

Original article

## Late Middle to Late Frasnian Atrypida, Pentamerida, and Terebratulida (Brachiopoda) from the Namur–Dinant Basin (Belgium)

### Atrypida, Pentamerida et Terebratulida (Brachiopoda) de la partie supérieure du Frasnien moyen et du Frasnien terminal du Bassin de Namur-Dinant (Belgique)

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#### Abstract

In the Namur–Dinant Basin (Belgium), the last Atrypida and Pentamerida originate from the top of the Upper *Palmatolepis rhenana* Zone (Late Frasnian). Within this biozone, their representatives belong to the genera *Costatrypa*, *Desquamatia* (*Desquamatia*), *Radiatrypa*, *Spinatrypa* (*Spinatrypa*), *Spinatrypina* (*Spinatrypina*?), *Spinatrypina* (*Exatrypa*), *Waiotrypa*, *Iowatrypa* and *Metabolipa*. No representative of these orders occurs within the *Palmatolepis linguiformis* Zone. The disappearance of the last pentamerids, mostly confined to reefal ecosystems, is clearly related to the end of the edification of the carbonate mounds; it precedes shortly the atrypid one. This event, resulting from a transgressive episode, which induces a progressive and dramatic deterioration of the oxygenation conditions, takes place firstly in the most distal zones of the Namur–Dinant Basin (southern border of the Dinant Synclinorium; Lower *P. rhenana* Zone). It is only recorded within the Upper *P. rhenana* Zone in the Philippeville Anticlinorium, the Vesdre area, and the northern flank of the Dinant Synclinorium. It would seem that the terebratulids were absent during the Famennian in this basin, probably due to inappropriate facies. Among the 13 species described or briefly discussed (*Palmatolepis hassi* to Upper *P. rhenana* zones), *Pseudoatrypa godefroidi* nov. sp. and *Spinatrypina* (*Exatrypa*) *marmoris* nov. sp. are proposed as new.

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#### Résumé

Dans le Bassin de Namur-Dinant (Belgique), les derniers Atrypida et Pentamerida proviennent du sommet de la Zone à *Palmatolepis rhenana* supérieure (Frasnien terminal). Au sein de cette biozone, leurs représentants appartiennent aux genres *Costatrypa*, *Desquamatia* (*Desquamatia*), *Radiatrypa*, *Spinatrypa* (*Spinatrypa*), *Spinatrypina* (*Spinatrypina* ?), *Spinatrypina* (*Exatrypa*), *Waiotrypa*, *Iowatrypa* et *Metabolipa*. À ce jour, aucun représentant de ces ordres n'a été collecté au sein de la Zone à *Palmatolepis linguiformis*. La disparition des derniers pentamerides, confinés pour la plupart aux écosystèmes récifaux, est clairement liée à la fin de l'édification des monticules carbonatés ; elle précède de peu celle des derniers atrypides. Cet événement, résultant d'un épisode transgressif qui provoque une dégradation sévère et progressive des conditions d'oxygénation, se déroule d'abord dans les zones les plus distales du bassin (bord sud du Synclinorium de Dinant ; Zone à *P. rhenana* inférieure). Il n'est enregistré qu'au sein de la Zone à *P. rhenana* supérieure dans l'Anticlinorium de Philippeville, dans la région de la Vesdre ainsi qu'au bord nord du Synclinorium de Dinant. Il semblerait que les térébratulidés furent absents durant le Famennien dans ce bassin. Parmi les 13 espèces décrites ou brièvement discutées (depuis la Zone à *Palmatolepis hassi* jusque la Zone *P. rhenana* supérieure), deux sont nouvelles : *Pseudoatrypa godefroidi* nov. sp. et *Spinatrypina* (*Exatrypa*) *marmoris* nov. sp.

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**Keywords:** Brachiopoda; Atrypida; Pentamerida; Terebratulida; Frasnian; Belgium

**Mots clés :** Brachiopoda ; Atrypida ; Pentamerida ; Terebratulida ; Frasnien ; Belgique

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## 1. Introduction

The Atrypida reached a peak of generic diversity during the Devonian; they were characteristic of carbonate and clastic environments from tropical and subtropical areas (Copper, 1986) but they were absent from cool water regions (Copper in Brice et al., 2000). It is generally accepted that the atrypids became extinct at the end of the Frasnian concurrent with the disappearance of the reefal ecosystems with calcimicrobes, stromatoporoids, sponges, rugose and tabulate corals. Nevertheless, some authors pointed out their presence in the lowermost Famennian (*Palmatolepis triangularis* conodont Zone) in South Urals (Mizens et al., 2000) as well as in South China (with pentamerids) (Chen and Tucker, 2003), indeed in the Upper *Palmatolepis crepida* Zone according to Schindler (1990) who mentioned the genus *Peratos* (Glassioidea) in Morocco but, after Racki (1998), it could be juvenile forms of Rhynchonellida. The atrypid occurrences in the Famennian should be considered with caution; in South China, some of them have been reinterpreted as reworked Frasnian material by Ma (1998). According to Godefroid (in Brice et al., 2000), the pentamerids disappeared in the Upper *Palmatolepis rhenana* Zone, but they were still present in the *Palmatolepis linguiformis* Zone (Rzhonsnitskaia in Rzhonsnitskaya et al., 1998; Ma et al., 2002), indeed in *P. triangularis* Zone (see above) but this latter should be confirmed. The Terebratulida, which appeared in lower part of the Lochkovian (Boucot and Wilson, 1994), rank among the rare brachiopod orders to have survived several mass extinctions (García-Alcalde in Brice et al., 2000).

This paper deals mainly with the atrypids from the late Middle to Late Frasnian (*Palmatolepis hassi* to Upper *P. rhenana* zones) from southern Belgium. However, as numerous species have been already described by Godefroid (1970, 1994), Godefroid and Helsen (1998) and Mottequin (2003, 2004a), the emphasis is placed on the new ones as well as on some previously described taxa. Additional data concern also the Pentamerida and the Terebratulida from the considered interval. The pentamerids from the carbonate mounds of the Lion and Petit-Mont members (see below) have been studied in detail by Godefroid (1974).

All figured and/or measured specimens are housed at the Royal Belgian Institute of Natural Sciences at Brussels, where they are registered under the numbers IRScNB a12224–12264.

## 2. Stratigraphy and biostratigraphy

The studied material originates from 14 late Middle-Late Frasnian sections (*P. hassi* to Upper *P. rhenana* zones) of different localities from the Namur and Dinant synclinoria, the Philippeville Anticlinorium and the Vesdre area (Fig. 1). During the time of deposition, these Variscan structural units constituted the Namur–Dinant Basin, which developed along the south-eastern margin of Laurussia. The succession of facies reflects a ramp setting with several breaks of slope (Fig. 2). The distal part of the Namur–Dinant Basin (southern flank of the Dinant Synclinorium) recorded the development of three

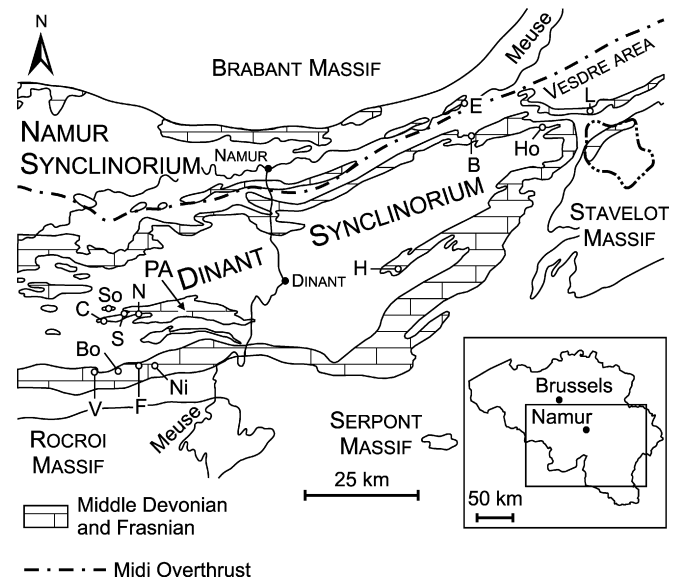


Fig. 1. Schematic geological map of southern Belgium with location of the fossiliferous localities. Abbreviations: B, Baugnée; Bo, Boussu-en-Fagne; C, Cerfontaine; E, Engis; F, Frasnes; H, Heure; Ho, Hony; L, Lambermont; N, Neuville; Ni, Nismes; PA, Philippeville Anticlinorium; S, Senzeille; So, Soumoy; V, Vaulx.

Fig. 1. Carte géologique schématique du Sud de la Belgique avec la localisation des sites fossilifères. Abréviations : B, Baugnée ; Bo, Boussu-en-Fagne ; C, Cerfontaine ; E, Engis ; F, Frasnes ; H, Heure ; Ho, Hony ; L, Lambermont ; N, Neuville ; Ni, Nismes ; PA, Anticlinorium de Philippeville ; S, Senzeille ; So, Soumoy ; V, Vaulx.

carbonate mud mound levels (Arche, Lion and Petit-Mont members) separated by argillaceous episodes. The material belongs to six formations; the Matagne Formation (Fm) is also described though, till now, it did not yield atrypids, pentamerids and terebratulids. For more details concerning the Frasnian lithostratigraphic units from Belgium, see Boulvain et al. (1999) and Bultynck and Dejonghe (2002).

### 2.1. Southern border of the Dinant Synclinorium and Philippeville Anticlinorium

#### 2.1.1. Grands Breux Formation

The Grand Breux Fm (*P. hassi* to Lower *P. rhenana* zones) is composed of the Bieumont, Lion and Boussu-en-Fagne members. In the Frasnes area, where the reference sections are located, the Bieumont Member begins with 16 m of micritic to bioclastic, argillaceous to nodular limestone and ends with 21 m of micritic to argillaceous limestone (Coen-Aubert, 1994). The Lion Member includes greyish massive carbonate buildups, up to 250 m thick. The Boussu-en-Fagne Member attains up to 81 m in thickness (Coen-Aubert and Boulvain in Boulvain et al., 1999) and is mainly composed of shales with some nodular levels and limestone beds.

#### 2.1.2. Neuville Formation

The Neuville Fm (Lower *P. rhenana* Zone) consists of nodular limestone with intercalations of shales in the Philippeville Anticlinorium where its thickness is always

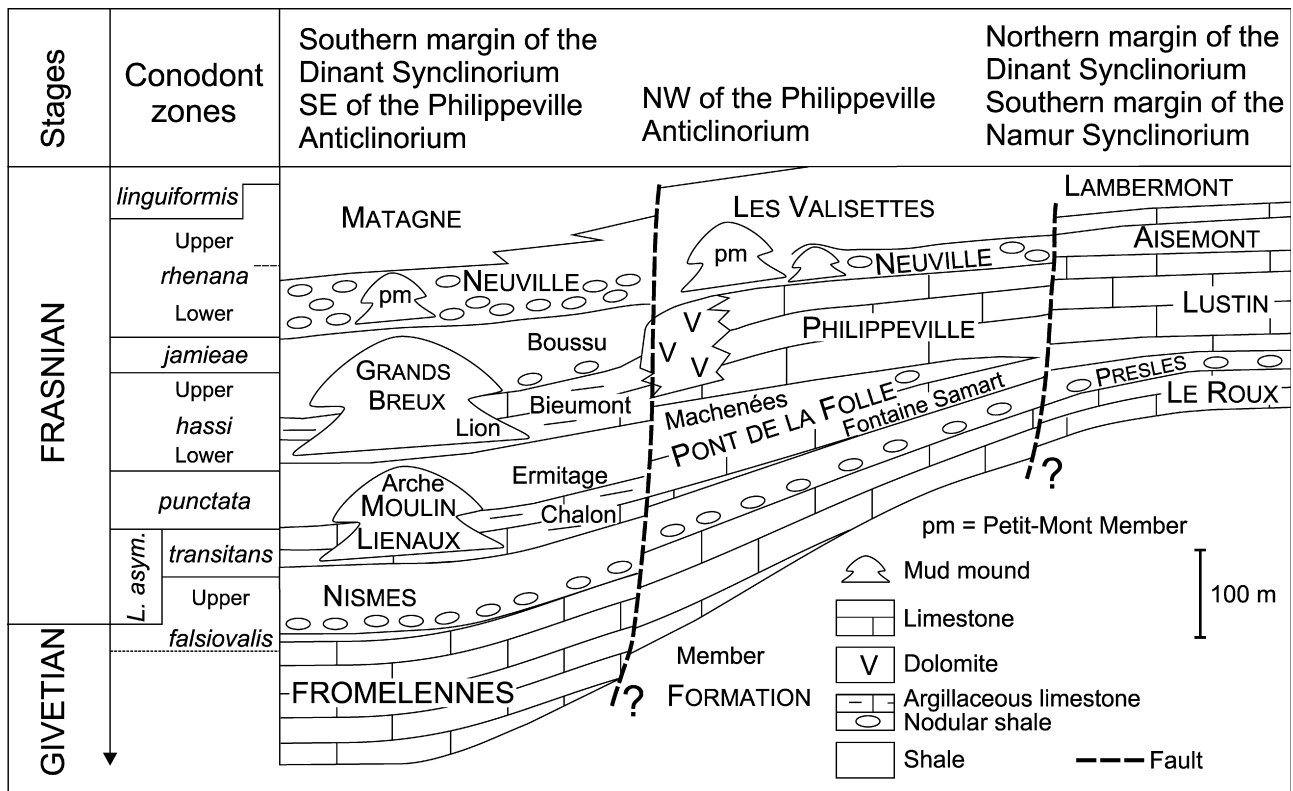


Fig. 2. Schematic N–S cross section and main lithostratigraphic units of the Namur–Dinant Basin before the Variscan Orogeny (modified from Boulvain et al., 2004). Abbreviations: *L. asym.*: Lower *asymmetrica* Zone.

Fig. 2. Coupe schématique N–S et principales unités lithostratigraphiques du Bassin de Namur–Dinant avant l’orogénèse varisque (d’après Boulvain et al., 2004). Abréviation : *L. asym.* : Zone à *asymmetrica* inférieure.

low (about 10 m). On the southern flank of the Dinant Synclinorium, the shales with limestone nodules predominate and the formation attains up to 110 m in thickness (Coen, 1977) but this latter lithofacies decreases eastward. The reddish carbonate buildups (30 to 80 m thick), developed within the formation, are assigned to the Petit-Mont Member (Boulvain et al. in Boulvain et al., 1999).

### 2.1.3. Les Valisettes Formation

The Les Valisettes Fm (Upper *P. rhenana* Zone), about 90 m thick in the Philippeville Anticlinorium, is essentially shaly. Greenish to reddish nodular limestones and shales develop in the vicinity of the buildups of the Petit-Mont Member (Boulvain et al. in Boulvain et al., 1999). It occurs also on the south-eastern border of the Dinant Synclinorium, between the Neuville and Barvaux formations, where its thickness is considerably reduced.

### 2.1.4. Matagne Formation

The Matagne Fm starts with one or several beds of limestone with goniatites and bivalves followed by fine greenish-brown to black shales. Its thickness attains more than 50 m on the southern flank of the Dinant Synclinorium but is reduced to about 10 m in the Philippeville Anticlinorium (Coen et al. in Boulvain et al., 1999). It is highly diachronous because it begins in the basal part of the Upper *P. rhenana* Zone on the southern flank of the Dinant Synclinorium whereas it is only developed

in the *P. linguiformis* Zone in the Philippeville Anticlinorium (Bultynck et al., 1998).

### 2.1.5. Barvaux Formation

On the south-eastern border of the Dinant Synclinorium, the Matagne Fm is replaced by the Barvaux Fm (about 90 m thick; Upper *P. rhenana* to Lower *P. triangularis* zones), characterized by purplish to green shales with some sandy layers and nodules (Coen in Boulvain et al., 1999).

## 2.2. Northern border of the Dinant Synclinorium, southern border of the Namur Synclinorium and Vesdre area

### 2.2.1. Aisemont Formation

The Aisemont Fm (22 m thick in the type area; Lower to basal part of the Upper *P. rhenana* zones) comprises limestones and argillaceous limestones in its lower and upper parts; the middle part consists of shales and nodular shales (Lacroix in Boulvain et al., 1999). Both limestone horizons are known in the Belgian literature as the first and second “biostromes with *Phillipsastrea*” of Coen-Aubert and Lacroix (1979) but the “second biostrome” is devoid of biostromal units (Poty and Chevalier, 2007).

### 2.2.2. Lambermont Formation

The Lambermont Fm (50 to 100 m thick) mainly consists of shales and nodular shales with intercalations of limestone beds

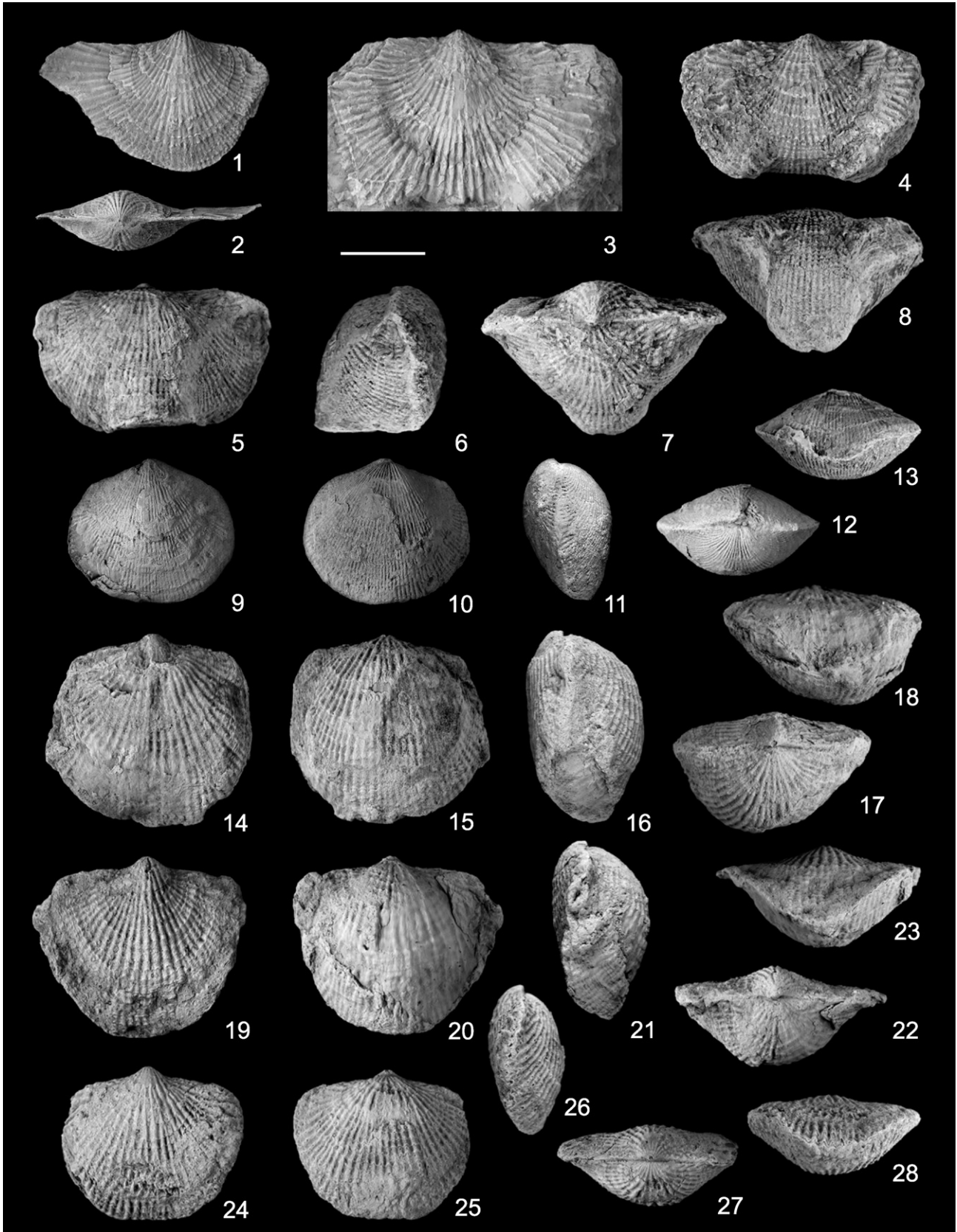


Fig. 3. 1–8. *Costatrypa variabilis* (Godefroid, 1970). 1–3. Boussu-en-Fagne (BM-2003-10), Grands Breux Fm (Boussu-en-Fagne Member). 1, 2. IRScNB a12224. 3. IRScNB a12225. 4–8. IRScNB a12226, Neuville (BM-2002-8), Les Valisettes Fm. 9–13. *Desquamatia* (*Desquamatia*) *alticoliformis* Rzhonsnitskaia, 1975. IRScNB a12227, Boussu-en-Fagne (BM-2003-10), Grands Breux Fm (Boussu-en-Fagne Member). 14–28. *Pseudoatrypa godefroidi* nov. sp. Neuville (BM-2002-8), Neuville Fm. 14–18. IRScNB a12228 (Holotype). 19–23. IRScNB a12229 (Paratype). 24–28. IRScNB a12230 (Paratype). 1, 3, 4, 9, 14, 19, 24: ventral views; 5, 10, 15, 20, 25: dorsal views; 6, 11, 16, 21, 26: lateral views; 2, 7, 12, 17, 22, 27: posterior views; 8, 13, 18, 23, 28: anterior views. Scale bar = 15 mm.

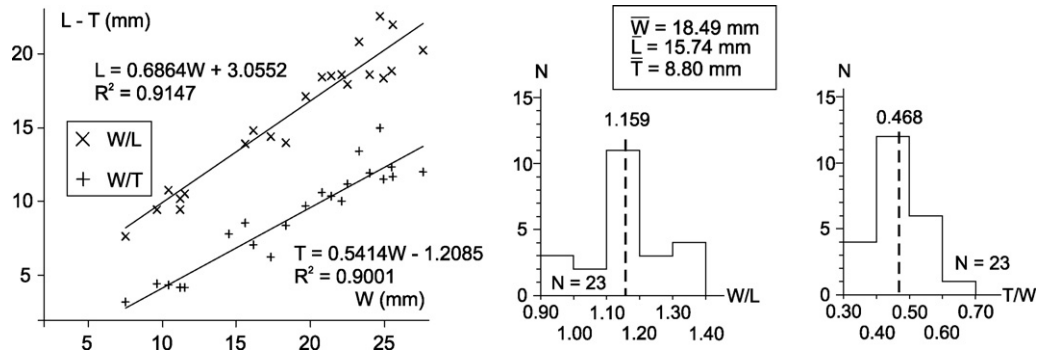


Fig. 4. *Pseudoatrypa godefroidi* nov. sp. Neuville (BM-2002-8), Neuville Fm. Scatter diagram plotting  $W/L$  and  $W/T$ ; frequency diagram  $W/L$  and  $T/L$ .  
 Fig. 4. *Pseudoatrypa godefroidi* nov. sp. Neuville (BM-2002-8), Fm de Neuville. Diagrammes de dispersion  $W/L$  (largeur/longueur) et  $W/T$  (largeur/épaisseur) ; histogrammes de fréquence  $W/L$  et  $T/L$ .

(Laloux and Ghysel in Boulvain et al., 1999). Its middle part is characterized by the “third biostrome with *Phillipsastrea*” (Coen-Aubert and Lacroix, 1979), especially developed in the Vesdre area and consisting of argillaceous, nodular limestones and calcareous shales with a biostromal bed with numerous massive rugose corals. The upper part of the formation is of lowermost Famennian age (Lower to Upper *P. triangularis* zones).

### 3. Systematic palaeontology

Abbreviations: *G*, distance in millimeter between two succeeding growth lamellae in the middle part of the shell; *L*, length of the shell; R-5, R-10, number of ribs per 5 or 10 mm near anterior shell margin (adult shells); R-10\*, number of ribs per 10 mm at 15 mm of the beak of the ventral valve; *T*, thickness of the shell; *T<sub>d</sub>*, thickness of the dorsal valve; *T<sub>v</sub>*, thickness of the ventral valve; *W*, width of the shell.

Measurements and ratios put between brackets are less frequent. The BM and JG prefixes indicate respectively B. Mottequin and J. Godefroid’s outcrops (Appendix A). The name of a locality followed by a number (e.g. Senzeille 7048a) corresponds to the name of an outcrop as it is recorded in the files of the Royal Belgian Institute of Natural Sciences.

Order ATRYPIDA Rzhonsnitskaia, 1960

Suborder ATRYPIDINA Moore, 1952

Superfamily ATRYPOIDEA Gill, 1871

Family ATRYPIDAE Gill, 1871

Subfamily ATRYPINAE Gill, 1871

Genus *Costatrypa* Copper, 1973

**Type species:** *Atrypa varicostata* Stainbrook, 1945

*Costatrypa variabilis* (Godefroid, 1970)

Fig. 3 (1–8)

1970. *Atryparia?* *variabilis* n. sp. – Godefroid, p. 98, Figs. 6–10, Pl. 5, Fig. 3.

1998. *Costatrypa variabilis* (Godefroid) – Godefroid, p. 110, Figs. 4 and 5.

1998. *Costatrypa variabilis* (Godefroid) – Godefroid and Helsen, p. 245, Fig. 3.

1999. *Costatrypa variabilis* – Godefroid in Boulvain et al., Fig. BIO5.

2002. *Atryparia* (*Costatrypa*) *variabilis* Godefroid – Copper, p. 1394, Fig. 943d–i.

2003. *Costatrypa* sp. – Mottequin, Fig. 6.

**Material:** BM-2002-1 (one articulated specimen); BM-2002-8 (175 articulated specimens); BM-2003-3 (77 articulated specimens, 11 ventral valves, three dorsal valves); BM-2003-4a (41 articulated specimens); BM-2003-6 (four articulated specimens); BM-2003-7 (two articulated specimens); BM-2003-8 (21 articulated specimens); BM-2003-10 (310 articulated specimens, five ventral valves, eight dorsal valves); BM-2004-1 (51 articulated specimens); BM-2004-2 (five articulated specimens, one ventral valve).

**Description:** See Godefroid (1970). Specimens from the locality BM-2003-10 (Boussu-en-Fagne Member) have R-10\* varying between (9) 11–13 (15) while those from the locality BM-2003-3 (Les Valisettes Fm) are characterized by R-10\* varying between 13–17.

**Discussion:** After the number of ribs observed on specimens from two sections of distinct age (see above), there appears to be a tendency for this number to increase stratigraphically upwards. Nevertheless, it would be necessary to effect measurements on specimens from the Neuville Fm, but the presently available material is not sufficient for comparison with the results already obtained.

**Occurrence:** At the southern border of the Dinant Synclinorium, some specimens collected within the Moulin Liénaux Fm (Ermitage Member, *Palmatolepis punctata* Zone to lower part of the *P. hassi* Zone) have been assigned with doubt to *Costatrypa variabilis* by Godefroid (1998). The species become especially abundant in the Boussu-en-Fagne Member,

Fig. 3. 1–8. *Costatrypa variabilis* (Godefroid, 1970). 1–3. Boussu-en-Fagne (BM-2003-10), Fm des Grands Breux (Membre de Boussu-en-Fagne). 1, 2. IRScNB a12224. 3. IRScNB a12225. 4–8. IRScNB a12226, Neuville (BM-2002-8), Fm des Valisettes. 9–13. *Desquamatia* (*Desquamatia*) *alticoliformis* Rzhonsnitskaia, 1975. IRScNB a12227, Boussu-en-Fagne (BM-2003-10), Fm des Grands Breux (Membre de Boussu-en-Fagne). 14–28. *Pseudoatrypa godefroidi* nov. sp. Neuville (BM-2002-8), Fm de Neuville. 14–18. IRScNB a12228 (Holotype). 19–23. IRScNB a12229 (Paratype). 24–28. IRScNB a12230 (Paratype). 1, 3, 4, 9, 14, 19, 24 : vues ventrales ; 5, 10, 15, 20, 25 : vues dorsales ; 6, 11, 16, 21, 26 : vues latérales ; 2, 7, 12, 17, 22, 27 : vues postérieures ; 8, 13, 18, 23, 28 : vues antérieures. Barre d'échelle = 15 mm.

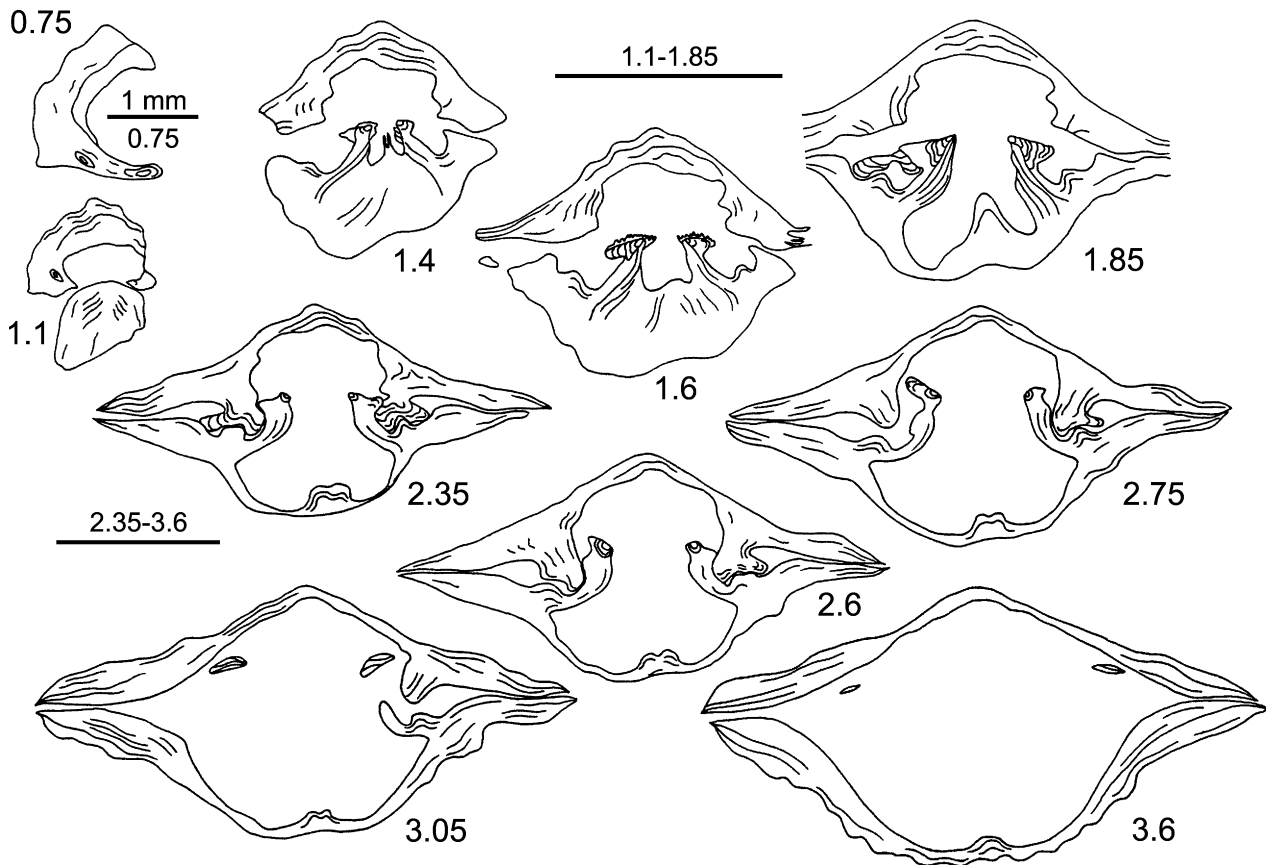


Fig. 5. *Pseudoatrypa godefroidi* nov. sp. IRScNB a12233. Neuville (BM-2002-8), Neuville Fm. Transverse serial sections; distances measured in millimeter from the top of the ventral umbo. Scale bars = 5 mm (except where otherwise stated).

Fig. 5. *Pseudoatrypa godefroidi* nov. sp. IRScNB a12233. Neuville (BM-2002-8), Fm de Neuville. Sections s riees transverses ; distances en millim tre mesur es   partir du sommet de l'umbo ventral. Barres d' chelle = 5 mm (sauf indication contraire).

but only close to the Lion Member mounds. According to Godefroid and Helsen (1998), *C. variabilis* would disappear at the base of the Matagne Fm in the section of the by-pass road of Frasnes, but the layers yielding its last representatives must be assigned to the top of the Neuville Fm after the definition proposed by Coen et al. (in Boulvain et al., 1999). Indeed, these layers are located below the first limestone beds with goniatites and bivalves, which characterize the base of the Matagne Fm. In the Philippeville Anticlinorium, this taxon is recognized within the Neuville Fm where it is not frequent but, on the other hand, it is more abundant within the Les Valisettes Fm. The presence of *C. variabilis* is confirmed in the Frasnian part of the Lambermont Fm (Vesdre area).

Subfamily VARIATRYPINAE Copper, 1978

Genus *Desquamatia* Alekseeva, 1960

Subgenus *Desquamatia (Desquamatia)* Alekseeva, 1960

**Type species:** *Atrypa (Desquamatia) khavae* Alekseeva, 1960

*Desquamatia (Desquamatia) alticoliformis* Rzhonsnitskaia, 1975

Fig. 3 (9–13)

1975. *Desquamatia (Desquamatia) alticoliformis* sp. nov. – Rzhonsnitskaia, p. 131, Fig. 41, Pl. 28, Figs. 10–13.

1998. *Desquamatia (Desquamatia) alticoliformis* Rzhonsnitskaia – Godefroid and Helsen, p. 255, Figs. 10B, 11A–G, 12.

1999. *Desquamatia (Desquamatia) alticoliformis* – Godefroid in Boulvain et al., Fig. BIO5.

**Material:** BM-2002-8 (15 articulated specimens, one ventral valve); BM-2003-6 (two articulated specimens); BM-2003-9 (one articulated specimen); BM-2003-10 (four articulated specimens); BM-2004-1 (two articulated specimens).

**Description:** See Godefroid and Helsen (1998).

**Occurrence:** *Desquamatia (D.) alticoliformis* is recognized within the Grands Breux (Boussu-en-Fagne Member) and Neuville formations at the southern border of the Dinant Synclinorium (Godefroid and Helsen, 1998) as well as in the Les Valisettes Fm (Philippeville Anticlinorium).

Genus *Pseudoatrypa* Copper, 1973

**Type species:** *Atrypa devoniana* Webster, 1921

*Pseudoatrypa godefroidi* nov. sp.

Figs. 3(14–28), 4 and 5; Table 1

**Derivatio nominis:** In honour of Dr Jacques Godefroid for his contribution to the knowledge of the Devonian brachiopods from Belgium.

**Locus and stratum typicum:** Neuville railway section (BM-2002-8), Neuville Fm (Upper *P. rhenana* Zone).

Table 1

Dimensions ( $W$ ,  $L$ ,  $T$  = width, length, thickness), apical angle (Aa) and shoulder angle (Sa) of selected specimens of the species studied herein

Table 1

Dimensions ( $W$ ,  $L$ ,  $T$  = largeur, longueur, épaisseur), angle apical (Aa) et angle d'épaules (Sa) de quelques échantillons choisis des espèces étudiées dans la présente étude

	IRScNB	W (mm)	L (mm)	T (mm)	Aa	Sa
<i>Pseudoatrypa godefroidi</i> nov. sp.	a12228	24.7	22.5	15	115°	143°
	a12229	25.6	21.95	11.65	93°	146°
	a12230	21.6	18.6	10	107°	144°
	a12231	22.5	17.9	11.2	92°	137°
	a12232	25.5	18.8	12.3	95°	144°
<i>Radiatrypa</i> sp.	a12234	16.1	16.7	8.5	91°	–
<i>Spinatrypina</i> ( <i>S.</i> ?) cf. <i>comitata</i>	a12236	16.6	15.2	8.6	113°	128°
	a12237	17.1	15.4	10.15	93°	114°
	a12238	19.3	16.8	8.4	98°	127°
	a12239	14.4	13.7	7.7	93°	115°
<i>S.</i> ( <i>Exatrypa</i> ) <i>marmoris</i>	a12240	20.5	16.5	8.6	130°	141°
	a12241	18.3	13.45	7.5	92°	148°
	a12242	18.4	15.4	7.6	98°	143°
	a12243	17.9	15.4	6.2	105°	139°
	a12244	18.8	15	7	119°	133°
	a12246	12.3	9.1	4.6	108°	153°
<i>Waiotrypa</i> sp.	a12247	11.9	9.4	3.9	102°	140°
	a12248	14.7	11.2	5.4	124°	154°
	a12252	19.8	19.3	13.7	88°	92°
<i>Metabolipa</i> sp.	a12253	15.7	16.4	11.3	71°	85°
	a12255	8.3	10.9	5.3	72°	–
<i>Cranaena</i> cf. <i>rigauxi</i>	a12256	9.5	10.6	5.8	81°	–
	a12257	9.2	10.85	5.7	89°	–
	a12258	7.8	10.3	4.7	79°	–
	a12260	14.4	18.6	9.9	67°	–
<i>Cranaena</i> sp.	a12261	18.3	21.5	10.1	–	–
	a12262	10.3	12.9	6.6	78°	–
	a12263	11.7	17.9	9.4	83°	–

**Material:** Holotype IRScNB a12228 (Fig. 3 (14–18)) and paratypes IRScNB a12229 (Fig. 3 (19–23)), a12230 (Fig. 3 (24–28)), a12231–a12232 (not figured), a12233 (Fig. 5) from the locus and stratum typicum (between 6.7–9.15 m above the base of the Neuville Fm); BM-2002-7 (five articulated specimens); BM-2002-8 (38 articulated specimens); BM-2004-4 (seven articulated specimens); JG-1996-3 (16 articulated specimens).

**Diagnosis:** Species of *Pseudoatrypa* characterized by a generally wider than long ( $W/L$ : 0.95–1.37), convexoplane to dorsibiconvex shell ( $T_v/T_d$ : 0.35–0.54) with a semi-elliptic to semi-rounded outline (maximum  $W$ : 27.6 mm; maximum  $L$ : 22.5 mm; maximum  $T$ : 15 mm); anterior commissure uniplicate;  $R-10^* = 9-12$ ;  $G = 0.5-1.5$  (2).

**Description:** Shell convexoplane to dorsibiconvex ( $T_v/T_d$ : 0.35–0.54) with a semi-elliptic to semi-rounded outline; generally wider than long ( $W/L$ : 0.95–1.37), only 11% of the specimens having a  $W/L$  ratio slightly less than the unit (Fig. 4); maximum width situated in the posterior part of the shell or near the posterior margin; anterior commissure uniplicate.

Ventral valve 5.88–7.76 times wider than thick and 5.22–6.27 longer than thick; in posterior view, median part isolated from the posterolateral areas (in the case of the convexoplane specimens, these latter are flattened or weakly concave); in profile, its upper surface is irregularly inflated; shallow sulcus sometimes present (poorly defined and only perceptible near

the anterior margin); semi-rounded to semi-elliptic tongue (2.03–3.68 times wider than high) and not perpendicular to the commissural plane; shoulder lines indented by a prominent umbo; shoulder angle varying between 137°–146°, apical angle between 91°–117°; interarea orthocline to anacline; delthyrium closed by a deltidium with a wide apical foramen; internally, teeth bilobed; short dental supports thick and devoid of cavities (Fig. 5).

Dorsal valve 2.12–2.86 times wider than thick; in posterior view, upper surface inflated and flanks sloping moderately to strongly towards the lateral commissure; posterolateral areas being inclined to become flat; maximum height at about the midvalve, never at the front; internally, cardinal process filling the notothyrial pit and extending on the internal crests of the dental sockets; median crest dividing the dental sockets; crural plates and crura respectively ventrolaterally and laterally oriented; jugal processes, jugal plates and spiral cones not observed; muscle field divided by a crest displaying a median furrow in transverse section (Fig. 5).

Tubular ribs increasing by bifurcation and intercalation on both valves;  $R-10^* = 9-12$ ;  $G = 0.5-1.5$  (2).

**Discussion:** *Pseudoatrypa godefroidi* nov. sp. is distinguished from *P. devoniana* (Webster, 1921) by its more spaced growth lamellae, its less rounded outline and its smaller size. *P. godefroidi* differs from *P. lineatea* (Webster, 1921), *P. missouriensis* (Miller, 1894) and *P. witzkei* Day and Copper,

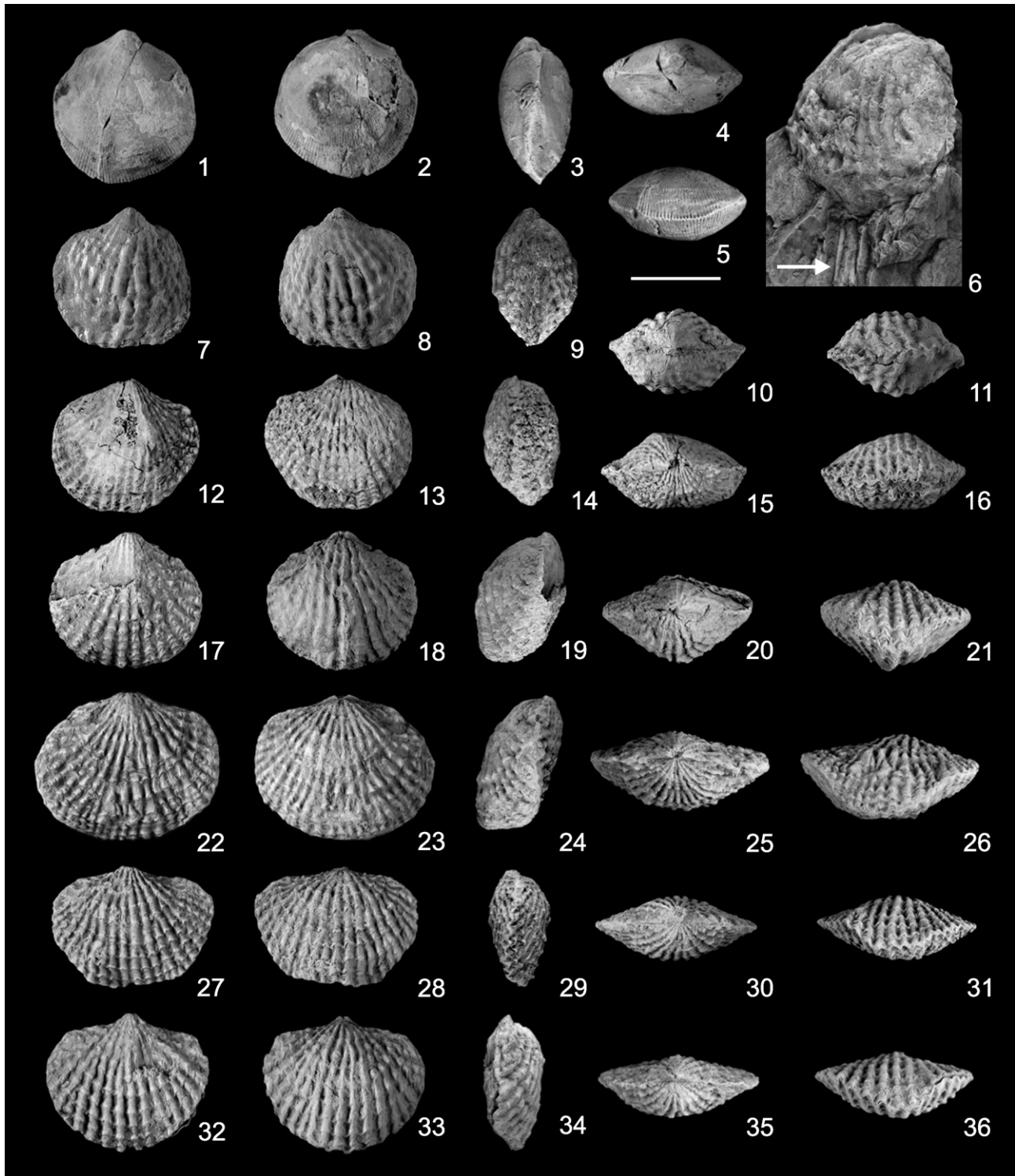


Fig. 6. 1–5. *Radiatrypa* sp. IRScNB a12234. Hony (BM-2001-2), Lambermont Fm. 6. *Spinatrypa (Spinatrypa) lambermontensis* Mottequin, 2003. IRScNB a12235 with spine (arrow). Lambermont (BM-2002-1), Lambermont Fm. 7–11. *Spinatrypa (Isospinatrypa?) tumuli* (Godefroid and Helsen, 1998). IRScNB a10593 (Holotype). Boussu-en-Fagne (JG-1995-4), Neuville Fm (Petit-Mont Member). 12–21. *Spinatrypina (Spinatrypina?) cf. comitata* Copper, 1967. Senzeille (BM-2004-1), Les Valisettes Fm. 12–16. IRScNB a12236. 17–21. IRScNB a12237. 22–36. *Spinatrypina (Exatrypa) marmoris* nov. sp. Soumoy (Senzeille 7048a), Les Valisettes Fm. 22–26. IRScNB a12240 (Holotype). 27–31. IRScNB a12241 (Paratype). 32–36. IRScNB a12242 (Paratype). 1, 7, 12, 17, 22, 27, 32: ventral views; 2, 8, 13, 18, 23, 28, 33: dorsal views; 3, 6, 9, 14, 19, 24, 29, 34: lateral views; 4, 10, 15, 20, 25, 30, 35: posterior views; 5, 11, 16, 21, 26, 31, 36: anterior views. Scale bar = 15 mm.

Fig. 6. 1–5. *Radiatrypa* sp. IRScNB a12234. Hony (BM-2001-2), Fm de Lambermont. 6. *Spinatrypa (Spinatrypa) lambermontensis* Mottequin, 2003. IRScNB a12235 avec épine (flèche). Lambermont (BM-2002-1), Fm de Lambermont. 7–11. *Spinatrypa (Isospinatrypa?) tumuli* (Godefroid and Helsen, 1998). IRScNB a10593 (Holotype). Boussu-en-Fagne (JG-1995-4), Fm de Neuville (Membre du Petit-Mont). 12–21. *Spinatrypina (Spinatrypina?) cf. comitata* Copper, 1967. Senzeille (BM-2004-1), Fm des Valisettes. 12–16. IRScNB a12236. 17–21. IRScNB a12237. 22–36. *Spinatrypina (Exatrypa) marmoris* nov. sp. Soumoy (Senzeille 7048a), Fm



1998 by its smaller size and its coarser ribs. *P. godefroidi* is separable from *P. rugatula* (Stainbrook and Ladd, 1924) by its dorsibiconvex profile and its coarser ribs. *P. godefroidi* differs from *P. symmetrica* (Liashenko, 1959) by a coarser ornamentation, a less rounded outline and a little more developed tongue. From *Atrypa petinensis* Liashenko, 1959, possibly a *Pseudoatrypa* species according to Copper (1973), *P. godefroidi* differs by its coarser ribs and its more closely spaced growth lamellae.

**Occurrence:** *P. godefroidi* occurs within the Neuville (southern and south-eastern border of the Dinant Synclinorium; Philippeville Anticlinorium) and Aisemont formations (northern flank of the Dinant Synclinorium).

Genus *Radiatrypa* Copper, 1978

**Type species:** *Atrypa gregeri* Rowley, 1900

*Radiatrypa* sp.

Fig. 6 (1–5); Table 1

2003. *Radiatrypa?* sp. – Mottequin, Fig. 6.

**Material:** BM-2001-2 (one articulated specimen); BM-2002-1 (one articulated specimen).

**Description:** Two poorly preserved shells are assigned to the genus *Radiatrypa*. Their main external characters are the following: weakly dorsibiconvex shell ( $T_v/T_d$ : 0.93), ovate outline ( $W/L$ : 0.96), very fine ribs ( $R-10 = 25$ ) and excessively rare growth lamellae. The lack of material does not permit to compare these specimens to the other species of this genus.

**Occurrence:** *Radiatrypa* sp. has been only collected within the Frasnian part of the Lambermont Fm (northern flank of the Dinant Synclinorium and Vesdre area).

Subfamily SPINATRYPINAE Copper, 1978

Genus *Spinatrypa* Stainbrook, 1951

Subgenus *Spinatrypa* (*Spinatrypa*) Stainbrook, 1951

**Type species:** *Atrypa hystrix* var. *occidentalis* Hall, 1858

*Spinatrypa* (*Spinatrypa*) *lambermontensis* Mottequin, 2003

Fig. 6 (6); Table 1

2003. *Spinatrypa* (*Spinatrypa*) *lambermontensis* n. sp. – Mottequin, p. 75, Figs. 2B, 4, 5a–o, 6, Pl. 1, Figs. 6 and 7.

**Description:** See Mottequin (2003).

**Occurrence:** *Spinatrypa* (*S.*) *lambermontensis* is recognized within the Frasnian part of the Lambermont Fm on the northern border of the Dinant Synclinorium and in the Vesdre area. The presence of this species in the lower part of the Les Valisettes Fm (Philippeville Anticlinorium) as well as in the Barvaux Fm (south-eastern border of the Dinant Synclinorium) is probable, but needs confirmation because collected material is insufficient. Some specimens originating from the Barvaux Fm and assigned to “*Atrypa longispina* (Bouchard)” by Maillieux (1939: p. 4) may be conspecific with *S.* (*S.*) sp. sensu Mottequin (2003).

Subgenus *Spinatrypa* (*Isospinatrypa*) Struve, 1966

**Type species:** *Terebratulites asper* von Schlotheim, 1813

*Spinatrypa* (*Isospinatrypa?*) *tumuli* (Godefroid and Helsen, 1998)

Fig. 6 (7–11)

1998. *Spinatrypa tumuli* sp. n. – Godefroid and Helsen, p. 245, Figs. 4A–F, 5A.

1999. *Spinatrypa tumuli* – Godefroid in Boulvain et al., Fig. BIO5.

**Description:** See Godefroid and Helsen (1998).

**Discussion:** By its generally weakly dorsibiconvex shell, more rarely equibiconvex or slightly ventribiconvex, its small size and its well-defined ribs, this species is close to the representatives of the subgenus *Isospinatrypa*. However, this suggestion remains doubtful because its spines and its internal characters are still unknown due to the recrystallization of the specimens, which complicates the study of their internal morphology.

**Occurrence:** According to Godefroid and Helsen (1998: p. 247) and till now, this taxon is only recognized within the Petit-Mont Member (Neuville Fm, southern flank of the Dinant Synclinorium).

Genus *Spinatrypina* Rzhonsnitskaia, 1964

Subgenus *Spinatrypina* (*Spinatrypina*) Rzhonsnitskaia, 1964

**Type species:** *Spinatrypina* (*Spinatrypina*) *margaritoides* Rzhonsnitskaia, 1964

*Spinatrypina* (*Spinatrypina?*) cf. *comitata* Copper, 1967

Fig. 6 (12–16); Table 1

cf. 1967. *Spinatrypina* (?*Spinatrypina*) *comitata* n. sp. – Copper, p. 129, Pl. 22, Figs. 4 and 5.

1998. *Spinatrypina* (?*Spinatrypina*) cf. *comitata* Copper – Godefroid and Helsen, p. 248, Fig. 4L–P.

1999. *Spinatrypina* cf. *comitata* – Godefroid in Boulvain et al., Fig. BIO5.

**Material:** BM-2004-1 (seven articulated specimens); Senzeille 7048a (four articulated specimens).

**Description:** Middle-sized shell (maximal  $W$ : 19.3 mm; maximal  $L$ : 16.8 mm; maximal  $T$ : 10.15 mm), relatively equidimensional ( $W/L$ : 0.93–1.15), dorsibiconvex to slightly ventribiconvex ( $T_v/T_d$ : 0.5–1.05), with a rounded outline; anterior commissure rectimarginate to weakly uniplicate; interarea orthocline to apsacline;  $R-10 = 8-10$ ;  $G = 1-1.5$  mm.

**Discussion:** Similar specimens have been described under this identification by Godefroid and Helsen (1998) from the Petit-Mont Member at the cemetery quarry at Boussu-en-Fagne (BM-2003-10).

**Occurrence:** *Spinatrypina* (*S.?*) cf. *comitata* occurs at the southern border of the Dinant (Neuville Fm, Petit-Mont Member) as well as within the Philippeville Anticlinorium (Les Valisettes Fm) in the vicinity of the Petit-Mont carbonate mounds.

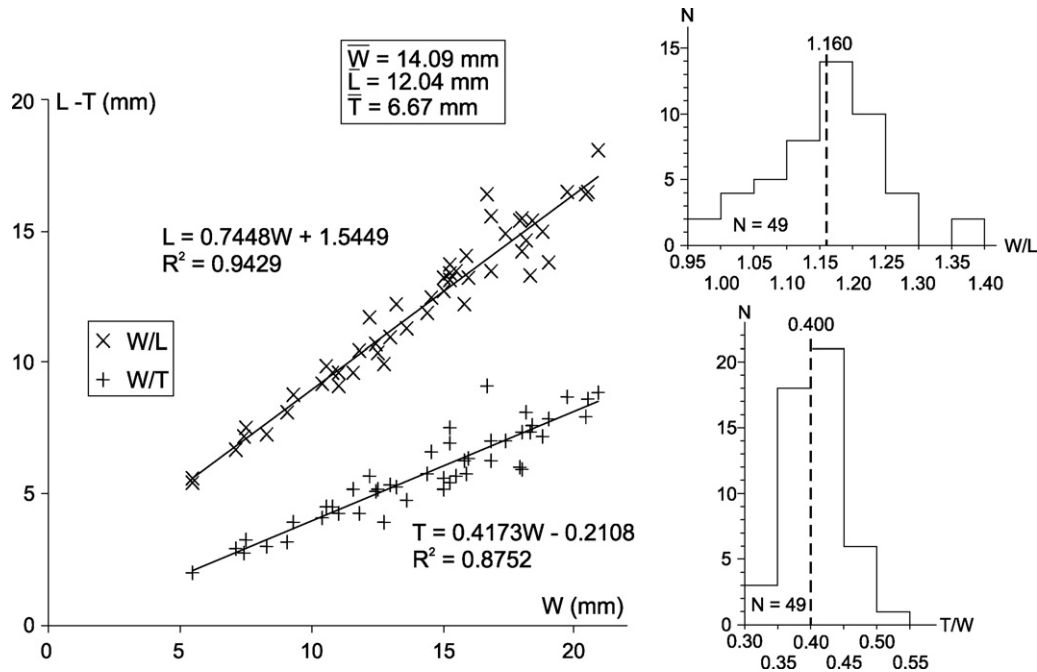


Fig. 7. *Spinatrypina (Exatrypa) marmoris* nov. sp. Soumoy (Senzeille 7048a), Les Valisettes Fm. Scatter diagram plotting  $W/L$  and  $W/T$ ; frequency diagram  $W/L$  and  $T/L$ .

Fig. 7. *Spinatrypina (Exatrypa) marmoris* nov. sp. Soumoy (Senzeille 7048a), Fm des Valisettes. Diagrammes de dispersion  $W/L$  (largeur/longueur) et  $W/T$  (largeur/épaisseur) ; histogrammes de fréquence  $W/L$  et  $T/L$ .

#### Subgenus *Spinatrypina (Exatrypa)* Copper, 1967

**Type species:** *Terebratulites explanatus* von Schlotheim, 1820

*Spinatrypina (Exatrypa) marmoris* nov. sp.

Figs. 6(22–36), 7 and 8; Table 1

1998. *Spinatrypina (Exatrypa)* sp. B – Godefroid and Helsen, p. 248, Fig. 4G–K.

1999. *Spinatrypina* sp. B – Godefroid in Boulvain et al., Fig. BIO5.

**Derivatio nominis:** *Marmor, oris* (Latin): marble. Reference to the numerous quarries, which exploited the Petit-Mont Member for the production of ornamental stone (“marble”).

**Locus and stratum typicum:** Soumoy, disused Gorgimont quarry (Senzeille 7048a); Les Valisettes Fm (Upper *P. rhenana* Zone, in the vicinity of the carbonate mounds of the Petit-Mont Member).

**Material:** Holotype IRScNB a12240 (Fig. 6 (22–26)) and Paratypes IRScNB a12241 (Fig. 6 (27–31)), a12242 (Fig. 6 (32–36)), a12243–a12244 (not figured), a12245 (Fig. 8) from the locus and stratum typicum; BM-2003-7 (13 articulated specimens, four ventral valves, two dorsal valves); BM-2004-1 (13 articulated specimens); BM-2004-2 (one articulated specimen); Senzeille 7048a (105 articulated specimens).

**Diagnosis:** A species of *Spinatrypina (Exatrypa)* characterized by its wider than long [ $W/L$ : (0.98) 1.02–1.38], dorsibiconvex to slightly ventribiconvex shell ( $T_v/T_d$ : 0.42–1.06) with a semioval outline (maximum  $W$ : 20.9 mm; maximum  $L$ : 18.1 mm; maximum  $T$ : 12.1 mm); anterior commissure vaguely undulose to uniplicate;  $R-10 = 6-7$  (8);  $G = 2-2.5$  mm.

**Description:** Small sized shell generally wider than long [ $W/L$ : (0.98) 1.02–1.38] (Fig. 7), dorsibiconvex to very slightly ventribiconvex ( $T_v/T_d$ : 0.42–1.06), with a semioval outline; greatest width measured at about mid-length or, more frequently, close to cardinal margin; anterior margin and posterolateral extremities rounded; lateral commissures rectilinear; anterior commissure vaguely undulose to uniplicate.

Ventral valve 5.22–8.32 times wider than thick and 4.17–6.42 times longer than thick; in posterior view, upper surface slightly convex or subrectilinear; anterolateral parts inclined to become flat; in profile, curvature regular and moderate; shallow and poorly defined sulcus sometimes developed near the front; tongue semi-ovate to subtrapezoidal and sometimes more or less perpendicular to the commissural plane; shoulder lines clearly indented; shoulder angle between 128°–165°; apical angle between 92°–126°; interarea apsacline and flat; foramen small; deltidial plates partly joined; apical foramen; internally, stout dental plates with dental nuclei supporting simple teeth; central apical cavity not filled in (Fig. 8).

Dorsal valve 3.45–5.53 times wider than thick; upper surface slightly to moderately inflated in posterior view; greatest thickness at about midvalve or close to the anterior margin (in the first case, thickness decreases progressively or maintains anteriorly); poorly defined and low fold occurring in specimens with a well developed tongue; internally, no traces of cardinal process observed in the notothyrial pit; dental socket large and relatively deep; their internal crests giving rise to the crural bases leading to the laterally oriented fibrous crura; muscular field divided by a prominent myophragm; jugal processes and spiral cones not observed (Fig. 8).

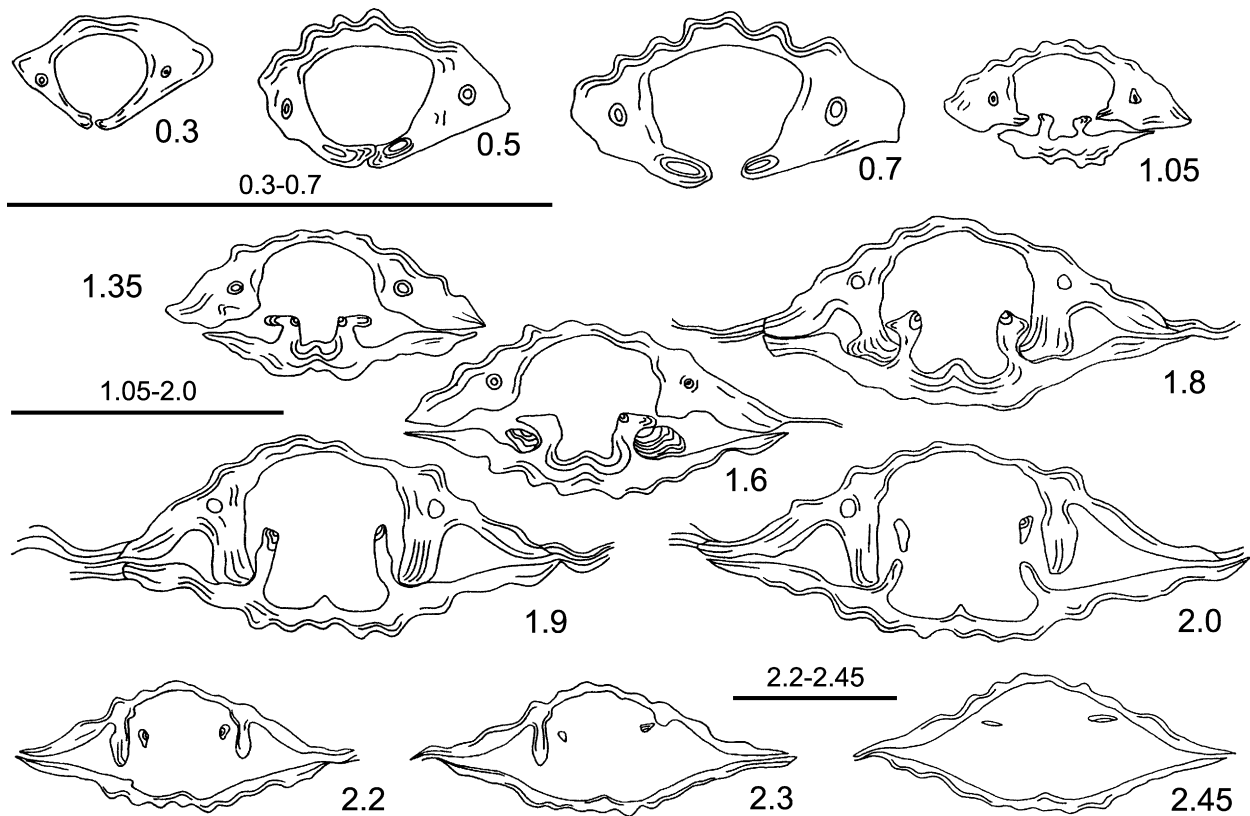


Fig. 8. *Spinatrypa (Exatrypa) marmoris* nov. sp. IRScNB a12245. Soumoy (Senzeille 7048a), Les Valisettes Fm. Transverse serial sections; distances measured in millimeter from the top of the ventral umbo. Scale bars = 5 mm.

Fig. 8. *Spinatrypa (Exatrypa) marmoris* nov. sp. IRScNB a12245. Soumoy (Senzeille 7048a), Fm des Valisettes. Sections s riees transverses ; distances en millim tre mesur es   partir du sommet de l'umbo ventral. Barres d' chelle = 5 mm.

Tubular–imbricate ribs increasing principally by bifurcation on the ventral valve and by intercalation on the dorsal valve; R-10 = 6–7 (8);  $G = 2\text{--}2.5$  (3) mm; growth lamellae covered by concentric microlines ( $\pm 8$  per mm) and more closely spaced near the commissure.

**Discussion:** The specimens identified as *S. (E.)* sp. B by Godefroid and Helsen (1998) are assigned to *Spinatrypa (Exatrypa) marmoris*. *S. (E.) marmoris* is clearly distinguished of *S. (E.) explanata* (von Schlotheim, 1820) by its lower maximal size and its coarser ribs. *S. (E.) marmoris* has been misidentified with *S. (E.) tubaecostata* (Paeckelmann, 1913) by Maillieux (1940: p. 26) and Maillieux (1941: p. 11) from which it differs however by its less systematically rounded outline and its smaller size. *S. (E.) marmoris* is distinguishable from *S. (E.) robusta* Copper, 1967 by its greater size, its coarser ribs, its more flattened shell and its less rounded outline. *S. (E.) marmoris* is smaller and less inflated than *S. (E.) copperi* Komarov, 1990.

**Occurrence:** *Spinatrypa (E.) marmoris* occurs at the southern border of the Dinant Synclinorium within the Boussu-en-Fagne Member (in the vicinity of the Lion Member mud mounds) and the Petit-Mont Member (Neuville Fm). In the Philippeville Anticlinorium, the new species is abundant within the Les Valisettes Fm, near mud mounds of the Petit-Mont Member.

Genus *Waiotrypa* Baliński, 1997

**Type species:** *Waiotrypa sulcicarina* Baliński, 1997

*Waiotrypa* sp.

Figs. 9(1–5) and 10; Table 1

**Material:** BM-2002-8 (two articulated specimens); BM-2003-3 (one articulated specimen); JG-1996-3 (two articulated specimens).

**Description:** Shell wider than long ( $W/L$ : 1.27–1.35), equibiconvex to ventribiconvex ( $T_v/T_d$ : 1.00–1.25), semi-elliptic in outline; cardinal extremities rounded; greatest width in the posterior half of the shell; anterior commissure slightly sulcate to slightly paraplicate; lateral commissures rectilinear.

Ventral valve 4.90 to 5.35 times wider than thick and 3.73 to 3.96 times longer than thick; in profile, upper surface slightly convex; in lateral view, curve of the valve regular and poorly developed; low fold appearing in the umbonal area and extending towards the anterior border; poorly developed tongue and only marked by an undulation of the anterior commissure; shoulder lines clearly indented; shoulder angle between  $140^\circ\text{--}154^\circ$ ; apical angle between  $102^\circ\text{--}124^\circ$ ; interarea apsacline and slightly concave; foramen small; deltidial plates partly joined; internally, teeth bilobed and supported by short dental plates; lateral apical cavities free; layer of prismatic calcite developed on the internal faces of the dental plates (Fig. 10).

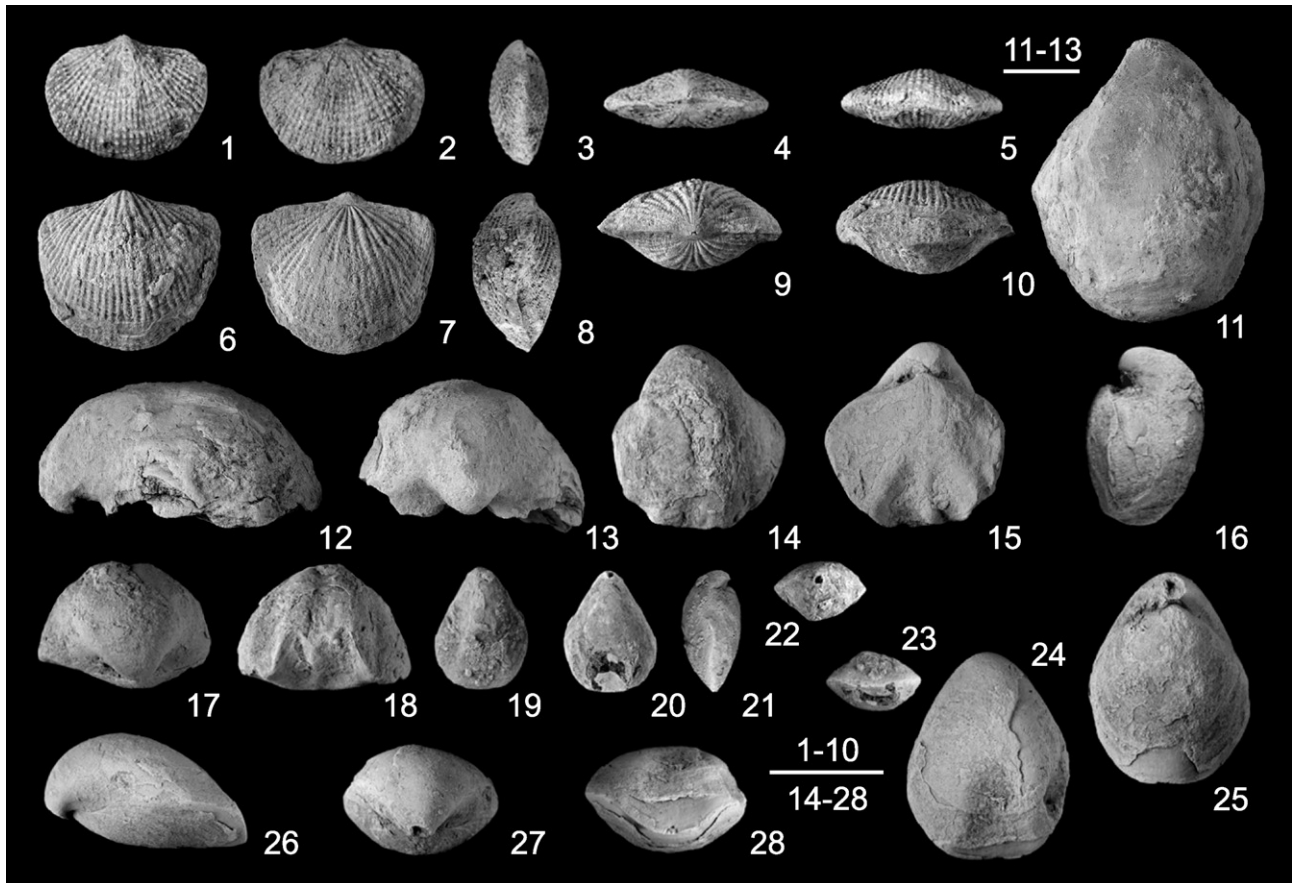


Fig. 9. 1–5. *Waiotrypa* sp. IRScNB a12248. Neuville (JG-1996-3), Les Valisettes Fm. 6–10. *Waiotrypa? pluvia* Godefroid and Helsen, 1998. IRScNB a12250. Vaulx (BM-2003-9), Neuville Fm. 11–13. *Physemella maillieuxi* Godefroid, 1974. IRScNB a12251. Ventral valve, Frasnes (BM-2003-7), Grands Breux Fm (Boussu-en-Fagne Member). 14–18. *Metabolipa* sp. IRScNB a12253. Neuville (BM-2002-8), Les Valisettes Fm. 19–23. *Cranaena* cf. *rigauxi* Brice, 1988. IRScNB a12255. Nismes (BM-2003-8), Neuville Fm. 24–28. *Cranaena* sp. IRScNB a12260. Hony (BM-2001-2), Lambermont Fm. 1, 6, 11, 14, 19, 24: ventral views; 2, 7, 15, 20, 25: dorsal views; 3, 8, 12, 16, 21, 26: lateral views; 4, 9, 13, 17, 22, 27: posterior views; 5, 10, 18, 23, 28: anterior views. Scale bars = 15 mm (except 11–13, 10 mm).  
 Fig. 9. 1–5. *Waiotrypa* sp. IRScNB a12248. Neuville (JG-1996-3), Fm des Valisettes. 6–10. *Waiotrypa? pluvia* Godefroid et Helsen, 1998. IRScNB a12250. Vaulx (BM-2003-9), Fm de Neuville. 11–13. *Physemella maillieuxi* Godefroid, 1974. IRScNB a12251. Valve ventrale, Frasnes (BM-2003-7), Fm des Grands Breux (Boussu-en-Fagne Membre). 14–18. *Metabolipa* sp. IRScNB a12253. Neuville (BM-2002-8), Fm des Valisettes. 19–23. *Cranaena* cf. *rigauxi* Brice, 1988. IRScNB a12255. Nismes (BM-2003-8), Fm de Neuville. 24–28. *Cranaena* sp. IRScNB a12260. Hony (BM-2001-2), Fm de Lambermont. 1, 6, 11, 14, 19, 24: vues ventrales; 2, 7, 15, 20, 25: vues dorsales; 3, 8, 12, 16, 21, 26: vues latérales; 4, 9, 13, 17, 22, 27: vues postérieures; 5, 10, 18, 23, 28: vues antérieures. Barres d'échelle = 15 mm (exceptées 11–13, 10 mm).

Dorsal valve 3.96 to 4.67 times wider than thick; in posterior view, upper surface slightly convex, flanks gently sloping towards the lateral commissures; sulcus with a flat bottom originating in the posterior half of the valve and extending towards the front; internally, cardinal process slightly developed in the posterior part of the notothyrial platform and extending on the posterior part of the external crests of the dental sockets, median crest dividing the dental sockets; fibrous crura laterally oriented. Jugal processes disjunct; no jugal plate observed in the serial sections; dorsomedially oriented spiral cones (up to six whorls); muscle field divided by a median crest (Fig. 10).

Imbricate ribs increasing by bifurcation on the ventral valve and by intercalation on the dorsal valve; R-5 = 7–10; *G* less than 1 mm; growth lamellae more crowded near the anterior and lateral margins.

**Discussion:** The restricted number of specimens does not allow a useful comparison with *W. sulcicarina* Baliński, 1997 although both species seem to be quite similar.

**Occurrence:** *Waiotrypa* sp. is recognized presently within the Les Valisettes Fm (Philippeville Anticlinorium).

*Waiotrypa? pluvia* Godefroid and Helsen, 1998

1998. ?*Waiotrypa pluvia* sp. n. – Godefroid and Helsen, p. 252, Figs. 5C, 8, 9.

1999. ?*Waiotrypa pluvia* – Godefroid in Boulvain et al., Fig. BIO5.

**Material:** BM-2003-6 (four articulated specimens); BM-2003-8 (four articulated specimens); BM-2003-9 (nine articulated specimens, one ventral valve).

**Description:** See Godefroid and Helsen (1998).

**Occurrence:** Godefroid and Helsen (1998: p. 255) reported the species in the Neuville Fm in various localities of the southern margin of the Dinant Synclinorium as well as in the Matagne Fm at Vaulx. However, in this locality, the layers which yielded the last *Waiotrypa? pluvia* have been transferred by Mottequin (2004b: p. 50) to the top of the Neuville Fm.

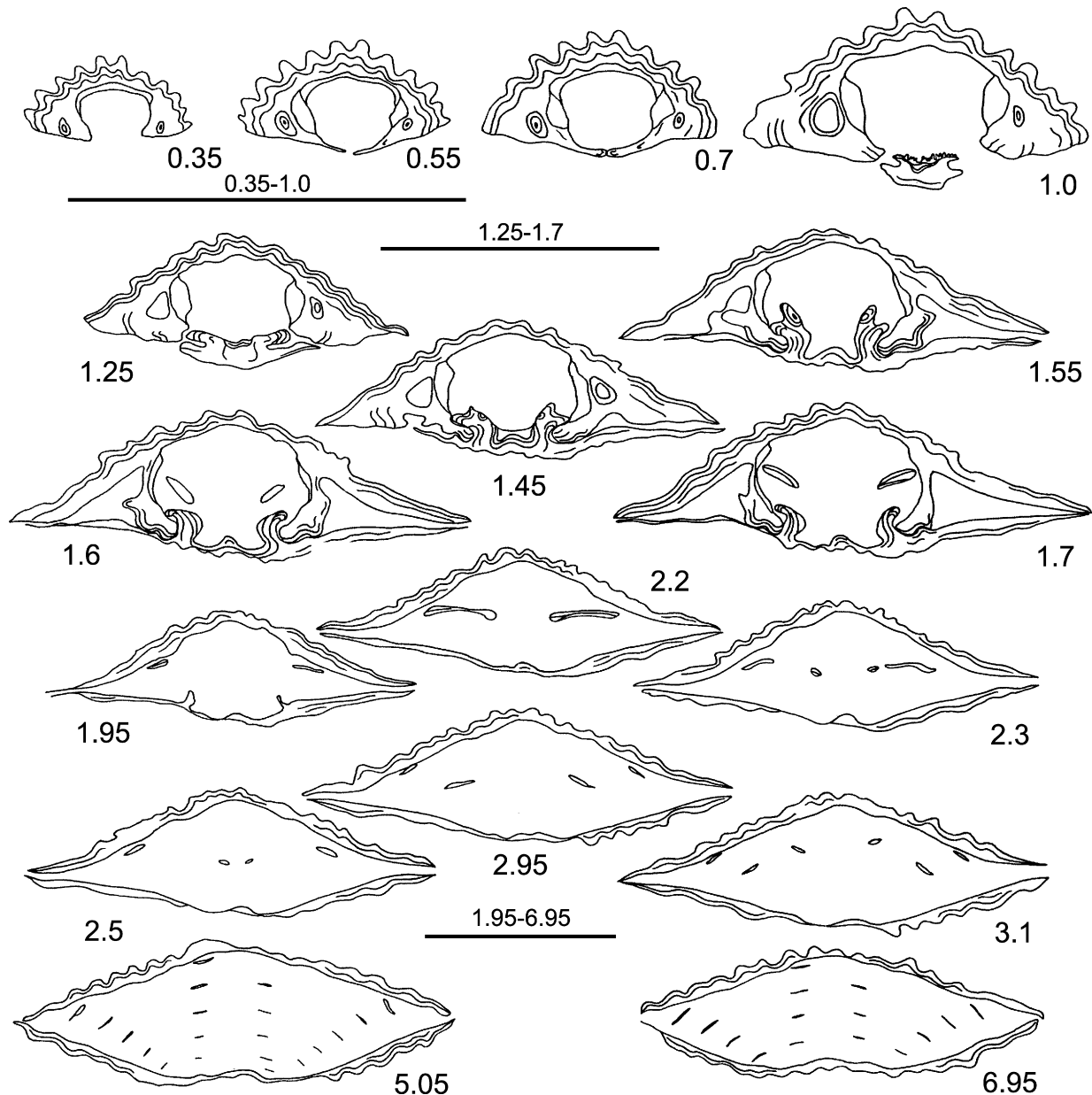


Fig. 10. *Waiotrypa* sp. IRScNB a12249. Neuville (BM-2002-8), Les Valisettes Fm. Transverse serial sections; distances measured in millimeter from the top of the ventral umbo. Scale bars = 5 mm.

Fig. 10. *Waiotrypa* sp. IRScNB a12249. Neuville (BM-2002-8), Fm des Valisettes. Sections s riees transverses ; distances en millim tre mesur es   partir du sommet de l'umbo ventral. Barres d' chelle = 5 mm.

Order PENTAMERIDA Schuchert and Cooper, 1931  
Suborder PENTAMERIDINA Schuchert and Cooper, 1931  
Superfamily GYPIDULOIDEA Schuchert and LeVene, 1929

Family GYPIDULIDAE Schuchert and LeVene, 1929  
Subfamily GYPIDULINAE Schuchert and LeVene, 1929  
Genus *Physemella* Godefroid, 1974

**Type species:** *Physemella maillieuxi* Godefroid, 1974

*Physemella maillieuxi* Godefroid, 1974

Fig. 9 (11–13)

1974. *Physemella maillieuxi* n. gen., n. sp. – Godefroid, p. 52, Pl. 6, Figs. 5 and 6, Pl. 7, Figs. 1 and 2, Text–Figs. 14, 15.

1990. *Physemella maillieuxi* – Godefroid and Racki, p. 63, Fig. 9.

1999. *Physemella maillieuxi* – Godefroid in Boulvain et al., Fig. BIO4.

2002. *Physemella maillieuxi* – Blodgett et al. in Carlson et al., p. 1013, Fig. 1a–i.

**Material:** BM-2003-7 (one ventral valve).

**Description:** See Godefroid (1974).

**Occurrence:** Godefroid and Racki (1990: Fig. 9) mentioned the species ranging from the “F2h” (Lion Member) to the “F2j” (Petit-Mont Member) at the southern flank of the Dinant Synclinorium but Godefroid (in Boulvain et al., 1999: Fig. BIO4) is less affirmative as indicated by the question mark

concerning its stratigraphic range. Reworked specimens occur in the Boussu-en-Fagne Member, at the contact with the Lion mud mounds.

Genus *Metabolipa* Godefroid, 1974

**Type species:** *Pentamerus Greindli* Maillieux, 1909a

*Metabolipa* sp.

Figs. 9(14–18) and 11; Table 1

**Material:** BM-2002-8 (three articulated specimens, two ventral valves); BM-2003-3 (two articulated specimens).

**Description:** Shell longer than wide to wider than long ( $W/L$ : 0.96–1.03), ventribiconvex ( $T_v/T_d$ : 2.43–2.90), with a subpentagonal outline (rounded anterior margin); anterior commissure sulcate.

Ventral valve 1.87–2.04 times wider than thick and 1.95–1.99 times longer than thick; in posterior view, dome-shaped with flanks sloping strongly towards the lateral commissures; well-defined fold beginning posteriorly to the mid-length; shoulders angle varying between  $85^\circ$ – $91^\circ$ ; the apical angle between  $71^\circ$ – $88^\circ$ ; umbo extending posteriorly well beyond the hinge line, but ventral beak not overhanging the dorsal umbo; interarea poorly delimited and apsacline; delthyrium open; internally, short median septum supporting the spondylium; teeth stout with concentric structure (Fig. 11).

Dorsal valve 4.95–5.41 times wider than thick and 3.93–4.43 times longer than thick; in posterior view, top rounded with flanks sloping gently towards the lateral commissures; moderately deep sulcus appearing at about the mid-length ( $W_s/W$ : 0.48–0.57); subtrapezoidal tongue 1.86–2.09 times wider than long and more or less perpendicular to the

commissural plane; internally, inner hinge plates disjunct; their bases are clearly separated on the floor of the valve; it seems that the outer hinge plates are slightly longer than these latter but the specimen is somewhat deformed; dental sockets separated from the floor of the valve (Fig. 11).

Simple ribs developed near the anterior margin in adult shells; best preserved specimen showing two well-defined ribs and a poorly visible third on the fold and one rib in the sulcus; three weak ribs on the ventral flanks of the largest specimen.

**Discussion:** These specimens are assigned to the genus *Metabolipa* rather than to *Neometabolipa* Godefroid, 1974 because their inner hinge plates are not joined on the floor of the valve. The small number of specimens does not permit identifying them more precisely. Blodgett et al. (in Carlson et al., 2002: p. 1006) considered *Metabolipa* and *Neometabolipa* as synonyms of *Gypidula* Hall, 1867 but the distinctive characters stated by Godefroid (1974: pp. 7, 24) and specified later (Godefroid, 1979: p. 8) appear to me sufficient to distinguish *Gypidula* from *Metabolipa* and *Neometabolipa*.

**Occurrence:** *Metabolipa* sp. occurs within the perireefal facies developed within the Les Valisettes Fm (Philippeville Anticlinorium).

Order TEREBRATULIDA Waagen, 1883

Suborder TEREBRATULIDINA Waagen, 1883

Superfamily CRYPTONELLOIDEA Thomson, 1926

Family CRANAENIDAE Cloud, 1942

Subfamily CRANAENINAE Cloud, 1942

Genus *Cranaena* Hall and Clarke, 1893

**Type species:** *Terebratula romingeri* Hall, 1863

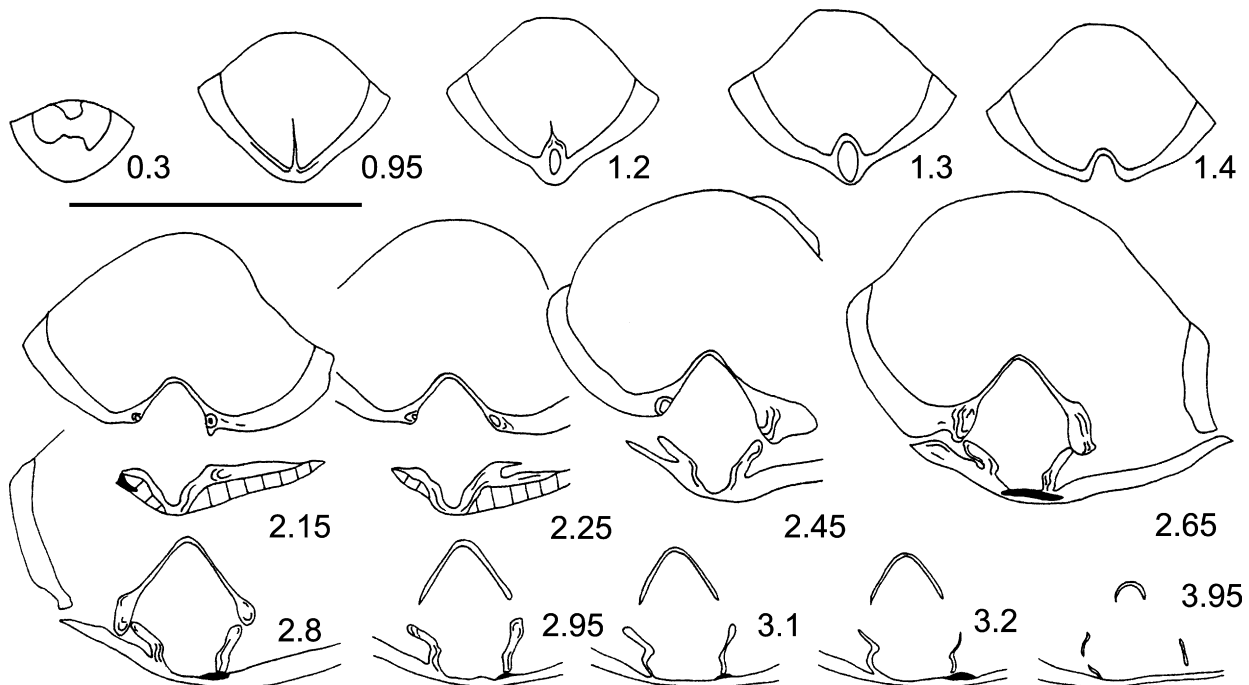


Fig. 11. *Metabolipa* sp. IRScNB a12254. Neuville (BM-2002-8), Les Valisettes Fm. Transverse serial sections; distances measured in millimeter from the top of the ventral umbo. Scale bars = 5 mm.

Fig. 11. *Metabolipa* sp. IRScNB a12254. Neuville (BM-2002-8), Fm des Valisettes. Sections s riees transverses ; distances en millim tre mesur es   partir du sommet de l'umbo ventral. Barres d' chelle = 5 mm.

*Cranaena* cf. *rigauxi* Brice, 1988

Figs. 9(19–23) and 12(1); Table 1

e.p. 1909b. *Dielasma elongata* Schloth. – Maillieux, p. 138.

e.p. 1940. *Cryptonella juvenis* (Sowerby) – Maillieux, p. 27.

e.p. 1941. *Cryptonella juvenis* (Sowerby) – Maillieux, p. 14.

cf. 1988. *Cranaena rigauxi* n. sp. – Brice, p. 384, Pl. 43, Figs. 20, 21, Text–Fig. 1F.

**Material:** BM-2002-8 (10 articulated specimens); BM-2003-3 (17 articulated specimens); BM-2003-8 (14 articulated specimens); BM-2004-1 (two articulated specimens); JG-1995-5 (nine articulated specimens).

**Description:** Small sized shell for the genus, wider than long ( $W/L$ : 0.76–0.94), ventribiconvex ( $T_v/T_d$ : 1.09–1.65), elliptical in outline; greatest width near the mid-length, more rarely in front of this one; in ventral view, anterior margin flattened to rounded; anterior commissure rectimarginate.

Ventral valve 2.52–3.18 times wider than thick and 3.21–4.20 times longer than thick; in posterior view, inflated with their flanks sloping moderately towards the lateral commissures; in lateral profile view, upper surface regularly curved except in the umbonal area (accentuation of the convexity); no sulcus; shoulder lines subrectilinear; shoulder and apical angles identical, varying between 69°–93°; beak is erect to weakly incurved (sometimes in contact with the dorsal umbo); foramen small, permesothyrid to epithyrid; palintropes weakly individualized; internally, short and thin dental plates supporting teeth suboval in transverse serial section; lateral and central apical cavities not filled in; muscle field not excavated (Fig. 12 (1)).

Dorsal valve 3.47–4.15 wider than thick, devoid of fold, roughly rounded to elliptic in outline; greatest height located in its posterior half and then, decreasing progressively toward the front; internally, slightly thickened and moderately concave hinge plate perforated in front of the beak; internal crests of the dental sockets relatively well-developed (Fig. 12 (1)).

Growth lamellae with an average spacing of about 0.6 mm in the anterior part of the valve (one specimen).

**Discussion:** With their absence of sulcus and fold as well as their rectimarginate anterior commissure, these specimens are close to *C. rigauxi* Brice, 1988 from the Frasnian of the Boulonnais (France). Nevertheless, they do not attain the size of this latter and their apical angle is more open; these features lead me to maintain the doubt concerning their specific assignation.

**Occurrences:** *Cranaena* cf. *rigauxi* occurs within the Neuville (southern flank of the Dinant Synclinorium) and the Les Valisettes formations (Philippeville Anticlinorium).

*Cranaena* sp.

Figs. 9(24–28) and 12(2); Table 1

**Material:** BM-2001-2 (10 articulated specimens).

**Description:** Shell middle-sized, generally longer than wide ( $W/L$ : 0.65–1.03), ventribiconvex ( $T_v/T_d$ : 1.19–1.64), elliptic in outline; in ventral view, anterior margin rounded to flattened; greatest width located between 56–75% of the unrolled length

of the ventral valve measured from the beak; anterior commissure variably uniplicate.

Ventral valve 2.29–3.16 times wider than thick and 3.15–3.71 times longer than thick; in posterior view, its superior surface drawing roughly half an ellipse; in lateral profile view, valve strongly inflated in its posterior part where is located its greatest height, anterior part inclined to become flat; sulcus absent in most of the specimens or very shallow, wide [ $W_s/W$ : 0.67 (one specimen!)], poorly defined and appearing at about midvalve; tongue 2.67 times wider than high (one specimen!), not perpendicular to the commissural plane, rounded; shoulder lines subrectilinear; shoulder angle identical with the apical one and varying between 67°–90°; beak suberect to erect; foramen marginate, permesothyrid; palintropes poorly defined; internally, thin and short dental plates supporting teeth suboval in transverse serial section; central and apical cavities not filled in; muscle field not observed (Fig. 12 (2)).

Dorsal valve 2.72–4.26 wider than thick with an elliptic outline; greatest height located in its posterior half and then, decreasing progressively or remaining steady towards the anterior margin; no fold; internally, hinge plate weakly thickened, relatively flat, perforated in front of the beak; internal crests of the dental sockets well-developed (Fig. 12(2)).

$G$  about 1 mm; growth lamellae more crowded near the lateral and anterior margins.

**Discussion:** The material is not sufficiently abundant to permit a comparison with the numerous species belonging to *Cranaena*. According to Brice (1988: p. 385), some Ardennian species, assigned to *Dielasma elongatum* by the former authors, could belong to *C. rigauxi* Brice, 1988. From that latter, *C. sp.* differs by the occasional presence of a sulcus and by its variably uniplicate anterior commissure.

**Occurrence:** *C. sp.* occurs at the top of the Aisemont Fm as well as in the Frasnian part of the Lambermont Fm (northern border of the Dinant Synclinorium).

#### 4. Stratigraphic summary

The stratigraphic range and the geographic distribution of the atrypid, pentamerid and terebratulid brachiopods for the considered biostratigraphical interval (*P. hassi* Zone to Upper *P. rhenana* Zone) across the Dinant Synclinorium [except its south-eastern border, see Mottequin (2005)] are presented on Fig. 13. Data concerning the atrypids from the Vesdre area are available in Mottequin (2003); Godefroid (in Boulvain et al., 1999) provided the stratigraphic ranges for all the Frasnian Atrypida and Pentamerida from the Dinant Synclinorium known at that time.

#### 5. Atrypida and Pentamerida extinction in the Namur–Dinant Basin

In the Namur–Dinant Basin, the Late Frasnian recorded dysaerobic–anaerobic facies whose intensity depended on the proximal or distal position along the ramp. They have been correlated with the Lower and Upper Kellwasser horizons (dark to black limestones with positive  $\delta^{13}\text{C}$  excursions) occurring

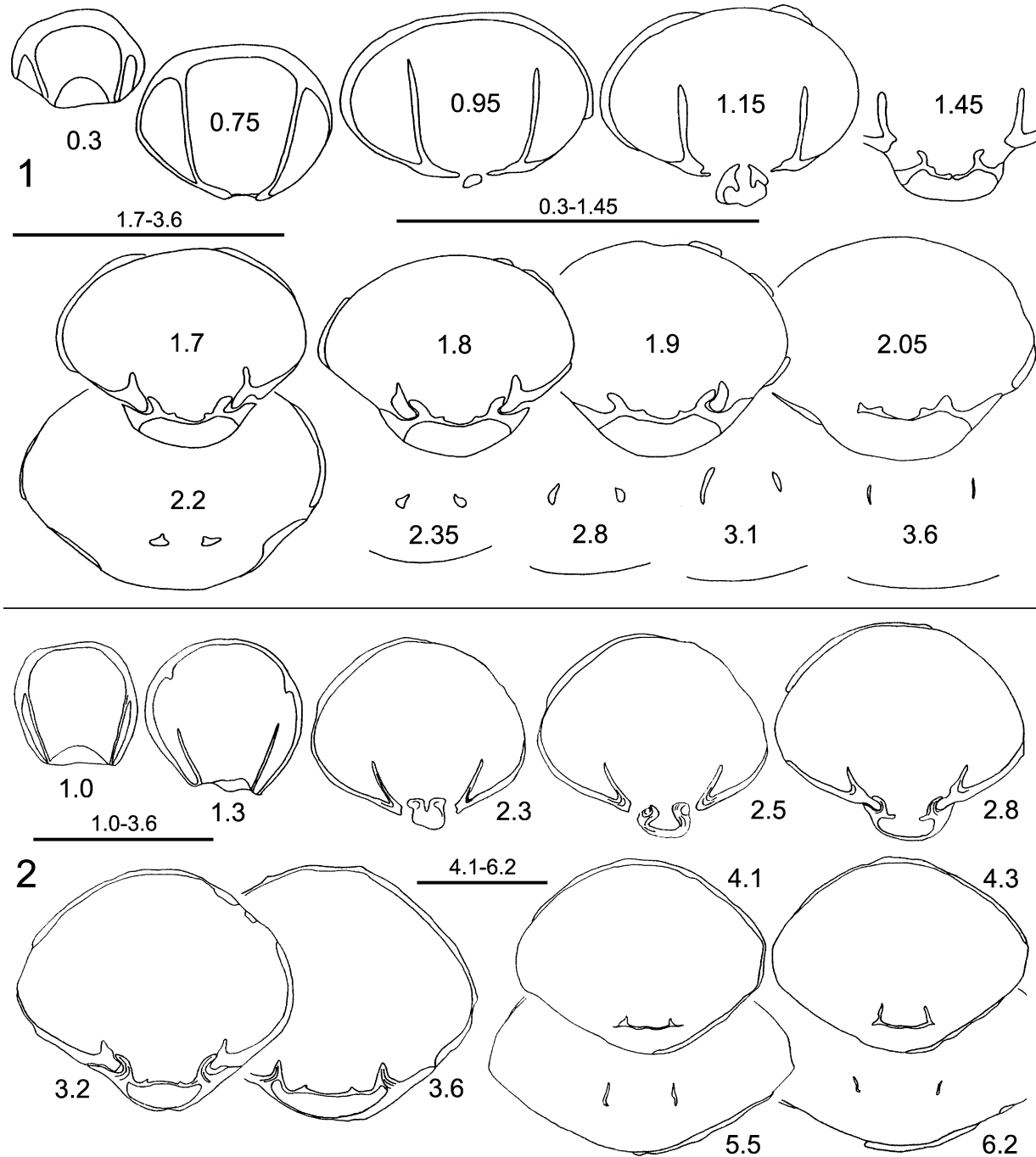


Fig. 12. 1. *Cranaena* cf. *rigauxi* Brice, 1988. IRScNB a12259. Nismes (BM-2003-8), Neuville Fm. 2. *Cranaena* sp. IRScNB a12264. Hony (BM-2001-2), Lambermont Fm. 1, 2. Transverse serial sections; distances measured in millimeter from the top of the ventral umbo. Scale bars = 5 mm.

Fig. 12. 1. *Cranaena* cf. *rigauxi* Brice, 1988. IRScNB a12259. Nismes (BM-2003-8), Fm de Neuville. 2. *Cranaena* sp. IRScNB a12264. Hony (BM-2001-2), Fm de Lambermont. 1, 2. Sections s rie es transverses ; distances en millim tre mesur es   partir du sommet de l'umbo ventral. Barres d' chelle = 5 mm.

within condensed sequences in Germany (Harz); both would be formed during highstand periods (Joachimski and Buggisch, 1993). The Lower Kellwasser Horizon (LKW; lower part of the Upper *P. rhenana* Zone) is placed in the lowermost part of the Matagne Fm on the southern border of the Dinant Synclinorium whereas in the Philippeville Anticlinorium, it would be situated in the basal part of the Les Valisettes Fm (Bultynck et al., 1998) (Fig. 13). On the south-eastern margin of the Dinant

Synclinorium, the fissile and azoic shales of the middle part of the Les Valisettes Fm could correspond to the LKW. Moreover, the middle part of the intermediate shales of the Aisemont Fm, that is the dysaerobic–anaerobic unit of Poty and Chevalier (2007), could be the record of the LKW according to these authors (Fig. 13). The Upper Kellwasser Horizon (UKW; *P. linguiformis* Zone) corresponds to the Matagne Fm in the Philippeville Anticlinorium (Bultynck et al., 1998). The black



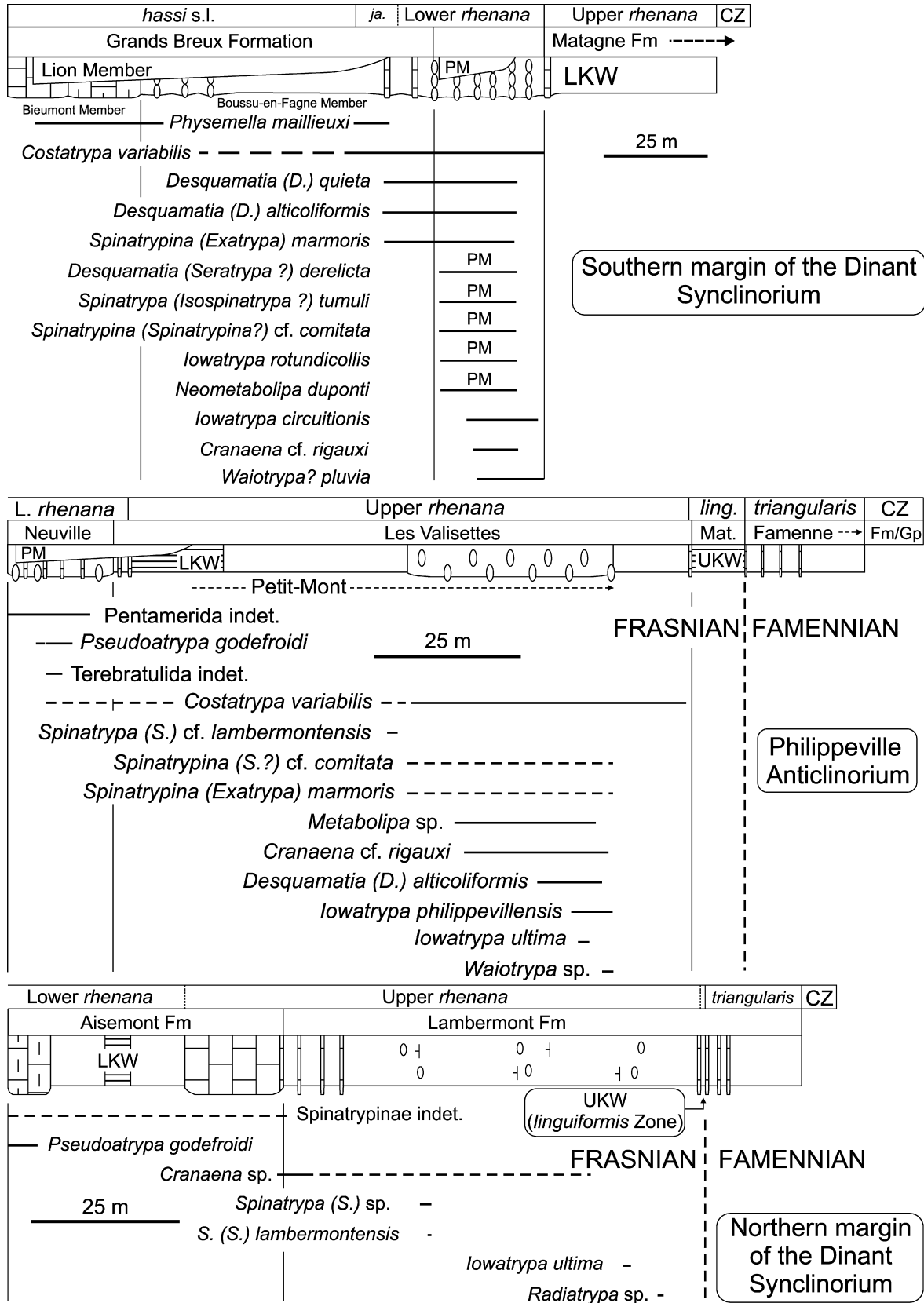


Fig. 13. Distribution of the Atrypida, Pentamerida (only some selected species) and Terebratulida across the Dinant Synclinorium. Conodont zones according to Bultynck et al. (1998). Brachiopod extensions for the southern flank of the Dinant Synclinorium after Godefroid (in Boulvain et al., 1999 : Figs. BIO4-5). Abbreviations: CZ, conodont zones; Fm, Formation; Gp, Group; LKW, Lower Kellwasser; PM, Petit-Mont Member; UKW, Upper Kellwasser.

Fig. 13. Distribution des Atrypida, Pentamerida (seulement quelques espèces sélectionnées) et des Terebratulida à travers le Synclinorium de Dinant. Zones à conodontes d'après Bultynck et al. (1998). Extensions des brachiopodes au bord sud du Synclinorium de Dinant d'après Godefroid (in Boulvain et al., 1999 : Figs. BIO4-5). Abréviations : CZ, zones à conodontes ; Fm, Formation ; Gp, Groupe ; LKW, Kellwasser inférieur ; PM, Membre du Petit-Mont ; UKW, Kellwasser supérieur.

shale horizons recognized at the top of the Frasnian part of the Lambermont Fm in the Vesdre area and on the northern margin of the Dinant Synclinorium have been correlated with the UKW by Herbosch et al. (1996) (Fig. 13).

In southern Belgium, the atrypid extinction is diachronous as rightly indicated by Godefroid and Helsen (1998: Fig. 20) for the southern margin of the Dinant Synclinorium and the Philippeville Anticlinorium, but this diachronism is also highlighted for the rest of the Namur–Dinant Basin. In its distal part, that is on the southern flank of the Dinant Synclinorium and according to the definition of the Matagne Fm proposed by Coen et al. (in Boulvain et al., 1999), the last atrypids (*Costatrypa variabilis* and *Waiotrypa? pluvia*) occur at the top of the Neuville Fm (Lower *P. rhenana* Zone) and not at the base of the Matagne Fm as previously mentioned by Godefroid and Helsen (1998: Fig. 19). In the Philippeville Anticlinorium, only *C. variabilis* reaches the top of the Les Valisettes Fm (Upper *P. rhenana* Zone); it disappears less than 1 m below the bottom of the Matagne Fm (Mottequin, 2004a: p. 35). This taxon is also the last to disappear in the Vesdre area (Lambermont; BM-2002-1) within the Lambermont Fm, just before the dark shales with lingulids formerly placed in the Matagne Fm by Bultynck et al. (1988: Fig. A12/A). On the northern flank of the Dinant Synclinorium (Hony; BM-2001-2), the genus *Costatrypa* is absent; on the other hand, *Radiatrypa* occurs there as well as in Lambermont, where this latter is known in a level stratigraphically lower to the one of the late *C. variabilis*. *Iowatrypa ultima* is the last atrypid to become extinct within the Barvaux Fm (south-eastern flank of the Dinant Synclinorium). Till now, no atrypid has been collected within the Matagne Fm which yielded a particular fauna composed notably of brachiopods such as the leiorhynchid *Ryocarhynchus tumidus* adapted to poorly oxygenated environments, bivalves of the family Buchiolidae, goniatites and cricoconarids. In the adjacent areas and notably in the Boulonnais (northern France) corresponding to the western extension of the Namur–Dinant Basin, the last atrypids (Spinatrypinae) have been collected in the Gris Member (upper part of the Ferques Fm) according to Godefroid (1988: Fig. 7). After Brice (2003: pp. 414, 416), the age of this member, in terms of standard conodont zones, is still uncertain. In Eifel (Germany), Godefroid and Hauser (2003) described species belonging to the genera and subgenera *Costatrypa*, *Desquamatia* (*Desquamatia*), *Spinatrypina* (*Exatrypa*) and *Iowatrypa* within the Lower and Upper *P. rhenana* zones. In the Aachen area, Copper (1973: p. 495) mentioned *Iowatrypa* in the late Frasnian (“F3”). In the Holy Cross Mountains (Poland), Racki and Baliński (1998: Fig. 17) reported the presence of *Costatrypa*, *Spinatrypina* and *Iowatrypa* within the *P. linguiformis* Zone. In conclusion, the final atrypid extinction occurs below the UKW in the Namur–Dinant Basin, that is at the top of the Upper *P. rhenana* Zone.

A similar pattern is also recognized for the pentamerids, which disappear parallel to the end of the carbonate buildup edification (Petit-Mont Member; Upper *P. rhenana* Zone). On the southern border of the Dinant Synclinorium, the last representatives of the Pentamerida, namely *Neometabolipa*

*duponti* Godefroid, 1974, have been collected in the Neuville Fm (Petit-Mont Member, Lower *P. rhenana* Zone) according to Godefroid (in Boulvain et al., 1999: Fig. BIO4) (Fig. 13). In the Philippeville Anticlinorium, the youngest pentamerids (*Metabolipa* sp.) originate from the perireefal facies developed within the Les Valisettes Fm (Upper *P. rhenana* Zone). On the southern flank of the Namur Synclinorium, more precisely at Engis [Parc des Tchaornis section, see Poty and Chevalier (2007)], the “first biostrom with *Phillipsastrea*” (Lower *P. rhenana* Zone) occurring in the lower part of the Aisemont Fm yielded some unidentified pentamerids. The Lambermont Fm seems to be devoid of pentamerids, though their presence in the “third biostrom with *Phillipsastrea*” (Vesdre area) is not unlikely. However, a modern systematic study of the pentamerids from the Les Valisettes Fm (Philippeville Anticlinorium) as well as those present within the carbonate mounds is still needed to provide a global view of the extinction of these brachiopods in southern Belgium. In the Boulonnais, the youngest pentamerids originate from the term (d) of the La Parisienne Member (Ferques Fm, Upper *Mesotaxis asymmetrica* Zone) (Brice, 1988: p. 346). According to Ziegler and Sandberg (1990: p. 18), the Upper *M. asymmetrica* Zone is included in the Lower *P. hassi* Zone. In Eifel (Germany), Godefroid and Hauser (2003: p. 55) described *Neometabolipa?* sp. from the Lower and Upper *P. rhenana* zones. In Poland (Jablonna), Biernat (1983) described *Gypidula* sp. A from limestones of early Famennian age but, according to Racki (in Godefroid and Racki, 1990), this report needs confirmation. In the Holy Cross Mountains the last pentamerids are present in light coloured algal limestones corresponding to front-reef facies (undifferentiated *P. rhenana* Zone); this may suggest a narrowing of the pentamerids niches after this author. In conclusion, the last pentamerids observed till now in the Namur–Dinant Basin, have been collected in the Upper *P. rhenana* Zone, but they disappear before the atrypids.

Terebratulida survived to the Late Frasnian mass extinction, but they are poorly represented in the studied lithostratigraphic units. Moreover, the study of those present in the mud mounds was beyond the scope of this paper due to the difficulties extracting them from these massive carbonate rocks. So far, only the genus *Cranaena*, known from the Emsian (García-Alcalde in Brice et al., 2000), is recognized in the Late Frasnian of the Namur–Dinant Basin. No terebratulid has been collected in the lower part of the Famennian (Famenne Group; *P. triangularis* to *P. crepida* zones) from southern Belgium. Besides, Maillieux (1941) did not mention them in the Belgian Famennian although the data concerning the species from that stage were only provisional according to him. Demanet (1958) did not report their presence in the uppermost Famennian (Strunian substage); according to his faunal lists, it would be only in the Tournaisian “Sous-assise des Calcschistes de Maredsous (“Tn2c”)” (= Maurenne Fm, latest Hastarian) that these brachiopods would be present again in the Namur–Dinant Basin. Their absence in the Namur–Dinant Basin during the Famennian could be due to inappropriate facies.

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## Appendix A

Geological and geographical data (IGN map on a scale of 1:25,000) of the sampled localities.

**Remark:** Only the formations from where the studied specimens originate are mentioned below. See Mottequin (2005) for more details concerning the species ranges for each outcrop mentioned below.

BM-2001-2. Hony, railway section, east of the station (IGN map 49/1-2) (Mottequin, 2003); Lambermont Fm. Grid references (Belgian Lambert system) (East–North): 245.555–137.350.

BM-2002-1. Lambermont, western access road to the highway Verviers–Prüm (Laloux and Ghysel in Boulvain et al., 1999) (IGN map 42/7-8); Lambermont Fm. Grid references: 254.335–143.600.

BM-2002-7. Heure, small disused quarry in the north-eastern flank of the N929, west of Heure (Coen, 1974) (IGN map 57/3-4); Neuville Fm. Grid references: 215.218–109.450.

BM-2002-8. Neuville, south-west of the village of Neuville, on the eastern side of a trench dug for the Couvin–Charleroi railway (Godefroid and Helsen, 1998) (IGN map 57/3-4); Neuville and the Les Valisettes formations. Grid references: 159.395–95.275.

BM-2003-10. Boussu-en-Fagne, eastern wall of the disused cemetery quarry and along the access-path (Godefroid and Helsen, 1998) (IGN map 57/7-8). Grands Breux (Boussu-en-Fagne Member) and Neuville formations. Grid references: 157.690–84.985.

BM-2003-3. Cerfontaine, eastern side of the by-pass road of Cerfontaine at the La Redoute locality (Mottequin, 2004a) (IGN map 57/3-4); Les Valisettes Fm. Grid references: 152.300–94.850.

BM-2003-6. Frasnes, railway cut Couvin–Charleroi South of Frasnes (Coen-Aubert, 1994) (IGN map 57/7-8); Grands Breux (Boussu-en-Fagne Member) and Neuville formations. Grid references: 159.780–84.425.

BM-2003-7. Frasnes, southern access to the disused Lion quarry (Coen-Aubert, 1994) (IGN map 57/7-8); Grands Breux (Boussu-en-Fagne Member) and Neuville formations. Grid references: 160.160–84.545.

BM-2003-8. Nismes, railway section between Mariembourg and Nismes (Helsen and Bultynck, 1992; Godefroid and Helsen, 1998) (IGN map 58/5-6); Neuville Fm. Grid references: 162.600–86.075.

BM-2003-9. Vaulx, eastern side of a short blind road to the north of Vaulx (Godefroid and Helsen, 1998; Mottequin, 2004b) (IGN 57/7-8); Neuville Fm. Grid references: 150.050–84.550.

BM-2004-1. Senzeille, northern wall of the disused Beauchâteau quarry, south-east of Senzeille (Boulvain, 1993) (IGN map 57/3-4); Les Valisettes Fm. Grid references: 158.300–94.300.

BM-2004-2. Neuville, Tapoumont quarry south-west of Neuville (Boulvain, 1993) (IGN map 57/3-4); Les Valisettes Fm. Grid references: 159.600–94.675.

BM-2004-4. Bagnée, along the road from Nandrin to Esneux, north-west of the Tavier stream (Poty and Chevalier, 2007) (IGN map: 49/1-2). Aisemont Fm. Grid references: 228.565–133.625.

JG-1995-4: See BM-2003-10.

JG-1996-3. See BM-2002-8.

Senzeille 7048a. Soumoy, disused Gorgimont quarry, south-east of Soumoy (Boulvain, 1993) (IGN map 57/3-4); Les Valisettes Fm. Grid references: 156.075–94.475.

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