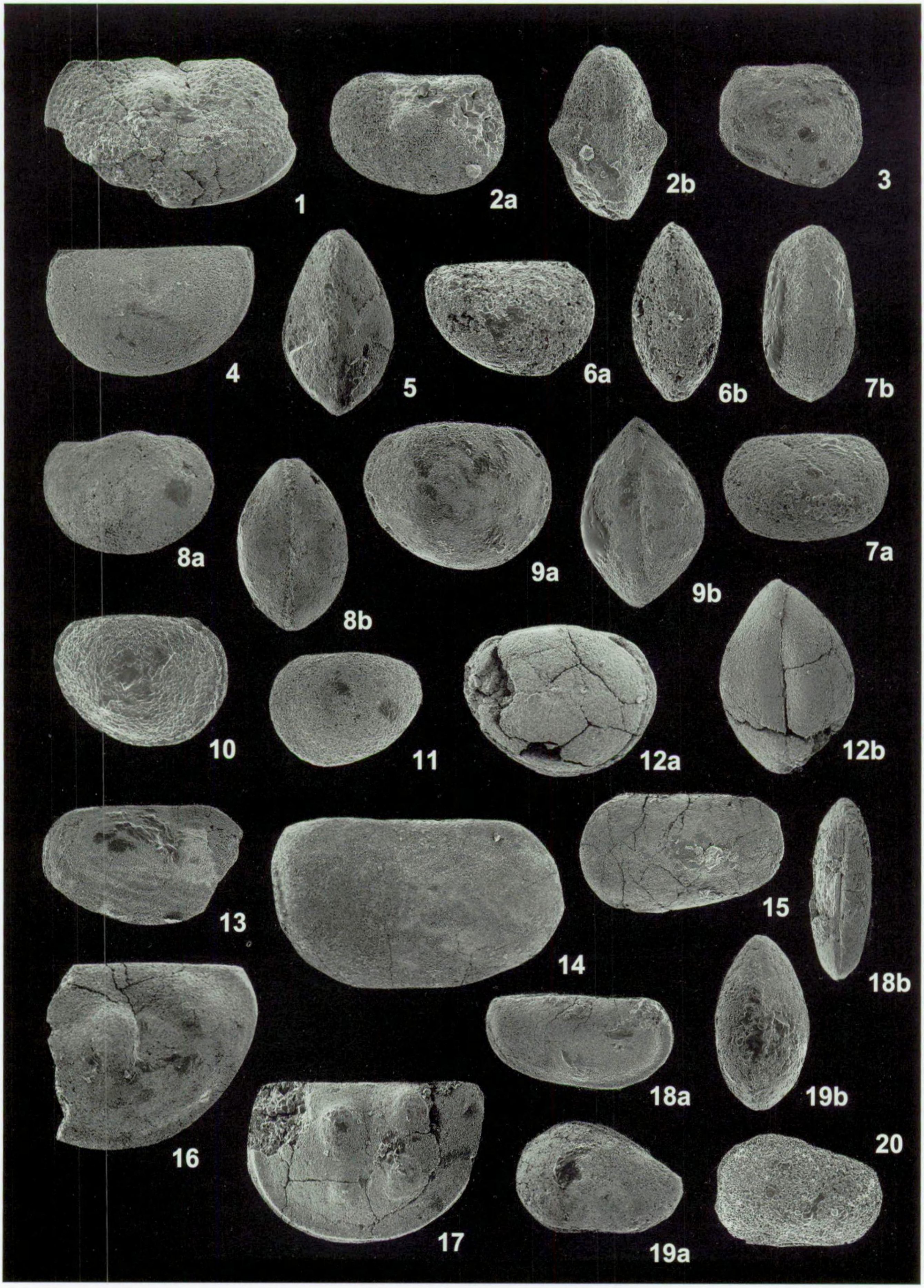
Upper Devonian (upper Frasnian to lower Famennian) calcareous sediments in the Kostomloty Hills, Holy Cross Mountains, Poland. Microfacies.

Fig. 1 — Microfacies 1 (or MF1): bioturbated bioclastic packstone composed of dasycladacean Algae fragments, a few Foraminifera (*Eonodosaria* in the center of the picture), ostracods, tentaculids. Thin section KYA 39. Scale bar 1 mm.
Fig. 2 — Microfacies 2 (or MF2): micritic to microsparitic packstone enriched in tentaculids, ostracods, a few Foraminifera, calcispheres and dasycladaceans Algae. The matrix contains numerous peloids. Thin section KYA 29''. Scale bar 1 mm.
Fig. 3 — Microfacies 3 (or MF3): micritic packstone containing abundant small-sized peloids, numerous fragments of dasycladacean Algae (*Issinella* essentially) as well as few Foraminifera, brachiopods, ostracods and calcispheres. Thin section KYA 3. Scale bar 1 mm.
Fig. 4 — Microfacies 4 (or MF4): dasycladacean packstone enriched in fragments of *Issinella* with brachiopods, crinoids, calcispheres, trilobites, ostracods, and peloids. Thin section KYA 23. Scale bar 250 µm.
Fig. 5 — Microfacies 5 (or MF5): coarse grained dasycladacean grainstones and bafflestones dominated by algal fragments of *Issinella* (up to several mm in size). Thin section KYA 48. Scale bar 1 mm.
Fig. 6 — Microfacies 6 (or MF6): packstones and grainstones enriched in ooids, peloids, lumps, intraclasts with brachiopods, crinoids, molluscs, ostracods, trilobites, green and red algal fragments and coated grains. The microfacies is poorly laminated. Thin section KYA 60. Scale bar 0,5 cm.

PLATE 6

Upper Devonian (upper Frasnian to lower Famennian) calcareous sediments in the Kostomloty Hills, Holy Cross Mountains, Poland. Microfacies

Fig. 1 — Microfacies 6 (or MF6): ooidal grainstone composed of radial-concentric ooids, superficial and radial ooids, algal lumps and coated grains. Ooids are spherical, elongated or irregularly bumpy, with a general tendency to attain sphericity. Thin section KYA 85''. Scale bar 250 µm.
Fig. 2 — Microfacies 7 (or MF7): fine peloidal grainstones with calcispheres and ostracods. Thin section KYA 86. Scale bar 250 µm.
Fig. 3 — Microfacies 8 (or MF8): alternation of thin peloidal packstone laminae and thicker peloidal laminae containing numerous molds of molluscans shells, small ostracods, calcispheres and lumps. These laminae are sometimes interrupted by large fissures (several mm width, left part of the picture) filled with numerous molluscs, crinoids, peloids, lumps and angular breccia fragments of the same microfacies in all positions including vertical ones. Thin section KYA 66. Scale bar 0,5 cm.
Fig. 4 — Microfacies 9 (or MF9): bioturbated wackestones with trilobites, connected spicule sponges and perforated echinoderms. Thin section KYA 87''. Scale bar 0,5 cm.
Fig. 5 — Microfacies 10 (or MF10): polygenic conglomeratic limestone composed of angular to subnodular intraclasts (up to several cm in length). These intraclasts consist of different microfacies including those from shoal and back-shoal environments. They are mixed with algal lumps, crinoids, brachiopods, dissolved molluscan shells and red algal remains (up to 1 cm thick, in the lower left part of the picture). Thin section KYA 92. Scale bar 0,5 cm.
Fig. 6 — Microfacies 11 (or MF11): monogenic micro-conglomerate consisting of mudstones intraclasts (up to several cm in length) containing few calcispheres and sponge spicules. Intraclasts are embedded in a spar cement which contains scarce brachiopods. The morphology of spar crystals indicates a sulphate origin (not visible at this scale). Thin section KYA 97. Scale bar 0,5 cm.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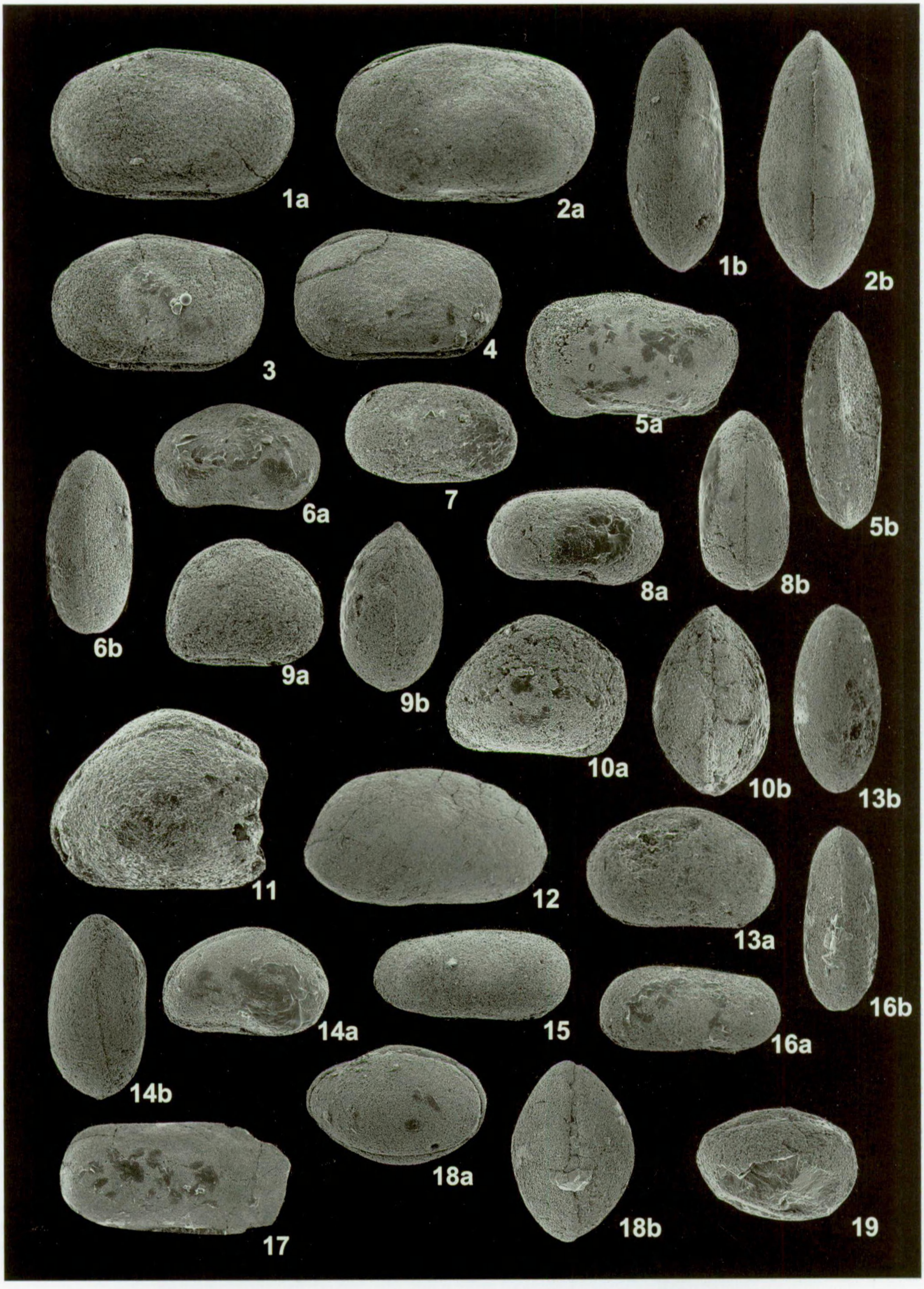
17
19a

PLATE 1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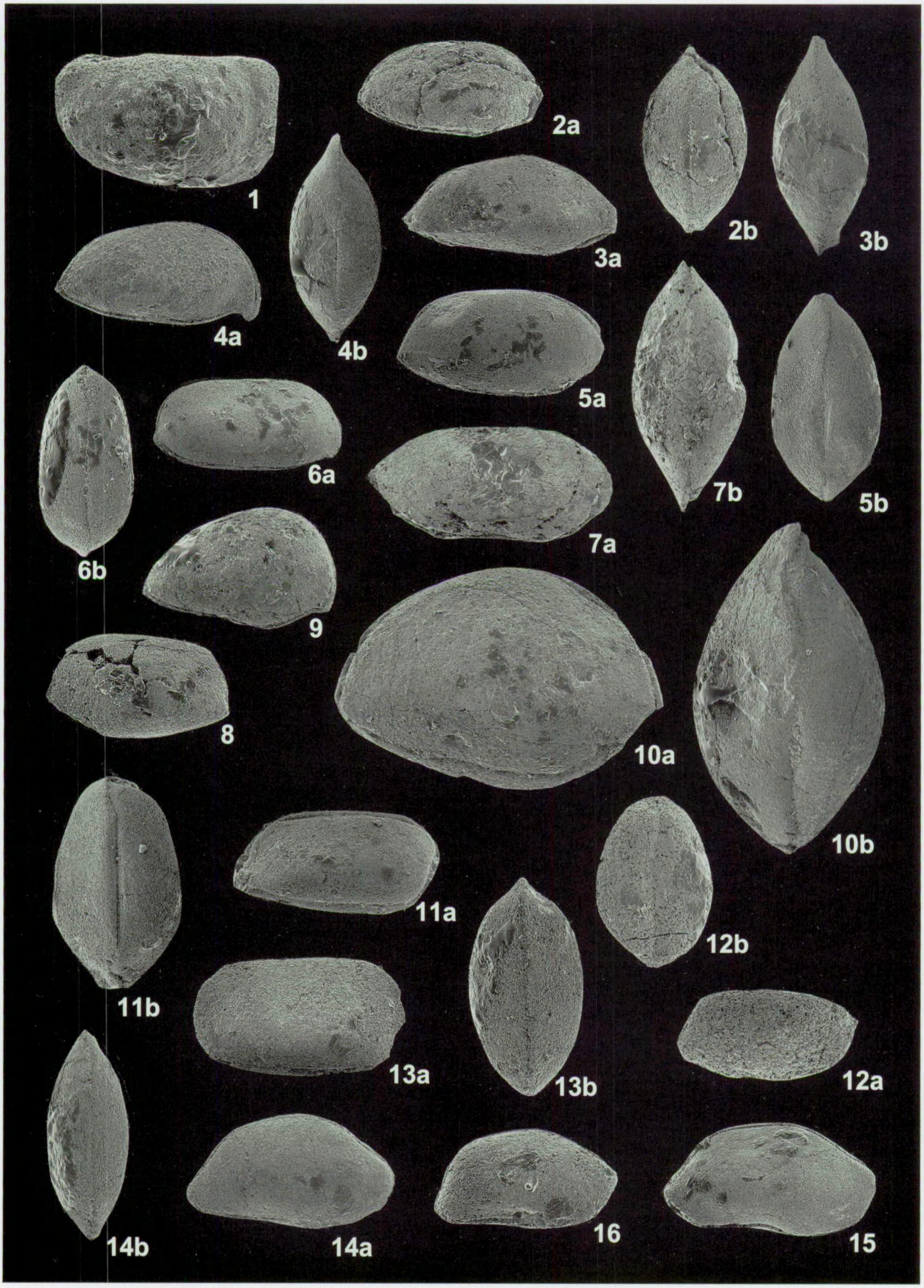
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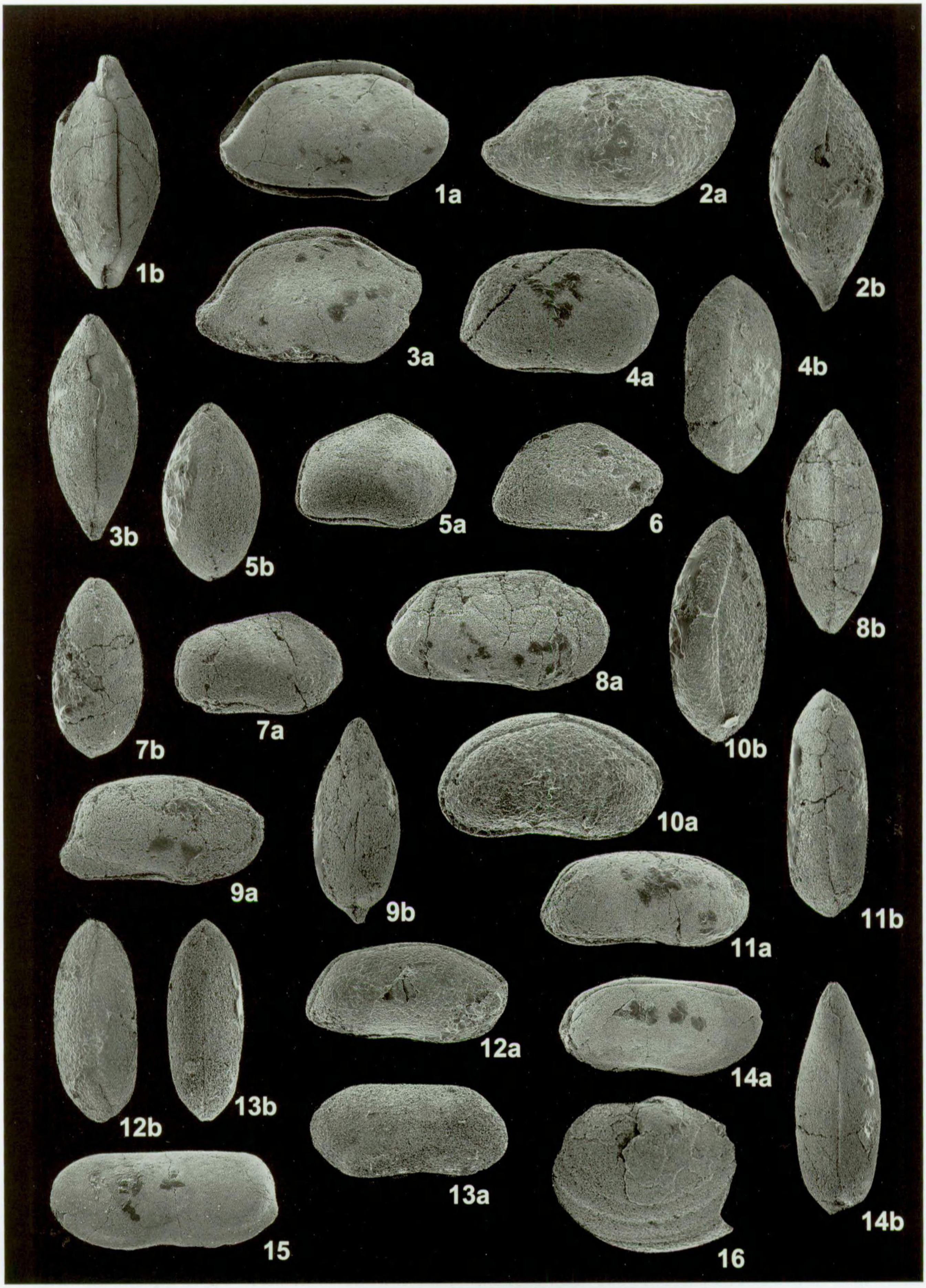
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PLATE 4

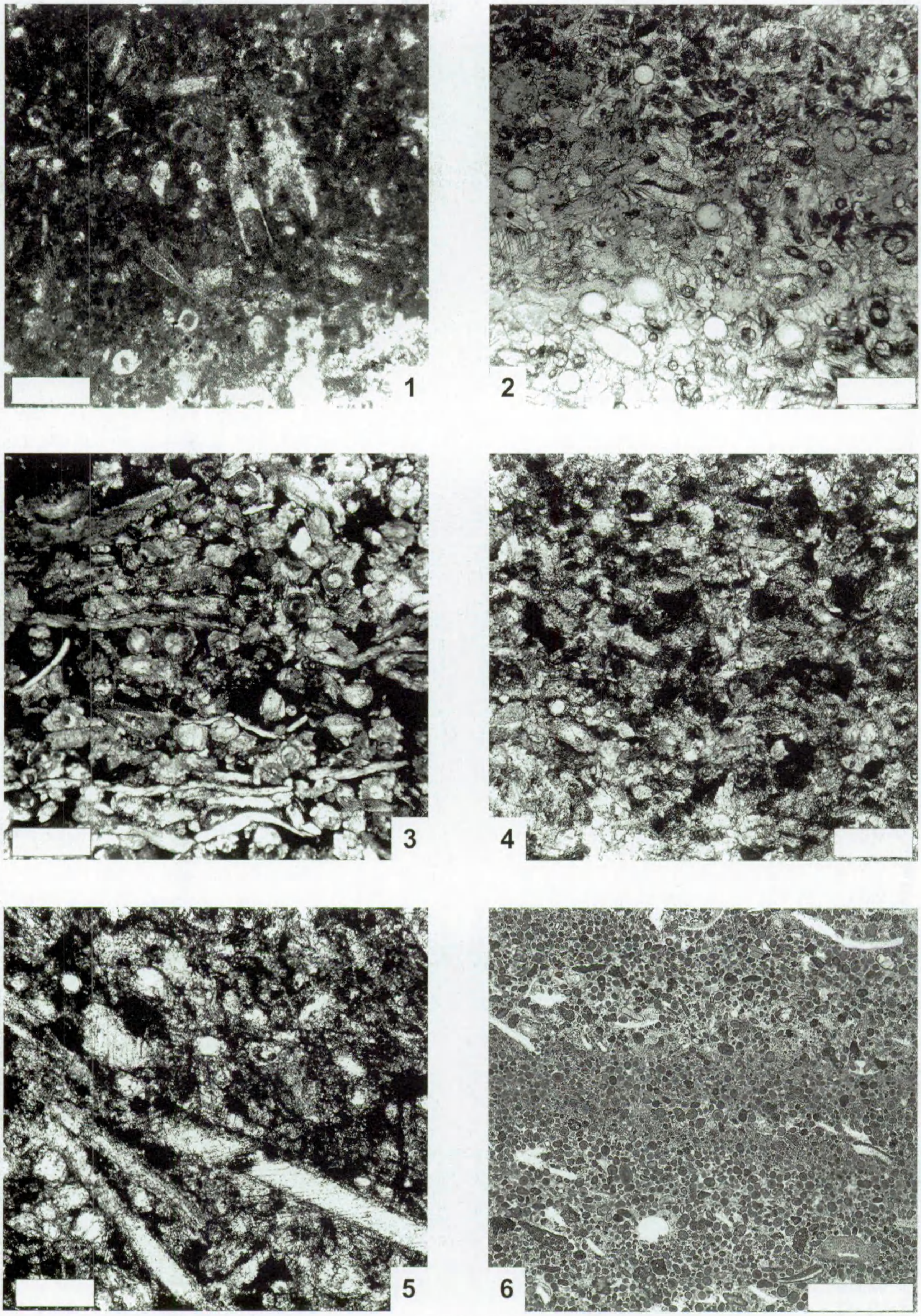

PLATE 5

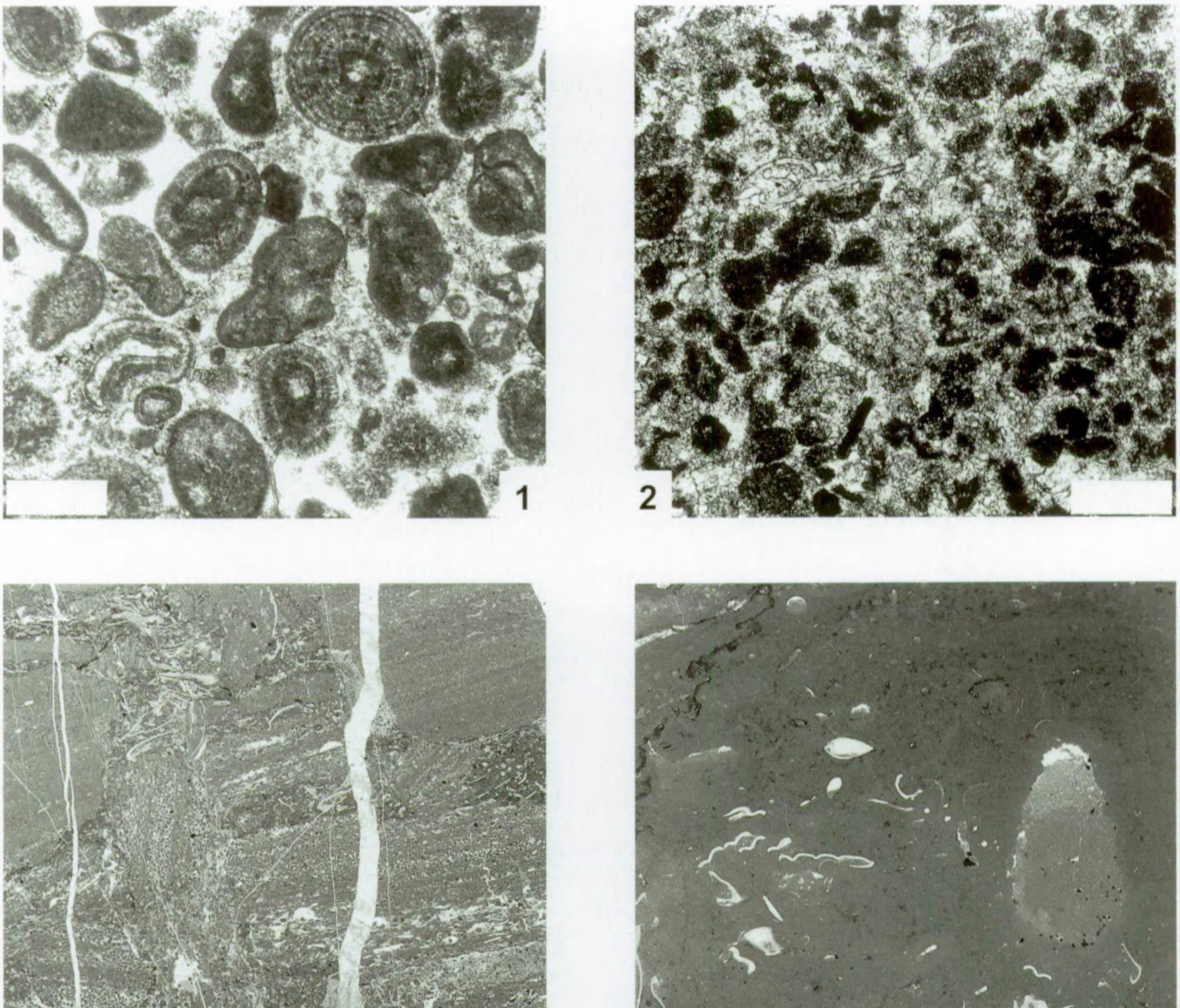

PLATE 6