OSTRACODES, MICROFACIES AND MAGNETIC SUSCEPTIBILITY OF THE LOWER GIVETIAN IN THE TYPE-LOCALITY

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For the study of the Lower Givetian in the type-locality at Givet, 184 samples were collected for the study of ostracodes, and 475 for the petrography and the magnetic susceptibility (MS), from the upper part of the Hanonet Fm to the base of the Mont d'Haurs Fm, including the Trois-Fontaines Fm and the Terres d'Haurs Fm. The four investigated sections are located along the ramparts of a historic entrenched military camp built during the XVIIth century at the Mont d'Haurs. More than 9,000 ostracodes were extracted by the hot acetolysis method and approximately 100 species are recognized. The abundance and diversity of ostracodes are extremely variable, linked to the environmental conditions. Ostracodes belong exclusively to the Eifelian Mega-Assemblage and are indicative of shallow marine, semi-restricted and lagoonal environments. Three new species are proposed: the first one belongs to the genus *Cavellina*, the second one to the genus *Parabolbinella*, and the last one is brought closer the genus *Coryellina*.

In the upper part of the Hanonet Fm, ostracodes are at first indicative of a calm and well oxygenated environment below fair weather wave-base. Then the abundance and diversity of ostracodes decrease but the Podocopina increase in number of species and specimens. That is indicative of an increase of the water motion. So great is the energy of the environment at the Hanonet Fm / Trois-Fontaines Fm transition, that ostracodes are broken or missing. After that the monospecificity prevails, at first during a short time with the genus *Coeloenellina* indicative of semi-restricted environmental conditions, and then in about 40 m with the genus *Herrmannina* (Leperditicopida) proxy for real lagoonal conditions. In this level the absence of ostracodes in two series of samples demonstrates the existence of very stressful environments. In the Terres d'Haurs Fm, environments are anew semi-restricted or more generally shallow marine but the water energy is never very high.

Microfacies organization reveals that the Trois-Fontaines Fm consists of a protected shallow lagoon with environments from the back-reef area to the continental plain and that the Hanonet and Terres d'Haurs Fms are characterized by open marine environments. In the first formation, the organisms are endemic (algae, ostracodes), in the others they are diversified and abundant. The sedimentary system shows the evolution of a biohermal (stromatopores and corals) mixed ramp (Hanonet Fm) to a restricted carbonate platform (Trois-Fontaines Fm) and finally to a carbonate ramp (Terres d'Haurs Fm). This evolution is probably related to synsedimentary tectonism and block faulting.

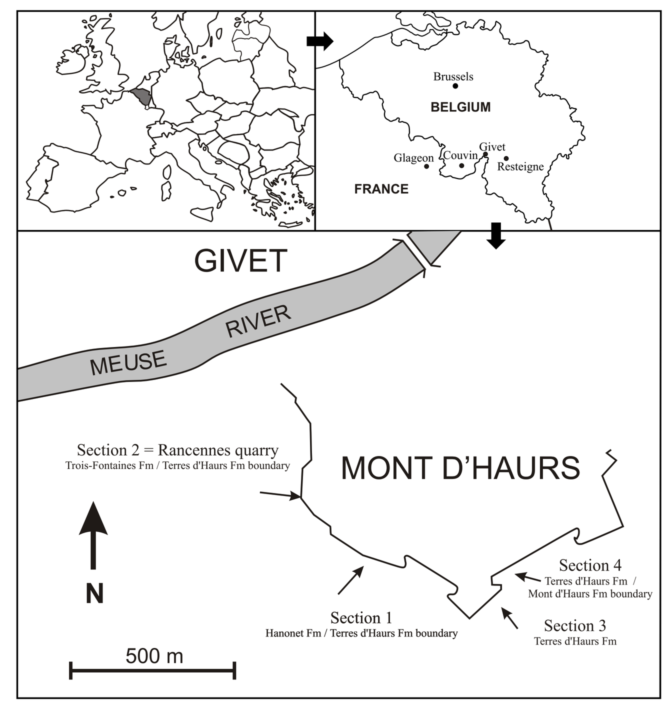
MS values range between 2.42 x 10^{-9} and 3.0 x 10^{-7} m³/kg. The MS curve presents numerous fluctuations corresponding to sedimentary regressive or transgressive cycles. The comparison between the microfacies and MS curve is particularly well established in the Trois-Fontaines Fm. MS values are always very weak or even negative in biostromal units. Strong MS values are recorded in the lagoonal sediments of the Trois-Fontaines Fm. The MS values decrease at the end of the Trois-Fontaines Fm during a transgressive event and then increase towards moderately high MS values (< 1.5 x 10^{-7} m³/kg) in the Terres d'Haurs Fm. Ferromagnetic and paramagnetic minerals control the MS signal.

A general good correlation is observed between the results obtained by the ostracode study, the sedimentlogical analysis and the SM. Especially, in the Trois-Fontaines Fm, there is a correspondence between the highest SM values, the restricted environments displayed by the sedimentological analysis and the presence of Leperditicopida.

The section 2 (the Rancennes quarry) could usefully complete the stratotype of the Terres d'Haurs Fm located along the southwestern ramparts of the Mont d'Haurs entrenched camp (= sections 3 and 4) because the base of the formation is not visible there.

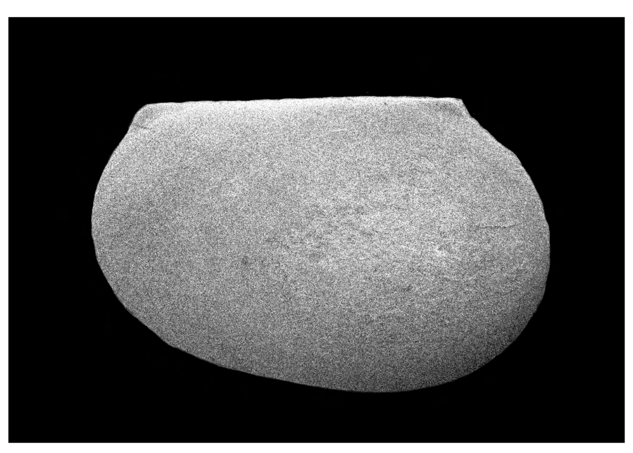
POSITION OF THE EIFELIAN / GIVETIAN BOUNDARY AT THE MONT D'HAURS

The position of the base of the Givetian in the Givet type-locality is still in debate. *Icriodus obliquimarginatus* defining a zone of the alternative conodont zonation based on *Icriodus* has been collected in the Hanonet Fm by P. Bultynck (1987), 4 m below the base of the Givet Group. But this author estimated that it is certainly not the earliest record for the type-region because at Wellin, 24 km east of Givet, *Icriodus obliquimarginatus* occurs 18 m below. Moreover in the La Couvinoise quarry at Couvin, 25 km west of Givet, the *hemiansatus* Zone defining the base of the Givetian in the standard zonation (SDS, Rennes, 1988) is recorded in the Hanonet Fm a few dozens of meters below the base of the Givet Group (Bultynck & Hollevoet, 1999). See Casier & Préat, 2009, 2010.



Locality map of the investigated sections

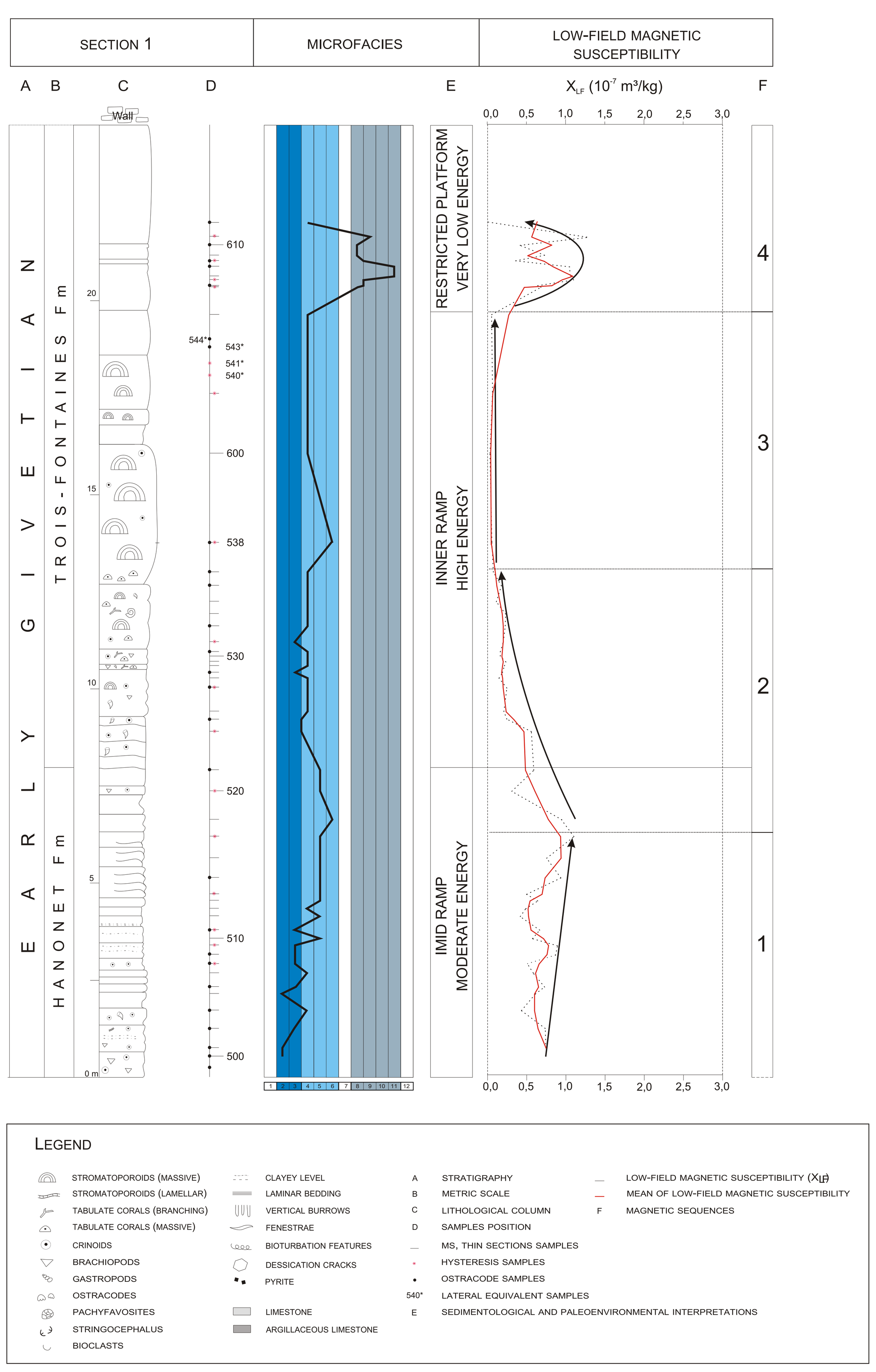
The Hanonet Fm / Trois-Fontaines Fm boundary in section 1

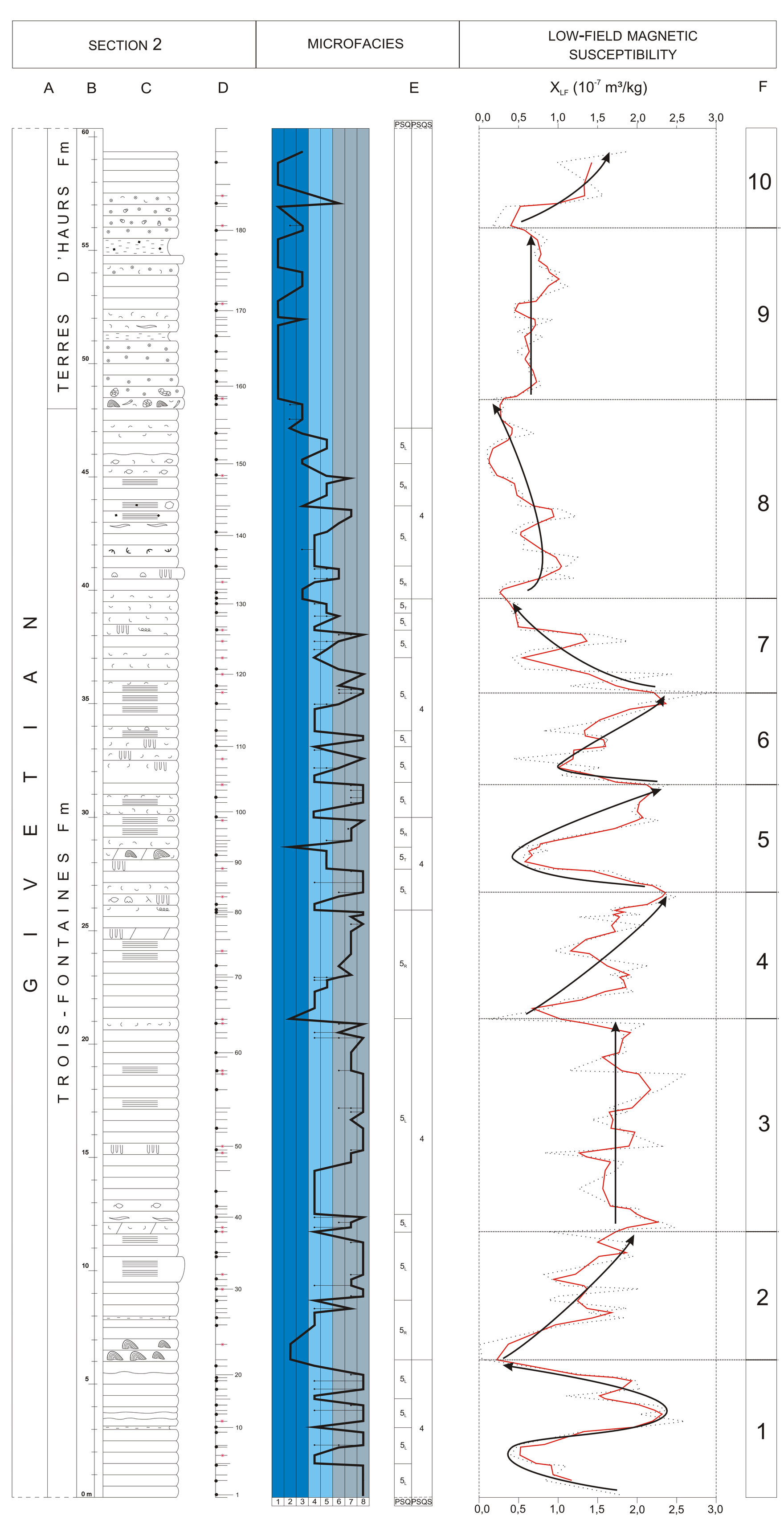


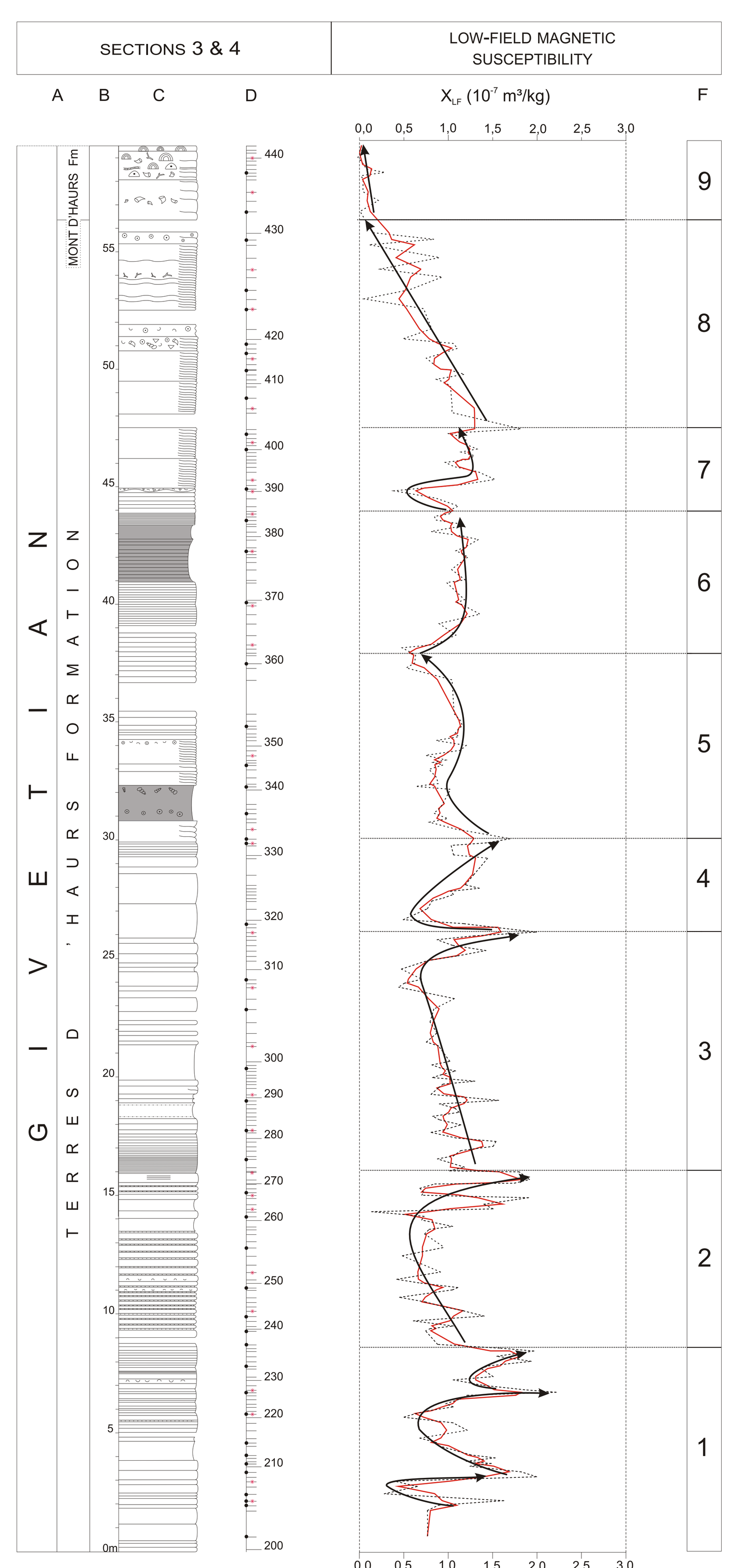
Leperditicopida proxy for lagoonal environments

Middle part of the Terres d'Haurs Fm in section 3

The Trois-Fontaines Fm / Terres d'Haurs Fm boundary in the section 2 (= Rancennes quarry)







Remark: The sedimentological analysis of sections 3 and 4 is still in progress, but the study of ostracodes shows that environments were generally semi-restricted in a great part of the Terres d'Haurs Fm cropping out in these sections. The monospecificity indicative of semi-restricted water conditions prevailed in numerous samples, with the genera *Cytherellina* (MH-201, 233, 333, 400), *Quassilites* (MH-243, 267, 289, 298), *Cavellina* (MH-360, 369) and *Parapribylites* (MH-243, 249). However the presence of Podocopina in several samples and, but more rarely, of the genera *Amphissites* (MH-438) and *Polyzygia* (MH-404, 413), is on the contrary indicative of a salinity normal or close to the normal. The presence of stacked ostracodes valves due to the lapping in several samples (MH-201, 233, 239, 298, 332, 400) is also indicative of very shallow settings. In the upper part of the Terres d'Haurs Formation (From sample MH-419) and in the base of the Mont d'Haurs Formation, the environments were agitated marine as attested by the abundance of thick shelled *Bairdia, Baitrdiocypris* and *Tubulibairdia*. This change corresponds to an important shift of the low-field magnetic susceptibility.

Plate 1 (Open marine environment): **1, 2.** Burrowed bioclastic (echinoderms, bryozoa, cricoconarids, ostracods) wackestone with a slightly recrystallized fine-grained calcitic microspar. Blackish zones are filamentous, spheroidal pyrite (Fig. 2) also concentrated along the pressure solution seams (Fig. 1). Open marine environment near the storm wave base-level. MF2, MH-501, Ha Fm; **3-5.** *Girvanella* oncoid developed on a coral fragment (tabulata) in a bioclastic packstone (Fig. 3). The cortex is mutlilayered (here two layers are visible, a blackish one encrusted by a greyish one). *Girvanella* can bind the bioclasts (crinoids in Fig. 4 or brachiopods and bryozoa in Fig. 5). Framboidal pyrite is trapped in the *Girvanella* mats (Fig. 5). Open marine environment with intermittent agitation near the storm wave base-level. MF3, MH-508, Ha Fm; **6.** Bioclastic packstone with a brachiopod shell and slightly altered crinoids. Undeterminable microbioclasts are present between the bioclasts and crinoids, and mixed in the microparitized calcite matrix. The punctae of the brachiopod are filled with very small-sized pyrite spheres. The peloid below the brachiopod shell is a micritized *Girvanella* fragment. Irregular pressure solution seams are observed between the bioclasts. Open marine environment near the storm wave base-level. MF3, MH-507, Ha Fm; **7, 8.** Stromatoporoid floatstone with a bioclastic (issinellids, Fig. 7; crinoids, Fig. 8) packstone matrix. Peloids and crinoids exhibit an oblique stratification and a few crinoidal fragment with a syntaxial cement (center of the photo). Agitated peri-reefal environment near a bioconstruction. MF4, MH-600, 3-F Fm

Plate 2 (Fore-shoal and restricted lagoonal environments): **1.** Peloidal molluscan-crinoidal packstone. Former geopetal infillings in the gastropods. The large bioclasts represent a storm layer in a peloidal wackestone-packstone. Open marine fore-shoal near the fairweather wave-base level. MF5, MH-513, Ha Fm; **2.** Peloidal bioclastic packstone with *Bisphaera* Birina, 1948 (*incertae sedis*). The matrix is a medium-grained calcite microsparite. Open marine fore-shoal near the fairweather wave-base level. MF5, MH-513, 3-F Fm; **3.** Calcispherid (*Calcisphaera*) wackestone (="calcispherite") with *Kamaena* (alga) and an ostracod valve in a dense dark micrite. Restricted lagoon. MF8, MH-609, 3-F Fm; **4.** Peloidal calcispherid (*Parathurammina dagmarae*) wackestone (="calcispherite"). The matrix is slightly recrystallized and most of the white calcite comes from the dissolution of molluscs. Restricted lagoon. MF8, MH-610, 3-F Fm; **5.** Homogeneous wackestone with Leperditicopid valves overlain by an issinellid (alga). Framboidal pyrite in the dense micritic matrix. Restricted lagoon. MF9, MH-611, 3-F Fm; **6.** abundant bipyramidal quartz microcrystals with tiny micritic inclusions. The dense micritic matrix contains a few peloids and one strongly altered (microsparitized) pelecypod fragment (upper left corner of the photo). MF9, MH-5393-F Fm; **7, 8.** Wackestone with an umbrella "cavity" giving upward a particular fenestrae starting from the base of a gastropod (Fig. 7). The fenestra is filled with yellowish thick fibrous and white granular calcitic cements. The dense micritic matrix contains abundant microparitized (fine-grained calcite microspar) sponge spicules (Fig. 8). The photo displays an ostracod valve. Restricted lagoon. MF11, MH-540, 3-F Fm.

Plate 3 (Microfacies 9, 10 and 11 : Restricted lagoonal environment): **1.** Wackestone with archaegastropods, issinellids, *Kamaena* and calcispheres. Shallow restricted lagoonal environment. MF9, MH-43; **2.** Calcispherid wackestone with a large cyanobacterial (*Bevocastria*) lump or nodule. Restricted lagoon. MF9, MH-105; **3.** Calcispherid wackestone (="calcispherite") with *Labyrinthoconus* (alga). Restricted lagoon. MF9, MH-116; **4.** Packstone with stacked Leperdicopida ? valves, *Labyrinthoconus* and calcispheres. Numerous small-sized 'umbrella' fenestrae below the ostracods. Very shallow restricted lagoon. MF9, MH-109; **5.** Bioclastic (gastropods, pelecypods,) packstone with a few peloids. Tempestite in a restricted lagoon. MF9, MH-123; **6.** Peloidal issinellid packstone-bafflestone. Intralagoonal algal shoals. MF10, MH-89; **7.** Mudstone with a vadose cavity filled with laminar mud followed by yellow fibrous and white granular calcitic cements. Subaerial intertidal-supratidal restricted environment. MF11, MH-101; **8.** Mudstone with vertical dolomitic burrows. The matrix contains a few microbioclasts (kamaenids, issinellids). Intertidal lagoonalenvironment. MF11, MH-143.

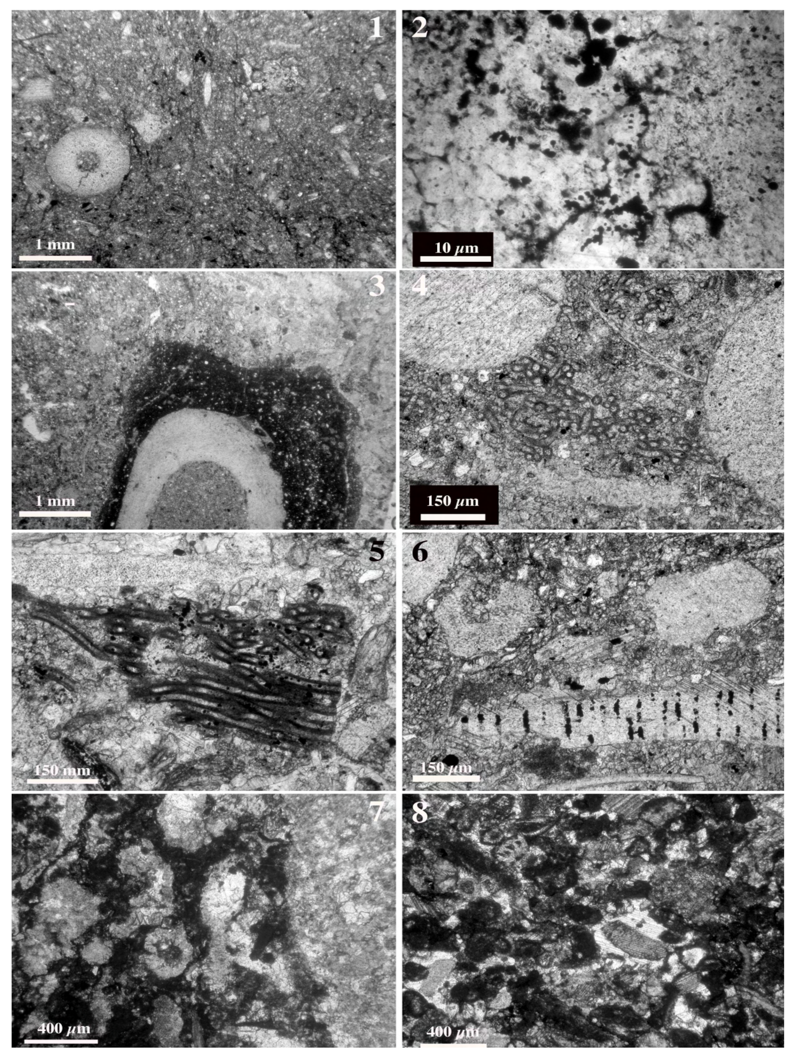


Plate 1

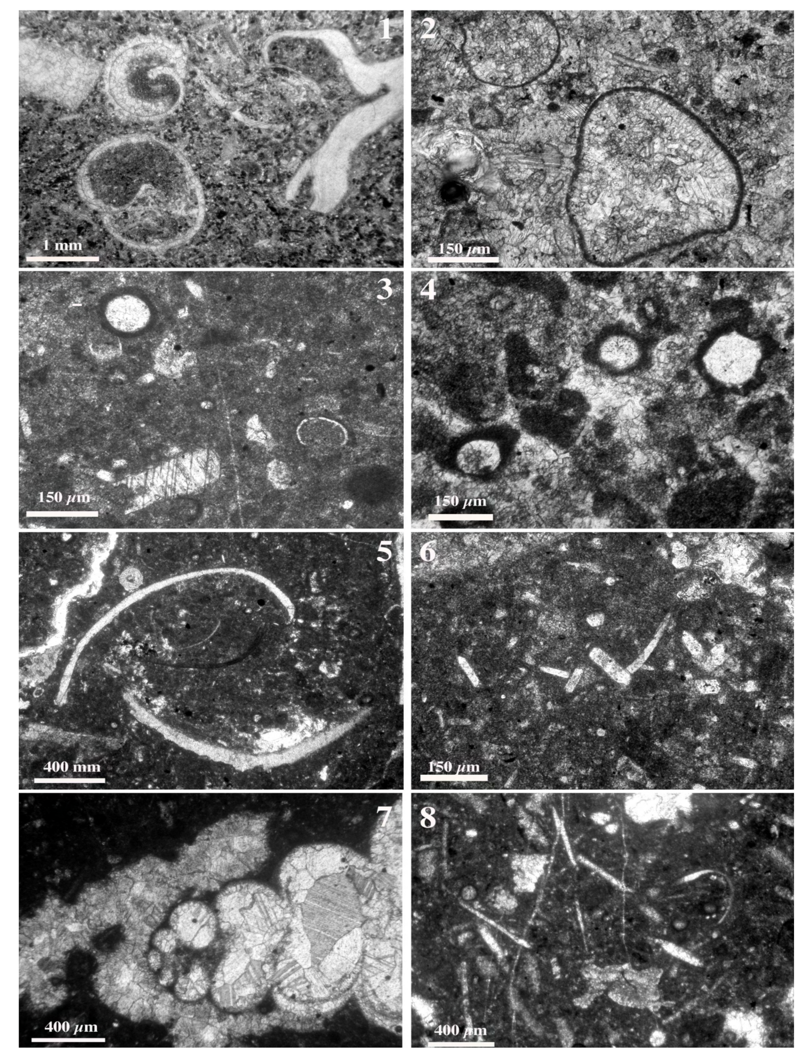


Plate 2

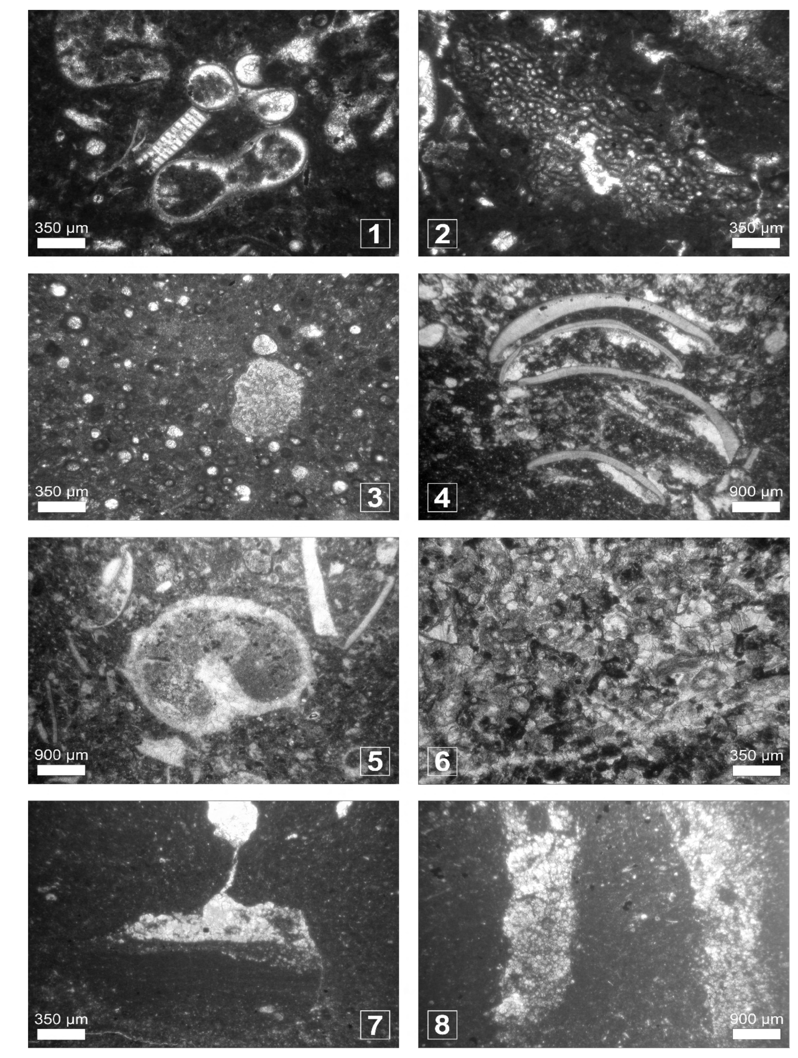


Plate 3

Hanonet Formation = Ha Fm; Trois-Fontaines Formation = 3-F Fm; Terres d'Haurs Formation = TH Fm; Mont d'Haurs Formation = MH Fm.

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?

Main features of Mont d'Haurs microfacies (MF1-8 = first column; lithology = second column and palaeoenvironment = third column) and comparison with Givetian microfacies of the Standard Sequence established by Préat & Mamet (1989) in fourth column.

Plate 4: 1. *Herrmannina consobrina* (JONES, 1896), MH-14, 3-F Fm; **2.** *Amphissites tener* BECKER, 1964, MH-25, 3-F Fm; **3.** *Parabolbinella coeni* nom. nud., MH-501, Ha Fm; **4.** *Ctenoloculina* sp. A, aff. *kelletae* POKORNY, 1950, MH-165, TH Fm; **5.** *Kozlowskiella mamillata* (KUMMEROW, 1953), MH-165, TH Fm; **6.** *Kozlowskiella* sp. C *in* CASIER *et al.* (1994), MH-543, 3-F Fm; **7.** *Kozlowskiella? rugulosa* (KUMMEROW, 1953), MH-227, TH Fm; **8.** *Kozlowskiella* sp. A BECKER, 1964, MH-309, TH Fm; **9.** *Kozlowskiella* sp. C, MH-309, TH Fm; **10.** "*Kozlowskiella*" sp. B, MH-243, TH Fm; **11.** *Aparchites* sp. A *in* CASIER *et al.* (2010), MH-525, Ha Fm; **12.** *Fellerites crumena* (KUMMEROW, 1953), MH-527, Ha Fm; **13.** *Parapribylites hanaicus* POKORNY, 1950, MH-612, 3-F Fm; **14.** *Parapribylites cingulatus* (KUMMEROW, 1953), MH-186, TH Fm; **15.** *Gravia alata* (KUMMEROW, 1953), MH-24, 3-F Fm.

Plate 5: 16. *Kielciella fastigans* (BECKER, 1964), MH-267, TH Fm; **17.** *Kielciella* cf. *arduennensis* ADAMCZAK & COEN, 1992, MH-417, TH Fm; **18.** *Roundyella patagiata* (BECKER, 1964), MH-429, TH Fm; **19.** *Aparchites* sp. indet., MH-436, MH Fm; **20.** *Coryellina? audiarti* nom. nud.., MH-503, Ha Fm; **21.** *Urftella adamczacki* BECKER, 1970, MH-505, Ha Fm; **22.** *Refrathella struvei* BECKER, 1967, MH-501, Ha Fm; **23.** *Buregia ovata* (KUMMEROW, 1953), MH-43, 3-F Fm; **24.** Palaeocopida indet. 1, MH-221, TH Fm; **25.** *Coeloenellina minima* (KUMMEROW, 1953), MH-110, 3-F Fm; **26.** *Coeloenellina* sp. A, aff. *minima* (KUMMEROW, 1953), MH-612, 3-F Fm; **27.** *Coeloenellina vellicata* COEN, 1985, MH-429, TH Fm; **28.** *Samarella* n. sp., aff. *laevinodosa* POLENOVA, 1952 *in* CASIER & PREAT (1991), MH-429, TH Fm; **29.** *Samarella* cf. *laevinodosa* BECKER, 1964, MH-523, HA Fm; **30.** *Samarella?* sp. A, MH-25, 3-F Fm.

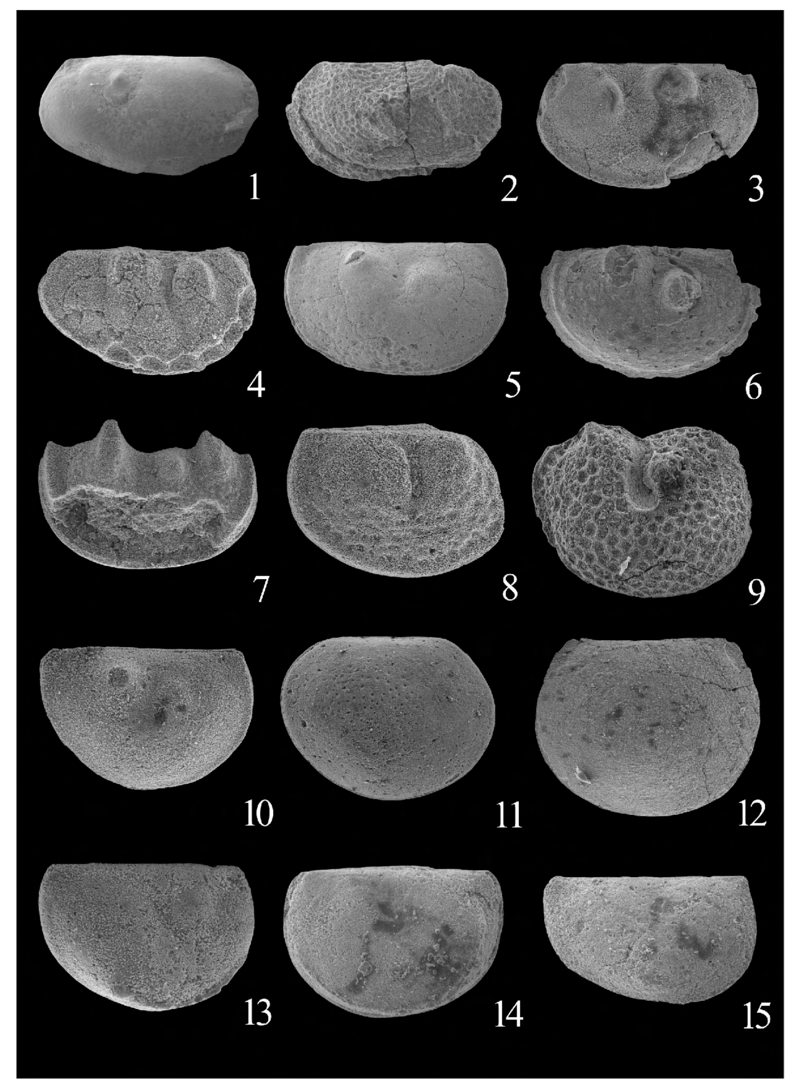


Plate 4

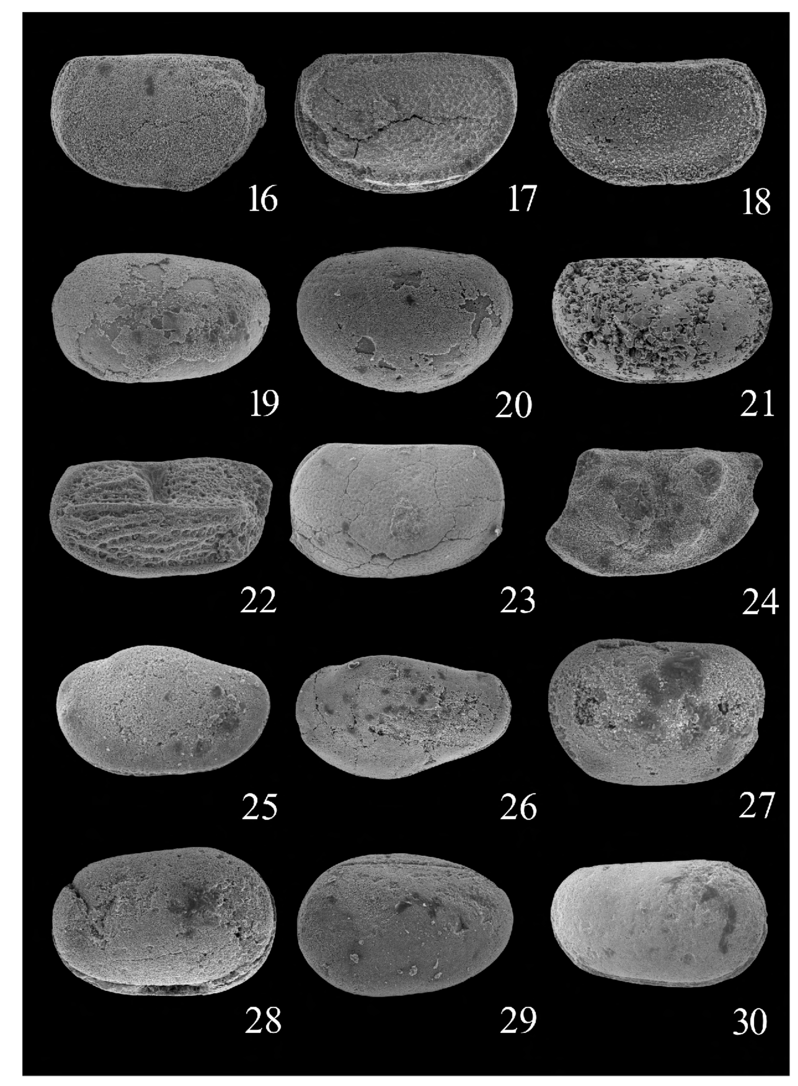
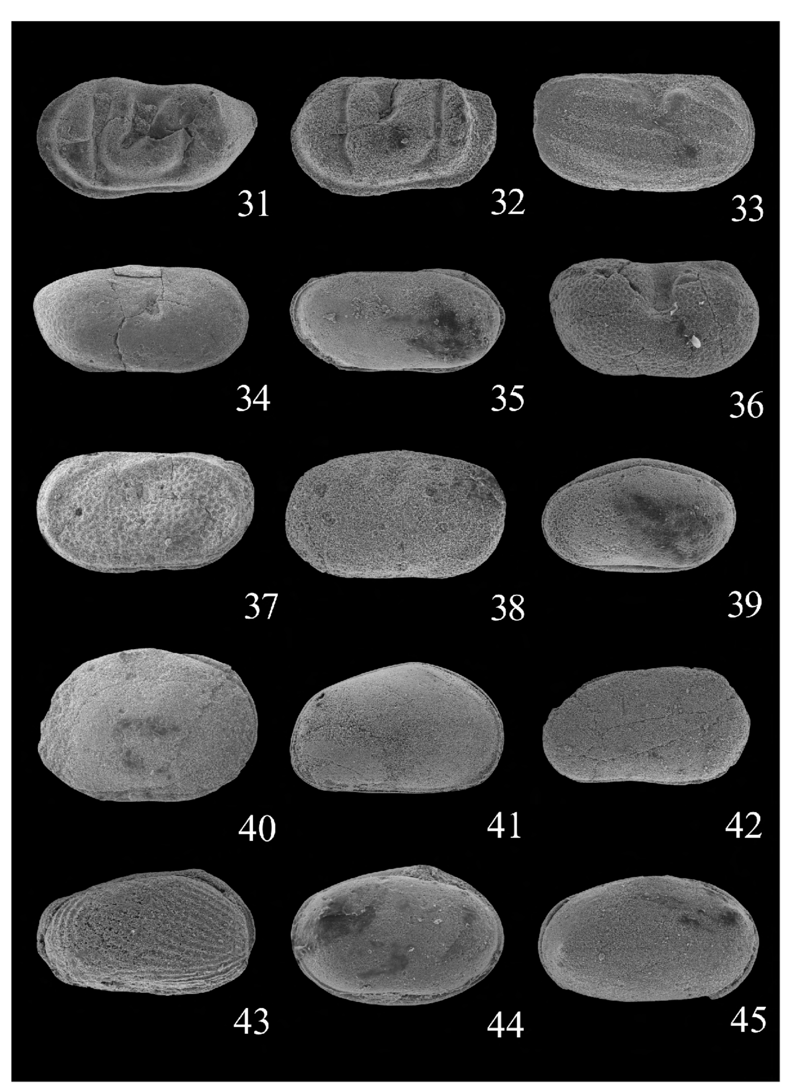


Plate 5

Plate 6: 31. *Poloniella tertia* KRÖMMELBEIN, 1953, MH-333, TH Fm; **32.** *Poloniella claviformis* (KUMMEROW, 1953), MH-298 TH Fm; **33.** *Marginia sculpta multicostata* POLENOVA, 1953, MH-131, 3-F Fm; **34.** *Uchtovia kloedenellides* (ADAMCZAK, 1968), MH-25, 3-F Fm; **35.** *Uchtovia abundans* (POKORNY, 1950), MH-503, Ha Fm; **36.** *Evlanella mitis* ADAMCZAK, 1968, MH-341, TH Fm; **37.** *Evlanella germannica* BECKER, 1964, MH-165, TH Fm; **38.** *Evlanella* cf. *lessensis* CASIER, 1991, MH-289, TH Fm; **39.** *Cavellina devoniana* EGOROV, 1950, MH-417, TH Fm; **40.** *Cavellina macella* (KUMMEROW, 1953)?, MH-116, 3-F Fm; **41.** *Cavellina haursensis* nom. nud., MH-523, Ha Fm; **42.** *Cavellina* cf. *rhenana* KRÖMELBEIN, 1954, MH-239; **43.** *Svantovites primus* POKORNY, 1950, MH-507, Ha Fm; **44.** *Jefina romei* COEN, 1985?, MH-501, Ha Fm; **45.** *Bufina schaderthalensis* ZAGORA, 1968, MH-500, Ha Fm.

Plate 7: 46. *Ropolonellus ketneri* (POKORNY, 1950), MH-503, Ha Fm; **47.** *Cytherellina obliqua* (KUMMEROW, 1953) *sensu* BECKER, 1965, MH-501, Ha Fm; **48.** *Cytherellina* sp. A, aff. *obliqua* (KUMMEROW, 1953), MH-239, TH Fm; **49.** *Cytherellina* sp. B, aff. *obliqua* (KUMMEROW, 1953), MH-201, TH Fm; **50.** *Cytherellina perlonga* (KUMMEROW, 1953), MH-429, MH Fm; **51.** *Jenningsina heddebauti* MILHAU, 1983, MH-404, TH Fm; **52.** *Quasillites fromelennensis* MILHAU, 1983, MH-298, TH Fm; **53.** *Polyzygia symmetrica* GüRICH, 1896, MH-201, TH Fm; **54.** *"Cytherellina" dubia* (KUMMEROW, 1953), MH-43, 3-F Fm; **55.** *Cytherellina?* cf. *brassicalis* BECKER, 1965, MH-501, Ha Fm; **56.** *Cytherellina* sp. A, MH-508, Ha Fm; **57.** *"Healdianella" budensis* OLEMPSKA, 1979, MH-298, TH Fm; **58.** *"Healdianella"* sp. A, aff. *budensis* OLEMPSKA, 1979, MH-527, 3-F Fm; **59.** *Healdianella? longissima* (KUMMEROW, 1953), MH-9, 3-F Fm; **60.** *Bairdiocypris rauffi* KRÖMELBEIN, 1952, MH-503, Ha Fm.

Plate 8: 61. *Bairdiocypris* aff. *marginata* ADAMCZAK, 1976, MH-43, 3-F Fm; **62.** *Bairdiocypris* sp. A, aff. *eifliensis* (KEGEL, 1928), MH-507, Ha Fm; **63.** *Orthocypris cicatricosa* COEN, 1985, MH-332, TH Fm; **64.** *"Orthocypris"* sp. indet. 1, MH-413, TH Fm; **65.** *"Orthocypris"* sp. indet. 2, MH-341, TH Fm; **66.** *Microcheilinella affinis* POLENOVA, 1955, MH-43, 3-F Fm; **67.** *Tubulibairdia clava* (KEGEL, 1933), MH-523, Ha Fm; **68**. *Acratia* sp. A, aff. *Celechovites cultratus* POKORNY, 1950, Ha Fm; **69.** *Acratia lucea* MAILLET, 2010 nom. nud., MH-341; **70.** *Acratia* cf. *lucea* MAILLET, 2010 nom. nud., MH-384, TH Fm; **71.** *Bairdia paffrathensis* KUMMEROW, 1953, MH-417, TH Fm; **72.** *Bairdia* cf. *paffrathensis* KUMMEROW, 1953, MH-201, TH Fm;**73.** *Bairdia* cf. *tischendorfi* BECKER, 1965, MH-43, 3-F Fm; **74.** *Bairdia* cf. *carinata* POLENOVA, 1960, *sensu* COEN (1985), MH-525, Ha Fm; **75.** *Bairdia* sp. B, MH-525, Ha Fm; **76.** *Bairdia* sp. A, MH-503, Ha Fm; **77.** *Bairdiacypris* sp. *in* COEN (1985), MH-43, 3-F Fm; **78.** *Cryptophyllus* sp. indet., MH-129, 3-F Fm; **79.** *Cryptophyllus* sp. indet., MH-608, Ha Fm.



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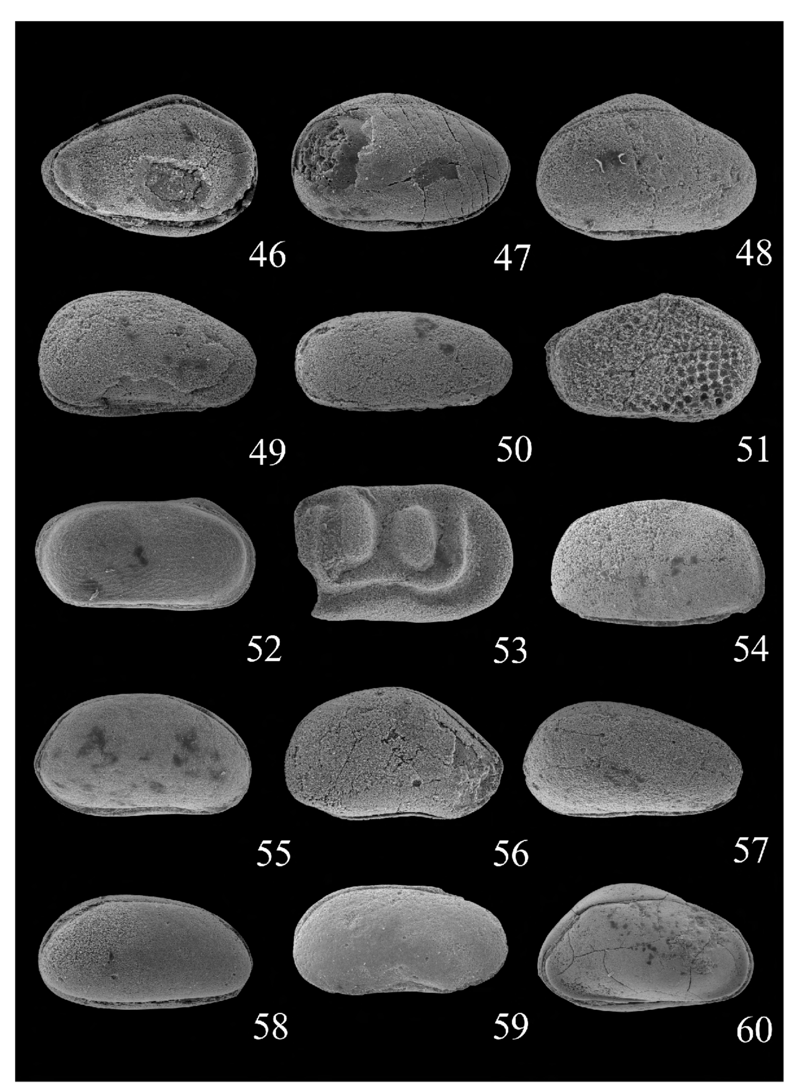


Plate 7

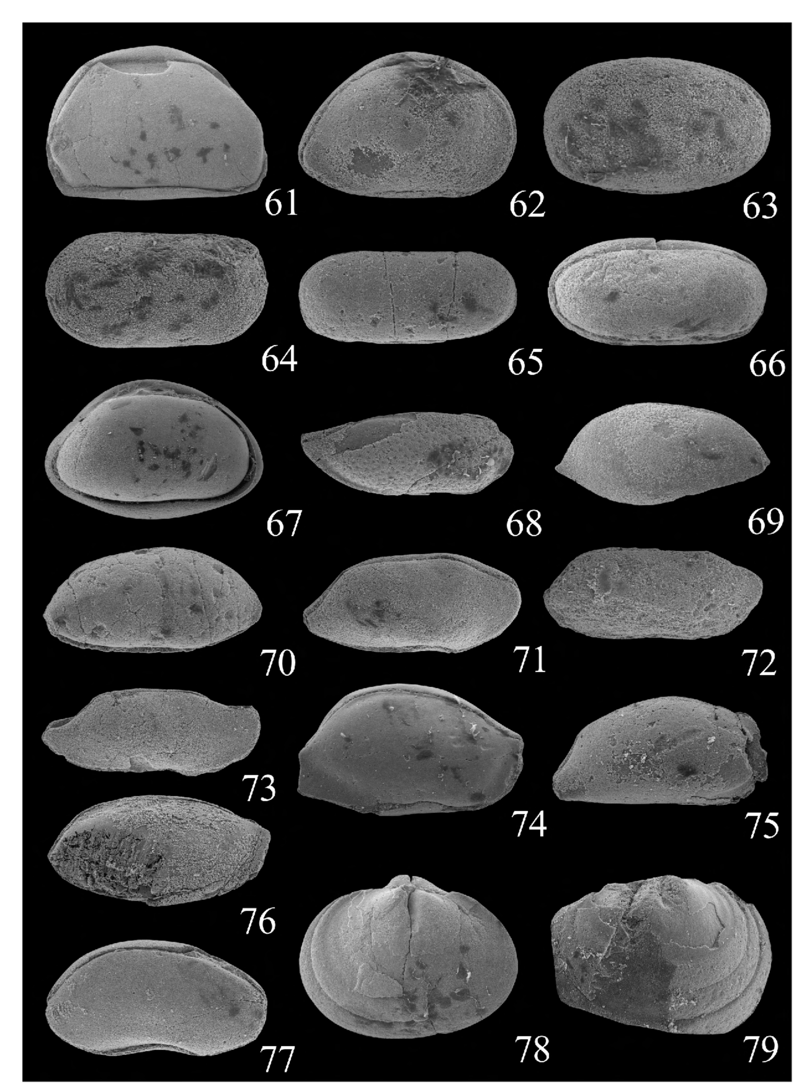
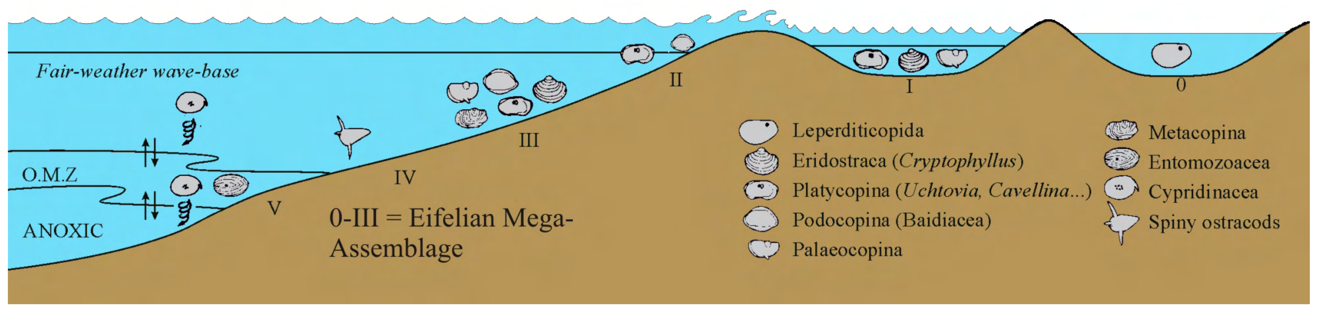


Plate 8



Devonian ostracode assemblages

Three mega-assemblages are recognized in the Devonian: 1. The Eifel Mega-Assemblage (0-III) generally characterized by a rich and diversified ostracode fauna is indicative of shallow marine (neritic), semi-restricted or lagoonal environments; 2. The Thuringe Mega-Assemblage (IV) characterized by spiny ostracodes is indicative of deep and (or) cold marine environments; 3. The Myodocopida Mega-Assemblage (V) characterized by entomozoid and (or) cyprinoid ostracodes is indicative of poorly oxygenated water conditions (After Casier, 2008).

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