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DETAILED LITHOLOGY AND FAUNAL OCCURRENCE OF THE FROMELENNES FORMATION IN THE TYPE AREA (MIDDLE/UPPER GIVETIAN, SOUTHERN PART OF THE DINANT SYNCLINORIUM, ARDENNE)

Description lithologique détaillée et distribution faunique de la Formation de Fromelennes dans la région type (Givétien moyen/supérieur, bord sud du synclinorium de Dinant, Ardenne)

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Abstract. — The Flohimont and Nichet sections, located in the southern part of the French Ardenne, expose parts of the Fromelennes Formation series (Middle/Upper Givetian - Middle Devonian). This work presents the detailed, bed by bed, stratigraphic columns for the two sections along with data on the macro- and microfauna occurrence and abundance. Characteristic beds and zones are recognized. Correlations between these different sections and the close Cul d'Houille section allow proposing the most complete up to date stratigraphic synthesis for the Fromelennes Formation in the type area.

Résumé. — *Les coupes de Flohimont et de Nichet, situées dans la partie méridionale des Ardennes françaises, permettent d'observer différentes séquences de la série sédimentaire de la Formation de Fromelennes (Givétien moyen/supérieur - Dévonien moyen). Ce travail présente les colonnes stratigraphiques détaillées de ces deux coupes ainsi qu'un relevé, banc par banc, de l'abondance des macro- et microfaunes. L'identification de bancs et zones repères permet de corréler entre eux ces différents affleurements et la coupe du Cul d'Houille et de reconstituer ainsi la séquence stratigraphique la plus complète possible à ce jour pour la Formation de Fromelennes dans la région type.*

Keywords. — Flohimont, Nichet, Stratigraphic columns, Microfauna, Correlations.
Mots clés. — Flohimont, Nichet, Colonnes stratigraphiques, Microfaune, Corrélations.

I. — INTRODUCTION

The Fromelennes Formation, firstly recognized along the Meuse river in Ardenne as a carbonated unit by Gosselet (1871) and defined by Errera *et al.* (1972), has never been completely studied in detail despite the fact that two different reference sections are usually mentioned (Bultynck, 1974; Brice, 1980; Bultynck *et al.*, 1991; Brice & Mistiaen, 2008) : respectively the Flohimont section along the Flohimont-Fromelennes road (D46) and the Cul d'Houille section on the western bank of the Houille stream.

After the detailed work on the Cul d'Houille section (Hubert & Pinte, 2009; Maillet *et al.*, 2010), this paper describes, bed by bed, the lithology and the occurrence and abundance of the main macro- and microfaunas in two other complementary sections : the Flohimont section and the new Nichet section.

Finally, the correlation of the three studied sections, by means of fifteen characteristic beds or zones allow to propose the most complete stratigraphic column for the Fromelennes Formation in its type area.

II. — STRATIGRAPHY

The Givet Group (Errera *et al.*, 1972) is currently divided into 4 formations from the Trois-Fontaines Formation at the base to the Fromelennes Formation at the top (Fig. 1) : the latter is subdivided into three members (Flohimont Member, Moulin Boreux Member and Fort Hulobiet Member) (Bultynck *et al*., 1991).

According to Bultynck (1974), Cornet (1975), Bultynck *et al.* (1991), Bultynck (2001), Lacquement *et al.* (2006) and Maillet *et al.* (2010), the historical boundary between the Mont d'Haurs Formation and the Fromelennes Formation is defined at the base of the first clayey bed containing brachiopods. We considered this boundary here.

The Fromelennes Formation is usually reported to Upper Givetian (Milhau, 1983; Bultynck *et al.*, 1991). Nevertheless, according to the sub-commission on Devonian Stratigraphy (Becker, 2007; Bultynck & Gouwy, 2008), the Middle/Upper Givetian boundary is fixed at the transition between *P. varcus* and *S. hermanni* conodonts zones. Then, the Flohimont Member displaying *P. varcus* and *P. ansatus*

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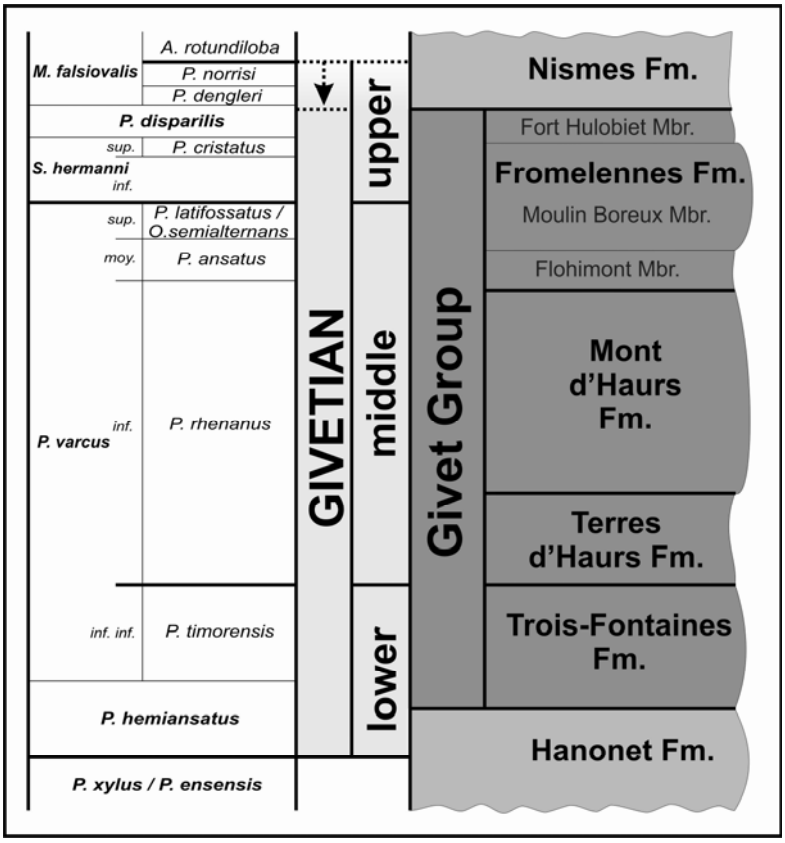

Fig. 1. — Standard conodont zonation, chronostratigraphy and lithostratigraphy in the southern border of the Dinant synclinorium.

Fig. 1. — Zonation standard des conodontes, chronostratigraphie et lithostratigraphie pour le bord sud du synclinorium de Dinant.

(Bultynck *et al.*, 1991; Bultynck, 2001; Gouwy & Bultynck, 2003), is consequently referred to Middle Givetian. Defining the beginning of the Upper Givetian, *S. hermanni* appears 83 meters above the base of the Fromelennes Formation in the Flohimont section, in the second half of the Moulin Boreux Member (Gouwy & Bultynck, 2003).

The Givetian/Frasnian (Middle/Upper Devonian) boundary is located inside the Nismes Formation (Casier, 1987; Bultynck *et al.*, 1991; Lacquement *et al.*, 2006). However, this boundary currently tends to be considered as closer to the lithostratigraphical boundary between the Fromelennes Formation and the Nismes Formation (Casier & Préat, 2009).

III. — **STUDIED SECTIONS**

The Givet area belongs to the southern border of the Dinant synclinorium (Fig. 2A). Several outcrops expose the carbonated Fromelennes Formation. Three sections have been sampled.

1**) Cul d'Houille section**

In this section, located on the western bank of the Houille stream (Fig. 2B1), the Fromelennes Formation is about 136 meters-thick (Hubert & Pinte, 2009 *emend* Maillet *et al*., 2010). The contacts Mont d'Haurs Formation/Fromelennes Formation and Flohimont Member/Moulin Boreux Member have been recognized (Maillet *et al.*, 2010). The Moulin Boreux Member is visible in an abandoned quarry but the contact between the Moulin Boreux Member and the Fort Hulobiet Member was not identified. The upper part of the Fort Hulobiet Member is lacking.

2**) Flohimont section**

This section crops out along the road D46, from the north of Flohimont to the south of Fromelennes, on the eastern bank of the Houille stream (Fig. 2B2). The Fromelennes Formation is about 84 meters-thick. The lower contact (Mont d'Haurs Formation/Fromelennes Formation) and the upper contact (Fromelennes Formation/Nismes Formation) are well exposed (Bultynck, 1974; Milhau, 1983). Boundaries between the different members are faulted and unclear.

3**) Nichet section**

This new section is located in Fromelennes, along the way leading to the Nichet caves (Fig. 2B3). Only the upper half of the Fromelennes Formation and the base of the Nismes Formation were studied. The Fort Hulobiet Member is about 13 meters-thick but all the boundaries are faulted.

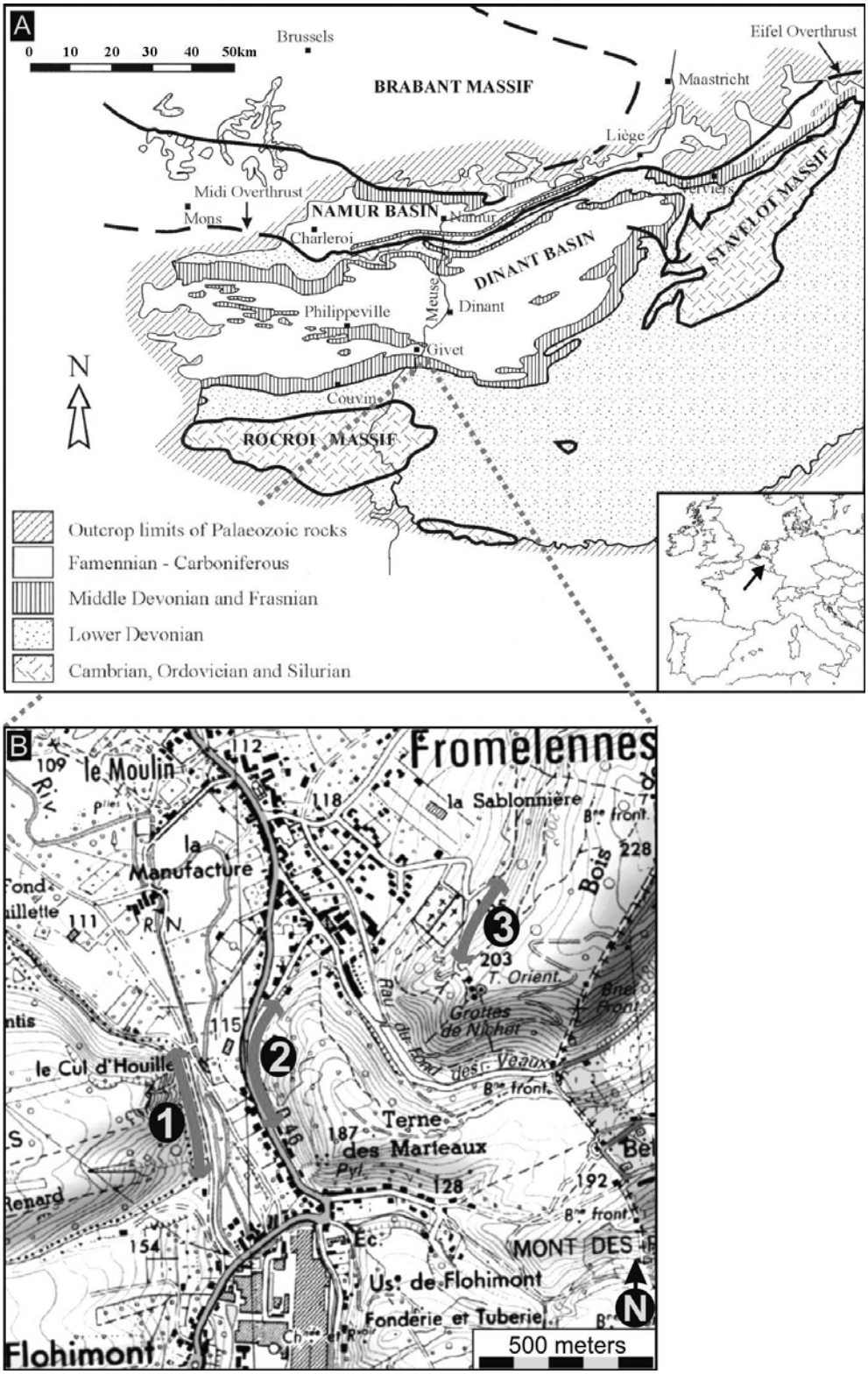

Fig. 2. — Location of the studied sections, A. in the Dinant synclinorium (modified from Bultynck *et al.*, 2001). B. in the Fromelennes area (topographic map of Givet (25,000^{e}), IGN France, *http://www.brgm.fr/numerique.jsp*). 1. Cul d'Houille section; 2. Flohimont section (D46); 3. Nichet section.

Fig. 2. — Localisation des coupes étudiées, A. à la bordure sud du synclinorium de Dinant (modifié d'après Bultynck et al.*, 2001). B. dans la région de Fromelennes (carte topographique de Givet au 25 000e, IGN France,* http://www.brgm.fr/numerique.jsp*). 1. Coupe du Cul d'Houille ; 2. Coupe de Flohimont (D46) ; 3. Coupe de Nichet.*

IV. — **PREVIOUS WORKS**

Historical review of the Cul d'Houille section works can be found in Hubert & Pinte (2009) *emend* Maillet *et al*. (2010).

Few authors studied the Flohimont section. Thus, Coen & Coen-Aubert (1971) described lithological units and macrofauna in the F1a (currently the Flohimont Member). Bultynck (1974) focussed his work on boundaries and conodonts in the upper part of the Mont d'Haurs Formation and the base of the Fromelennes Formation. Cornet (1975) described the reefal organisms (stromatoporoids, rugose and tabulate corals) in the upper part of the Mont d'Haurs Formation. Milhau (1983) was the first one to study ostracodes from the base and the top of the Fromelennes Formation. Coen (1985) studied ostracodes from the lower part of the Flohimont Member. Bultynck (2001) recorded the occurrences of conodonts taxa at the Mont d'Haurs Formation/Fromelennes Formation transition. Boulvain *et al.* (2009a and b) published sedimentological studies, magnetic susceptibility measurements and provided a synthetic stratigraphic column of the section.

The Nichet section has never been studied.

V. — **MATERIAL AND METHODS**

Sampling of the Cul d'Houille section was made according to the stratigraphic column of Hubert & Pinte (2009) and Maillet *et al.* (2010). Bed by bed measurements and sampling have been performed in the Flohimont and Nichet sections. More than 250 samples were collected (Tabl. I.).

To extract ostracodes and other calcitic microfossils from the carbonated gangue, we used the well known hot acetolysis method (Milhau, 1983 and 1984; Coen, 1985; Lethiers & Crasquin-Soleau, 1988; Casier & Préat, 2009).

More than 12,000 carapaces, valves and fragments of ostracodes have been collected and identified under binocular lens.

The material and fossils are housed in the collections of the Faculté Libre des Sciences et Technologies (FLST) in Lille.

VI. — **DESCRIPTION OF THE SERIES**

The upper part of the Mont d'Haurs Formation and the Fromelennes Formation are described, from bottom to top, for the Flohimont and Nichet sections. For the Cul d'Houille section, refer to Hubert & Pinte (2009) and Maillet *et al.* (2010).

1**). Flohimont section.**

In this section, the sedimentary series presents a N70 orientation and a reversed dip of 70°S.

a*). The Mont d'Haurs Formation*

The described upper part of the Mont d'Haurs Formation is 29.7 meters-thick (beds 969-1000; Annex I).

Bed 969 : 0.25m, calcareous, macrofauna composed of stromatoporoids and tabulate corals. Calcitic bevel-edged base due to a fault.

Bed 970 : 0.80m, sedimentary bias.

Beds 971 to 975 : 3.10m, calcareous, macrofauna composed of some stromatoporoids, rugose and branching tabulate corals (*Thamnopora* sp.), rare brachiopods and gastropods.

Bed 976 : 1.60m, sedimentary bias.

Beds 977 to 980 : 7.05m, massive, calcareous, macrofauna composed of some laminar stratifications and rare stromatoporoids, tabulate corals and brachiopods.

Bed 981 : 0.45m, nodular, calcareous.

Beds 982 to 985 : 6.15m, thick reef-limestone, providing rugose corals, stromatoporoids and brachiopods (*Stringocephalus burtini* DEFRANCE, 1827). Poor microfauna with some brachiopods, crinoids, echinoids spines and sponge spicules.

Beds 986 to 987 : 3.75m, massive biostromal unit, with abundant stromatoporoids (Amphiporidae), tabulate corals (*Thamnopora* sp., *Scoliopora* sp. and *Caliapora* sp.), solitary rugose corals, some brachiopods and crinoids. Microfauna mainly composed of brachiopods, gastropods and crinoids.

Beds 988 to 992 : 3.65m, thinner reef-limestones with solitary rugose corals and massive and branching tabulate corals (*Crassialveolites* sp., *Thamnopora* sp.) alternating with crinoidal limestones. Common microfossils, particularly ostracodes, brachiopods, crinoids and tentaculitids.

Beds 993 to 1000 : 2.90m, thin crinoidal argillaceous limestones. Very abundant macro- and microfauna with numerous ostracodes, brachiopods, gastropods and crinoids, some reefal organisms, conodonts and trilobites fragments, presence of tentaculitids, perireefal charophyta (*Sycidium* sp., D. Vachard pers. comm.) and foraminifera.

b*). The Fromelennes Formation*

The Fromelennes Formation crops out on about 92 meters in this section, compared to about 136 meters in the Cul d'Houille section (Tabl. I), due to numerous faults.

- *Flohimont Member* (Annex I)

Bed 1001 : 0.45m, incompetent argillaceous limestone showing a brachiopods coquina (1001), accompanied by crinoids. Microfauna well diversified, including charophyta (*Sycidium* sp.), tentaculitids, gastropods, reefal organisms fragments and very abundant brachiopods, crinoids and ostracodes (*Quasillites fromelennensis* MILHAU, 1983 as dominant species).

Beds 1002 to 1005 : 2.30m, thin argillaceous crinoidal limestones, rich in brachiopods. Some solitary rugose corals and bioclasts. Well diversified microfauna, with dominant ostracodes, brachiopods and crinoids.

Section	Cul d'Houille	Flohimont (D46)	Nichet	Synthetic stratigraphical column
Fromelennes Fm. thickness	136.00m	92.20m	23.75m	140.00m
Flohimont Mb.	29.60m	12.15m	-	29.60m
Moulin Boreux Mb.	84.80m	64.60m	Only 11.05m sampled, more about 25.00m	84.80m
Fort Hulobiet Mb.	21.60m	15.45m	12.70m	25.60m
Number of samples	122	121	15	258
Number of ostracodes	7.100	4.900	350	12.350

Tabl. I. — Data synthesis for the Fromelennes Formation.

Tabl. I. — Synthèse des données pour la Formation de Fromelennes.

Bed 1006 : 0.70m, incompetent bioclastic siltstone, showing a plate-splitting. Microfauna mainly composed of brachiopods, crinoids and tentaculitids.

Beds 1007 to 1013 : 2.15m, bioclastic to crinoidal argillaceous limestones with brachiopods, some trilobites and tabulate corals. Abundant microfauna, with numerous ostracodes, brachiopods, crinoids and tentaculitids, some reefal organisms, trilobites and conodonts fragments, foraminifera (*Parathurammina* sp.), gastropods, echinoids spines and sponges spicules.

Bed 1014 : 1.10m, sedimentary bias.

Bed 1015 : 0.20m, calcareous. Poor microfauna.

Bed 1016 : 0.75m, sedimentary bias.

Bed 1017 : 0.30m, nodular, calcareous. Common microfauna providing ostracodes, echinoids spines, rare brachiopods and reefal organisms fragments.

Bed 1018 : 0.65m, sedimentary bias.

Bed 1019 to 1026 : 3.55m, nodular calcareous unit, with abundant small trilobites exuviae (*Dechenella* sp., C. Crônier pers. comm.) and brachiopods. Very abundant crinoids in the lower part. Some solitary rugose corals, branching and massive tabulate (*Thamnopora* sp., Alveolitidae) at the top. Bed 1023 particularly rich in gastropods. Well-diversified microfauna, with abundant ostracodes, brachiopods and trilobites fragments.

Bed 1027 : 15m, sedimentary bias. In comparison with the close Cul d'Houille section (Hubert & Pinte, 2009 ; Maillet *et al.*, 2010), most of the Flohimont Member is missing, due to a fault.

- *Moulin Boreux Member* (Annex I)

Beds 1028 to 1038 : 6.45m, decimeters-thick dark thin-grained limestones, with some bioclasts, crinoids and rare stromatoporoids. Microfauna displaying abundant gastropods, some ostracodes, crinoids, algae, rare brachiopods and reefal organisms fragments.

Bed 1039 : 2.50m, sedimentary bias.

Bed 1040 : 0.25m, thin, argillaceous, with some bioclasts and brachiopods valves. Microfauna providing abundant ostracodes and some brachiopods, gastropods, reefal organisms fragments, sponges spicules, charophyta and foraminifera.

Beds 1041 to 1042 : 2.75m, massive biostromal limestones, providing stromatoporoids and solitary rugose corals.

Beds 1043 to 1044 : 0.40m, thin, calcareous, with rare crinoids.

Beds 1045 to 1046 : 4.40m, massive thin-grained limestones, with some bioclasts and brachiopods valves. Poor microfauna with rare ostracodes, crinoids and algae.

Bed 1047 : 1.00m, sedimentary bias.

Beds 1048 to 1050 : 3.65m, massive thin-grained limestones. Bed 1049 is biostromal, with stromatoporoids and solitary rugose corals.

Beds 1051 to 1061 : 7.70m, decimeters to meters-thick limestones, showing some brachiopods valves and rare crinoids, bioclasts and small solitary rugose corals. Poor microfauna.

Beds 1062 to 1065 : 4.35m, massive biostromal limetones, providing abundant stromatoporoids, some solitary rugose corals, rare tabulate corals fragments and crinoids. Bed 1065 especially rich in large globular stromatoporoids. Poor microfauna.

Beds 1066 to 1074 : 10.75m, massive meters-thick thin-grained limestones. Bed 1067 yielding some solitary rugose corals.

Bed 1075 : 3.30m, massive bioclastic limestone, with some globular stromatoporoids.

Beds 1076 to 1077 : 3.40m, thick limestones showing clayey seals, the latter with rugose corals.

Beds 1078 to 1080 : 2.05m, massive limestones alternating with thin argillaceous beds, showing rare crinoids. Very rare microfauna.

Bed 1081 : 0.25m, very nodular, irregular brown siltstone, with a conglomeratic appearance and containing rare badly-preserved rugose corals fragments.

Beds 1082 to 1085 : 1.60m, thin-grained limestones, with iron oxides, rare crinoids, rugose corals and bioclasts.

Beds 1086 to 1089 : 5.25m, massive reef-limestones, with rugose corals and globular stromatoporoids and rare tabulate corals fragments.

Beds 1090 to 1095 : 4.55m, decimeters to meter-thick thin-grained limetones, with iron oxides, rare bioclasts and some solitary rugose corals, especially in bed 1095.

Bed 1096 : 17.00m, sedimentary bias.

Fort Hulobiet Member (Annex I)

Beds 1097 to 1101 : 1.50m, calcareous, sometimes nodular, with some brachiopods and bioclasts. Microfauna well diversified at the base of this unit. Abundant ostracodes, with *Cavellina rhenana* KRÖMMELBEIN, 1954 as dominant species.

Bed 1102 : 0.70m, sedimentary bias.

Bed 1103 : 0.40m, thin argillaceous limestone, providing abundant small gastropods.

Bed 1104 : 1.00m, sedimentary bias.

Beds 1105 to 1107 : 0.60m, competent reef-limestones, showing a bevel surface with striated calcite due to a fault. Very abundant tabulate (*Thamnopora* sp., *Crassialveolites* sp.) and rugose corals (particularly *Disphyllum virgatum* HINDE, 1890). Abundant and diversified ostracodes.

Beds 1108 to 1111 : 0.65m, nodular argillaceous limestones. Microfauna essentially yielding foraminifera and algae (Umbellidae).

Beds 1112 to 1116 : 1.50m, competent limestones unit, sometimes slightly dolomitic, with massive and branching tabulate corals and abundant solitary rugose corals. Bed 1114 particularly rich in *Disphyllum virgatum* HINDE, 1890.

Beds 1117 to 1122 : 1.00m, thin argillaceous dolomitic limestones, with some rugose corals, brachiopods, bivalves, bioclasts and crinoids. Common microfauna with abundant ostracodes.

Beds 1123 to 1124 : 0.50m, siltstones, with very abundant rugose corals, some crinoids and bioclasts. Bed 1124 very rich in disphyllids. Microfauna mainly composed of ostracodes, brachiopods, echinoids spines and foraminifera.

Beds 1125 to 1128 : 1.20m, competent bioclastic limestones. Very rare macrofossils. Common microfauna with abundant ostracodes.

Beds 1129 to 1130 : 0.65m, siltstones, very poor in fauna.

Bed 1131 : 0.15m, thin dolomitic limestone, with brachiopods and bivalves.

Beds 1132 to 1148 : 3.40m, thin-grained limestones, with rare macrofossils. Microfauna mainly composed of ostracodes, brachiopods and echinoderms fragments and foraminifera. Beds 1149 to 1153 : 2.20m, nodular limestones unit, rich in brachiopods. Abundant microfauna, mainly with well-diversified ostracodes, brachiopods, echinoderms fragments, foraminifera (*Nanicella* sp., D. Vachard pers. comm.) and tentaculitids.

c*) The Nismes Formation*

Beds 1154 to 1166 : 4.75m, incompetent brown siltstones, with abundant huge brachiopods (Spiriferids, Atrypids…), belonging to the “zone des monstres” (Gosselet, 1871; Errera *et al.*, 1972).

2**) Nichet section**

In this section, the sedimentary series present a mean N40 orientation and a reversed dip of 70°S.

a*) The Fromelennes Formation*

The lower part of the Fromelennes Formation (Flohimont Member and base of the Moulin Boreux Member) is not exposed, hidden by the access to the Nichet cave. Only the upper part of the formation can be observed on a few tens of meters, of which about 23 meters were sampled for this study. We especially focussed on the boundary between the Moulin Boreux and the Fort Hulobiet members.

- *Moulin Boreux Member* (Annex II)

About 25 meters of thick dolomitic limestone beds, belonging to this member, could be observed below the following described series.

Bed 86 : 1.00m, massive meter-thick grey reef-limestone, very rich in stromatoporoids. Some rugose corals. Bed identical to the stromatoporoid wall in the Cul d’Houille quarry (bed 136 *in* Hubert & Pinte, 2009).

Beds 87 to 89 : 0.35m, thin nodular very bioclastic limestones, with some rugose corals.

Beds 90 to 99 : 5.20m, bioclastic limestones alternating with reef-limestones, with some crinoids, rugose corals and stromatoporoids.

Bed 100 : 1.25m, massive reef-limestone, with some stromatoporoids. Bed analogous to the bed 165 in the Cul d’Houille section (Hubert & Pinte, 2009).

2.00m, sedimentary bias.

Beds 101 to 102 : 0.45m, thin bioclastic, slightly dolomitic limestones, providing a monospecific ostracodes fauna (*Cryptophyllus* sp.3 *sensu* Magne, 1964).

0.80m, sedimentary bias.

- *Fort Hulobiet Member* (Annex II)

Beds 103 to 105 : 0.60m, very calcitic limestones, with striated calcite and iron oxides. Change into the orientation of the series (N50), putting forward a fault.

Beds 106 to 108 : 0.95m, thin dark dolomitic and bioclastic limestones, with iron oxides, some dislocated brachiopods valves and rugose corals. Abundant ostracodes.

6,00m, sedimentary bias.

Bed 109 : 0.50m, argillaceous limestone, rich in small gastropods.

0,50m, sedimentary bias.

Beds 110 to 111 : 0.85m, dolomitic limestones, rich in gastropods. Microfauna mainly composed of ostracodes, gastropods and algae (Umbellidae). Change in the orientation of the series (N40) and bed 110 with a bevel-edged base and striated calcite due to a fault. Presence of a reworked globular stromatoporoid in this bed.

Bed 112 : 0.40m, bioclastic argillaceous limestone. Rare microfauna.

0,50m, sedimentary bias.

Bed 113 : 0.50m, competent limestone, with abundant rugose corals, branching and massive tabulate corals (*Thamnopora* sp., *Crassialveolites* sp.), some brachiopods and bioclasts. Very abundant *Disphyllum virgatum* HINDE, 1890, comparable to the bed 1114 in the Flohimont section. Common microfauna.

Beds 114 to 115 : 0.90m, bioclastic limestones, with brachiopods and some tabulate corals. Microfossils quite rare, with some ostracodes and algae (Umbellidae).

1,00m, sedimentary bias.

b*) The Nismes Formation* (Annex II).

Bed 116 and above : 2.15m, incompetent brown siltstones alternating with brown argillaceous limestones, with huge brachiopods (Spiriferids, Atrypids…). Unit similar to the beds cropping out in the Flohimont section and belonging to the “zone des monstres” (Gosselet, 1871; Errera *et al.*, 1972).

VII. — **CORRELATIONS**

Lithology, macrofossils, ostracode populations and associated microfauna contents allow recognizing fifteen characteristic beds or zones. Then, fine correlations between the three complementary studied sections (Fig. 3) provide an almost complete 140 meters-thick sedimentary series for the Fromelennes Formation in the Givet area.

We can recognize the following characteristic beds and zones:

1) A 3 meters-thick biostrome (reef-limestone), with abundant tabulate and solitary rugose corals, and stromatoporoids (particularly amphiporidae) : Flohimont bed 986 and Cul d’Houille bed 85’’.

2) A brachiopod argillaceous-carbonated coquina bed, at the base of the Fromelennes Formation : Flohimont bed 1001 and Cul d’Houille bed 102’’a.

3) A *Quasillites fromelennensis* MILHAU, 1983 and *Poloniella tertia* KROËMMELBEIN, 1953 very rich zone around the Mont d’Haurs Formation/Fromelennes Formation boundary : Flohimont beds 997 to 1026 and Cul d’Houille beds 95” to 108”.

4) Calcareous beds bearing small trilobites : Flohimont beds 1019 to 1026 and Cul d’Houille beds 103” to 108”.

5) Two beds bearing gastropods and serpulids (*Spirorbis* sp.) and also providing *Evlanella germanica* BECKER, 1964 and *Kozlowskiella* aff. *boloniensis* MILHAU, 1983 : Cul d’Houille beds 109’’g and 109’’h. No equivalence was found in the other sections, but these characteristic beds might be use for basin-wide correlation.

6) A thick biostrome : Flohimont bed 1041 and Cul d’Houille bed 11.

7) A biostromal unit with abundant globular stromatoporoids : Flohimont beds 1063 to 1065 and Cul d’Houille beds 53 to 58.

8) A paleosol bed, already reported by Boulvain *et al.* (2009a) : Flohimont bed 1081 and Cul d’Houille bed 109.

9) A one meter-thick biostrome (“stromatoporoids wall”) : Cul d’Houille bed 136 and Nichet bed 86.

10) *Cryptophyllus* sp.3 *sensu* Magne, 1964 almost monospecific beds at the top of the Moulin Boreux Member : Cul d’Houille beds 138 to 165 and Nichet beds 90 to 108.

11) Few beds with dominant *Cavellina rhenana* KRÖMMELBEIN, 1954, sometimes in association with *Evlanella germanica* BECKER, 1954, *Cryptophyllus* sp.3 *sensu* Magne, 1964 and *Kozlowskiella plana* (KUMMEROV, 1953) at the base of the Fort Hulobiet Member : Flohimont beds 1097 to 1103, Cul d’Houille beds 166 to 190, and Nichet beds 109 to 112.

12) A succession of disphyllids (rugose corals) beds. The first one is rather argillaceous : Cul d’Houille bed 198. The second one is more calcareous : Flohimont bed 1114, Cul d’Houille bed 209 and Nichet bed 113. The third one is again argillaceous : Flohimont bed 1124.

13) An abundant *Cryptophyllus* aff. *materni* BASSLER & KELLET, 1934 bearing unit below the disphyllids calcareous bed : Flohimont beds 1105 to 1113 and Cul d’Houille beds 199 to 208.

14) Calcareous beds bearing bivalves : Flohimont beds 1117 to 1119 and Cul d’Houille coquina limestone bed 211.

15) Beds bearing *Polyzygia beckmanni beckmanni* KRÖMMELBEIN, 1954, at the base of the Nismes Formation (Lethiers, 1974; Milhau, 1983; Casier, 1987; Bultynck *et al.*, 1991; Lethiers & Raymond, 1991; Lacquement *et al.*, 2006) : Flohimont beds 1154 to 1166 and Nichet beds 116 and above.

We can note that Maillet *et al.* (2010) reported a faunal renewal in the uppermost part of the Mont d’Haurs Formation in the Cul d’Houille section, shyly beginning above the thick biostromal bed 85’’ and becoming more distinct from bed 93”. This diversification event, characterized by the appearance of deeper platform faunas, is also clearly discernable in the Flohimont section, beginning above the thick biostromal bed 986 and becoming clearer from bed 992. In relation with a Givetian major transgressive episode

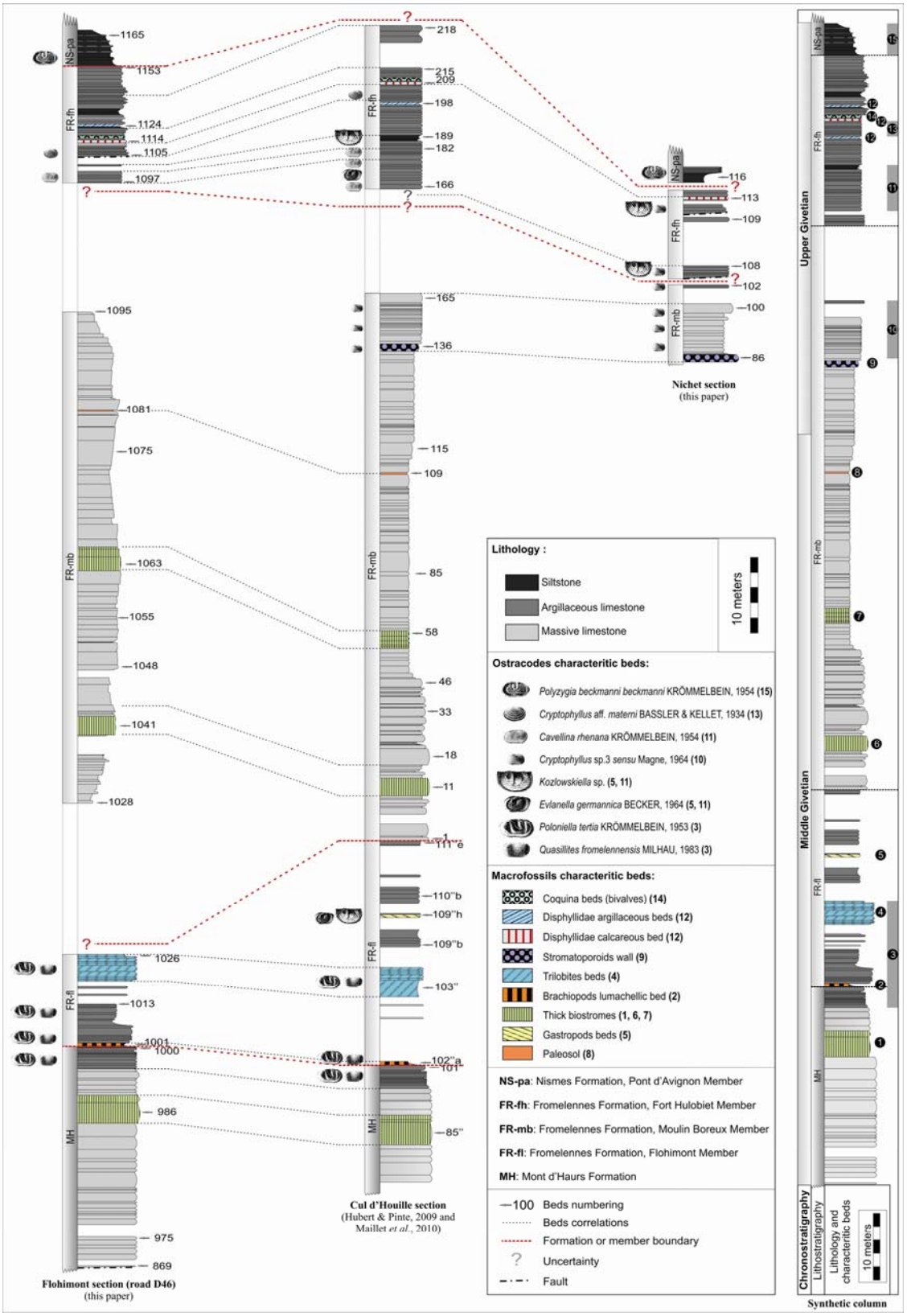

Fig. 3. — Correlation of the Flohimont, the Cul d'Houille and the Nichet sections and synthetic stratigraphic column of the Fromelennes Formation in the Givet area.

Fig. 3. — Corrélation des coupes de Flohimont, du Cul d'Houille et de Nichet et colonne stratigraphique composite synthétique de la Formation de Fromelennes dans la région de Givet.

(Milhau, 1983; Bultynck *et al.*, 2001), this faunal and sedimentary event should be found beyond the type area, and could be a useful correlation criterion in the Dinant synclinorium.

VIII. — **CONCLUSION**

The Fromelennes Formation, in its type area, is frequently faulted and the series, whatever the section, always presents numerous sedimentary biases.

The two studied sections, Flohimont and Nichet, in addition to the previously studied Cul d'Houille section, allow identifying, both on macro- and microfaunal criteria, fifteen characteristic beds or zones.

Correlations between the three sections lead to propose a new up to date synthetic stratigraphic column in which the Fromelennes Formation appears, using the same historical boundaries, to be slightly thicker than previously said : 140 meters instead of 135 meters-thick.

Finally, this work, bringing new data on the distribution and abundance of the macro- and microfauna, is a new contribution to the Givetian database of the southern border of the Dinant synclinorium. Adding to previous works (Hubert, 2008a and b; Hubert & Mabille, 2009; Hubert & Pinte, 2009; Maillet *et al*., 2010) it will be useful for future correlations.

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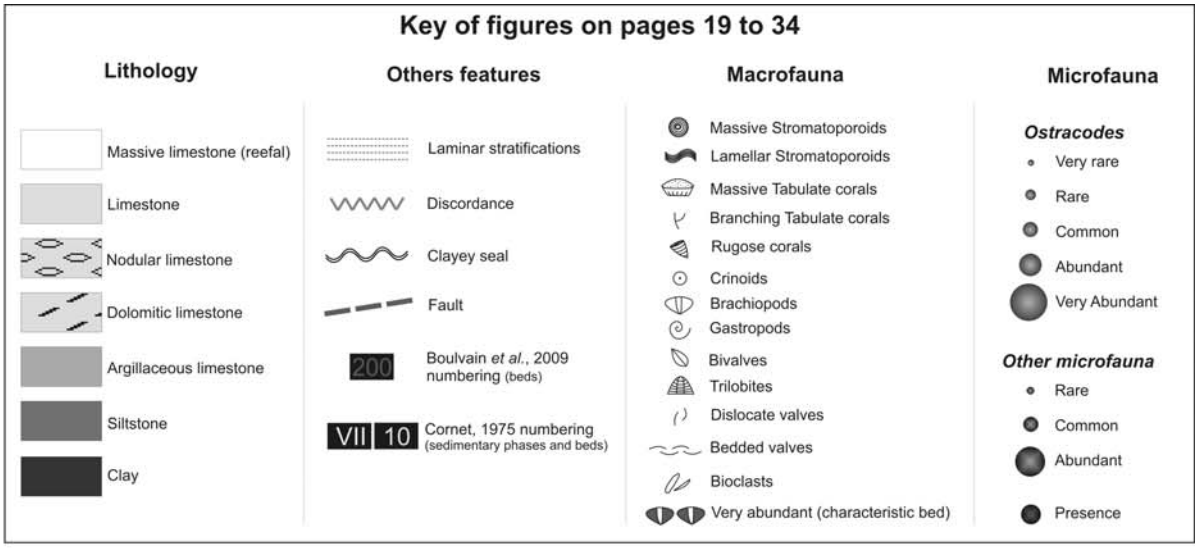
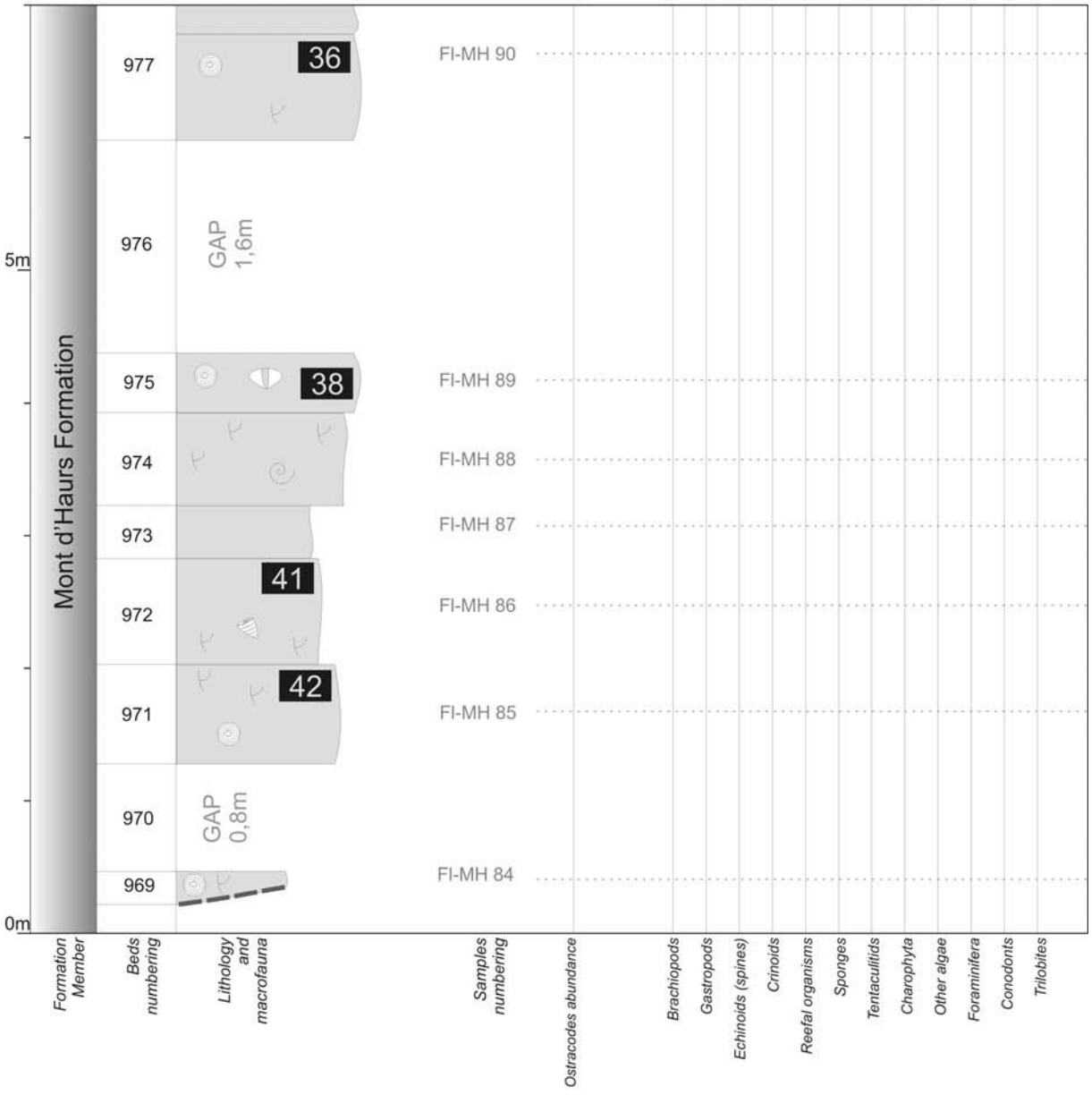
ANNEXES

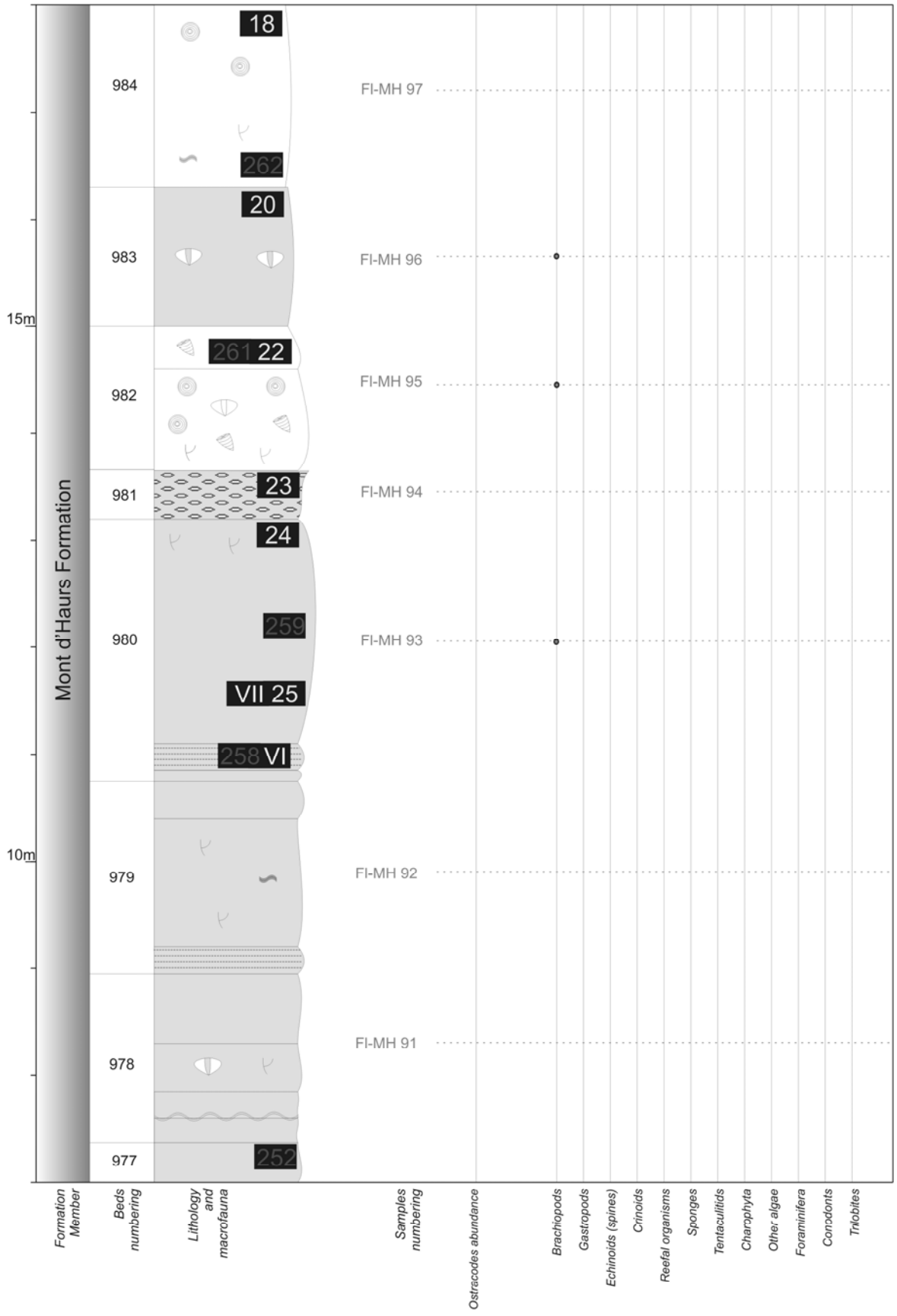
Annex I (pages 21-33)

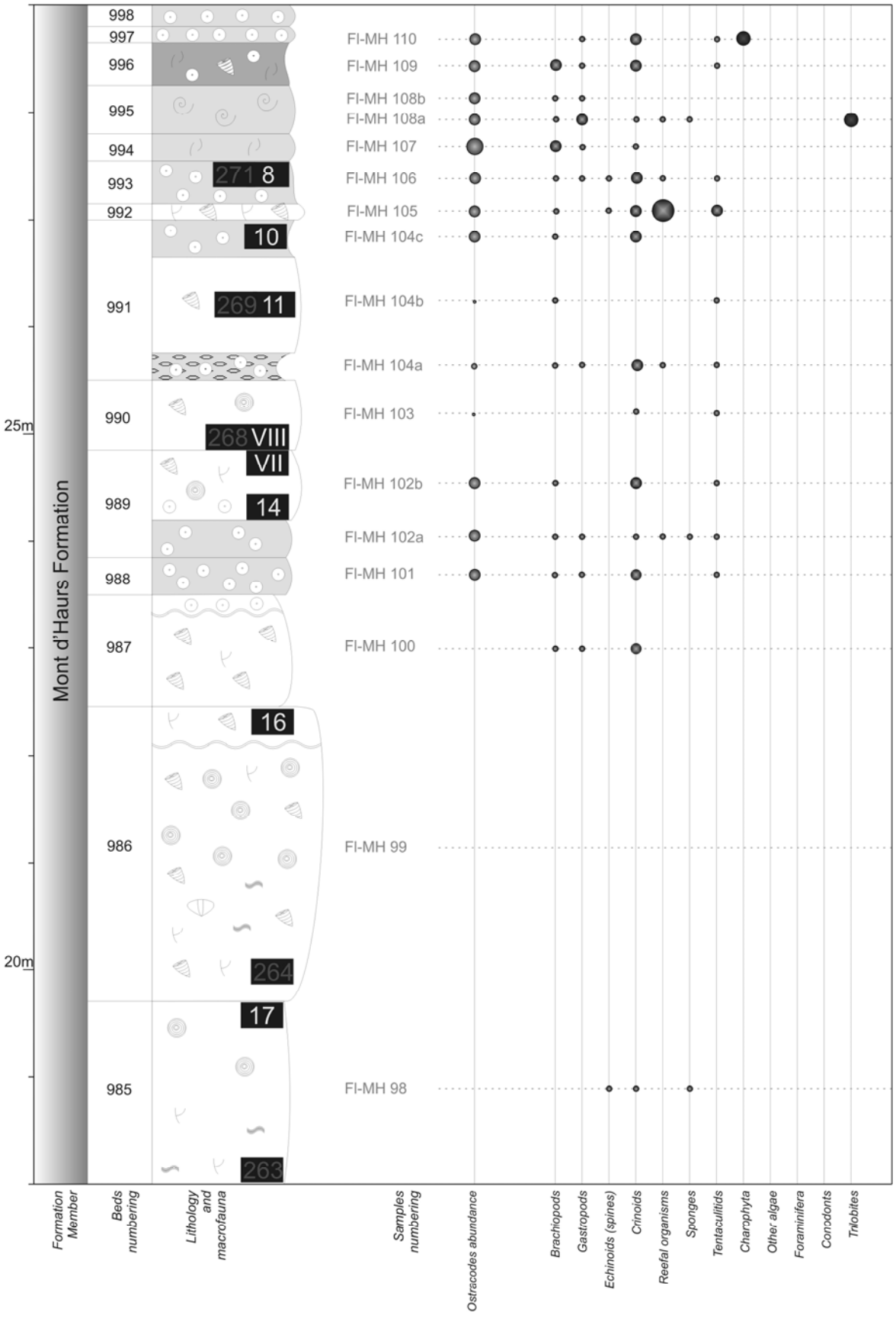
Detailed stratigraphic column of the Flohimont section (lithology and macrofauna, left part) and microfauna distribution (right part).
For caption, see Annex I, p.21.

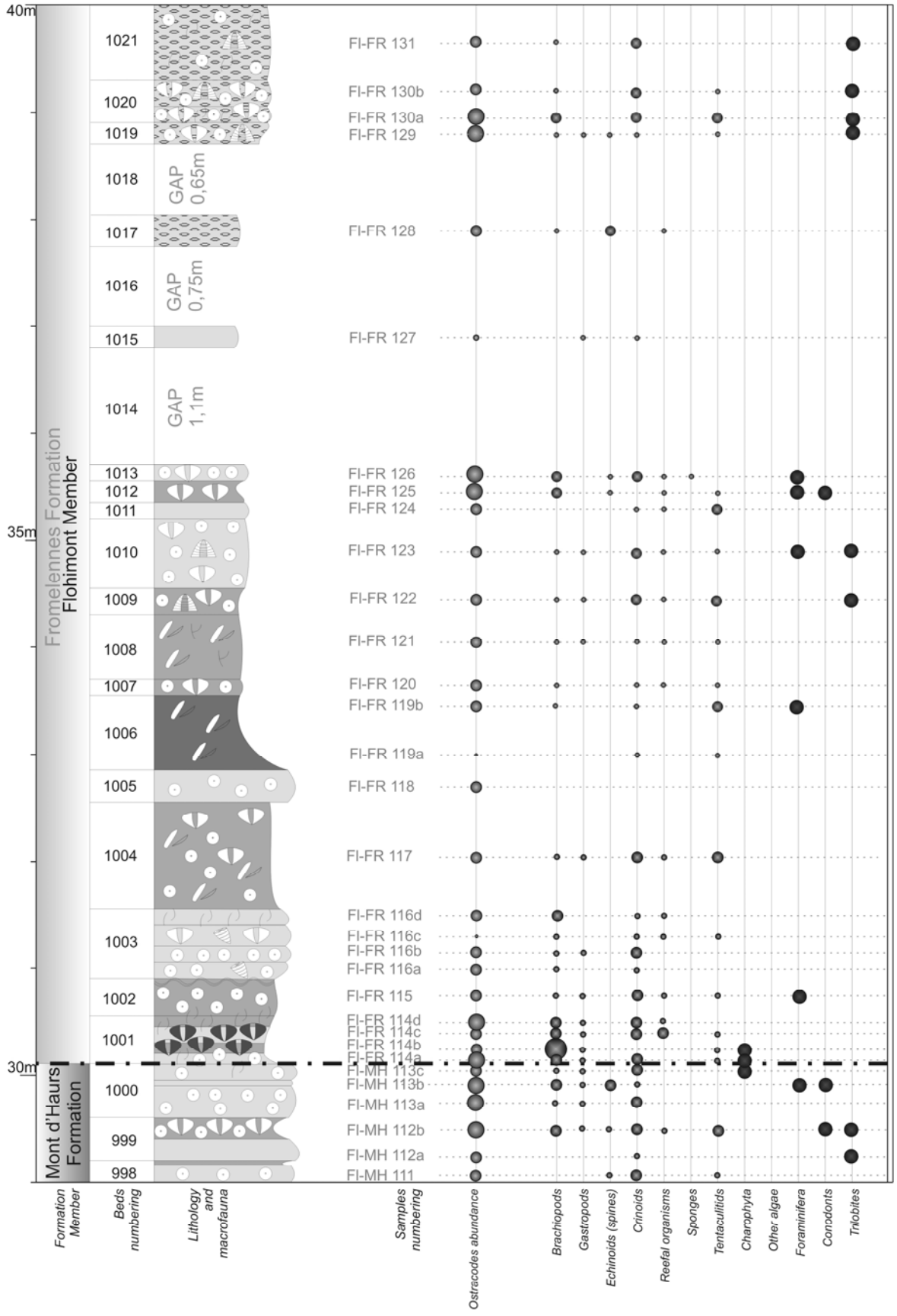
Colonne stratigraphique détaillée de la coupe de Flohimont (lithologie et macrofaune, partie gauche) et répartition de la microfaune (partie droite). Voir légende Annexe I, p. 21.

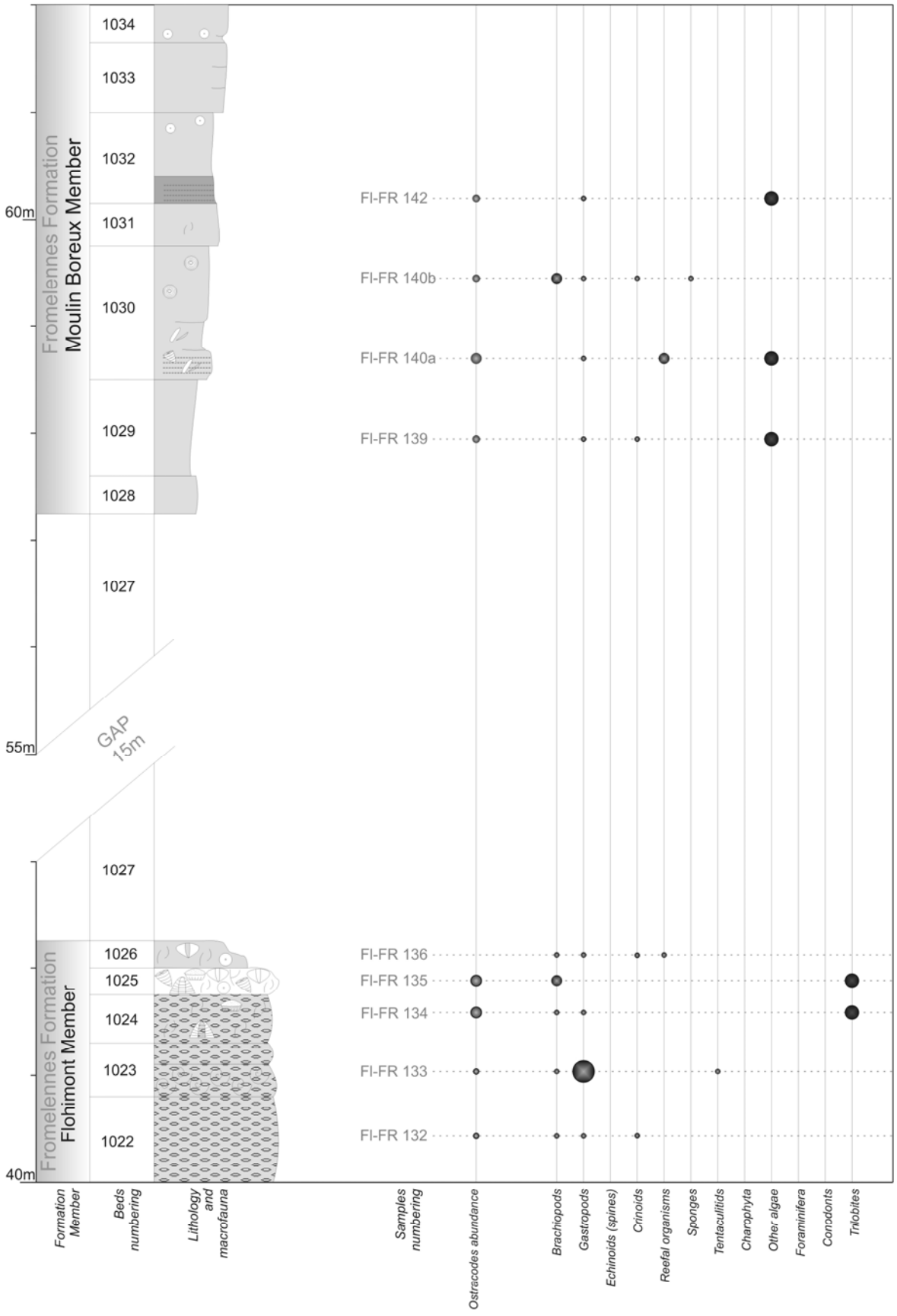

Key of figures on pages 19 to 34
Lithology
Massive limestone (reefal)
Limestone
Nodular limestone
Dolomitic limestone
Argillaceous limestone
Siltstone
Clay
Others features
Laminar stratifications
Discordance
Clayey seal
Fault
200
Boulvain et al., 2009 numbering (beds)
VII 10
Cornet, 1975 numbering (sedimentary phases and beds)
Macrofauna
Massive Stromatoporoids
Lamellar Stromatoporoids
Massive Tabulate corals
Branching Tabulate corals
Rugose corals
Crinoids
Brachiopods
Gastropods
Bivalves
Trilobites
Dislocate valves
Bedded valves
Bioclasts
Very abundant (characteristic bed)
Microfauna
Ostracodes
Very rare
Rare
Common
Abundant
Very Abundant
Other microfauna
Rare
Common
Abundant
Presence


Mont d'Haurs Formation
977
976
975
974
973
972
971
970
969
36
38
41
42
GAP 1,6m
GAP 0,8m
FI-MH 90
FI-MH 89
FI-MH 88
FI-MH 87
FI-MH 86
FI-MH 85
FI-MH 84
5m
0m
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


Mont d'Haurs Formation
15m
10m
984
983
982
981
980
979
978
977
18
262
20
261 22
23
24
259
VII 25
258 VI
252
FI-MH 97
FI-MH 96
FI-MH 95
FI-MH 94
FI-MH 93
FI-MH 92
FI-MH 91
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


Mont d'Haurs Formation
25m
20m
998
997
996
995
994
993
992
991
990
989
988
987
986
985
271 8
10
269 11
268 VIII
VII
14
16
264
17
263
Fl-MH 110
Fl-MH 109
Fl-MH 108b
Fl-MH 108a
Fl-MH 107
Fl-MH 106
Fl-MH 105
Fl-MH 104c
Fl-MH 104b
Fl-MH 104a
Fl-MH 103
Fl-MH 102b
Fl-MH 102a
Fl-MH 101
Fl-MH 100
Fl-MH 99
Fl-MH 98
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


40m
35m
30m
Fromelennes Formation
Flohimont Member
Mont d'Haurs Formation
1021
1020
1019
1018
1017
1016
1015
1014
1013
1012
1011
1010
1009
1008
1007
1006
1005
1004
1003
1002
1001
1000
999
998
GAP 0,65m
GAP 0,75m
GAP 1,1m
Fl-FR 131
Fl-FR 130b
Fl-FR 130a
Fl-FR 129
Fl-FR 128
Fl-FR 127
Fl-FR 126
Fl-FR 125
Fl-FR 124
Fl-FR 123
Fl-FR 122
Fl-FR 121
Fl-FR 120
Fl-FR 119b
Fl-FR 119a
Fl-FR 118
Fl-FR 117
Fl-FR 116d
Fl-FR 116c
Fl-FR 116b
Fl-FR 116a
Fl-FR 115
Fl-FR 114d
Fl-FR 114c
Fl-FR 114b
Fl-FR 114a
Fl-MH 113c
Fl-MH 113b
Fl-MH 113a
Fl-MH 112b
Fl-MH 112a
Fl-MH 111
Formation
Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


Fromelennes Formation
Moulin Boreux Member
Fromelennes Formation
Flohimont Member
60m
55m
40m
GAP
15m
1034
1033
1032
1031
1030
1029
1028
1027
1027
1026
1025
1024
1023
1022
FI-FR 142
FI-FR 140b
FI-FR 140a
FI-FR 139
FI-FR 136
FI-FR 135
FI-FR 134
FI-FR 133
FI-FR 132
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
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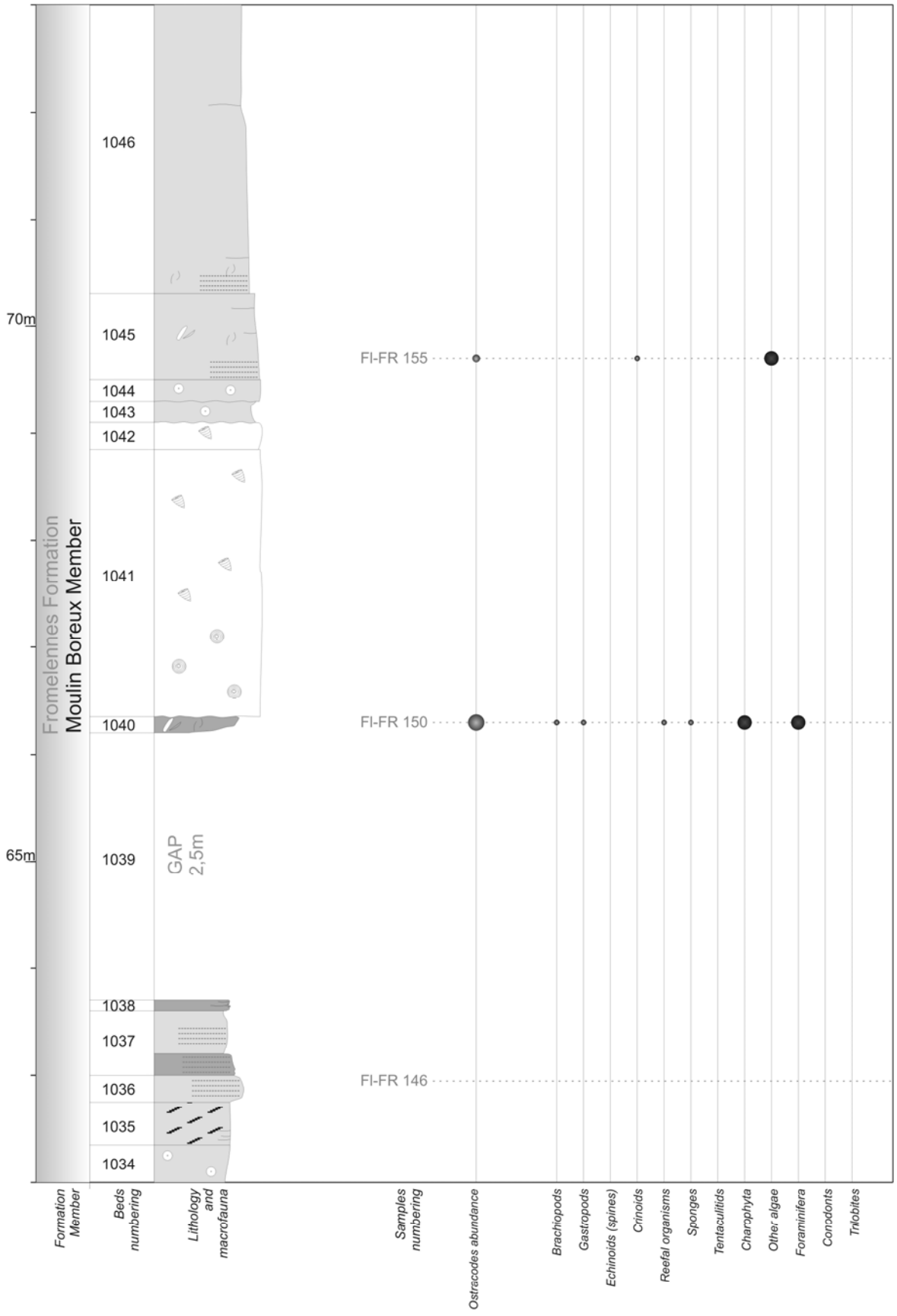
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


70m
65m
Fromelennes Formation
Moulin Boreux Member
1046
1045
1044
1043
1042
1041
1040
1039
1038
1037
1036
1035
1034
GAP
2,5m
FI-FR 155
FI-FR 150
FI-FR 146
Formation
Member
Beds
numbering
Lithology
and
macrofauna
Samples
numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
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Tentaculitids
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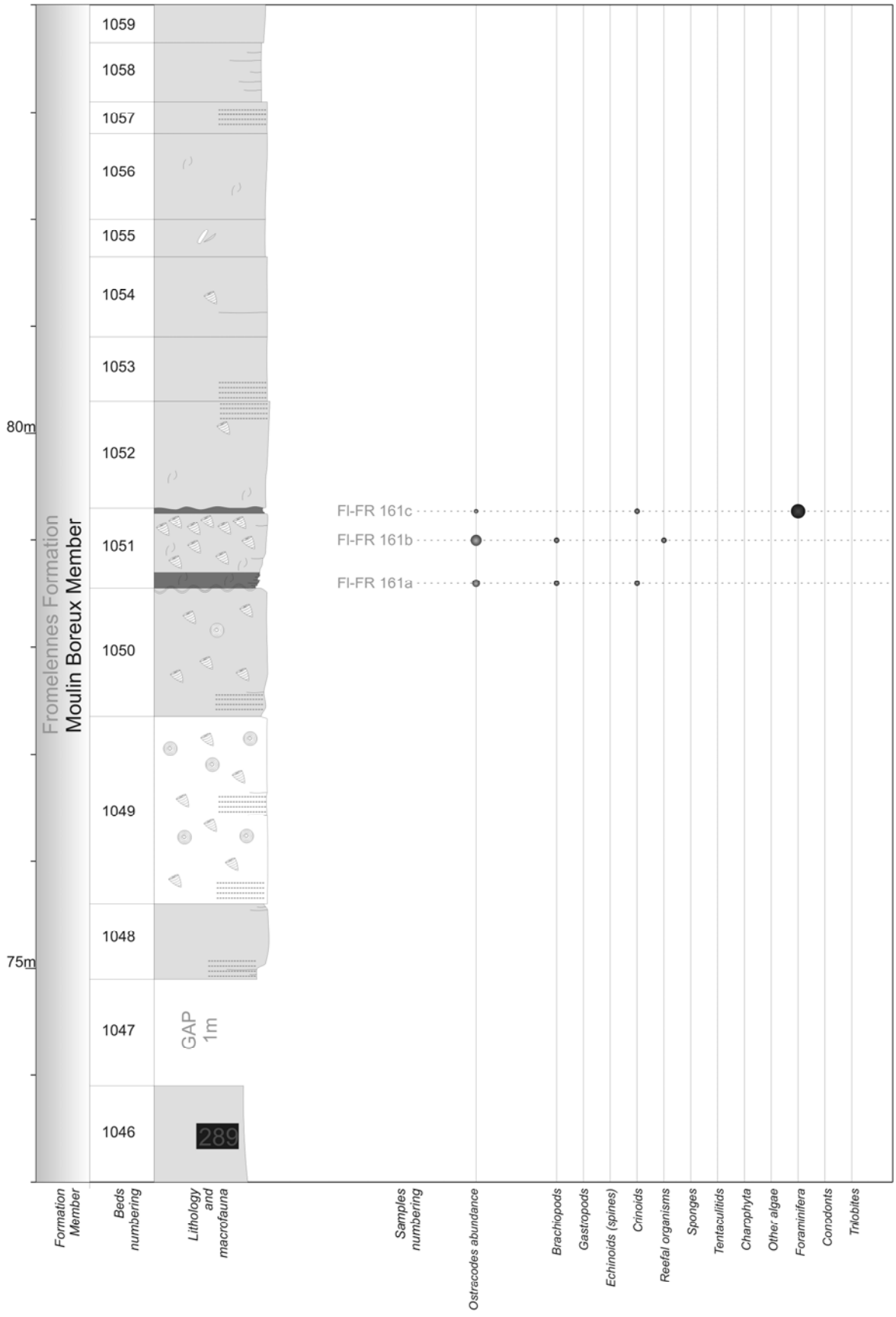
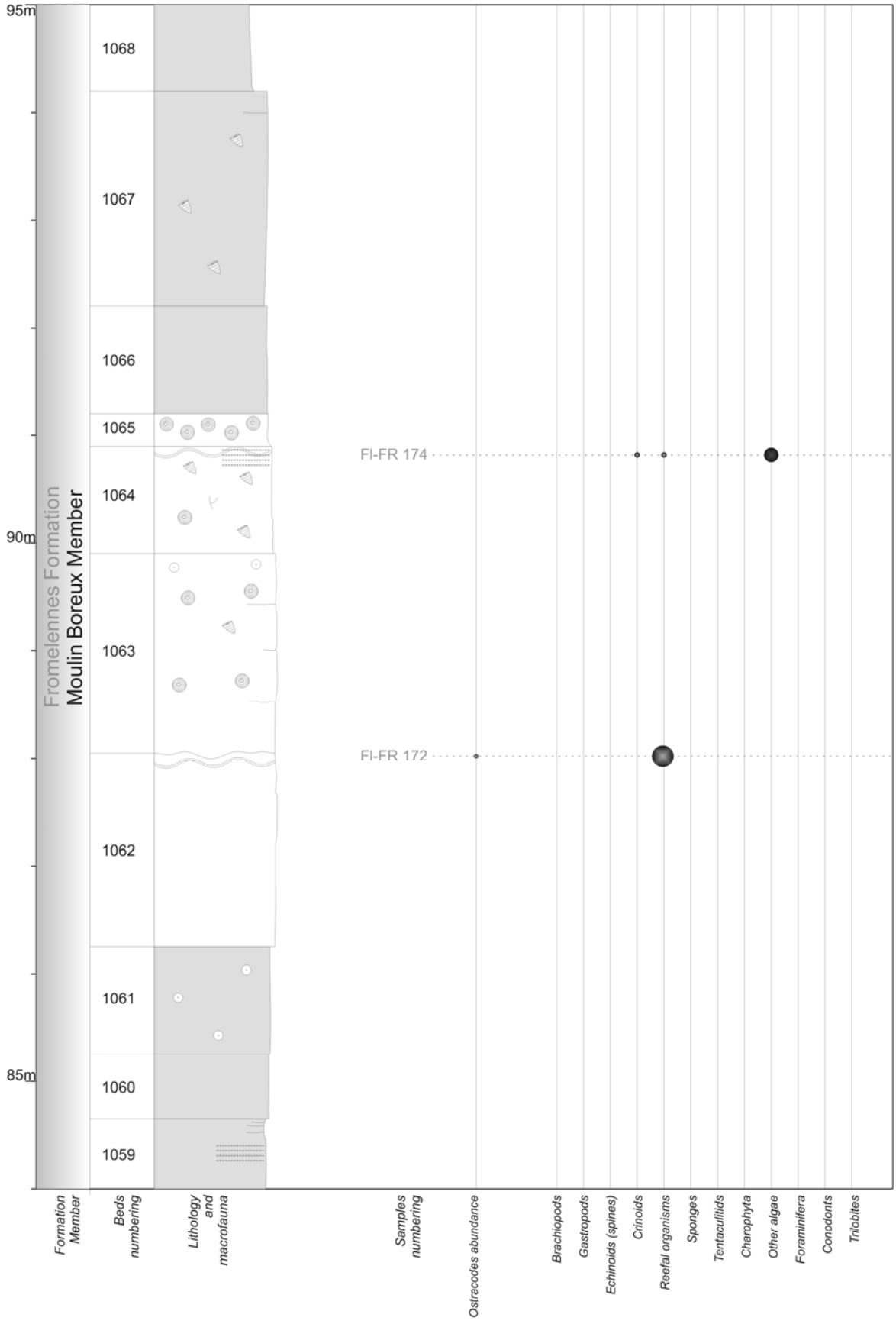
Other algae
Foraminifera
Conodonts
Trilobites


Fromelennes Formation
Moulin Boreux Member
80m
75m
1059
1058
1057
1056
1055
1054
1053
1052
1051
1050
1049
1048
1047
1046
GAP
1m
289
Fl-FR 161c
Fl-FR 161b
Fl-FR 161a
Formation
Member
Beds
numbering
Lithology
and
macrofauna
Samples
numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


95m
90m
85m
Fromelennes Formation
Moulin Boreux Member
1068
1067
1066
1065
1064
1063
1062
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1060
1059
FI-FR 174
FI-FR 172
Formation
Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
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Gastropods
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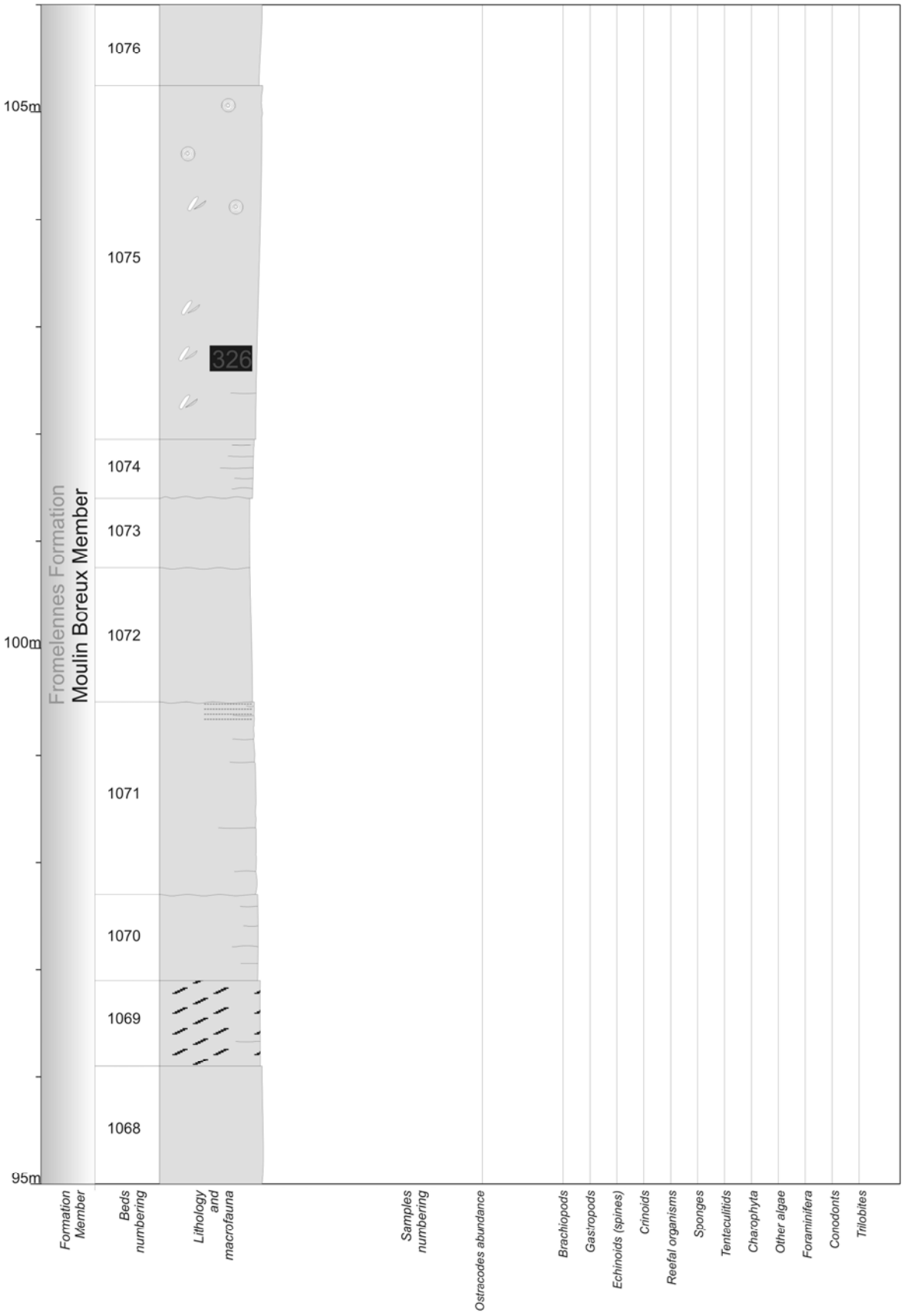
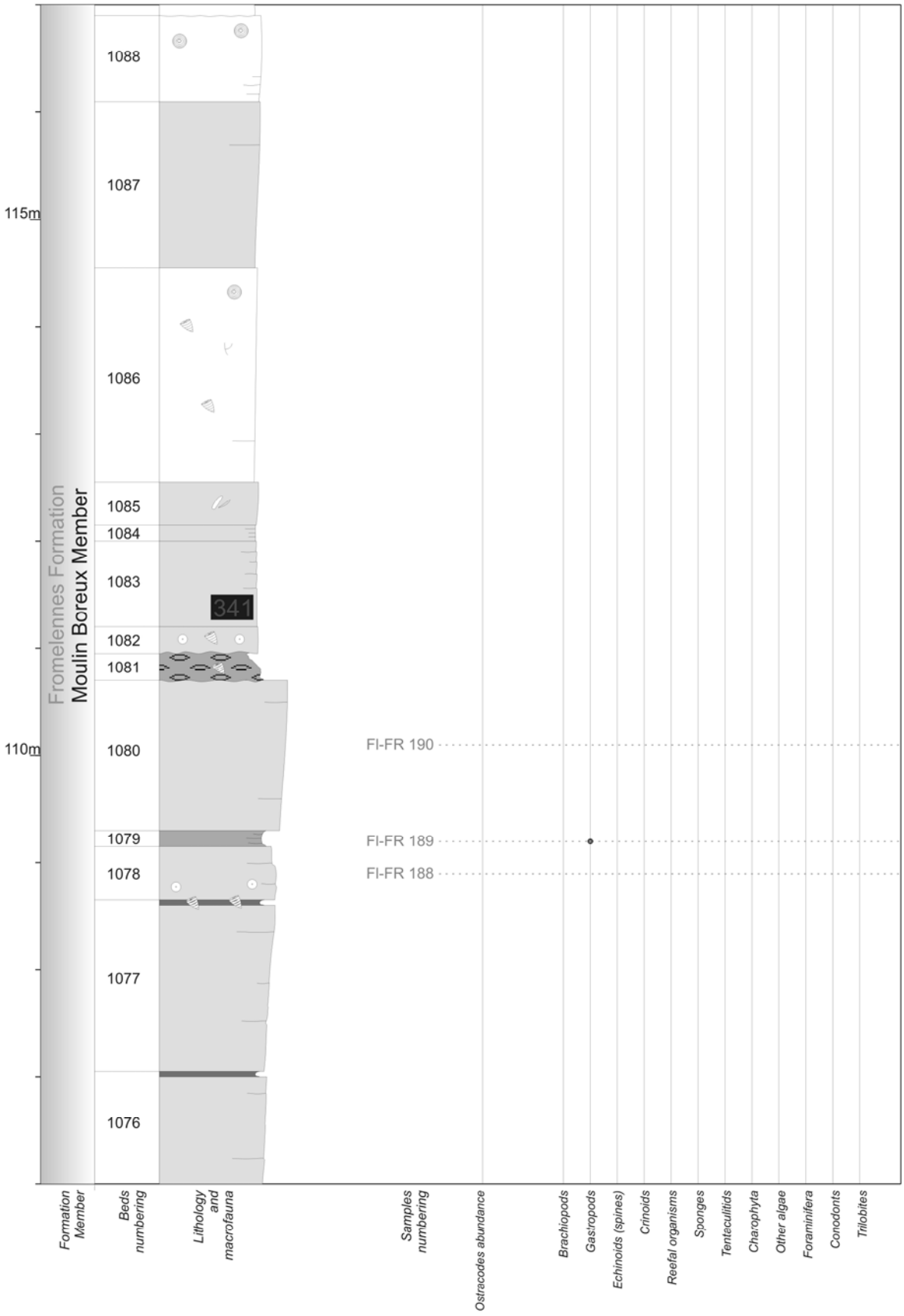
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


105m
100m
95m
Fromelennes Formation
Moulin Boreux Member
1076
1075
1074
1073
1072
1071
1070
1069
1068
326
Formation
Member
Beds
numbering
Lithology
and
macrofauna
Samples
numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


Fromelennes Formation
Moulin Boreux Member
115m
110m
1088
1087
1086
1085
1084
1083
1082
1081
1080
1079
1078
1077
1076
341
FI-FR 190
FI-FR 189
FI-FR 188
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
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Gastropods
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Reefal organisms
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Other algae
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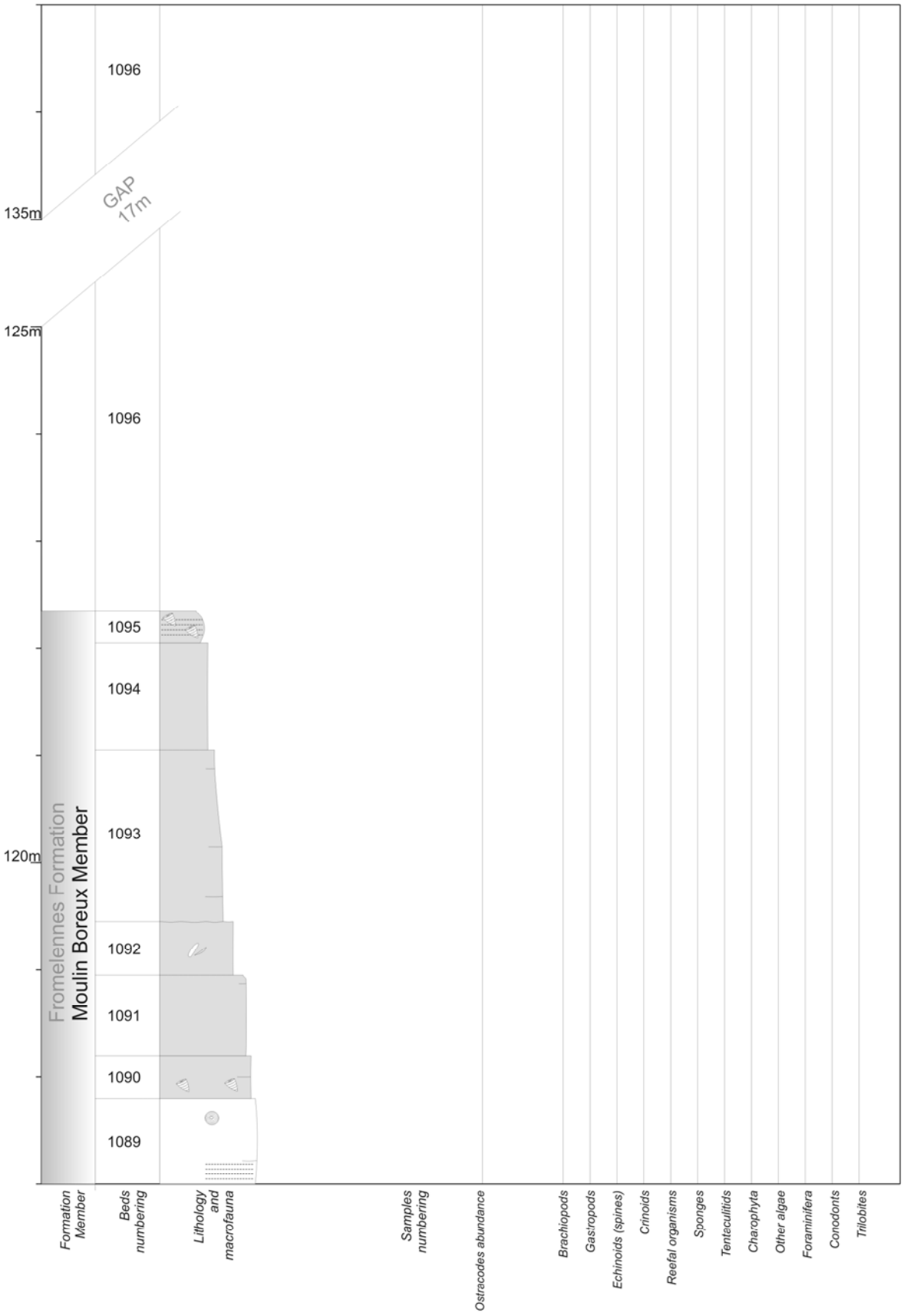
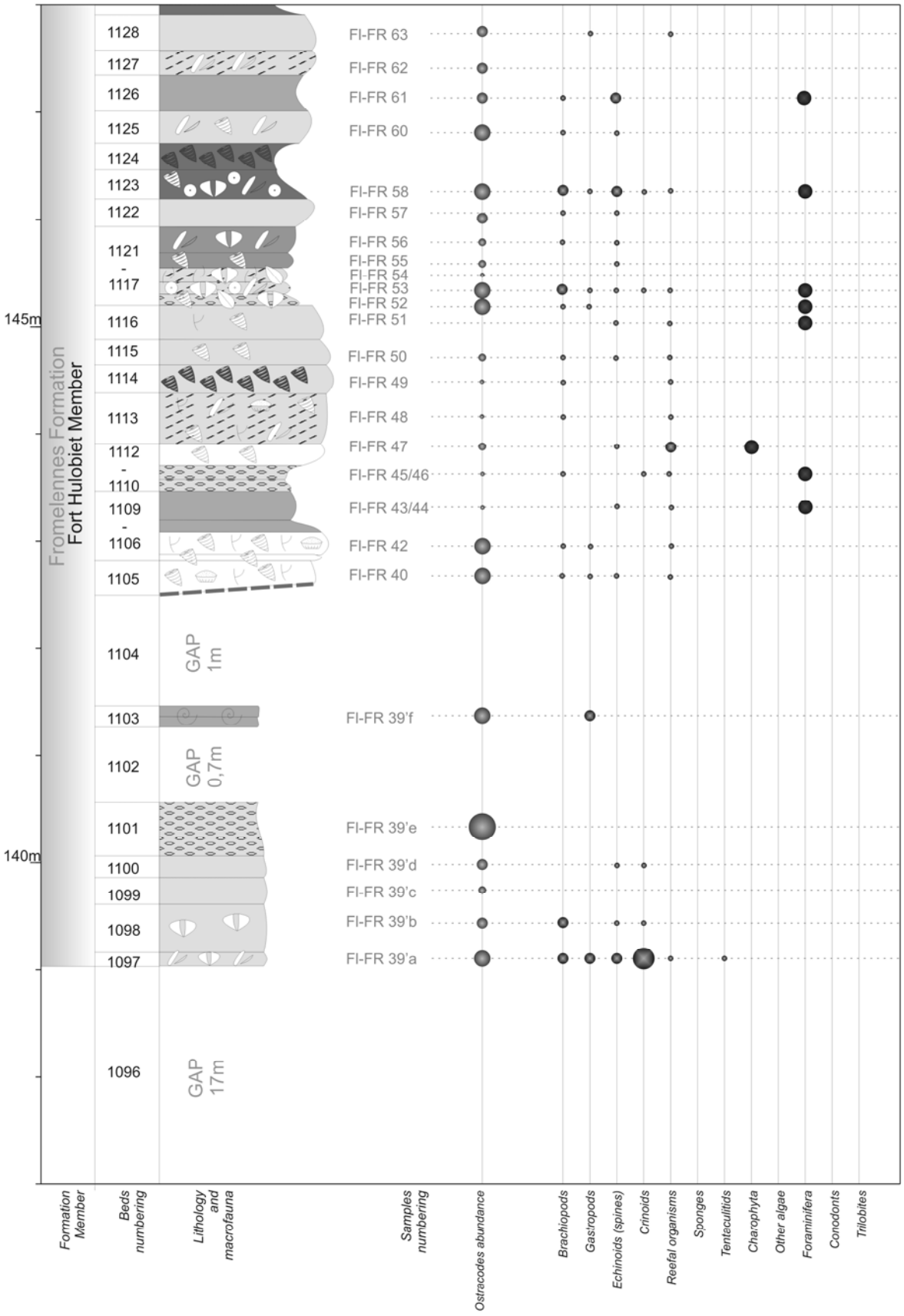
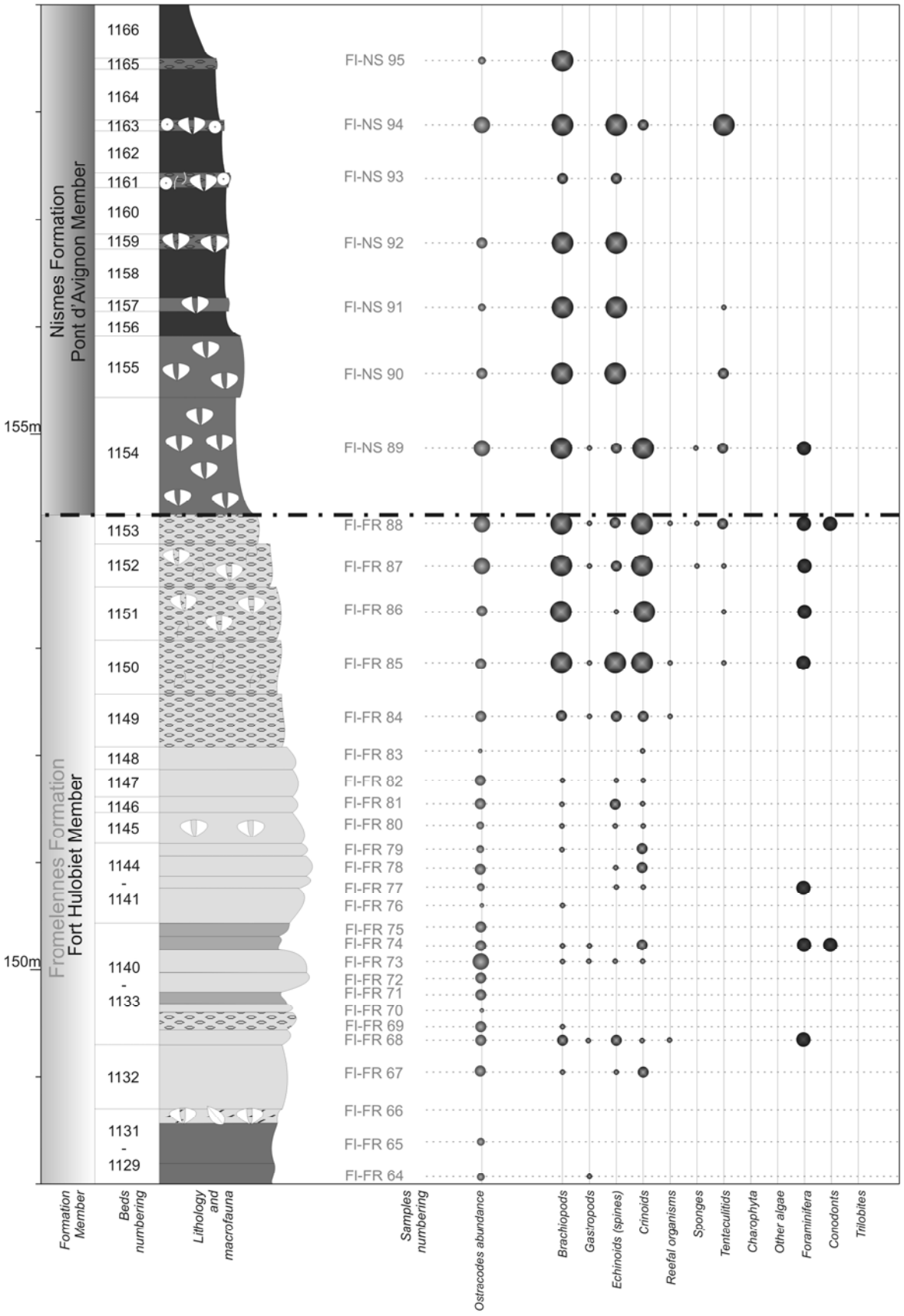
Conodonts
Trilobites


135m
125m
120m
GAP
17m
1096
1096
1095
1094
1093
1092
1091
1090
1089
Fromelennes Formation
Moulin Boreux Member
Formation
Member
Beds
numbering
Lithology
and
macrofauna
Samples
numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites

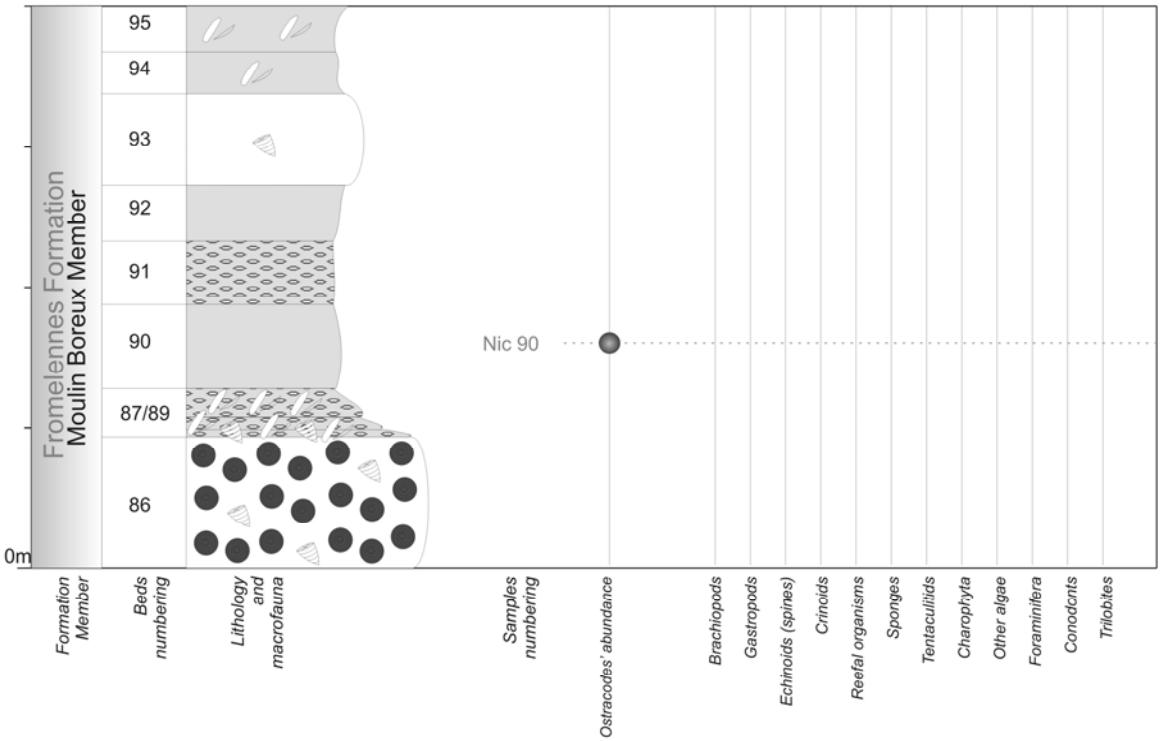

Fromelennes Formation
Fort Hulobiet Member
145m
140m
1128
1127
1126
1125
1124
1123
1122
1121 - 1117
1116
1115
1114
1113
1112 - 1110
1109 - 1106
1105
1104
1103
1102
1101
1100
1099
1098
1097
1096
GAP 1m
GAP 0,7m
GAP 17m
FI-FR 63
FI-FR 62
FI-FR 61
FI-FR 60
FI-FR 58
FI-FR 57
FI-FR 56
FI-FR 55
FI-FR 54
FI-FR 53
FI-FR 52
FI-FR 51
FI-FR 50
FI-FR 49
FI-FR 48
FI-FR 47
FI-FR 45/46
FI-FR 43/44
FI-FR 42
FI-FR 40
FI-FR 39'f
FI-FR 39'e
FI-FR 39'd
FI-FR 39'c
FI-FR 39'b
FI-FR 39'a
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites

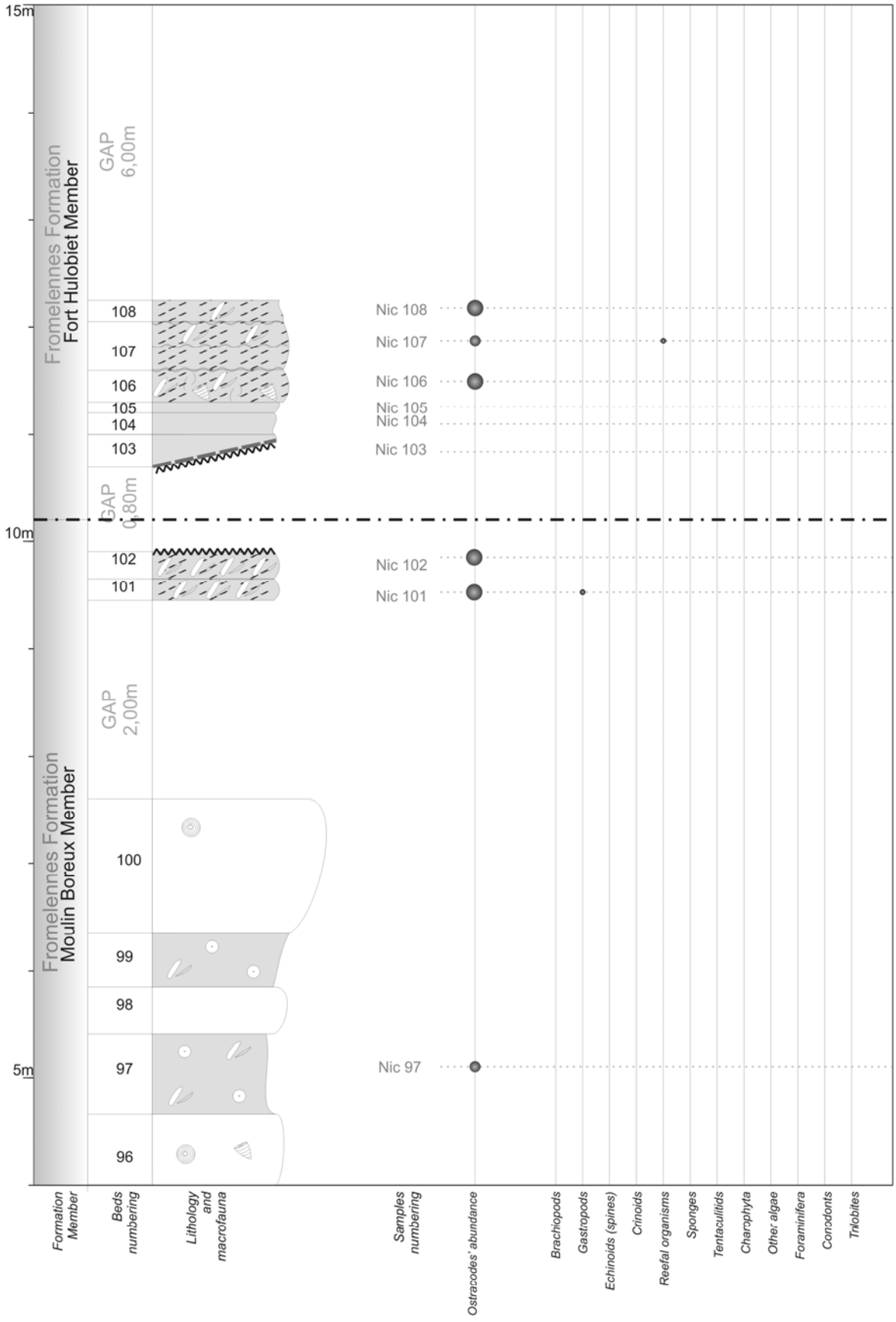

Nismes Formation
Pont d'Avignon Member
Fromelennes Formation
Fort Hulobiet Member
155m
150m
1166
1165
1164
1163
1162
1161
1160
1159
1158
1157
1156
1155
1154
1153
1152
1151
1150
1149
1148
1147
1146
1145
1144 - 1141
1140 - 1133
1132
1131 - 1129
FI-NS 95
FI-NS 94
FI-NS 93
FI-NS 92
FI-NS 91
FI-NS 90
FI-NS 89
FI-FR 88
FI-FR 87
FI-FR 86
FI-FR 85
FI-FR 84
FI-FR 83
FI-FR 82
FI-FR 81
FI-FR 80
FI-FR 79
FI-FR 78
FI-FR 77
FI-FR 76
FI-FR 75
FI-FR 74
FI-FR 73
FI-FR 72
FI-FR 71
FI-FR 70
FI-FR 69
FI-FR 68
FI-FR 67
FI-FR 66
FI-FR 65
FI-FR 64
Formation Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites

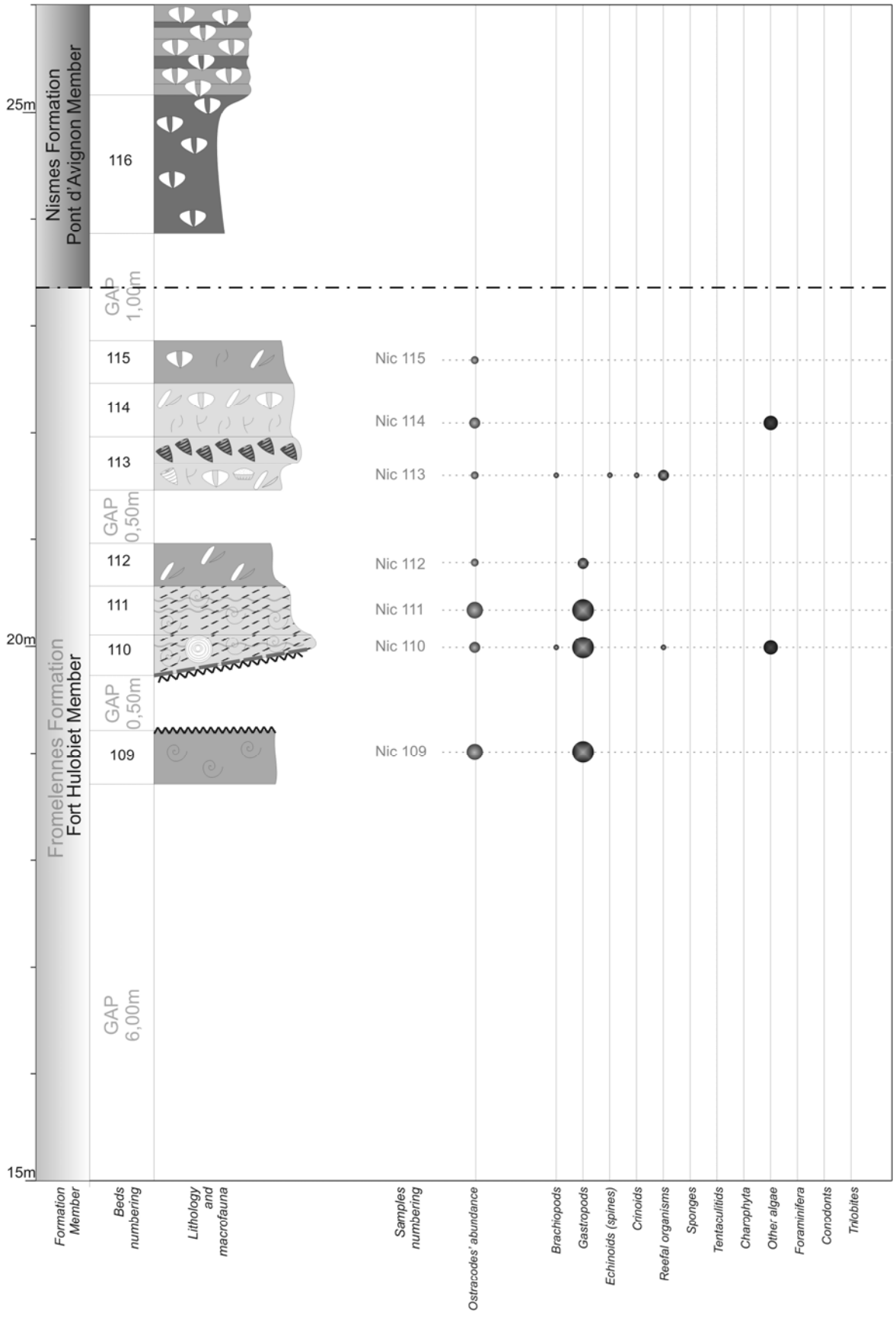
Annex II (pages 34-36)

Detailed stratigraphic column of the Nichet section (lithology and macrofauna, left part) and microfauna distribution (right part). For caption, see Annex I, p. 21.

Colonne stratigraphique détaillée de la coupe de Nichet (lithologie et macrofaune, partie gauche) et répartition de la microfaune (partie droite). Voir légende Annexe I, p. 21.




15m
10m
5m
Fromelennes Formation
Fort Hulobiet Member
Fromelennes Formation
Moulin Boreux Member
GAP 6,00m
GAP 0,80m
GAP 2,00m
108
107
106
105
104
103
102
101
100
99
98
97
96
Nic 108
Nic 107
Nic 106
Nic 105
Nic 104
Nic 103
Nic 102
Nic 101
Nic 97
Formation
Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes' abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites


Nismes Formation
Pont d'Avignon Member
Fromelennes Formation
Fort Hulobiet Member
25m
20m
15m
116
GAP 1,00m
115
114
113
GAP 0,50m
112
111
110
GAP 0,50m
109
GAP 6,00m
Nic 115
Nic 114
Nic 113
Nic 112
Nic 111
Nic 110
Nic 109
Formation
Member
Beds numbering
Lithology and macrofauna
Samples numbering
Ostracodes' abundance
Brachiopods
Gastropods
Echinoids (spines)
Crinoids
Reefal organisms
Sponges
Tentaculitids
Charophyta
Other algae
Foraminifera
Conodonts
Trilobites