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Ostracods, rock facies and magnetic susceptibility of the Trois-Fontaines and Terres d'Haurs Formations (Early Givetian) in the Rancennes quarry at the Mont d'Haurs (Givet, France)

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Abstract

About 1,200 ostracods were extracted from 64 samples collected in the upper part of the Trois-Fontaines Formation (Fm) and in the base of the Terres d'Haurs Fm in the Rancennes quarry located along the western rampart of an historic entrenched military camp at the Mont d'Haurs (southern part of the Dinant Synclinorium, Ardennes Department, France). The ostracod richness and diversity are quite variable, and monospecificity prevails in numerous samples. Forty-nine ostracod species are recognised. In the Trois-Fontaines Fm, environments were lagoonal or semi-restricted, and the level containing numerous Leperditicopid ostracods (*Herrmannina*) indicative of (brackish?) lagoonal environments is 40 m thick. In the Terres d'Haurs Fm the environment was semi-restricted or more frequently shallow marine but the energy of the environment was apparently never very high. The level rich in Leperditicopida (*Herrmannina*) in the Trois-Fontaines Fm corresponds remarkably to the highest magnetic susceptibility (MS) value.

The Rancennes microfacies point to a tidal flat system with various subenvironments such as restricted intertidal, supratidal and channel deposits. The system was bordered by subtidal open marine deposits where former reefal constructions have been destroyed. Frequent oscillations in this low-gradient shallow platform led to the exposure and modification of marginal ponds, floodplain environments or palustrine areas. No evidence of evaporitic environments or sabkha were encountered. The sedimentary system records the evolution of a shallow restricted carbonate platform (Trois-Fontaines Fm) to a carbonate ramp setting (Terres d'Haurs Fm). The evolution of the platfom to a ramp could be related to the cessation of the active role of a reefal barrier possibly as a response to synsedimentary tectonism and block faulting.

The magnetic susceptibility curve established for the Rancennes quarry highlights 26 short-term magnetic evolutions that can be grouped into 10 major long-term magnetic sequences characterized by decreasing, increasing or stable magnetic susceptibility fluctuations. Magnetic susceptibility values range between 3.75 x 10^{-9} and 2.98 x 10^{-7} m^3/kg. There is a general good correspondence between the microfacies and magnetic susceptibility curves, which are clearly mimetic at the smaller scale (*i.e.*, 5th-order parasequences). The magnetic susceptibility curve could thus be interpreted as sea-level oscillations. A part of the magnetic minerals carrying the MS signal must have a detrital origin. Magnetization and coercivity ratios deduced from hysteresis loops indicate the presence of detrital coarse-grained multi-domain magnetite and authigenic mixtures of fine-grained superparamagnetic and single-domain magnetite. The MS signal of the Rancennes quarry seems to be controlled by the ferrimagnetic fraction (magnetite) with minor paramagnetic contribution (clay minerals and pyrite).

The Rancennes quarry completes the stratotype of the Terres d'Haurs Fm because the section exposes the boundary with the Trois-Fontaines Fm unlike the previously proposed stratotype located on the south-eastern flank of the Mont d'Haurs entrenched camp.

Keywords: Ostracods, Sedimentology, Palaeoecology, Magnetic Susceptibility, Givetian, Dinant Synclinorium, Ardennes, France.

Résumé

Environ 1.200 ostracodes ont été extraits de 64 échantillons récoltés dans le sommet de la Formation (Fm) de Trois-Fontaines et dans la base de la Fm des Terres d'Haurs exposés dans la carrière de Rancennes. Elle est située le long des remparts ouest du camp militaire retranché du Mont d'Haurs (bord sud du Synclinorium de Dinant, Département des Ardennes, France). L'abondance et la diversité des ostracodes sont extrêmement variables, et la monospécificité prévaut dans de nombreux échantillons. Quarante-neuf espèces sont reconnues. Dans la Fm de Trois-Fontaines, les environnements étaient soit lagunaires soit semi-restreint et le niveau contenant des Leperditicopida appartenant au genre *Herrmannina* indicateur de milieux lagunaires, est épais d'une quarantaine de mètres. Dans la Fm des Terres d'Haurs, les environnements étaient semi-restreints ou plus généralement marins peu profonds mais le milieu n'était jamais fort agité.

L'analyse sédimentologique des microfaciès montre que les dépôts de la carrière de Rancennes sont caractéristiques d'un tidal flat lagunaire ou ensemble de marais maritimes disséqué de divers environnements intertidaux et supratidaux ("'shoals", chenaux, levées, mares). Ce système est bordé de milieux subtidaux marins plus francs où des constructions récifales ont été détruites. Les variations relatives du niveau marin, étaient probablement de faible amplitude, et ont permis de partielles expositions des facies de plate-forme carbonatée avec développement de sédiments palustres de plaine littorale sans dépôts hypersalins de type sebkha. L'évolution sédimentaire est celle d'une plate-forme carbonatée dominée par les milieux restreints, riches en faunes et microflores endémiques (Formation de Trois-Fontaines), passant à une rampe carbonatée plus argileuse (Formation des Terres d'Haurs) à faunes et microflores diversifiées. Cette évolution, accompagnée d'une réduction ou destruction d'une barrière récifale, est probablement liée à une activité tectonique synsédimentaire de type blocs basculés.

La courbe de susceptibilité magnétique établie pour la carrière de Rancennes se décompose en 26 séquences magnétiques de court terme regroupées en 10 séquences magnétiques majeures à long terme qui sont caractérisées par des augmentations, des décroissances ou des phases de stabilité des valeurs de susceptibilité magnétique. La gamme des valeurs de susceptibilité magnétique varie entre 3,75 x 10^{-9} et 2,98 x 10^{-7} m^3/kg. Une bonne correspondance existe entre les courbes de microfaciès et de susceptibilité magnétique attestée par l'allure mimétique de ces dernières observée à la plus petite échelle (*i.e.* les paraséquences du 5^e ordre). La courbe de susceptibilité magnétique peut donc être interprétée en terme d'oscillations du niveau-marin. Une partie des minéraux magnétiques à l'origine du signal de susceptibilité magnétique doit donc être détritique. Les rapports d'aimantation et de coercivité déduits des courbes d'hystérésis indiquent la présence de grains détritiques grossiers de magnétite multi-domaine accompagnés par des fines magnétites authigéniques correspondant à un mélange de grains superparamagnetiques et mono-domaine. Le signal de susceptibilité magnétique de la carrière de Rancennes semble donc contrôlé par la fraction ferrimagnétique (magnétite) et par une contribution mineure des minéraux paramagnétiques (minéraux argileux et pyrite).

La carrière de Rancennes complète le stratotype de la Formation des Terres d'Haurs situé sur le flanc sud-est du camp retranché du Mont d'Haurs. En fait, celui-ci n'expose pas l'extrême base de cette formation, et par conséquent la limite avec la Fm des Trois-Fontaines sous-jacente.

Mots-clefs: Ostracodes, Sédimentologie, Paléoécologie, Susceptibilité Magnétique, Givétien, Synclinorium de Dinant, Ardennes, France.

Introduction

This paper forms part of a series on Middle Devonian ostracods and their lithological context in the type region for the definition of the Givetian Stage (Southern part of the Dinant Synclinorium, Ardennes Department, France). This first paper concerns a quarry located at Rancennes, 1 km south of Givet, and more precisely along the western rampart of an historic entrenched military camp at the Mont d'Haurs (Fig. 1). Vauban, the military architect of Louis XIV, built this entrenchment at the end of the XVIIth century. The series exposed in the quarry (GPS: N 50°07'46.8"; E 04°49'21.4") and in the access path to the quarry is particularly homogeneous and consists of 46 m of well bedded fine-grained greyish mudstones, wackestones and laminites (= Trois-Fontaines Formation (Fm), base of the Givetian Group) overlain by 14 m of thicker beds of clayey slightly nodular wackestones, packstones and floatstones with crinoids, corals and various shelly bioclasts (= Terres d'Haurs Fm). The base of the Terres d'Haurs Fm is marked by a clayey nodular biostrome.

Only the middle and upper parts of the approximately 80 m thick Trois-Fontaines Fm and the base of the approximately 70 m thick Terres d'Haurs Fm (PRÉAT & TOURNEUR *in* BULTYNCK *et al.*, 1991) are exposed in the Rancennes quarry and in the access path. The first biostrome at the base of the Trois-Fontaines Fm (PRÉAT & MAMET, 1989) is not present in the Rancennes quarry. The Trois-Fontaines Fm and the Terres d'Haurs Fm are the lowest recognised in the Givetian Group in the type region (BULTYNCK *et al.*, 1991). The stratotype of the Trois-Fontaines Fm is located in the nearby Trois-Fontaines quarry, on the north bank of the Meuse River. The stratotype of the Terres d'Haurs Fm is located on the south-eastern flank of the entrenched camp, at the Mont d'Haurs, but the boundary between the Trois-Fontaines Fm and the Terres d'Haurs Fm is not visible in the stratotype (HUBERT, 2008).

The Givetian of the Mont d'Haurs has been the subject of numerous papers (See: ERRERA *et al.*, 1972, and BULTYNCK *et al.*, 1991 for an exhaustive bibliography). Conodont distribution and frequency in the Mont d'Haurs sections have been established by BULTYNCK (1987). More recently, HUBERT (2008) published a lithological study and a faunal abundance analysis of the Mont d'Haurs sections with the exception of the Rancennes quarry.

Some ostracods have been reported from the Hanonet Fm, from the base of the Trois-Fontaines Fm and from the Terres d'Haurs Fm at the Mont d'Haurs by BECKER & BLESS (1974), COEN (1985) and MILHAU *in* HUBERT *et al.* (2007). According to GROESSENS (2008), several other quarries have been worked in the Givetian at Rancennes.

Rock and facies analysis (A. PRÉAT & G. CAMBIER)

PRÉAT & MAMET (1989) developed a standard microfacies sequence of 13 major microfacies types (MF) for the French-Belgian Givetian of the Dinant basin and correlated them with the corresponding microfacies of the idealized standard microfacies (SMF) sequence of WILSON (1975). As the Givetian microfacies of the Rancennes section are similar to the ones described in the above mentioned standard sequence, we give their

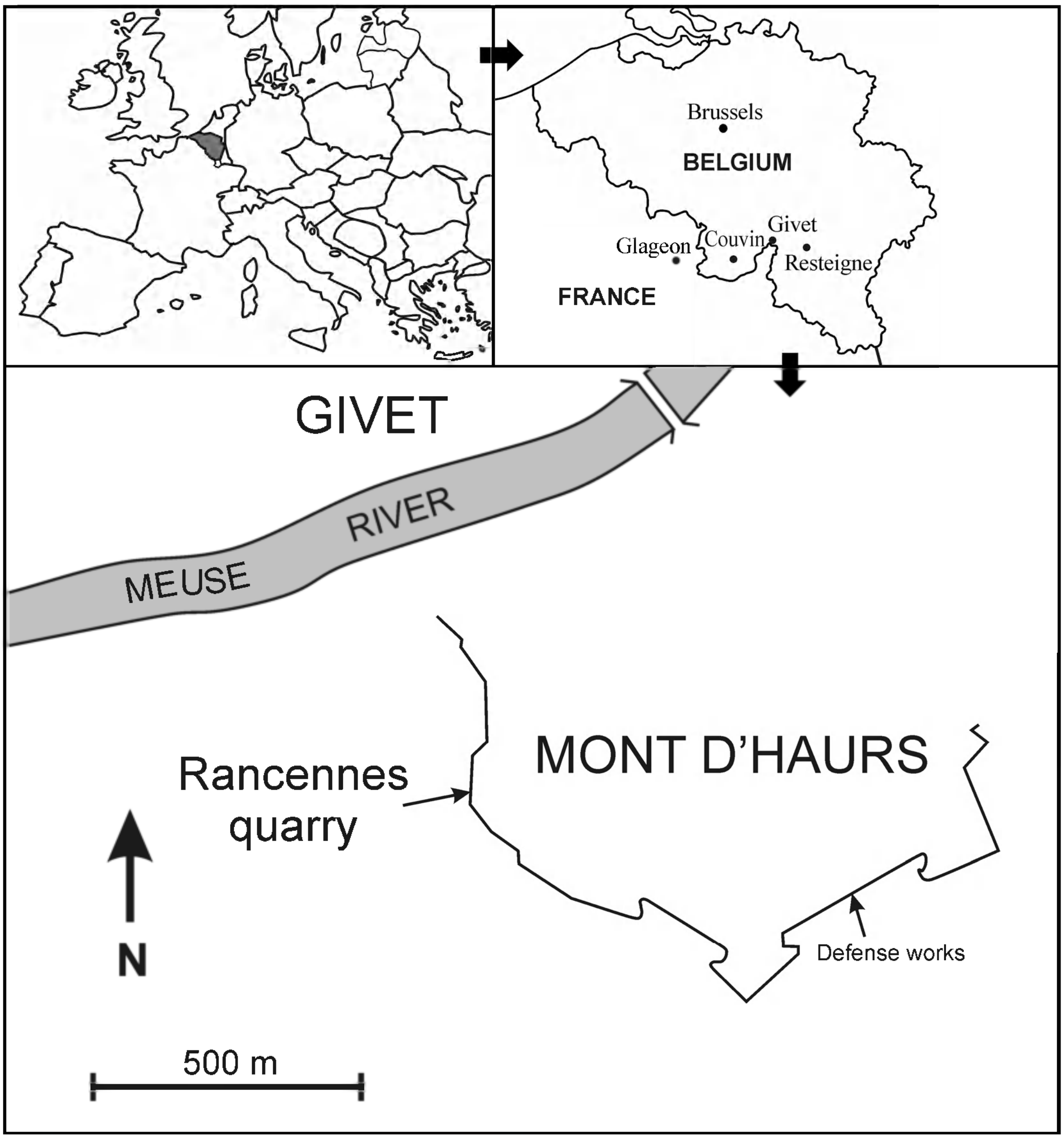

Fig. 1 – Locality map of the Rancennes quarry.

correspondent microfacies using the Préat & Mamet (1989) standard sequence.

One hundred eighty seven samples were collected (Figs 2, 3) for petrography in order to constrain the palaeoenvironments.

Microfacies description

Microfacies type 1 (or MF1) - Open marine fore-reef moderately agitated (Pl. 1)

Description: burrowed peloidal packstones with abundant issinellids (algae) and various bioclasts (crinoids, sea urchins, brachiopods, gastropods, ostracods, bryozoa, trilobites, archaegastropods, kamaenids and nodular codiacea). A few larger bioclasts consisting of stromatoporoids and corals (Tabulata) are sporadically observed forming coarse-grained floatstones with whole shells. Micritized and encrusted grains due to the activity of *Bevocastria* and *Ortonella* are present and a few grains appear as oncoids. The bioclasts display a weak oblique stratification and are well-sorted. Microbreccias, "blackened grains" (*sensu* Mamet & Préat, 2005) and pyrite are rare. The micritic matrix is generally a fine-grained calcite microspar and contains numerous irregular calcitic cavities giving to the facies the appearance of grainstone.

Interpretation: the sedimentation area consists of an accumulation surface of various bioclasts coming from different sources: destruction of biohermal framestones (Mamet & Préat, 2005, 2007), of crinoidal meadows, of algal banks (issinellid bafflestones) and input from lagoonal environments. This latter is not important

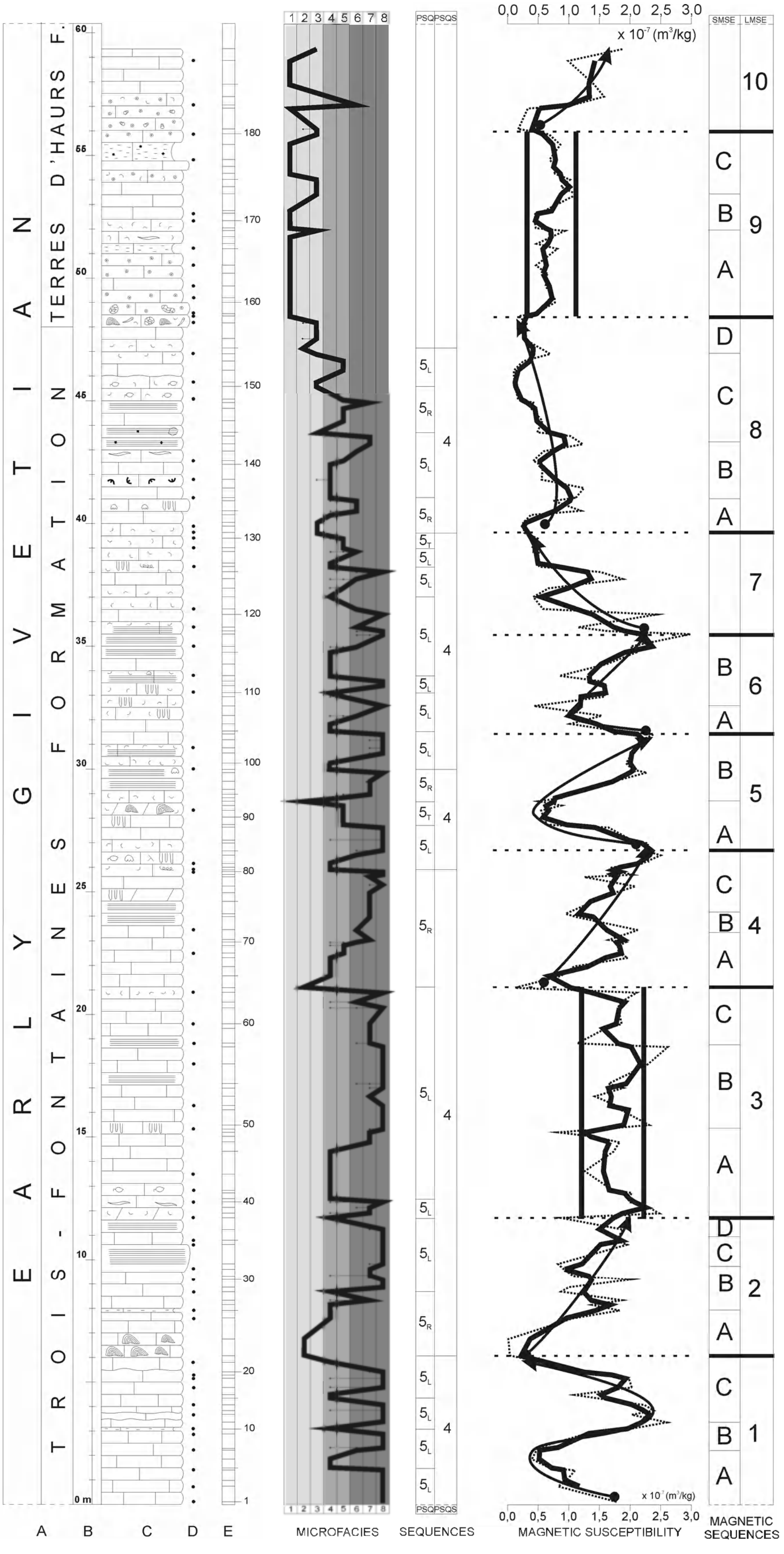

Fig. 2 – Rancennes quarry: lithological column, microfacies, microfacies sequences, magnetic susceptibility and magnetic sequences. (A) stratigraphy; (B) thickness; (C): lithology; (D) position of ostracod samples; (E) position of samples for thin sections and MS analysis. The dashed line corresponds to raw low-field magnetic susceptibility values (10^{-7} m^3/kg) and the black line represents the 3-period simple moving average. See Fig. 3 for key to symbols.

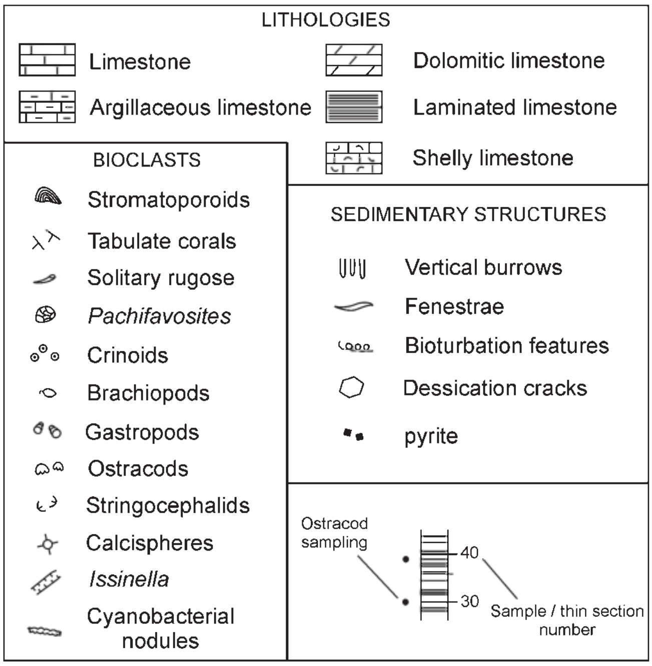

Fig. 3 – Key to symbols used in Figures 2 and 4.

as the debris (kamaenids, archaegastropods) are occasional. The abundance of marine organisms points to an open marine environment near a bioconstruction, as suggested by the presence of reworked stromatoporoids and corals. These are transported by proximal storms (*sensu* Aigner, 1985) and accumulated as interstratified coarse-grained floatstones characterizing reefal slopes in a general shallow water setting, probably in the photic zone (abundance of reworked issinellids and kamaenids). This microfacies is equivalent to MF3 of the Préat & Mamet (1989) standard sequence representing the open marine environment.

Microfacies type 2 (or MF2) - Open marine back-reef moderately agitated (Pl. 1)

Description: peloidal packstones and floatstones similar to the previous microfacies with more fragments of stromatoporoids and tabulata and less echinodermal plates. Bioclasts of brachiopods, mollusks, ostracods and trilobites are common. Within this microfacies microbreccias constituted by oolitic packstone and numerous oncolites with cortices formed by *Ortonella, Hedstroemia and Pseudohedstroemia* are visible. The micritic matrix contains abundant lumps of various sizes and abundant *Girvanella, Ortonella, Kamaena* and *Issinella.* As for MF1 the larger macrofaunal fragments display weak oblique stratification and also graded bedding.

Interpretation: The abundance of fragments of stromatoporoids and tabulata suggests the proximity of buildups as for MF1. The oolitic microbreccias, the lumps and oncolites of cyanobacteria (cyanoliths *sensu* Riding, 1983) point also to the proximity of semi-restricted and intertidal environments. Subtidal shoals probably constituted the environment with intermittent energy (oncolites) in a general back reefal setting close to intertidal channels where oolites formed. Mixing of open marine and semi-restricted bioclasts suggest that no effective reefal buildup was present. This microfacies is similar to MF5 and MF6 of the Préat & Mamet (1989) standard sequence. They represent the back-reefal area.

Microfacies type 3 (or MF3) - Semi-restricted back-reef environment (Pl. 1)

Description: oolitic and peloidal packstones with crinoids, brachiopods, ostracods, issinellids, kamaenids, *Triangulinella* and "cryptalgal" chips. The micritic matrix is partly micosparitized and contains a few microbreccias of oolitic and cyanobacterial wackestones-packstones, a few oncolites, mud-coated grains and various cavities related to the dissolution of molluskan bioclasts. These cavities can be abundant and become similar to "key vugs", the sediment appearing as a grainstone. The oolites are irregular and their diameters range from 0.1 mm to 1.1 mm, averaging 0.3 mm. Their nuclei are diverse and often constituted by a fragment of an issinellid or a crinoid. They are similar to the ß-oolites (Purser, 1980) or type-3 oolites of Strasser (1986) with 2 or 3 laminae constituting the cortex.

Interpretation: the fauna is poorly diversified and the microflora (and also the cyanobacterial chips) becomes abundant suggesting a semi-restricted environment still submitted to an open marine influence (crinoids, brachiopods). Oolites indicate a calm protected environment similar to the ß-oolites of the Persian Gulf (Purser, 1980) or intermittently agitated and calm waters as suggested by type-3 oolites of Strasser (1986). The general environment of the microfacies is intertidal and consists of slightly agitated shoals in semi-restricted areas submitted to a weak open marine influence. This microfacies is similar to MF7 of the Préat & Mamet (1989) standard sequence representing a back-reefal environment.

MF1, 2 and 3 are common in the Terres d'Haurs Fm in the Rancennes quarry and represent a general shallow open environment or "open" lagoon succeeding to the well-developed restricted lagoon of the Trois-

Fontaines Fm (see below). They are exceptional in the Trois-Fontaines Fm in the studied section and record an episodic pronounced marine influence.

Microfacies type 4 (or MF4) - Restricted or protected lagoonal environment (Pl. 2)

Description: homogeneous wackestones and packstones with pelecypods (disarticulated and joined shells), gastropods, ostracods (Leperditicopida), calcispheres, kamaenids, issinellids, cyanobacterial nodules and encrustments of *Bevocastria, Pseudohedstroemia* and *Ortonella*, proninellids, *Bisphaera* (*incertae sedis*), *Labyrinthoconus* and rare *Umbella*. Numerous cyanobacterial lumps and peloids are also observed. Rare fragments of trilobites, brachiopods and crinoids are present in the micritic matrix as thin layers. The micrite can also be replaced by a fine-sized calcitic microspar. Ostracods can be abundant and constitute thin packstone layers interstratified in the wackestones. Irregular fenestrae are present. Pyrite as small framboids (< 10 µm) and cubes (100 to 200 µm) are common in the wackestone matrix and are concentrated along the pressure dissolution seams or stylolithes.

Interpretation: the algae, the cyanobacteria and the low diversity of the fauna point to a restricted lagoon regularly colonized by endemic organisms. Salinity variations were the rule as indicated by local abundance of Leperditicopida and episodic presence of *Umbella*. Rare thin interstratified bioclastic levels (*e.g.*, with crinoids) are related to higher energy (storms) bringing open marine organisms into the lagoon. This microfacies is similar to MF9 of the PRÉAT & MAMET (1989) standard sequence corresponding to a protected lagoon. This MF9 is the best represented in the standard sequence and is the major facies of the Trois-Fontaines Fm in the Dinant Synclinorium, and probably also the most typical of all the Belgian Givetian. It belongs to the internal part of the shallow Givetian carbonate platform, with an associated lagoon over 60 km wide and extending from England to at least Germany (GARLAND, 1997; PRÉAT, 2006). As shown below, MF4 is common in the Trois-Fontaines Fm of the Rancennes quarry and constitutes the base or lower part of 5th-order cycles.

Microfacies type 5 (or MF5) - Intralagoonal shoals (Pl. 2)

Description: kamaenid and issinellid bafflestones with ostracods and peloids. A few gastropods, cyanobacterial nodules, calcispheres and microproblematica (*Bisphaera* and *Cribrosphaeroides*) are also observed with rare brachiopods and crinoids. The micritic matrix can be burrowed and contains irregular fenestrae similar to "key-vugs". Pyrite occurs as in the preceding microfacies.

Interpretation: the issinellids are delicate vertical branched algae, which disarticulate easily (MAMET & ROUX, 1981). They form algal meadows and their *in situ* fragmentation through local marine and tidal currents brings abundant skeletal grains near their production area. The accumulation of these bioclasts forms bars or shoals in a subtidal or intertidal setting as suggested by the "key-vugs". Peloids are probably formed under the same conditions as those forming the cyanobacterial mats present in the lagoon (MF4).

Microfacies type 6 (or MF6) - Intertidal-supratidal lagoonal margin (Pl. 2)

Description: spongiostromid packstones and bindstones with issinellids, kamaenids, *Bisphaera*, calcispheres and ostracods. Irregular and laminoid fenestrae, vertical burrows and occasional umbrella cavities give to the rock the appearance of a loferite. The spongiostromid structure is composed of millimeter- to centimeter-scale alternation of homogeneous very fine-grained dolomudstone and peloidal-lumpy packstone with abundant cyanobacterial filaments represented by networks of upward-anastomosing tubular fenestrae. The sediment laminae between the cyanobacterial layers or mats (spongiostromid fabric) are mainly peloidal or clotted micrite with scattered dense peloids. Pyrite is abundant as small framboids, cubes, filaments (*sensu* MAMET & PRÉAT, 2004) and as concentration in the microstylolites. Its filamentous form is observed in tubular dolomitic cavities and inside dolomitic fenestrae.

Interpretation: the organisms are not diversified and mainly represented by spongiostromids and algae. The previous open-marine fauna is totally absent and the environment is strongly protected. This community has in fact a lower diversity and abundance than communities in more open and semi-restricted previous microfacies. The microbial mats (spongiostromids) could occur abundantly in the tidal flat at higher tidal levels with unstable microenvironmental conditions (salinity, temperature, exposure) in the sediment. This microfacies is similar to MF10 of the PRÉAT & MAMET (1989) standard sequence representing a very restricted shallow environment near emersion. Present-day Andros Island (Bahamas) algal marshes and ponds with very low-diversified communities (HARDIE, 1977) could be a good equivalent of the sedimentary environment of MF6.

Microfacies type 7 (or MF7) - Intertidal-supratidal lagoonal margin (Pl. 3)

Description: laminites showing a millimeter-scale basic alternation of relatively well-sorted peloid silty to sandy laminae (packstone layer) and clotted mud laminae (mudstone layer). The boundaries between the mud laminae and peloid laminae are sharp or lenticular with peloid sand laminae pinching out against the mud laminae. In this case the sediment laminae appear wavy and discontinuous and their thickness varies from 0.1 to 2 mm. The sand laminae contain also small-sized algal bioclasts of issinellids and kamaenids. Peloids range in size from 20 to 500 µm and are ellipsoidal or rounded-irregular in shape. Mud-cracks and sheet-cracks are common and filled with peloidal sand from overlying laminae. Sheet-cracks are narrow, horizontal or slightly oblique, up to 1 cm long parallel to the bedding plane. They are often associated with dark, crinkled parts that could represent microbial mats or levels enriched with organic matter. Small-sized irregular and tubular fenestrae are present, with the matter resembling filament molds. Discrete irregular and vertical burrows are associated and filled with the sandy peloidal-bioclastic material or with a fine-grained hypiditopic dolomite. Thin beds (in the field) with thicker laminations are also observed.

Interpretation: Uniform millimeter-lamination characterizes the most elevated subenvironments of the Andros tidal flats (HARDIE & GINSBURG, 1977). The sediments below mean tide level in the offshore, beach and ponds are basically unaltered, homogenized by burrowing. Above mean tide level layering is preserved as thin millimeter laminations giving “laminites” typical of the levees, beach ridges and channel bar crests and thin beds with thicker laminations, as are also observed in the algal marshes on Andros Island. The continuous and discontinuous patterns of the Rancennes laminites are similar to the “smooth domal lamination” and the “disrupted flat lamination” of Andros Island where they are associated with intertidal channel banks, intertidal and supratidal levee crests. The absence of progradational layers in this microfacies and in the preceding one, in the field or under thin sections, suggests that the Givetian tidal flat was almost flat, the relief being measured in centimeters as for the Andros tidal flat. The vertical profile across a levee from channel to pond over a horizontal distance of more than 200 m is less than 50 cm on Andros Island. Peloids are probably imported from the restricted lagoon (MF6) as the bioclasts of issinelids and kamaenids. This microfacies is similar to MF12 of the PRÉAT & MAMET (1989) standard sequence representing the inundation of the littoral plain. The millimeter lamination could be produced by the alternation of physical sedimentation related to storms and the growth of cyanobacterial mats in a low energy tidal flat environment submitted to tropical cyclones (PRÉAT & BOULVAIN, 1987).

Microfacies type 8 (or MF8) - Palustrine? and continental sedimentation (Pl. 3)

Description: peloidal, lumpy and mottled wackestones and mudstones with calcispheres, Leperditicopida, kamaenids, issinellids, *Bevocastria* and *Labyrinthoconus*. The micritic matrix is commonly microsparitized and contains abundant dolomitic vertical cavities (decayed roots), subhorizontal clay-filled sheet-cracks, irregular mud-cracks and various fenestrae. Some cavities display a peloidal sedimentary infilling with vadose silt. Alveolar septal texture (*sensu* ADAMS, 1980), coatings of various types, patchy needle-fibers (diameter of 6 µm and length of 75 µm) similar to those described by KLAPPA (1980), calcite aggregates and aggregates with circumgranular cracks (“glaebules”) are regularly observed. Small pyrite (framboids and cubes) is preferentially associated with the geopetal fenestral cavities, at the interface between bottom micrite infilling and sparite cement of the upper part.

Interpretation: The organisms (algae, ostracods) and peloids are identical to those in the preceding and underlying microfacies (MF4 to MF7) and were presumably derived from them. The tubular cavities and fenestrae, the aggregates with circumgranular cracks and vadose silt infilling of irregular cavities may result from pedoturbations in a subaerial environment. The flattened sheet-cracks could indicate horizontal rhizoconcretions (ADAMS, 1980) associated with thin calcrete levels as suggested by the alveolar textures and the incipient glaebules (ESTEBAN & KLAPPA, 1983). Root moulds and fenestral and alveolar structures could indicate the influence of a vegetation cover. They typically occur in lakes with low gradients and low energy margins, and in short-lived ponds or in peritidal settings with flat surfaces and low water energy (ALONSO-ZARZA, 2003). Desiccation and subsequent formation of planar to curved cracks occur during relative base-level fall in this environment. All these features point to a palustrine environment affected by pedogenesis similar to those described in the literature (FREYTET & PLAZIAT, 1982; ALONSO-ZARZA, 2003). Palustrine carbonate can constitute cyclothems or elementary cycles, like their strikingly similar peritidal counterparts reflecting the aggradation of sediment surfaces through an oscillating hydrograph (WRIGHT & PLATT, 1995). MF8 does not display enough pronounced characteristics in order to clearly differentiate between calcretes and palustrine carbonates. A key element lies in the fact that palustrine carbonates necessarily form on previous lacustrine mud, whereas calcretes may form on any type of sediment or soil (ALONSO-ZARZA, 2003). MF8 preferentially developed on previous lagoonal mud, which can be equivalent to a lacustrine mud, and therefore suggest that a palustrine environment was present.

Microfacies discussion and sedimentary model

Most of the Rancennes microfacies have an equivalent in the Givetian standard sequence of PRÉAT & MAMET (1989) (table 1). However several microfacies have not been found in the Rancennes quarry from the Trois-Fontaines Fm and lower part of Terres d'Haurs Fm: MF1 and 2 are absent indicating that the studied series is of very shallow water and has been deposited near a continental margin. MF4 and 5 are also absent highlighting the absence of a reefal barrier (such as the one of Wellin, MAMET & PRÉAT, 2007; PRÉAT *et al.*, 2007). MF13 (dolomicrites with sulphate pseudomorphs) of the general standard sequence that is only present in the Mont d'Haurs and Fromelennes Formations (PRÉAT & MAMET, 1989) has not been found in the Rancennes quarry sequence, but MF8 (this work) could constitute an equivalent. The eight Rancennes microfacies point to a tidal flat system with various subenvironments such as restricted intertidal, supratidal and channel deposits (MF3-7). The system was bordered by more subtidal open marine deposits where former reefal constructions have been destroyed (MF3). Frequent oscillations in this low-gradient shallow platform led to the exposure and modification of marginal ponds, floodplain environments or palustrine areas (MF8). No evaporitic environments or sabkha were encountered.

Detailed distribution of the microfacies reveals that the Trois-Fontaines Fm consists mainly of a protected shallow lagoon with different environments from the back-reef area to the continental plain and that open marine environments characterize the Terres d'Haurs Fm. In the first formation, the fauna and microflora are endemic and dominated by a few species (algae, ostracods), in the second the organisms are diversified and abundant. The sedimentary system shows the evolution of a shallow restricted carbonate platform (Trois-Fontaines Fm) that is very extensive (PRÉAT & MAMET, 1989) to a carbonate ramp setting, which is probably of large extent (MABILLE & BOULVAIN, 2008). This evolution of the platform to a ramp could be related to the cessation of the active role of the reefal barrier (MAMET & PRÉAT, 2007) related or unrelated to synsedimentary tectonism and block faulting (KASIMI & PRÉAT, 1996; MAMET & PRÉAT, 2009).

Cyclostratigraphy

Cyclic sedimentation occurs when a cyclic variation is present in either or both of the two proximale controls on sedimentation: sediment budget (or "sediment supply") and sediment capacity (or "accommodation")

MF	LITHOLOGY	PALEOENVIRONMENT	GIVETIAN STANDARD SEQUENCE
1	Crinoidal-brachiopod packstones with reefal bioclasts	Open marine, fore-reef slope	MF3
2	Stromatoporoid floatstones	Subtidal peri-reefal channels	MF6
3	Oolitic bioclastic packstones	Intertidal sandy shoals	MF7c
4	Bioclastic packstones and Calcispherid-Lepediticopida wackestones	Subtidal restricted lagoon	MF8-9
5	Issinellid bafflestones	Intra-lagoonal algal shoals	MF10
6	Spongiostromid bindstones and loferites	Inter- supratidal lagoonal ridge	MF11
7	"Cryptalgal" laminites	Inter- supratidal levees	MF12
8	Mudstone-wackestones with laminar crusts and rhizoconcretions	Palustrine and paleosols	MF13?

Table 1 – Main features of Rancennes microfacies (MF1-8, first column; lithology, second column and paleoenvironment, third column) and comparison with Givetian microfacies of the standard sequence of PRÉAT & MAMET (1989) in fourth column.

(Tipper, 2000). The sediment supply may be considered as relatively constant in the Givetian platform as the microfacies are the same everywhere (Préat & Mamet, 1989). This is not the case with the accommodation capacity since subsidence probably varied greatly through the succession of the different formations or inside a formation due to block faulting (differential subsidence, Kasimi & Préat, 1996; Préat, 2006). A lithological curve has been established from microfacies succession based on the Rancennes standard sequence (Fig. 4). Its analysis reveals that the exposed portion of the Trois-Fontaines Fm consists of 23 meter-scale peritidal shallowing-upwards microfacies cycles. They can be considered as a type of parasequence or 5th-order cycle (Vail *et al.,* 1977; Van Wagoner *et al.,* 1987) being deposited in response to high-frequency, low-amplitude relative sea-level fluctuations. However the origin of the peritidal cyclicity is still a subject of controversy ("allocyclic" *versus* "autocyclic" (Tipper, 2000). Spence & Tucker (2007) suggested that the physical expression of peritidal cyclicity in the geologic record might vary stratigraphically and geographically within a single platform during the course of deposition. This is probably the case for the Givetian carbonate platform with variations of cycle types from the Lower to Upper Givetian (Préat & Mamet, 1989; Préat, 2006). Taking into account the Van Wagoner *et al.* (1987) original definition of a parasequence (or 5th-order cycle), which states "A parasequence is a relatively conformable succession of genetically related beds or bed sets bounded by marine flooding surfaces and their correlative surfaces", we recognize three different types of meter-scale cycles (from 0.6 to 8.6m thick), labeled 5_L, 5_R and 5_T ("5" is for fifth-order cycle, "L" is for lagoon, "R" is for "regressive" and "T" is for "transgressive") in the Trois-Fontaines Fm outcropping in the Rancennes quarry. They are defined by a composite stratigraphic signature that combines microfacies, stacking pattern and boundary surfaces (here MF2-MF4). The observed Terres d'Haurs Fm does not display a peritidal or a well-defined cyclicity and is not considered here.

Type-5_L peritidal cycles (average thickness of 2.2 m) deposited in the restricted lagoon are characterized by the relatively continuous succession of MF4 to MF8 that shallow-upward from calcispherid wackestones to spongiostromid bindstones and laminites capped by pedogenic wackestones and packstones recording subaerial exposure. The Type-5_L peritidal cycles are the most abundant cycles in the series (16 over 23) and display a large range of thicknesses (from less than 1m up to 8.6 m). They span the range of environments from shallow subtidal lagoon to supratidal floodplain. The thicker cycles related to important development of MF7-8 suggest that the depositional environment remained stable during long periods during which the progradation of the tidal flat sediments was the rule. Type-5_R peritidal cycles (average thickness of 2.2 m as for the previous cycles) encompass a larger microfacies range than the preceding ones, starting with MF2 and ending with MF8. Five type-5_R cycles are present in the Trois Fontaines Fm and they shallow -upward from subtidal stromatoporoid-coral floatstones to supratidal laminites through subtidal-intertidal oolitic or algal (issinellids) shoals. As for the type-5_L cycles they record the progradation of the tidal flat under stable relative sea-level periods.

Only two thin type-5_T cycles (average thickness of 0.8m) have been observed: they deepen-upward and follow type-5_L peritidal cycles whose upper parts were not flooded directly. These cycles could correspond to particular type-5_L cycles submitted to unstable depositional conditions. Here the general sharp contact between the supratidal cap of one cycle and the subtidal base of the overlying one is progressive.

The average cycle thickness of the Trois-Fontaines

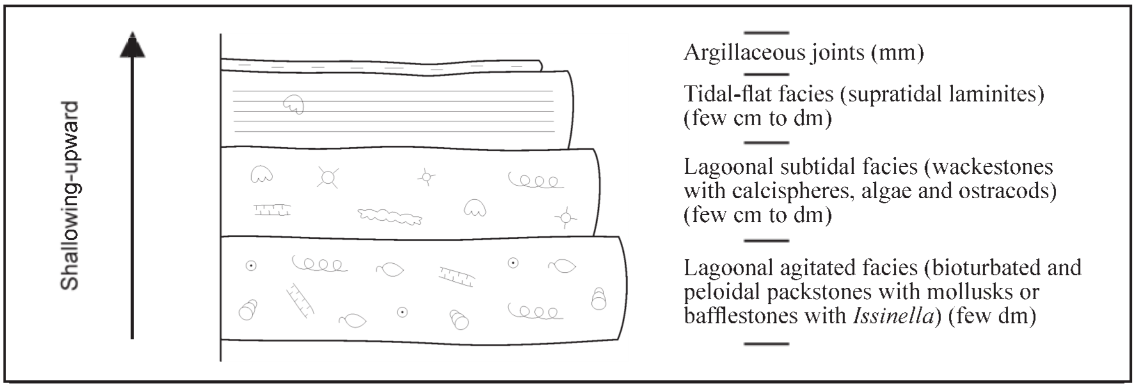

Fig. 4 – Lithological curve established from microfacies succession based on the Rancennes standard sequence.

Fm at Rancennes is 1.9 m, similar to the value for the lower Givetian cycles on the Belgian-French carbonate platform, which is around 2.4 m (PRÉAT & MAMET, 1989). The conclusion is the same, *i.e.*, the cyclic sedimentation is primarily controlled by subsidence that is in turn counterbalanced by algal and cyanobacterial carbonate production; eustatism is of secondary importance. The repetitive shallowing-upward succession of cycles within the Trois-Fontaines Fm suggests that progradation is one of the fundamental factors controlling the facies stratigraphy on the Givetian carbonate platform. Variations in the thicknesses of cycles are probably related to the shoreline migration during progradation, which may be relatively continuous (with 'constant' cycle thickness) or staggered. During periods of active progradation sediment accumulation rate must have exceeded rate of sea-level changes. Considering all these factors we suggest that the autocylic model proposed by GINSBURG, 1971 (and many others since this first publication) best explains the superimposed peritidal shallowing-upwards cycles of the Rancennes quarry.

Based on the thickness succession of the recognised 5th-order peritidal cycles, a 4th -order relative sea-level curve has been established for the Trois-Fontaines Fm (Fig. 2, column sequences). No clear stacking pattern of this 4th-order cycle package is observed, except a thickening-upward evolution in the second set. The other sets without any particular evolution could record aggradational processes. This integrated multi-signature succession of meter-scale peritidal cycles (Trois-Fontaines Fm) and non-cyclic decameter-scale units (Terres d'Haurs Fm) points probably to the succession of a lowstand sytems tract overlain by a transgressive systems tract during a 3rd-order sea-level rise. The lower part of the lowstand systems tract is not exposed in the Rancennes quarry but could correspond to the beachrock level at the base of the Trois-Fontaines Fm (PRÉAT, 2006).

Magnetic susceptibility (X. DEVLEESCHOUWER & E. PETITCLERC)

Material and methods

Rock magnetism analyses were conducted on the same samples as those used for the sedimentology (Fig. 2). Magnetic susceptibility (MS) data were acquired with a Kappabridge MFK1-A device at room temperature in a low magnetic field. The magnetic susceptibility of the empty plastic holder was removed to obtain only the MS value of the sample. Each sample was measured three times and weighed with a precision of 0.01 g to determine the mass low-field magnetic susceptibility. This gives information about the total concentration of dia-, para- and ferromagnetic *s.l.* minerals that are present in the rock. Thermomagnetic analyses and hysteresis measurements were undertaken on 30 selected samples based on MS values, microfacies and sedimentological observations. Thermomagnetic susceptibility measurements were realized using a CS3 furnace or high temperature control unit connected to the Kappabridge MFK1-A. The sample powder (<150 µm) corresponding to about a volume of 0.25 cm³ is heated progressively from ambient temperature up to 700° C and then cooled in an argon gas environment in order to prevent oxidation processes during the heating. This procedure allows measuring the evolution of the temperature dependence of bulk susceptibility. The hysteresis measurements were made with a J-Coercivity "rotation" magnetometer on rectangular parallelipiped sticks of rock placed in small paper boxes at the Geophysical Centre of the Belgian Royal Meteorological Institute. Magnetization was measured between +500 mT and –500 mT with averaged field increments of 0.5 mT per magnetization step. Four hysteresis parameters were deduced from the hysteresis loop: the saturation magnetization Ms (mAm²/kg), the saturation remanence magnetization Mrs (mAm²/kg), the coercitive force Bc (mT) and the coercivity of the remanence Bcr (mT). Ms and Mrs were obtained after correction by removing the dia- and paramagnetic contributions.

Whole-core magnetic susceptibility logging of deep-sea sediments, mainly for high-resolution lithostratigraphic correlation, has become a routine procedure on all Ocean Drilling Program (ODP) cruises since ODP Leg 108 in 1986 (BLOEMENDAL *et al.*, 1989). MS data were used mainly in Quaternary sediments for paleoclimate identification between glacial and interglacial sequences. Progressively during the nineties, MS studies were applied to older rocks such as the Devonian carbonate series of the Tafilalt and Ma'der basins (CRICK *et al.*, 1994). The detrital fraction changes in the sedimentary rocks constitute the major source of MS variations (ELLWOOD *et al.*, 2000). These MS evolutions are linked to eustasy because sea-level falls (regressions) imply an increase of erosional processes on exposed continental masses and lead to greater quantities of detrital minerals transported towards the marine realm. The higher concentration of detrital minerals will give high MS values. On the contrary, during sea-level rises (transgression), MS

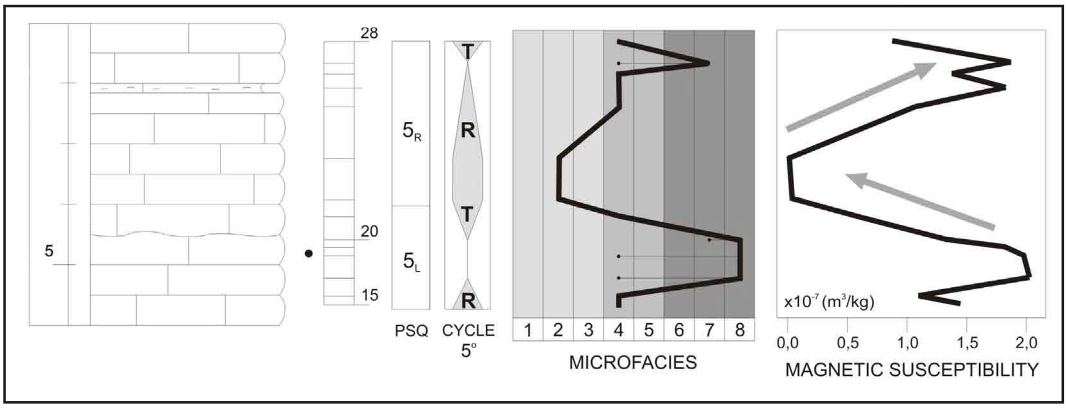

Fig. 5 – 5th-order peritidal cycles and comparison of microfacies and Ms curves.

decreases to low values. Input of detrital minerals in the marine environment could also arise from eolian, volcanic, impact ejecta and atmospheric circulation sources. MS fluctuations are thus considered as a high-resolution stratigraphic tool to correlate sedimentary sections inside the same basin or even between different basins (ELLWOOD *et al.*, 2001, 2007, 2008).

Magnetic susceptibility curve and magnetic mineralogy

MS values range between 3.75 x 10^{-9} and 2.98 x 10^{-7} m^3/kg. The lowest MS value is recorded at the base of the section in an open marine back-reef facies (MF2). The highest one is located in a paleosol-continental facies (MF8) in the upper part of the Trois-Fontaines Fm. Basically, most of the highest MS values are related to the paleosoil facies. The MS curve (or MSC) is presented with the bulk MS data (thin black dotted line) and simple moving average (thick black line). MSC is subdivided into 10 major sequences, numbered successively from 1 to 10 (Fig. 2), corresponding to long-term MS evolutions (LMSE) with thicknesses ranging between 4 and 10 meters. Some of these sequences could be subdivided into short-term MS evolutions with thicknesses ranging between 1 and 3 meters. Twenty-six short-term MS evolutions (SMSE) are recognized in the section (Fig. 2).

LMSE 1 corresponds to three successive trends of decreasing, increasing and lastly decreasing MS values towards the lowest MS value of the section, which corresponds also to the end of LMSE 1. LMSE 2 is subdivided into four successive SMSE recording a general positive increase of the MS values. Three successive SMSE form the LMSE 3, which lies between 8.56 x 10^{-8} and 2.11 x 10^{-7} m^3/kg during this long-term phase. LMSE 4 contains three SMSE with generally increasing MS values from 1.18 x 10^{-8} m^3/kg up to 2.36 x 10^{-7} m^3/kg. LMSE 5 and LMSE 6 contain two SMSE each, which correspond to decreasing MS values followed by an increasing evolution. The highest MS value of the section is located at the end of the LMSE 6 and marks a clear change in the MS curve. Decreasing MS trends are recognized successively in the next two LMSE (7 and 8). The boundary between LMSE 8 and LMSE 9 is very close to the boundary between the Trois-Fontaines Fm and Terres d`Haurs Fm. LMSE 9 contains three SMSE with MS values lying between 1.93 x 10^{-8} and 6.64 x 10^{-8} m^3/kg and corresponds to a relatively stable sequence. LMSE 10 shows a positive increase of the MS values but this last LMSE is not complete and this evolution could represent only one SMSE of a long-term magnetic susceptibility evolution. There is no clear evidence of MS evolutions at a larger scale.

The comparison between MS and sedimentological curves reveals a strong correlation, which indicates that MS and microfacies evolutions are correlated in the studied section (Fig. 2). More precisely, the microfacies curve of two peritidal 5th-order cycle is detailed in front of the MS evolution (Fig. 5). There is a similar evolution of these two parameters during the two parasequences recording successively regressive and transgressive evolutions of the microfacies, which are mimetics of increasing and decreasing MS evolutions. The first transgressive episode starts from a continental calcrete setting (MF8) towards reefal environment (MF2). This transgression is rapid and corresponds to a large decrease of the MS values from 2.03 x 10^{-7} to 3.75 x 10^{-9} m^3/kg. Following the transgression, a regression starts and reefal, lagoonal and tidal flat sedimentary environments were successively observed. This regressive episode corresponds to a gradual increase of MS values up to

2.03×10^{-7} m^3/kg. These similar evolutions between MS and microfacies are clearly observed during the Trois-Fontaines Fm at the scale of 5th-order cycles. Relatively good correlations between MF and MS curves are also mentioned in the Trois-Fontaines Fm studied in "Les Monts de Baileux" section (MABILLE & BOULVAIN, 2008). These data suggest that the MS signal could represent sea-level oscillations. In that case, a part of the magnetic minerals must be of primary (detrital) origin and are preserved in the sedimentary series.

In order to determine the magnetic mineralogy and to assess the primary origin, thermomagnetic and hysteresis measurements were carried out on 30 selected samples distributed throughout the studied section. Thermomagnetic susceptibility measurement (TSM) curves indicate the presence of three magnetic phases in the samples: 1) a contribution of paramagnetic minerals (probably clays) deduced from the progressive TSM decay during the first 300-400° C, 2) a large drop of the TSM values close to 320° C which could indicate the presence of pyrrhotite, Ti-rich magnetite or Ti-rich hematite and, 3) a clear TSM drop close to 580° C which corresponds to the Curie T° of magnetite grains. These data suggest that the MS signal is controlled by ferromagnetic minerals *s.l.* and paramagnetic minerals (mostly clays and pyrite).

Hysteresis data show that *Bcr* records values below 60 mT for all the samples, which reveal the presence of a low coercitive mineral phase (*i.e.*, magnetite). The high-field magnetic susceptibility, calculated on the hysteresis curves, reported graphically versus low-field magnetic susceptibility, shows a clear positive correlation line indicating that MS is mainly controlled by the ferrimagnetic phase. Samples with magnetite as the main carrier of the MS ($Bcr < 60$ mT) were plotted in a classical Day Plot diagram. The results indicate that most of the samples are plotted above the unremagnetized limestone line of CHANNELL and MCCABE (1994) and below the line of remagnetized limestones of North America and Craven Basin (CHANNELL & MCCABE, 1994). Following ZWING *et al.* (2005), our samples contain (1) a primary detrital fraction of coarse-grained magnetite (mostly multi-domain or MD) and (2) a secondary authigenic fraction of fine-grained magnetite (probably a mixture of multi-domain (MD) and superparamagnetic domain (SP)). These data confirm that magnetite grains are partly primary detrital and the main carrier controlling the MS signal in these Givetian limestones.

Ostracods (J.-G. CASIER)

Previous studies on ostracods from the Mont d'Haurs

Two studies concern ostracods present in the upper part of the Eifelian and in the Givetian of the Mont d'Haurs. In a paper titled "Ostracodes Givétiens de l'Ardenne", COEN (1985) published a list of taxa collected in the Terres d'Haurs Fm and in the overlying Mont d'Haurs Fm. More recently, on a poster presented during the 1st International Paleobiogeography Symposium held in Paris, MILHAU *in* HUBERT *et al.* (2007) mentioned the presence of 15 taxa in the base of the Trois-Fontaines Fm, and the occurrence of 25 taxa in the Hanonet Fm. This last formation is in large part Eifelian in age and precedes directly the Trois-Fontaines Fm.

The ostracods mentioned by MILHAU *in* HUBERT *et al.* (2007) in the base of the Trois-Fontaines Fm (beds 234 to 260 of HUBERT *et al.*, *ibid.)* are the following: *Amphicostella sculpturata (*POKORNY, 1950), *Bairdia paffrathensis* KUMMEROW, 1953, *Buregia ovata* (KUMMEROW, 1953), *Tubulibairdia seminalis* (KUMMEROW, 1953), *Uchtovia abundans* (POKORNY, 1950), *Microcheilinella affinis* POLENOVA, 1955, *Amphissites tener omphalotus* BECKER, 1964, *Samarella leavinodosa* BECKER, 1964, *Tubulibairdia clava* (KEGEL, 1933), *Bairdiocypris rauffi* KRÖMMELBEIN, 1952 and *Svantovites primus* POKORNY, 1950. MILHAU (*ibid.*) suspected also the presence of *Bairdiocypris symmetrica* (KUMMEROW, 1953) close to the base of the Trois-Fontaines Fm.

The ostracods described by COEN (1985) from the Terres d'Haurs Fm were extracted from a sample collected just above a hiatus corresponding to the entry of a subway in the fortification, probably in the middle or upper part of the stratotype located on the south-eastern flank of the defense works. The species recognised by COEN are the following: *Tetrasacculus* sp., *Falsipollex?* sp., *Coryellina curta* (POLENOVA *in* ROZHDETSVENSKAJA, 1959), *Roundyella patagiata* (BECKER, 1964), *Refrathella* cf. *struvei* BECKER, 1967, *Aechmina* sp., *Coeloenellina minima* (KUMMEROW, 1953), *C. vellicata* n. sp., *Balantoides brauni* (BECKER, 1968), *Poloniella tertia* KRÖMMELBEIN, 1953, *P. claviformis* (KUMMEROW, 1953), *Uchtovia abundans* (POKORNY, 1950), *Cavellina devoniana* EGOROV, 1950, *Polyzygia symmetrica* GÜRICH, 1896, *Jenningsina heddebauti* (MILHAU, 1983), *Jefina romei* n. sp., *Bufina schaderthalensis* ZAGORA, 1968, *Ropolonellus* cf. *aznajevaensis* (ROZHDETSVENSKAJA, 1962), *Leptoprimitia* sp., *Zeuscherina dispar* ADAMCZAK, 1976, *Cytherellina obliqua* (KUMMEROW, 1953), *C. groosae* n.sp., *Bairdia* cf. *paffrathensis* KUMMEROW, 1953, *Microcheilinella affinis* POLENOVA, 1955, *Orthocypris cicatricosa* n. sp. and *Cryptophyllus* sp. 2.

Finally, BECKER & BLESS (1974) mentioned and figured *Coryellina* sp. G MAGNE, 1964, and *Samarella* cf. *crassa* POLENOVA, 1952 in the Terres d'Haurs Fm at the Mont d'Haurs.

In the southern part of the Dinant Synclinorium, very rich and diversified ostracod faunas are known from the Trois-Fontaines Fm in the "La Couvinoise" quarry at Couvin, in Belgium (CASIER *et al.*, 1992), in the Resteigne quarry, at Resteigne, also in Belgium (CASIER & PRÉAT, 1990, 1991), and in the Glageon quarry, Avesnois, France (CASIER *et al.*, 1995). Ostracods are also known from the Terres d'Haurs Fm in the Resteigne quarry (CASIER & PRÉAT, 1991).

Material and methods

Sixty-four samples of about 500 g each were collected in the Rancennes quarry and in the access path. All the samples were crushed by a hydraulic press and about 100 g of each sample was processed with 99.8% glacial acetic acid, at nearly 90°C, for four days at a rate of eight hours a day. This mode of extraction, called the hot acetolysis method, was described by LETHIERS & CRASQUIN-SOLEAU (1988). The residues were sieved on 250 µm and 1600 µm mesh screens. For samples containing ostracods, after this first process, that part of the sample retained by the 1600 µm mesh screen was processed again. About 1,200 carapaces, valves and fragments of ostracods identifiable at any taxonomic level were thus extracted from the Trois Fontaines Fm and from the Terres d'Haurs Fm in the Rancennes quarry. The stratigraphic positions of ostracod samples collected for the study are shown in Figure 2.

Systematic position of ostracod species from the Rancennes quarry

Order Leperditicopida SCOTT, 1961
Family Leperditiidae JONES, 1856
Herrmannina consobrina (JONES, 1896)
Pl. 4, Fig. 1

Order Palaeocopida HENNINGSMOEN, 1953
Palaeocopida indet. *in* CASIER & PRÉAT (1990)

Suborder Palaeocopina HENNINGSMOEN, 1953
Superfamily Kirkbyoidea ULRICH & BASSLER, 1906

Family Amphissitidae KNIGHT, 1928
Amphissites tener omphalotus BECKER, 1964
Pl. 4, Fig. 2

Amphissites sp. indet.
Pl. 4, Fig. 3

Superfamily Hollinoidea SWARTZ, 1936
Famille Hollinidae SWARTZ, 1936
Parabolbinella nov. sp. A (= *Falsipollex?* sp. 3G *in* MILHAU (1988)
Pl. 4, Fig. 4

Family Ctenoloculinidae JAANUSSON & MARTINSSON, 1956
Ctenoloculina sp. A, aff. ***kelletae*** POKORNY, 1950
Pl. 4, Fig. 13

Superfamily Beyrichioidea MATTHEW, 1886
Family Beyrichiidae MATTHEW, 1886
Kozlowskiella mamillata (KUMMEROW, 1953)
Pl. 4, Fig. 6

Kozlowskiella n. sp. A, aff. ***mamillata***
in CASIER & PRÉAT (1991)
Pl. 4, Fig. 7

Kozlowskiella cf. ***wenniana*** GROOS, 1969
Pl. 4, Fig. 8

Superfamily Aparchitoidea JONES, 1901
Family Aparchitidae JONES, 1901
Aparchites sp. A
Pl. 4, Fig. 11

Family Rozhdestvenskajitidae MC GILL, 1966
Fellerites crumena (KUMMEROW, 1953)
Pl. 4, Fig. 9

Fellerites? sp. indet.
Pl. 4, Fig. 10

Superfamily Primitiopsoidea SWARTZ, 1936
Family Primitiopsidae SWARTZ, 1936
Parapribylites hanaicus POKORNY, 1950
Pl. 4, Fig. 15

Parapribylites cingulatus (KUMMEROW, 1953)
Pl. 5, Fig. 1

Gravia alata (KUMMEROW, 1953)
Pl. 4, Fig. 14

? Family Buregiidae POLENOVA, 1953
Buregia ovata (KUMMEROW, 1953)
Pl. 5, Fig. 2

Suborder uncertain
Family Scrobiculidae POSNER, 1951
Scrobicula sp. indet.
Pl. 4, Fig. 5

Suborder Paraparchitocopina GRAMM
in GRAMM & IVANOV (1975)
Superfamily Paraparchitoidea SCOTT, 1959
Family Paraparchitidae SCOTT, 1959
Coeloenellina minima (KUMMEROW, 1953)
Pl. 5, Fig. 6

Coeloenellina n. sp. A, aff. ***bijensis***
(ROZHDESTVENSKAJA, 1959)
sensu CASIER & PRÉAT (1991)
Pl. 5, Fig. 7

Coeloenellina sp. indet.
Pl. 5, Fig. 8

Suborder Platycopina SARS, 1866
Superfamily Kloedenelloidea ULRICH & BASSLER, 1908
Family Kloedenellidae ULRICH & BASSLER, 1908
Samarella? sp. A
Pl. 5, Fig. 3

Poloniella cf. ***tertia*** KRÖMMELBEIN, 1953
Pl. 5, Fig. 4

Uchtovia kloedenellides (ADAMCZAK, 1968)
Pl. 5, Fig. 5

Uchtovia cf. ***abundans*** (POKORNY, 1950)
Pl. 5, Fig. 15

Evlanella germanica BECKER, 1964
Pl. 5, Fig. 12

Evlanella lessensis CASIER, 1991
Pl. 5, Fig. 13

Evlanella cf. ***lessensis*** CASIER, 1991
Pl. 5, Fig. 14

Evlanella sp. indet.

Family Beyrichiopsidae HENNINGSMOEN, 1953
Marginia sculpta multicostata POLENOVA, 1952
Pl. 5, Fig. 9

Superfamily Cytherelloidea SARS, 1866
Family Cavellinidae EGOROV, 1950
Cavellina macella (KUMMEROW, 1953)
Pl. 5, Fig. 10

Cavellina sp. indet.
Pl. 5, Fig. 11

Order Palaeocopida HENNINGSMOEN, 1953?
Palaeocopida? indet.
Pl. 4, Fig. 12

Order Podocopida SARS, 1866
Suborder Metacopina SYLVESTER-BRADLEY, 1961
Superfamily Healdioidea HARLTON, 1933
Family Healdiidae HARLTON, 1933
Cytherellina obliqua (KUMMEROW, 1953)
sensu BECKER, 1965
Pl. 6, Fig. 2

Cytherellina perlonga (KUMMEROW, 1953)
Pl. 6, Fig. 3

"Cytherellina" dubia (KUMMEROW, 1953)
Pl. 6, Fig. 4

Superfamily Thlipsuroidea ULRICH, 1894
Family Thlipsuridae ULRICH, 1894
Svantovites primus POKORNY, 1950
Pl. 6, Fig. 1

Suborder Podocopina SARS,1866
Superfamily Bairdiocypridoidea SHAVER, 1961
Family Bairdiocyprididae SHAVER, 1961
Healdianella? longissima (KUMMEROW, 1953)
Pl. 6, Fig. 5

Bairdiocypris aff. ***marginata*** ADAMCZAK, 1976
Pl. 6, Fig. 7

Bairdiocypris symmetrica (KUMMEROW, 1953)
Pl. 6, Fig. 8

Bairdiocypris sp. indet. *in* CASIER & PRÉAT (1992)
Pl. 6, Fig. 9

Family Bairdiocyprididae SHAVER, 1961?
"Orthocypris" sp. indet.
Pl. 6, Fig. 10

Family Pachydomellidae BERDAN & SOHN, 1961
Microcheilinella affinis POLENOVA, 1955
Pl. 6, Fig. 6

Tubulibairdia clava (KEGEL, 1932)

Superfamily Bairdioidea SARS, 1888
Family Acratiidae GRÜNDEL, 1962
Acratia sp. A *in* CASIER & PRÉAT (1991)
Pl. 6, Fig. 11

Family Bairdiidae SARS, 1888
Bairdia paffrathensis KUMMEROW, 1953
Pl. 6, Fig. 12

Bairdia* cf. *paffrathensis Kummerow, 1953
Pl. 6, Fig. 13

Bairdia* cf. *tischendorfi Becker, 1965
Pl. 6, Fig. 14

Bairdia sp. A *in* Casier & Préat (1991)
Pl. 6, Fig. 15

Bairdia sp. B
Pl. 6, Fig. 16

Bairdiacypris sp. *in* Coen (1985)
Pl. 6, Fig. 17

Order Eridostraca Adamczak, 1961
Family Cryptophyllidae Adamczak, 1961
Cryptophyllus sp. indet.
Pl. 6, Fig. 18

Distribution of ostracods in the Rancennes quarry (Table 2)

The richness and diversity of ostracods in the Rancennes quarry are quite variable. Eleven samples out of 66 are barren (MH-34, 35, 49, 52, 56, 58, 60, 63, 149, 151, 161). In seven other samples, ostracods are very scarce, poorly preserved, and consequently indeterminate (MH-2, 32, 44, 81, 145, 157, 178). In 40 samples the richness varies from 1 to 10 per 10 g sorted after the acetolysis. In three samples the richness varies from 10 to 20 (MH-110, 116, 119) and in three other samples from 20 to 30 per 10 g sorted (MH-43, 32, 186). Finally, in samples MH-25 and MH-165, about 50 specimens were extracted per 10 g sorted. Monospecificity prevails in numerous samples.

Palaeoecology of ostracods

The order Leperditicopida and the order Eridostraca are represented each by 1 species in the Rancennes quarry. Twenty-nine species of which 14 belong to the Palaeocopina, 3 to the Paraparchiticopina, and 11 to the Platycopina represent the order Palaeocopida. The Podocopida are represented by 18 species of which 14 of Podocopina and 4 of Metacopina. All these ostracods appertain to the Eifelian Mega-Assemblage, and more precisely to several assemblages indicative of very shallow marine, semi-restricted and lagoonal environments. The rarity of metacopids and particularly the rarity and poor diversity of Thlipsuroidea (1 species in 1 sample) in the Rancennes quarry indicates that open marine environments were probably never below fair weather wave-base. The Leperditicopida extracted from several samples, and recognised in several others during the sedimentological analysis, are indicative of true lagoonal conditions. The absence of ostracods in two series of samples may demonstrate the existence of very stressful lagoonal conditions.

1. *Trois-Fontaines Fm*: The very base of the section investigated (MH-1 to MH-10) was generally shallow marine, agitated, and well oxygenated as indicated by the presence of broken carapaces and by the predominance of Podocopina belonging to two thick shelled genera of Pachydomellidae (*Tubulibairdia* and *Microcheilinella*). Then, from sample MH-12 to MH-119, the environment was generally lagoonal as attested by the abundance of Leperditicopida belonging to the genus *Herrmannina*. The absence of ostracods between samples MH30 and MH37, and between samples MH-43 and MH-68, is maybe indicative of more stressful lagoonal conditions. Sometimes the environment was semi-restricted with a strong marine influence (samples MH-25, MH-43).

In the top of the Trois-Fontaines Fm, ostracods are scarce and poorly diversified (MH-145, MH-154) and leperditicopid ostracods were also observed during the sedimentological analysis in thin sections (MH-140 and MH-144), attesting to very shallow semi-restricted or lagoonal water conditions. However sometimes the energy of the environment increased: in samples MH-149 and MH-151, rich in bioclasts, ostracods are apparently absent and sample MH-156 contains broken, probably reworked, carapaces of leperditicopid ostracods also observed during the sedimentological analysis.

2. *Terres d'Haurs Fm*: In the upper part of the investigated section, the environment was semi-restricted (MH-157, 158 and 180 in which the monospecificity prevails) or more frequently shallow marine (MH-165 and MH-186) but in that case, the energy of the environment was apparently never very strong. In sample MH-165 some stacked valves have been extracted. These stacked ostracod valves are related to the action of a moderate but continuous action of waves.

Comparison with ostracods previously recognised in the Trois-Fontaines Fm and Terres d'Haurs Fm at the Mont d'Haurs

Six species recorded by Milhau *in* Hubert *et al.* (2007) in the very base of the Trois-Fontaines Fm, are recognised in our study (*Bairdia paffrathensis* Kummerow, 1953, *Buregia ovata* (Kummerow, 1953),

MONT D'HAURS	**1**	**4**	**7**	**9**	**10**	**12**	**14**	**17**	**18**	**19**	**21**	**24**	**25**	**28**	**30**	**37**	**40**	**43**	**68**	**72**	**80**	**83**	**91**	**99**
Tubulibairdia clava (Kegel, 1932)	*																							
Fellerites? sp. indet.		*																						
Fellerites sp. indet.		*											*											
Kozlowskiella? sp. indet.		*										*												
Bairdiacypris sp. *in* Coen (1985)			?				?								?			*						
Healdianella? longissima (Kummerow, 1953)				*	*							*	*	*										
Bairdiocypris symmetrica (Kummerow, 1953)				?								*	*	?				*						
"Healdianella" budensis Olempska, 1979?					*																			
Microcheilinella affinis Polenova, 1955					*						*		*	*				*				*		
Herrmannina consobrina (Jones, 1896)						?	*	*		*		*					?		*	*	*			*
Evlanella cf. *lessensis* Casier, 1991							*						*					*						
Buregia ovata (Kummerow, 1953)									?			*						*						
Coeloenellina sp. indet.										*														
Uchtovia kloedenellides (Adamczak, 1968)										*		*	*					*					?	
Coeloenellina minima (Kummerow, 1953)										*		*												
"Orthocypris" sp. indet.											*													
Gravia alata (Kummerow, 1953)												*												
Parapribylites hanaicus Pokorny, 1950												?												
Amphissites sp. indet.													*											
Palaeocopida indet. *in* Casier & Préat (1990)													*											
Fellerites crumena (Kummerow, 1953)													*			*		*						
Bairdia cf. *tischendorfi* Becker, 1965													?					*						
Bairdia sp. B													*											
Bairdiocypris sp. indet. *in* Casier & Préat (1992)													?	*				*					*	
Bairdia sp. A *in* Casier & Préat (1991)													*											
Samarella? sp. A													*					*						
Bairdiocypris aff. *marginata* Adamczak, 1976													*					*						
Cavellina macella (Kummerow, 1953)													*											
Coeloenellina n. sp. A, aff. *bijensis sensu* C. & P. (1991)													?											
Cytherellina perlonga (Kummerow, 1953)													?	*				*						
Bairdia paffrathensis Kummerow, 1953													*			?								
"Cytherellina" dubia (Kummerow, 1953)													*					*						
Kozlowskiella mamillata (Kummerow, 1953)													*					*						
Amphissites tener omphalotus Becker, 1964													*											
Ctenoloculina sp. A, aff. *kelletae* Pokorny, 1950													?											
Cryptophyllus sp. indet.													*	*		*		*						
Evlanella germanica Becker, 1964													*										?	
Evlanella sp. indet.													*					*					*	
Bairdiocypris sp.														*										
Marginia sculpta multicostata Polenova, 1952														*				*						
Palaeocopida? indet.																*								
Evlanella lessensis Casier, 1991																?		*						
Scrobicula sp. indet.																		*						
Kozlowskiella n. sp. A, aff. *mamillata in* C. & P. (1991)																		*						
Uchtovia cf. *abundans* (Pokorny, 1950)																		*						
Aparchites sp. A																						*		
Cytherellina obliqua sensu Becker, 1965																								
Kozlowskiella cf. *wenniana* Groos, 1969																								
Bairdia cf. *paffrathensis* Kummerow, 1953																								
Cavellina sp. indet.																								
Acratia sp. A *in* Casier & Préat (1991)																								
Parapribylites cingulatus (Kummerow, 1953)																								
Svantovites primus Pokorny, 1950																								
Poloniella cf. *tertia* Krömmelbein, 1953																								
Parabolbinella nov. sp. A (= *Falsipollex?* sp. 3G)																								

Table 2 – Distribution of ostracods in the Trois-Fontaines Fm and Terres d'Haur Fm exposed in the Rancennes quarry. The

102	110	113	116	119	121	126	129	130	131	132	137	139	154	158	159	162	164	165	170	171	180	183	186	MONT D'HAURS
										?														*Tubulibairdia clava* (KEGEL, 1932)
																								Fellerites? sp. indet.
				*																				*Fellerites* sp. indet.
										*														*Kozlowskiella?* sp. indet.
	?								*	*							?							*Bairdiacypris* sp. *in* COEN (1985)
		*								*														*Healdianella? longissima* (KUMMEROW, 1953)
				*		*			*														*	*Bairdiocypris symmetrica* (KUMMEROW, 1953)
																								"Healdianella" budensis OLEMPSKA, 1979?
	*								*	*					*								*	*Microcheilinella affinis* POLENOVA, 1955
*											?	*										?		*Herrmannina consobrina* (JONES, 1896)
									*												*			*Evlanella* cf. *lessensis* CASIER, 1991
	*											*		?		*		*	*	?	*		*	*Buregia ovata* (KUMMEROW, 1953)
										*														*Coeloenellina* sp. indet.
									*	?														*Uchtovia kloedenellides* (ADAMCZAK, 1968)
	*								*	*	*												*	*Coeloenellina minima* (KUMMEROW, 1953)
	*																							*"Orthocypris"* sp. indet.
																								Gravia alata (KUMMEROW, 1953)
									*	*						?		*					*	*Parapribylites hanaicus* POKORNY, 1950
																								Amphissites sp. indet.
																								Palaeocopida indet. *in* CASIER & PRÉAT (1990)
																								Fellerites crumena (KUMMEROW, 1953)
																								Bairdia cf. *tischendorfi* BECKER, 1965
							*																	*Bairdia* sp. B
																								Bairdiocypris sp. indet. *in* CASIER & PRÉAT (1992)
									*															*Bairdia* sp. A *in* CASIER & PRÉAT (1991)
										*														*Samarella?* sp. A
									?	*														*Bairdiocypris* aff. *marginata* ADAMCZAK, 1976
			*	*						*														*Cavellina macella* (KUMMEROW, 1953)
									*	*					?									*Coeloenellina* n. sp. A, aff. *bijensis sensu* C. & P. (1991)
																		*						*Cytherellina perlonga* (KUMMEROW, 1953)
	*									*					*	*		*						*Bairdia paffrathensis* KUMMEROW, 1953
	*		*	*		?									*			*						*"Cytherellina" dubia* (KUMMEROW, 1953)
	*					*	*		*								*	*				*		*Kozlowskiella mamillata* (KUMMEROW, 1953)
										*		*											*	*Amphissites tener omphalotus* BECKER, 1964
																*		*					?	*Ctenoloculina* sp. A, aff. *kelletae* POKORNY, 1950
	*	*					*	*		*			*										*	*Cryptophyllus* sp. indet.
										*					*			*					*	*Evlanella germanica* BECKER, 1964
	*		*									*		*				*					*	*Evlanella* sp. indet.
																								Bairdiocypris sp.
							*		*									*	?				*	*Marginia sculpta multicostata* POLENOVA, 1952
																								Palaeocopida? indet.
																								Evlanella lessensis CASIER, 1991
																								Scrobicula sp. indet.
																								Kozlowskiella n. sp. A, aff. *mamillata in* C. & P. (1991)
									*															*Uchtovia* cf. *abundans (*POKORNY, 1950)
										*														*Aparchites* sp. A
	*		*	*											*	*	*	*					*	*Cytherellina obliqua sensu* BECKER, 1965
		*		*																				*Kozlowskiella* cf. *wenniana* GROOS, 1969
					*																			*Bairdia* cf. *paffrathensis* KUMMEROW, 1953
							*																	*Cavellina* sp. indet.
									*	*														*Acratia* sp. A *in* CASIER & PRÉAT (1991)
										?													*	*Parapribylites cingulatus* (KUMMEROW, 1953)
																*								*Svantovites primus* POKORNY, 1950
																		*						*Poloniella* cf. *tertia* KRÖMMELBEIN, 1953
																		*						*Parabolbinella* nov. sp. A (= *Falsipollex?* sp. 3G)

formation boundary is located between samples 154 and 158.

Tubulibairdia clava (KEGEL, 1933), *Microcheilinella affinis* POLENOVA, 1955, *Amphissites tener omphalotus* BECKER, 1964, and *Svantovites primus* POKORNY, 1950). Moreover, the presence of *Bairdiocypris symmetrica* (KUMMEROW, 1953) in the Trois-Fontaines Fm surmised by MILHAU *in* HUBERT *et al.* (2007), is confirmed. The absence in our samples of some species mentioned by MILHAU (*Ibid.*) is probably related to the shallower marine and to the semi-restricted water conditions observed in the middle and upper parts of the Trois-Fontaines Fm.

Four species recorded by COEN (1985) in the middle or upper part of the Terres d'Haurs Fm are recognised in our study (*Coeloenellina minima* (KUMMEROW, 1953), *Cytherellina obliqua* (KUMMEROW, 1953), *Bairdia* cf. *paffrathensis* KUMMEROW, 1953, and *Microcheilinella affinis* POLENOVA, 1955). Three others are probably also recognised herein: *Parabolbinella* nov. sp. A (= *Falsipollex?* sp. 3G *in* MILHAU (1988), *Poloniella tertia* KRÖMMELBEIN, 1953, and *Uchtovia abundans* (POKORNY, 1950). The ostracod assemblage found by COEN (1985) is indicative of deeper marine water conditions. This is attested by a more important number of species belonging to the metacopid genera *Polyzygia, Jenningsina, Jefina, Bufina, Ropolonellus, Leptoprimitia, Zeuscherina,* and *Cytherellina* in the sample of COEN (*Ibid.*).

Comparison with ostracods collected in other regions

Seven (+3?) species recognised in the Rancennes quarry are known from the Hanonet Fm in the Resteigne quarry, 27 km east of Givet. Fifteen (+2?) are also known from the Trois-Fontaines Fm and 16 (+3?) from the Terres d'Haurs Fm in the Resteigne quarry (CASIER & PRÉAT, 1990, 1991). The thickness (about 40 m) of the level rich in Leperditicopida corresponding to lagoonal and semi-restricted conditions is significantly the same in these two quarries.

Eight (+2?) species recognised in the Rancennes quarry are known from the Hanonet Fm and 6 (2?) from the Trois-Fontaines Fm in the "La Couvinoise" quarry at Couvin, 26 km west of Givet (CASIER *et al.*, 1992), but only the very base of the Trois-Fontaines Fm was investigated in this last quarry. A similar situation is observed at the Bocahut quarry at Glageon, 52 km west of Givet where 10 (+3?) species recognised in the Rancennes quarry are known from the Hanonet Fm and 9 (+1?) from the Trois-Fontaines Fm.

Close relationships exist also with ostracod faunas described from the Givetian of Germany. In total 16 (+4?) species recognised in our study have been described for the first time in this country by KEGEL (1933), KUMMEROW (1953), KRÖMMELBEIN (1953), BECKER (1964) and GROOS (1969). Relationships exist also with Poland and Czechia where 3 (+4?) species recognised in the Rancennes quarry have been described for the first time by POKORNY (1950), ADAMCZAK (1976) and OLEMPSKA (1979). The same semi-restricted and lagoonal environmental conditions prevailed a long time and on a very large extent during the Early Givetian.

Conclusions

Microfacies organization reveals that the Trois-Fontaines Fm consists of a protected shallow lagoon with different environments from the back-reef area to the continental plain and that open marine environments characterize the Terres d'Haurs Fm. In the first formation, the fauna and microflora are endemic and dominated by a few species (algae, ostracods), in the second the organisms are diversified and abundant. The sedimentary system shows the evolution of a shallow restricted carbonate platform (Trois-Fontaines Fm) to a carbonate ramp setting (Terres d'Haurs Fm). This evolution of the platform to a ramp could be related to the cessation of the active role of the reefal barrier (MAMET & PRÉAT, 2007) related or unrelated to synsedimentary tectonism and block faulting (KASIMI & PRÉAT, 1996; MAMET & PRÉAT, 2009).

The magnetic susceptibility curve of the Rancennes quarry reveals 10 major long-term magnetic sequences characterized by decreasing, increasing or stable magnetic susceptibility fluctuations. A general good correlation is established between the microfacies and magnetic susceptibility curves, which are clearly mimetic at the smaller scale (*i.e.*, 5th-order parasequences). The reported MS oscillations are interpretated in term of sea-level fluctuations. The MS signal of the Rancennes quarry seems to be controlled by the ferrimagnetic fraction (coarse-grained multi-domain magnetite and authigenic mixtures of fine-grained superparamagnetic and single-domain magnetite) with minor paramagnetic contribution (clay minerals and pyrite). A part of the ferrimagnetic minerals carrying the MS signal has been preserved and represents detrital magnetite grains even if the Givetian limestones are characterized by two natural remanent magnetization components, carried by magnetite and pyrrhotite, produced during the Variscan deformation and the circulation of high salinity hot fluids (ZEGERS *et al.*, 2003).

The ostracod fauna in the Rancennes quarry is diversified, abundant and appertains to several assemblages of the Eifelian Mega-Assemblage, characteristic of very shallow marine, semi-restricted and lagoonal environments. In the Trois-Fontaines Fm, the level containing numerous leperditicopid ostracods belonging to the genus *Herrmannina,* which are indicative of (brackish?) lagoonal conditions, is about 40 m thick. This level rich in Leperditicopida (*Herrmannina*) corresponds remarkably to the highest MS value. Such environmental conditions prevailed on a very large extent during the Early Givetian, from the Boulonnais in France, to the Holy Cross Mountains in Poland.

The succession straddling the Trois-Fontaines/Terres d'Haurs boundary in the Rancennes quarry, is continuous, very rich in fossils and can be reached easily. Consequently, we propose that the section exposed in the Rancennes quarry completes the stratotype of the Terres d'Haurs Fm located on the southeastern flank of the entrenched camp of the Mont d'Haurs. In the stratotype, the Trois-Fontaines Fm/Terres d'Haurs Fm boundary and the very base of the upper formation are not visible.

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Explanation of plates

The types are deposited in the collections of the Department of Paleontology (section Micropaleontology) of the Royal Belgian Institute of Natural Sciences (IRScNB n° b…). The thin sections are deposited in the Department of Earth Sciences and Environment of the University of Brussels (ulb/sed xxxx-yy). MH = sample number (see Fig. 2 for the stratigraphic position). TF Fm = Trois-Fontaines Fm; TH Fm = Terres d'Haurs Fm; SWB = storm wave base; FWWB = fair weather wave base.

PLATE 1

Microfacies 1, 2 and 3: Open marine environment

Fig. 1 – Dolomitized crinoidal packstone with a few issinellids (algae) and micritized molluskan bioclasts. Open marine environment near crinoidal meadows and issinellid shoals at the SWB/FWWB interface. MF1, ulb/sed 5014-08, MH163, TH Fm.
Fig. 2 – Peloidal packstone with abundant issinellid microbioclasts. The centre of the photo shows an oncoidal encrustment of *Bevocastria* (Cyanobacteria) around a pelecypod. Open marine environment, with intermittent agitation near the FWWB. MF1, ulb/sed 4993-08, MH-158, TH Fm.
Fig. 3 – Peloidal packstone with abundant issinellid microbioclasts. A subrounded oolitic microbreccia is present at the centre of the photo. It also contains a large *Bevocastria* fragment. Tempestite in the open marine environment. MF1, ulb/sed 4990-08, MH-158, TH Fm.
Fig. 4 – Stromatoporoid floatstone with a bioclastic (brachiopods, issinellids) packstone matrix. Agitated peri-reefal environment near a bioconstruction. MF2, ulb/sed 4586-08, MH-64, TF Fm.
Fig. 5 – Coral (*Trachypora*) floatstone. The matrix is an oolitic, peloidal and issinellid packstone. Agitated peri-reefal environment near intertidal channels. MF2-3, ulb/sed 4925-08, MH-145, TH Fm.
Fig. 6 – Peloidal and oolitic packstone with coarse-grained microbreccias (the left one is muddy with bipyramidal quartz, the right one contains a coral bioclast). Agitated back-reefal environment near buildups. MF3, ulb/sed 4984-08, MH-157, TH Fm.
Fig. 7 – Oolitic (ß oolite *sensu* PURSER, 1980 or 3- and 4-type oolite *sensu* STRASSER, 1986) wackestone with irregular lumps. MF3, ulb/sed 5168-08, MH-187, TH Fm.
Fig. 8 – Packstone with crinoids, gastropods, ostracods, kamaenids (very small fragments). The micritic matrix is slightly microsparitized. MF3, ulb/sed 5022-08, MH-187, TH Fm.

PLATE 2

Microfacies 4, 5 and 6: Restricted lagoonal environment

Fig. 1 – Wackestone with archaegastropods, issinellids, *Kamaena* and calcispheres. Shallow restricted lagoonal environment. MF4a, ulb/sed 4485-08, MH-43, TF Fm.
Fig. 2 – Calcispherid wackestone with a large cyanobacterial (*Bevocastria*) lump or nodule. Restricted lagoon. MF4a, ulb/sed 4756-08, MH-105, TF Fm.
Fig. 3 – Calcispherid wackestone (="calcispherite") with *Labyrinthoconus* (alga). Restricted lagoon. MF4a, ulb/sed 4809-08, MH-116, TF Fm.
Fig. 4 – Packstone with stacked Leperdicopida? valves (ostracods), *Labyrinthoconus* and calcispheres. Numerous small-sized "umbrella" fenestrae below the ostracods. Very shallow restricted lagoon. MF4a, ulb/sed 4775-08, MH-109, TF Fm.
Fig. 5 – Bioclastic (gastropods, pelecypods) packstone with a few peloids. Tempestite in a restricted lagoon. MF4b, ulb/sed 4839-08, MH-123, TF Fm.

Fig. 6 – Peloidal issinellid packstone-bafflestone. Intralagoonal algal shoals. MF5, ulb/sed 4695-08, MH-89, TF Fm.
Fig. 7 – Mudstone with a vadose cavity filled with laminar mud followed by yellow fibrous and white granular calcitic cements. Subaerial intertidal-supratidal restricted environment. MF6, ulb/sed 4737-08, MH-101, TF Fm.
Fig. 8 – Mudstone with vertical dolomitic burrows. The matrix contains a few microbioclasts (kamaenids, issinellids). Intertidal lagoonal environment. MF6, ulb/sed 4921-08, MH-143, TF Fm.

PLATE 3

Microfacies 7 and 8 (Figs 1-4); Continental environment and pyrite (Figs 5-8)

Fig. 1 – Laminite consisting of the alternation of continuous thin mudstone and thicker peloidal and algal (issinellids, kamaenids) packstone layers. Intertidal-supratidal levees between the shoreline and inland marshes. MF7, ulb/sed 4930-08, MH-174, TF Fm.
Fig. 2 – Mudstone with an alveolar-septal structure? or an altered *Aphralysia*-like algal thallus. Subaerial environment (calcrete?). MF8, ulb/sed 4921-08, MH-51, TF Fm.
Fig. 3 – Wackestone with abundant microbioclasts (ostracods, undetermined algae). Oblique and sub-horizontal sheet-cracks in the micrite. Continental environment ("calcrete") developed on a lagoonal parental micrite. MF8, ulb/sed 4549-08, MH-57, TF Fm.
Fig. 4 – Calcispherid and ostracod wackestone with concentric patches containing abundant thin calcite needle (probably related to rhizolites colonized by fungi). Pedogenetic alteration on a lagoonal parental micrite. MF8, ulb/sed 4559-08, MH-79, TF Fm.
Fig. 5 – Calcispherid, issinellid and microbioclastic wackestone. Pyrite is concentrated in large irregular zones, and present as cubic and hexagonal minerals of various sizes. MF4, ulb/sed 4918-08, MH-142, TF Fm.
Fig. 6 – Microbioclastic wackestone with irregular dissolution veins and cavities. Pyrite is preferentially observed in the cavities or along the veins and fissures. MF4, ulb/sed 4931-08, MH-147, TF Fm.
Fig. 7 – Microbioclastic wackestone with oblique dolomitic burrow or fenestrae ? Pyrite is hexagonal or cubic and preferentially associated with the lower part of the burrow. The finer pyrite between the dolomitic rhombs is sometimes filamentous. MF8, ulb/sed 4593-08, MH-67, TF Fm.
Fig. 8 – Microbioclastic (issinellids, calcispheres) wackestone with abundant very small-sized (<5µm) framboidal pyrite. MF8, ulb/sed 4580-08, MH-63, TF Fm.

PLATE 4

Fig. 1 – *Herrmannina consobrina* (JONES, 1896), MH-14, TF Fm, IRSCNB n° b5285, broken left valve, x10.
Fig. 2 – *Amphissites tener omphalotus* BECKER, 1964, MH-25, TF Fm, IRSCNB n° b5286, right valve, x70.
Fig. 3 – *Amphissites* sp. indet., MH-25, TF Fm, IRScNB n° b5287, left valve, x55.
Fig. 4 – *Parabolbinella* nov. sp. A (= *Falsipollex?* sp. 3G *in* MILHAU (1988), TH Fm, IRScNB n° b5288, broken left valve, x60.
Fig. 5 – *Scrobicula* sp. indet., MH-43, TF Fm, IRScNB n° b5289, left lateral view of a carapace, x55.
Fig. 6 – *Kozlowskiella mamillata* (KUMMEROW, 1953), MH-165, TH Fm, IRScNB n° b5290, right lateral view of a carapace, x40.
Fig. 7 – *Kozlowskiella* n. sp. A aff. *mamillata* (KUMMEROW, 1953) *in* CASIER & PRÉAT (1991). MH-43, TF Fm, IRScNB n° b5291, left lateral view of a carapace, x60.
Fig. 8 – *Kozlowskiella* cf. *wenniana* GROOS, 1969. MH-119, TF Fm, IRScNB n° b5292, broken left valve. x70.
Fig. 9 – *Fellerites crumena* (KUMMEROW, 1953), MH-25, TF Fm, IRSCNB n° b5293, right lateral view of a carapace, x45.
Fig. 10 – *Fellerites?* sp. indet. MH-4, TF Fm, IRScNB n° b5294, right lateral view of a broken carapace. x80.
Fig. 11 – *Aparchites* sp. A, MH-132, TF Fm, IRScNB n° b5295, right lateral view of a carapace, x45.
Fig. 12 – Palaeocopida? indet., MH-37, TF Fm, IRScNB n° b5296, left lateral view of a carapace, x85.
Fig. 13 – *Ctenoloculina* sp. A, aff. *kelletae* POKORNY, 1950, MH-165, TH Fm, IRSCNB n° b5297, right lateral view of a carapace, x55.
Fig. 14 – *Gravia alata* (KUMMEROW, 1953), MH-24, TF Fm, IRSCNB n° b5298, right lateral view of a carapace, x90.
Fig. 15 – *Parapribylites hanaicus* POKORNY, 1950, MH-132, TF Fm, IRSCNB n° b5299, left lateral view of a carapace, x75.

PLATE 5

Fig. 1 – *Parapribylites cingulatus* (KUMMEROW, 1953), MH-186, TH Fm, IRSCNB n° b5300, right lateral view of a carapace, x80.
Fig. 2 – *Buregia ovata* (KUMMEROW, 1953), MH-43, TF Fm, IRSCNB n° b5301, left lateral view of a carapace, x55.
Fig. 3 – *Samarella?* sp. A, MH-25, TF Fm, IRScNB n° b5302, left lateral view of a carapace, x65.
Fig. 4 – *Poloniella* cf. *tertia* KRÖMMELBEIN, 1953, MH-165, TH Fm, IRScNB n° b5303, right lateral view of a carapace, x80.
Fig. 5 – *Uchtovia kloedenellides* (ADAMCZAK, 1968), MH-25, TF Fm, IRSCNB n° b5304, right lateral view of a carapace, x50.
Fig. 6 – *Coeloenellina minima* (KUMMEROW, 1953), MH-110, TF Fm, IRSCNB n° b5305, right lateral view of a carapace, x105.
Fig. 7 – *Coeloenellina* n. sp. A, aff. *bijensis* (ROZHDESTVENSKAJA, 1959) *sensu* CASIER & PRÉAT (1991), MH-132, TF Fm, IRSCNB n° b5306, right lateral view of a carapace, x45.
Fig. 8 – *Coeloenellina* sp. indet., MH-132, IRScNB n° b5307, left lateral view of a carapace, x80.
Fig. 9 – *Marginia sculpta multicostata* POLENOVA, 1952, MH-131, TF Fm, IRSCNB n° b5308, right lateral view of a carapace, x60.
Fig. 10 – *Cavellina macella* (KUMMEROW, 1953), MH-119, TF Fm, IRSCNB n° b5309, left lateral view of a carapace, x75.
Fig. 11 – *Cavellina* sp. indet., MH-129, TF Fm, IRSCNB n° b5310, left lateral view of a broken carapace, x65.
Fig. 12 – *Evlanella germanica* BECKER, 1964, MH-165, TF Fm, IRSCNB n° b5311, left lateral view of a carapace, x75.
Fig. 13 – *Evlanella lessensis* CASIER, 1991, MH43, TF Fm, IRSCNB n° b5312, left lateral view of a carapace, x75.
Fig. 14 – *Evlanella* cf. *lessensis* CASIER, 1991, MH14, TF Fm, IRSCNB n° b5313, right lateral view of a carapace, x80.
Fig. 15 – *Evlanella* sp. indet., MH-43, TF Fm, IRScNB n° b5314, right lateral view of a carapace, x65.

PLATE 6

Fig. 1 – *Svantovites primus* POKORNY, 1950, MH-162, TF Fm, IRSCNB n° b5315, broken left valve, x90.
Fig. 2 – *Cytherellina obliqua* (KUMMEROW, 1953) *sensu* BECKER, 1965, MH-165, TH Fm, IRSCNB n° b5316, right lateral view of a carapace, x75.
Fig. 3 – *Cytherellina perlonga* (KUMMEROW, 1953), MH-28, TF Fm, IRSCNB n° b5317, right lateral view of a carapace, x60.
Fig. 4 – *"Cytherellina" dubia* (KUMMEROW, 1953), MH-43, TF Fm, IRSCNB n° b5318, right lateral view of a carapace, x65.
Fig. 5 – *Healdianella? longissima* (KUMMEROW, 1953), MH-9, TF Fm, IRSCNB n° b5319, right lateral view of a carapace, x60.
Fig. 6 – *Microcheilinella affinis* POLENOVA, 1955, MH-43, TF Fm, IRSCNB n° b5320, right lateral view of a carapace, x85.
Fig. 7 – *Bairdiocypris* aff. *marginata* ADAMCZAK, 1976, MH-43, TF Fm, IRSCNB n° b5321, right lateral view of a carapace, x45.
Fig. 8 – *Bairdiocypris symmetrica* (KUMMEROW, 1953), MH-43, TF Fm, IRSCNB n° b5322, right lateral view of a poorly preserved carapace, x50.
Fig. 9 – *Bairdiocypris* sp. indet. *in* CASIER & PRÉAT (1992), MH-43, TF Fm, IRSCNB n° b5323, right lateral view of a carapace, x50.
Fig. 10 – *"Orthocypris"* sp. indet., MH-110, TF Fm, IRScNB n° b5324, right lateral view of a poorly preserved carapace, x70.
Fig. 11 – *Acratia* sp. A *in* CASIER & PRÉAT (1991), MH-132, TF Fm, IRSCNB n° b5325, left lateral view of a carapace, x75.
Fig. 12 – *Bairdia paffrathensis* KUMMEROW, 1953, MH-165, TH Fm TH FM, IRSCNB n° b5326, right lateral view of a carapace, x55.
Fig. 13 – *Bairdia* cf. *paffrathensis* KUMMEROW, 1953. MH121, TF Fm, IRSCNB n° b5327, right lateral view of a carapace, x70.
Fig. 14 – *Bairdia* cf. *tischendorfi* BECKER, 1965, MH-43, TF Fm, IRSCNB n° b5328, right lateral view of a carapace, x45.
Fig. 15 – *Bairdia* sp. A *in* CASIER & PRÉAT (1991), MH-25, TF Fm, IRSCNB n° b5329, right lateral view of a poorly preserved carapace, x75.
Fig. 16 – *Bairdia* sp. B. MH-129, TF Fm, IRScNB n° b5330, right lateral view of a carapace, x60.
Fig. 17 – *Bairdiacypris* sp. *in* COEN (1985), MH-43, TF Fm, IRSCNB n° b531, right lateral view of a carapace, x70.
Fig. 18 – *Cryptophyllus* sp. indet., MH-43, TF Fm, IRScNB n° b5332, poorly preserved valve, x60.

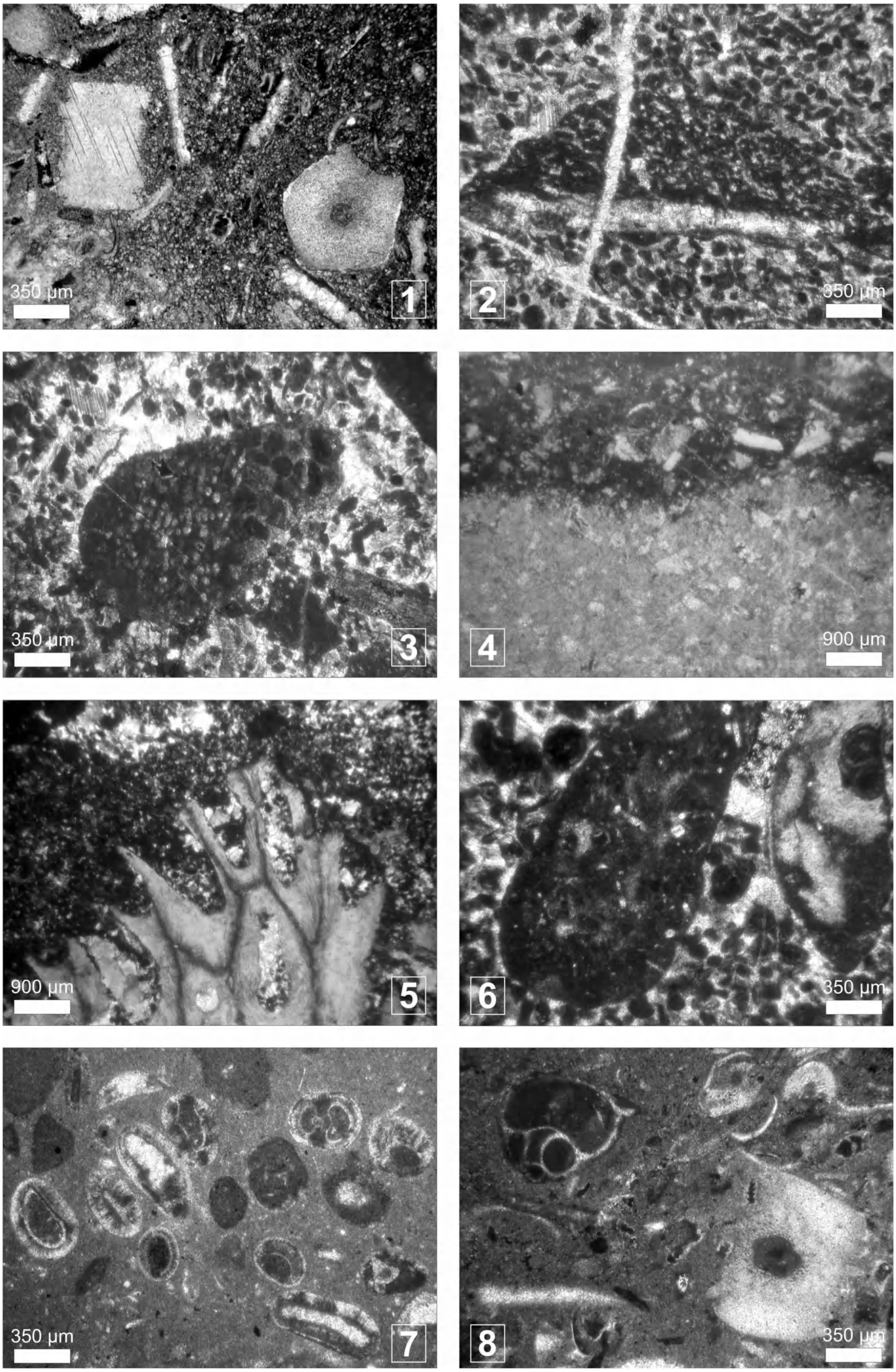
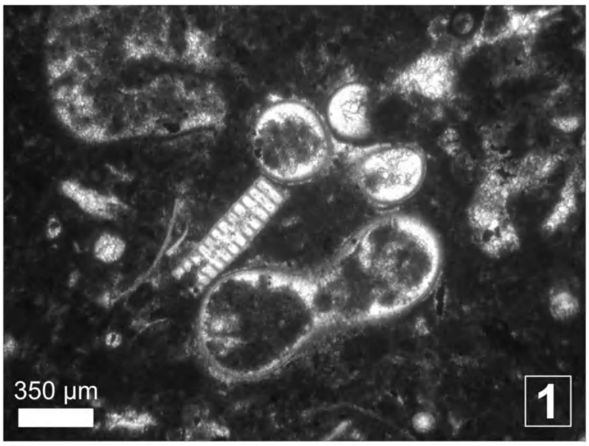


PLATE 1



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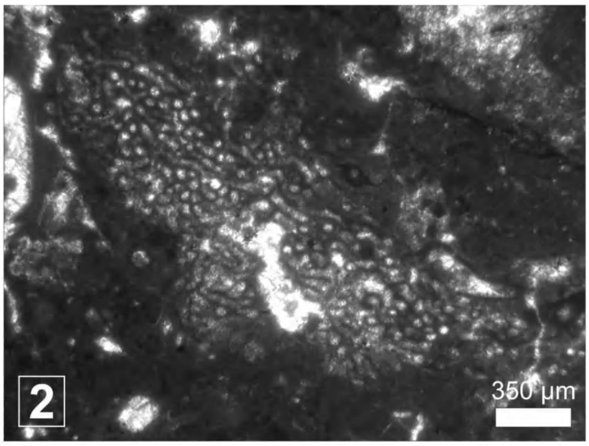

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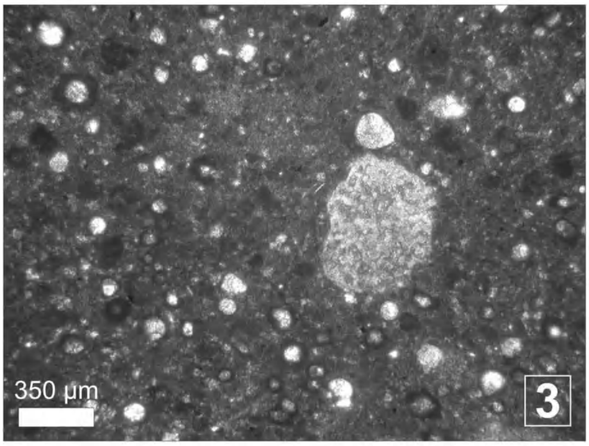

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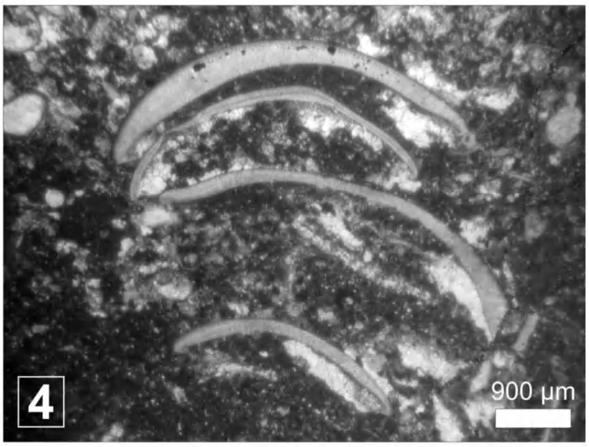

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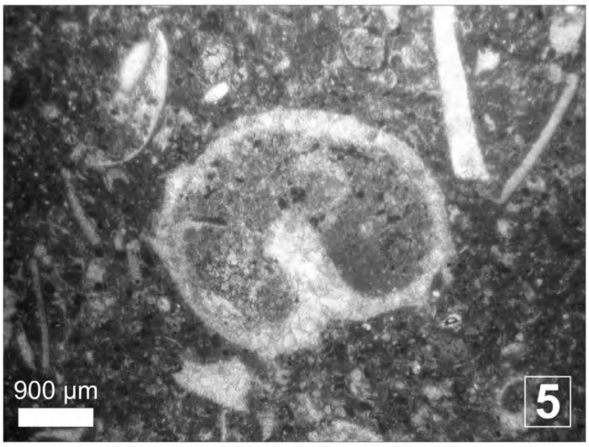

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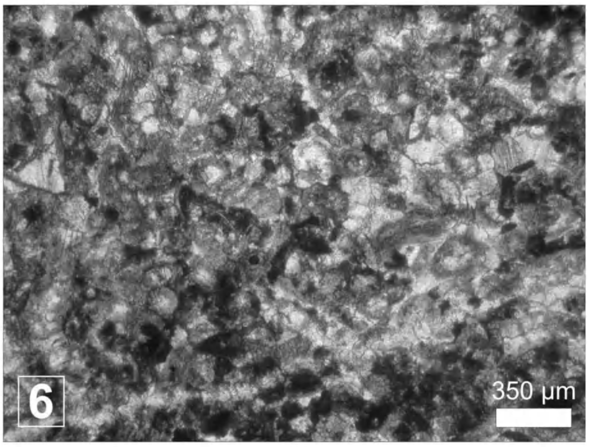

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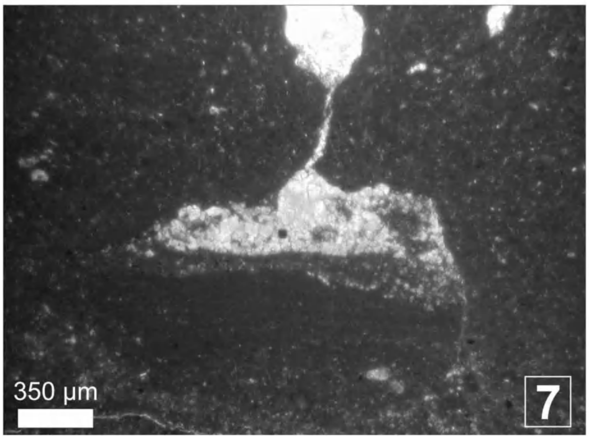

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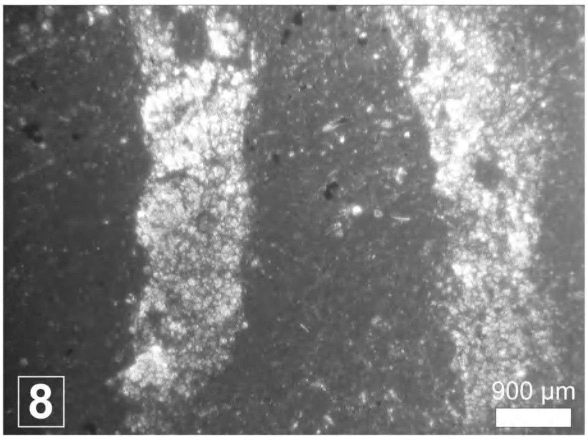

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Plate 2

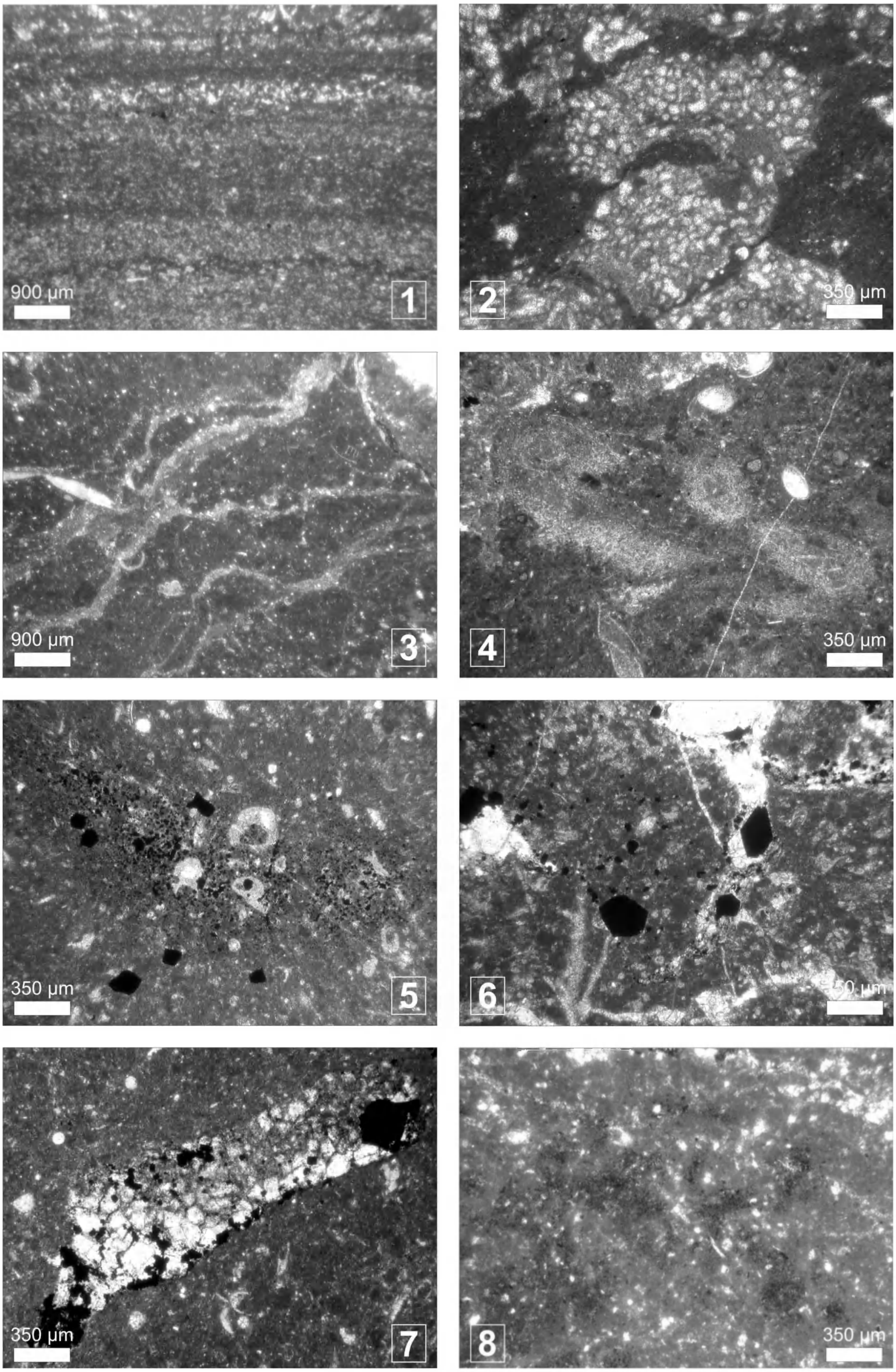

PLATE 3

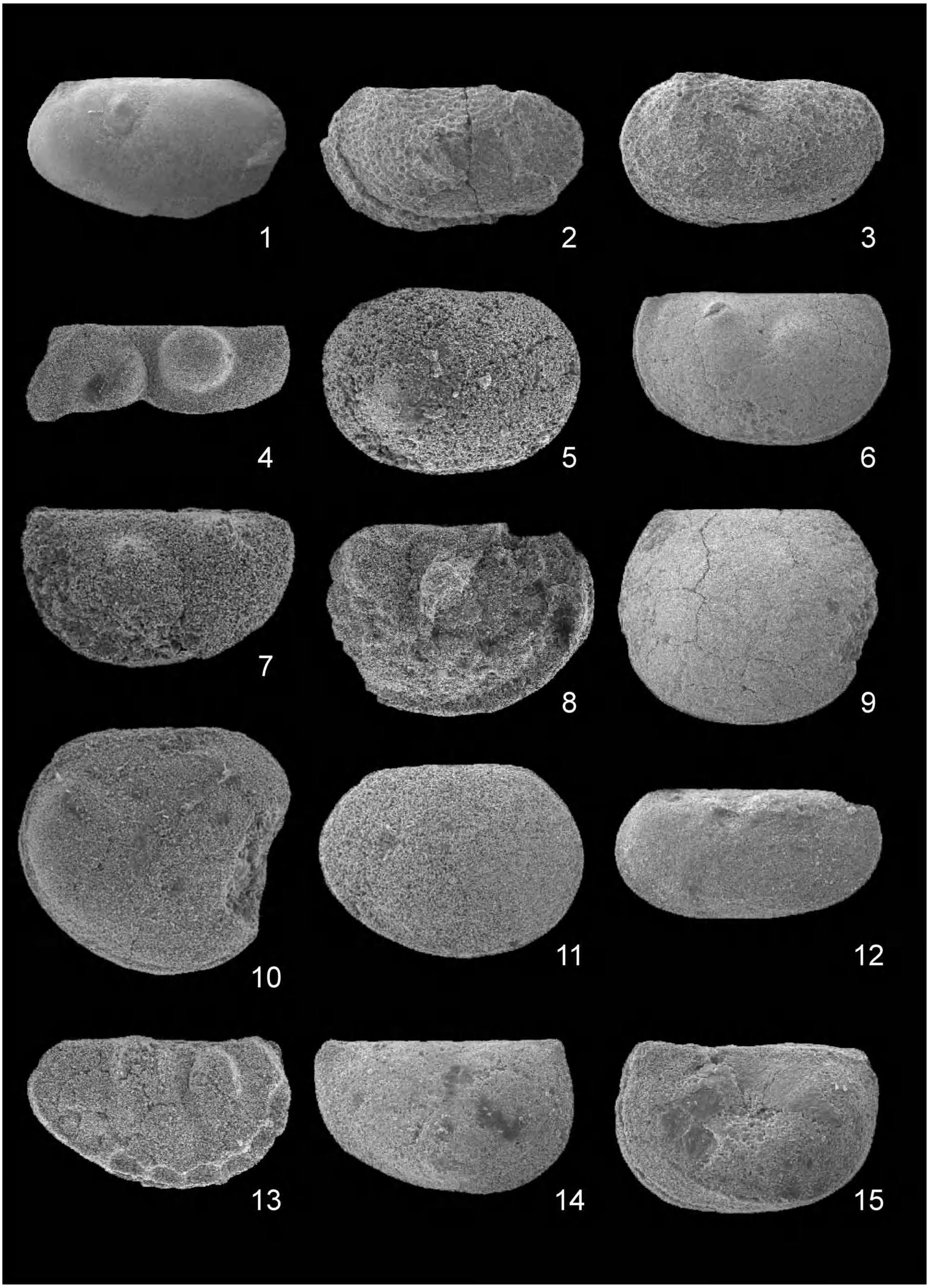

PLATE 4

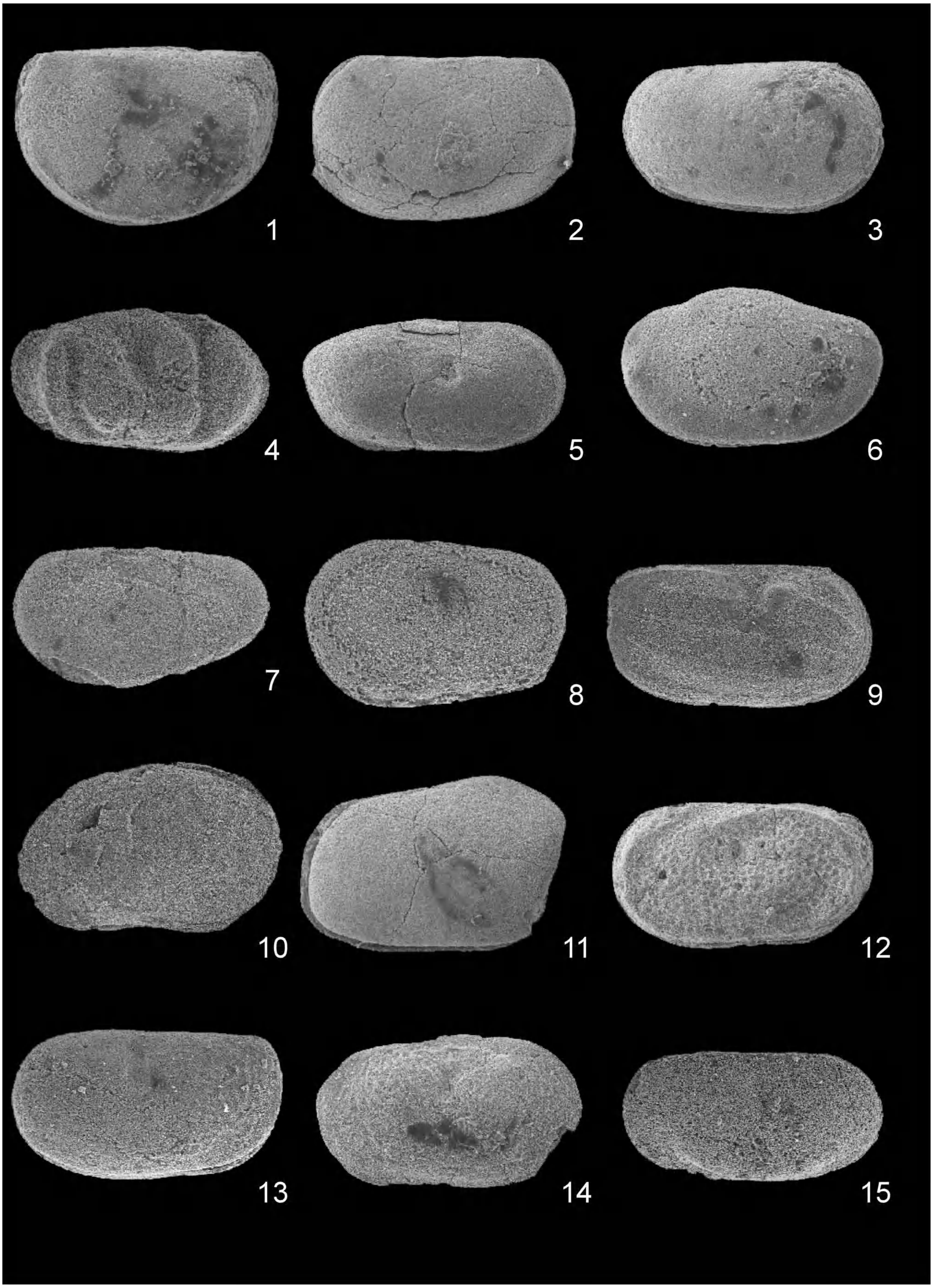

PLATE 5

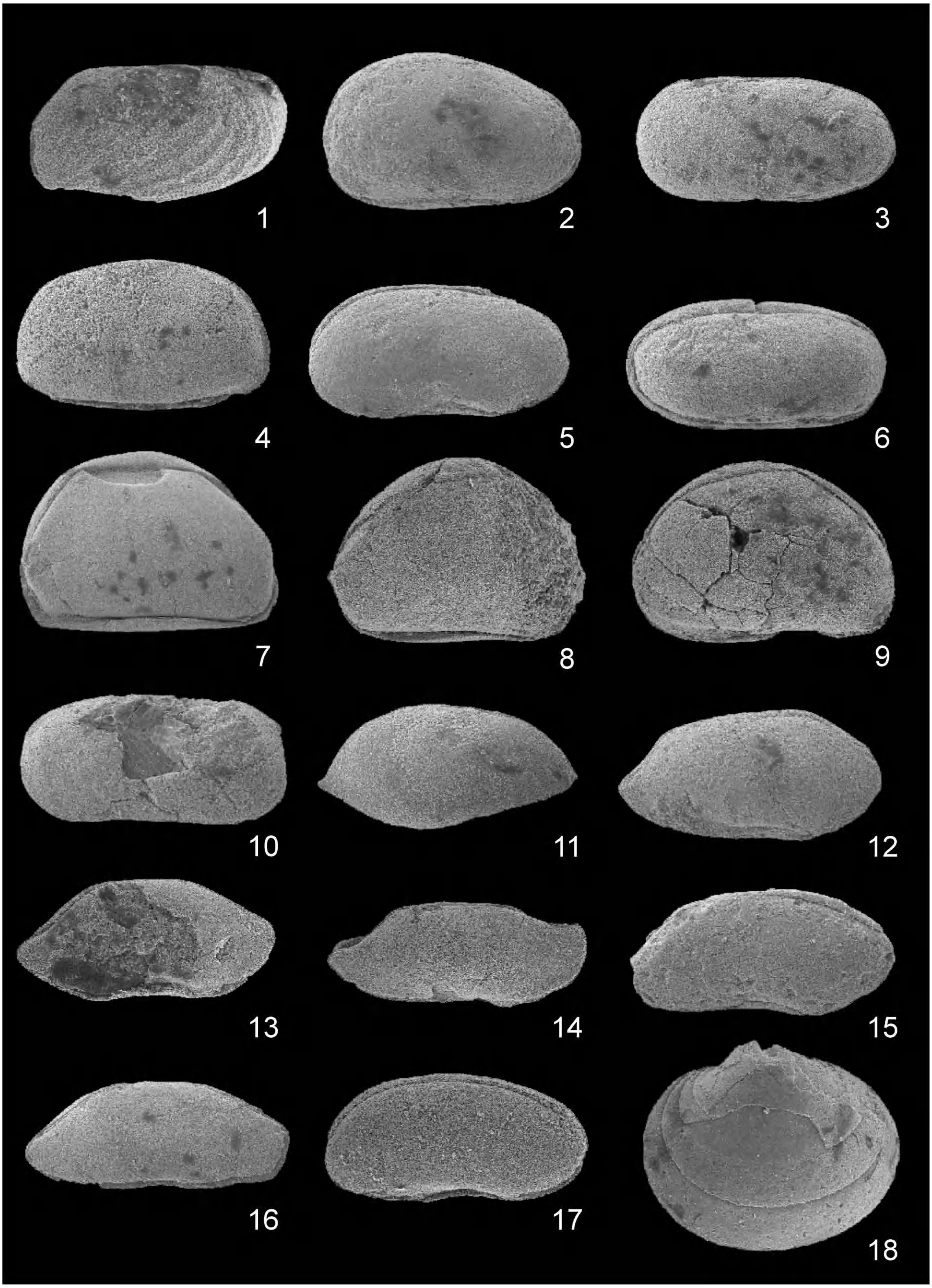

Plate 6