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THE BIOSTRATIGRAPHICAL DISTRIBUTION OF CARBONIFEROUS LIMESTONE TRILOBITES IN BELGIUM AND ADJACENT AREAS

by G. & R. HAHN (*)

ABSTRACT - The succession of trilobites in the Carboniferous Limestone of Belgium and adjacent areas is represented and compared with that of the Kulm basin in the Rhenish Slate Mountains. The ecology of the trilobites and, with that their facial dependence, is discussed. The most important taxa of the Belgian Limestone trilobites are figured.

RESUME - La succession des trilobites dans le Calcaire Carbonifère de la Belgique et les régions voisines est présentée et comparée à celle du bassin de type Kulm dans le massif Schisteux - Rhénan. L'écologie des trilobites et leur dépendance du faciès sont discutées. Les types les plus importants des trilobites trouvés dans le Calcaire Carbonifère sont figurés.

KEY WORDS - Belgian Carboniferous trilobites, biostratigraphy, ecology, facial dependence

MOTS-CLES - trilobites: Carbonifères de Belgique, biostratigraphie, écologie, dépendance facielle

INTRODUCTION

Text-fig. 1

Trilobites are important index-fossils in the lower part of the Palaeozoic ; in the Devonian they have already lost some of their importance, and during the last 100 millions of their lifetime they usually are little noticed fossils in Carboniferous and Permian strata. Nevertheless, they are useful biostratigraphically as well as ecologically also in the Carboniferous. The Lower Carboniferous Kulm sediments of the Rhenish Slate Moutains, the Bergisches Land and the Frankenwald can be subdivided by help of trilobites as well as by help of goniatites (see Arbeitsgemeinschaft für Dinant-Stratigraphie 1971: stratigraphical table). An essential prerequisite for the biostratigraphical use of Carboniferous trilobites is adequate knowledge of their morphology and systematics. Only if the trilobites are discussed and treated palaeozoologically, they can be helpful for stratigraphical purposes.

In the Carboniferous limestone of Belgium trilobites are rare in some strata but common in others, as for instance in the Ivorian of Tournai. Historically, these are the earliest Carboniferous trilobites ever mentioned in literature, see WITRY, 1780. [Louis-Hyacinthe d'Everlange-Witry was born in 1719 on the castle of Witry in Luxembourg - today Belgish Luxembourg (see text-fig. 2). Besides his ecclesiastical studies, he was engaged in natural sciences, and he became "physician and mineralogist". He was director of the "cabinet de curiosités" in the Austrichian Netherlands and, from 1773 on, member of the "Académie royale des sciences et lettres à Bruxelles". He died in 1791.] Afterwards, a first brief description of some taxa was given by de KONINCK, 1842/44 ; his figures are poor and useless for systematical determinations (see text-fig. 1). In the following decades after de KONINCK, very few work was done on Belgian Limestone trilobites, and they never were treated monographically (see G. HAHN, R. HAHN & BRAUCKMANN, 1980 : Historischer Überblick). Therefore, relatively little was known about their systematic diversity and

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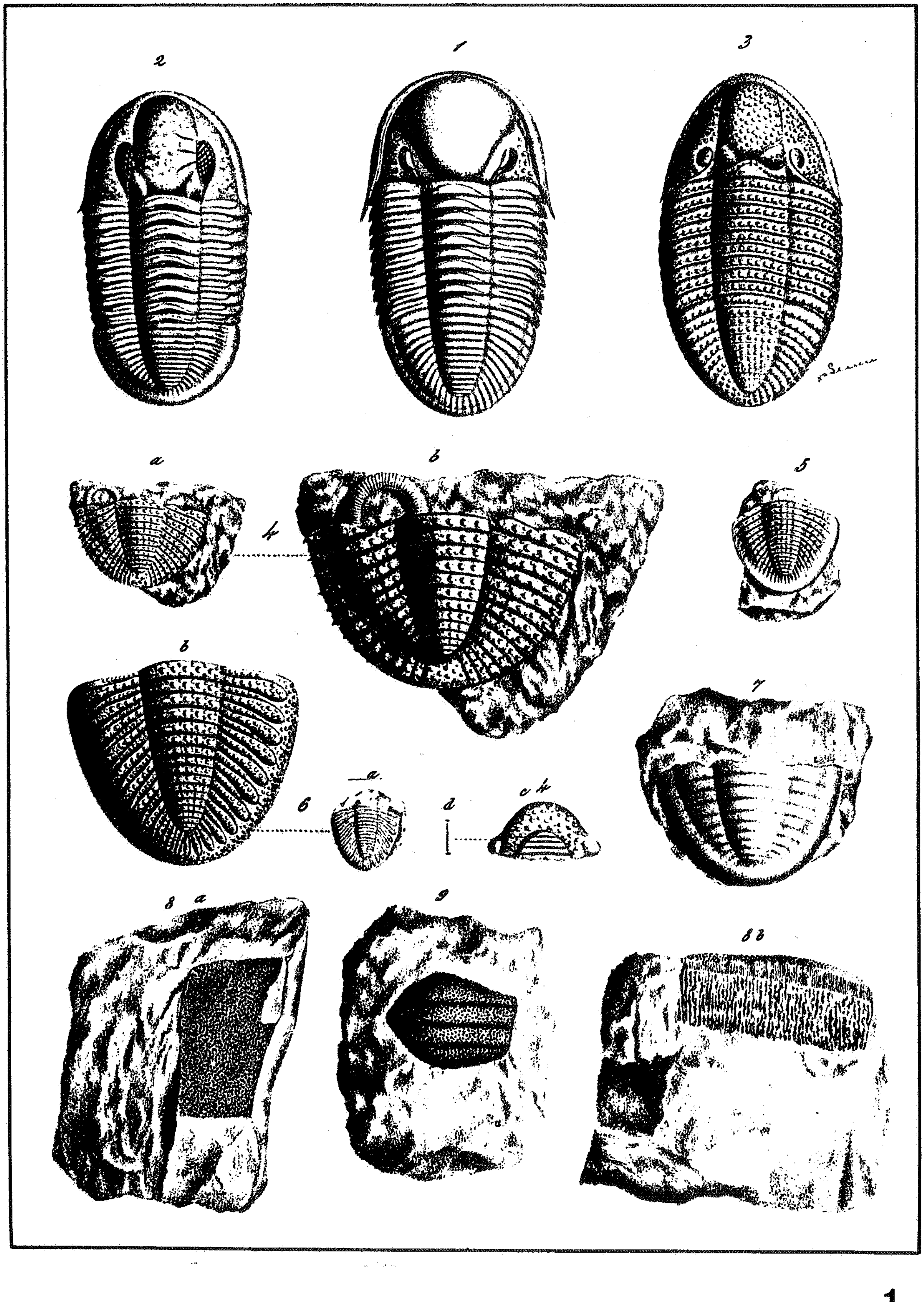

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their biostratigraphical distribution up to 1980. Then, a monographic treatment was started by G. HAHN, R. HAHN & BRAUCKMANN, supported financially by the Deutsche Forschungsgemeinschaft. The results are published in G. & R. HAHN, 1982a, b and in G. HAHN, R. HAHN & BRAUCKMANN 1980, 1982-1988 (Die Trilobiten des belgischen Kohlenkalkes, Teil 1-10). As one result, a chart of the biostratigraphical distribution of the Belgian Limestone trilobites can be drawn up now. It should be presented and discussed in this paper.

ECOLOGY OF CARBONIFEROUS TRILOBITES

Trilobites are primitive arthropods. Their most significant feature is, ecologically, the lack of differentiated masticatory organs, as claws, evolved by modification of legs. Only some genera, as *Phacops*, were able to bite off somewhat by help of differentiated basal joints on the cephalic legs. Their mouth was orientated ventrally, placed behind the hypostoma ; the stomach was within the glabella, as today in *Limulus*. Therefore, trilobites (or at least most of them) were able to feet only on the ground, as is discussed in detail by LAUTERBACH, 1973. Some of the Carboniferous trilobites were probably collecting small particles of organic remains from the bottom ; others (as the typical Kulm trilobites) were grubbing in the mud (G. & R. HAHN, 1981). Such forms as *Phacops* were perhaps climbing up the corals, nibbling at algae or small polyps, being able also to carve small carcasses. But it is very improbable that trilobites had evolved real predatory adaptions. Most of them were able to swim, perhaps bottom-up like *Limulus*.

As it is discussed above, trilobites were, in spite of their possibility to swim, bound to the floor of the sea. They were not able to cross an ocean, and adapted to a special depth. They rather are part of the vagil benthos than of the necton.

From that it follows that also Lower Carboniferous trilobites were restricted to a special type of facies. This is confirmed by their distribution : the trilobite fauna of the Kulm sediments differs completely from that of the limestone sediments. Very few genera, but no species, are known from both regions. This will be discussed in detail by help of the well known trilobite faunae of the Ivorian and the Erdbachian.

Most of the Lower Carboniferous trilobites belong to one family, the Phillipsiidae, which is represented by eight subfamilies : Archegoninae, Cystispininae, Linguaphillipsiinae, Griffithidinae, Permoproetinae, Cummingellinae and Ditomopyginae. The two first named subfamilies have their main distribution in the Kulm facies, the others in the Limestone facies. Represented by only one genus each are the Proetidae - with *Pudoproetus* - the Brachymetopidae - by *Brachymetopus* with several subgenera - and the Aulacopleuridae - with *Namuropyge*. Altogether, the trilobite fauna of the Carboniferous Limestone of Belgium (and adjacent areas) consists of 50 species, 21 subspecies, 21 genera and 19 subgenera (see G. HAHN, R. HAHN & BRAUCKMANN, 1988 : tab. 1). With that the number of taxa is similar as in the British Carboniferous Limestone.

GEOGRAPHIC DISTRIBUTION

Text-fig. 2, tab. 1.

The known trilobite faunas come predominantely from the southern part of Belgium and of some adjacent areas. These are the region of Avesnelles in France, the region of Maastricht in The Netherlands and the region of the Velbert Anticline in W-Germany. Altogether, trilobites are known from about 50 finding places, which are compiled in table 1 and text-fig. 2.

Most common are trilobites in three regions : Tournai, Visé and the Meuse Valley around Dinant. East of Tournai, many quarries are existing still today, which have yielded many trilobites of Ivorian age. The famous old quarries of Richelle, south of Visé, are barren palaeontologically today (at least with regard to trilobites). Fortunately, many old collections are stored in Brussels and elsewhere, which we could taken into account for our work.

In the Meuse Valley, many small outcrops exist, which are more or less important in view of trilobites. In the southern part of the province of Liège, the outcrop of Petit-Modave is remarkable; a rich trilobite fauna of Upper Ivorian age has been found here. In

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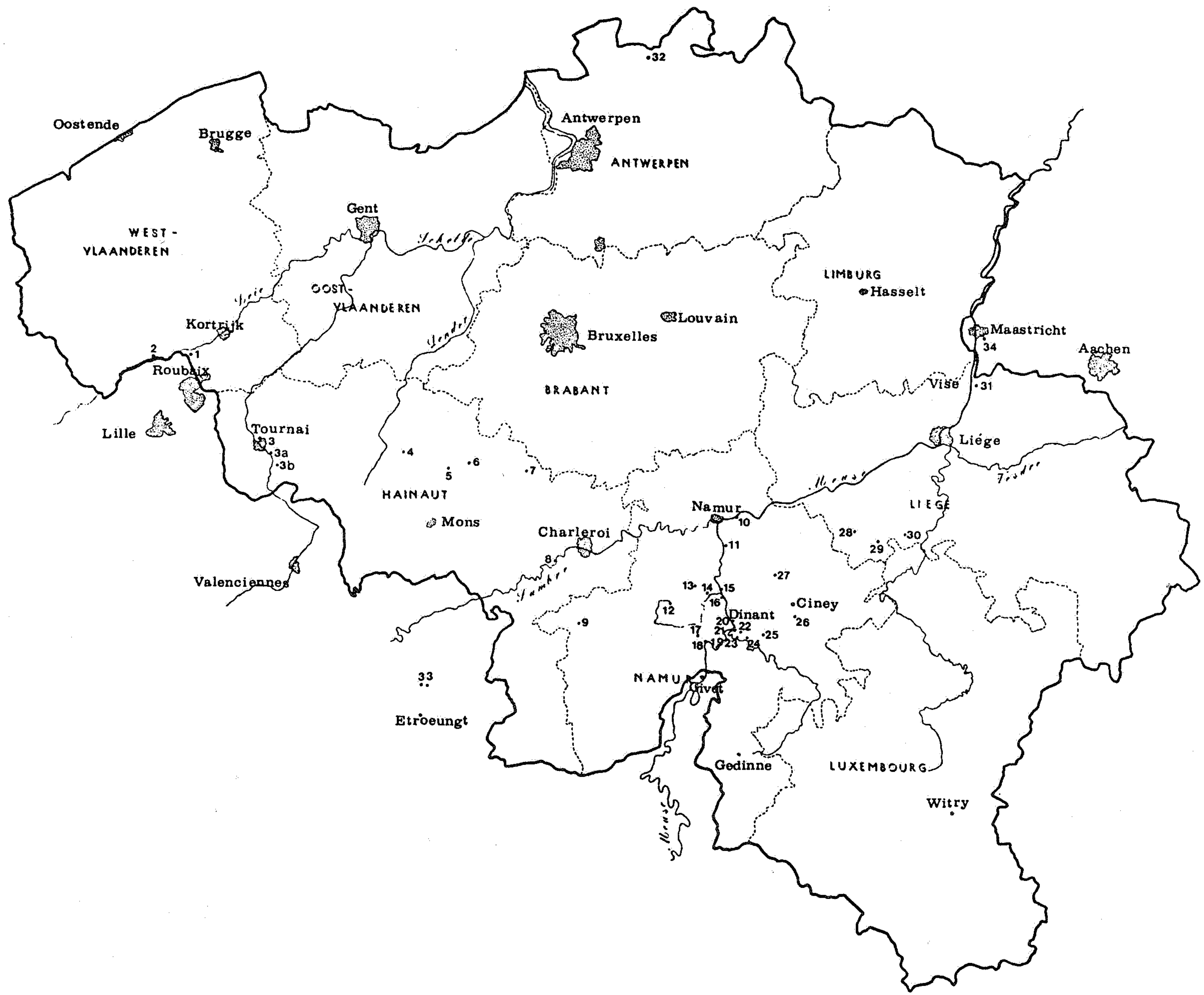
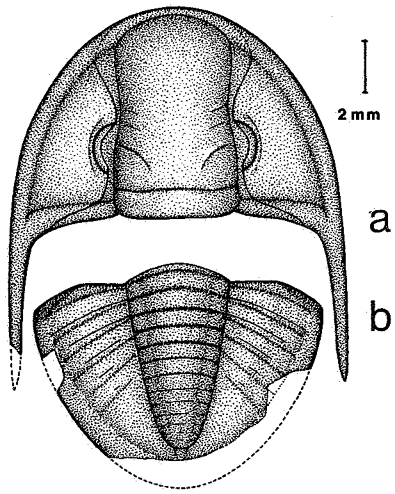
List of text-fig. 1. Drawings of Carboniferous Limestone trilobites given by de KONINCK (1842/44 : Pl. 53).

1. *"Phillipsia globiceps"* from Visé, probably *Griffithides (G.) acanthiceps* (see text-fig. 18a-b).
2. *"Phillipsia derbyensis"* from Visé and Soignies. The specimens from Visé may represent *Mahaiella belgica* (see text-fig. 19a-b), those of Soignies *Cummigella (C.) belisama* (see text-fig. 9a-d).
3, 4. *"Phillipsia gemmulifera"* from Tournai and Visé. This form is characterized by its spinous carapace It may refer to *Piltonia (P.) kuehnei* (see text-fig. 8a-b) or to *Phillipsia (Ph.) ornata ornata* (see text-fig. 10a-b).
5. *"Phillipsia pustulata* from Tournai. This pygidium probably also refers to *Phillipsia (Ph.) ornata ornata.*
6. *"Phillipsia jonesii"* from Visé. The thickened anterior bands fo the pleural ribs indicate that *Brachymetopus (Conimetopus) ornatus ornatus* is represented.
7. *"Phillipsia brongniarti"* from Visé. This pygidium with a smooth surface represents either *Mahaiella belgica* or *Cummigella (C.) carringtonensis carringtonensis* (see text-fig. 17 a-d).



Text-fig. 2. A geographic map of Belgium, showing the distribution of finding places of Carboniferous Limestone trilobites (numbered from 1 to 34). Explanation of the numbers see in tab. 1 - From G. HAHN, R. HAHN & BRAUCKMANN, 1988.



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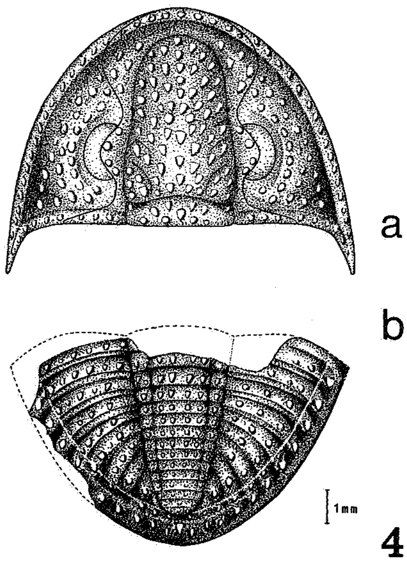

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Text-figs. 3-4. Characteristic trilobites of the Hastarian.
3. *Moschoglossis rhiannon* G. HAHN, R. HAHN & BRAUCKMANN, 1987. -- a) Cephalon. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1987, text-figs. 13 a-b.
4. *Piltonia (Piltonia) balor* G. HAHN, R. HAHN & BRAUCKMANN, 1987. -- a) Cephalon -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1987, text-figs. 8, 10.

Table 1. Compilation of the finding places of Carboniferous Limestone trilobites in Belgium and adjacent areas. Unnumbered finding places are not specified in text-fig. 2. From G. HAHN, R. HAHN & BRAUCKMANN, 1988, tab. 2.

A. BELGIUM

I. Province *West-Flanders*

1. Rekkem
2. Wervik

II. Province *Hainaut*

3. Tournai (3a : Vaulx ; 3b : Antoing ; -- : Allain)
4. Mévergnies
5. Neufvilles
6. Soignies
7. Feluy
8. Landelies

III. Province *Namur*

9. Walcourt
10. Lives (Meuse Valley)
11. Dave (Meuse Valley)
12. Ermeton-sur-Biert
13. Bioul
14. Warnant (Molignée Valley)
15. Yvoir (Meuse Valley)
16. Anhée (Meuse Valley)
17. Maurenne (Meuse Valley)
18. Hastière (Meuse Valley)
19. Waulsort (Meuse Valley)
20. Dinant (Meuse Valley)
21. Anseremme (Meuse Valley)
22. Dréhance (Meuse Valley)
23. Walzin (Lesse Valley)
24. Furfooz
25. Celles (incl. Gendron-Celles)
26. Leignon
27. Lez-Fontaine

-. Freyr (Meuse Valley)
-. Moniat (Molignée Valley, between Yvoir and Maredsous)
-. Pauquys (Meuse Valley)
-. Pont à Lesse (Lesse Valley)

IV. Province *Liège*

28. Modave (incl. Petit-Modave)
29. Clavier
30. Ouffet (incl. Petit-Ouffet)
31. Visé

-. Berwinne (Berwinne Valley near Visé)

V. Province *Antwerpen*

32. Heibaart-Loenhout

B. FRANCE

33. Avesnelles/Avesnoir

C. THE NETHERLANDS

34. Kastanjelaan

-. Grube Emma

D. FEDERAL REPUBLIC OF GERMANY (VELBERT ANTICLINE)

-. Heiligenhaus
-. Laupe bei Heiligenhaus
-. Ratingen
-. Sondern
-. Velbert

northern Belgium, finding places of trilobites are rare. In West-Flanders the bore-holes of Rekkem and Wervik must be stated, in the province of Antwerpen only the bore-hole of Heibaart-Loenhout has yielded trilobites. From East-Flanders, Brabant and Limburg trilobites are unknown.

BIOSTRATIGRAPHICAL DISTRIBUTION

Tabs. 2-3.

As base for the stratigraphical arrangement of the Carboniferous Limestone in Belgium, the subdivision in Hastarian + Ivorian (= Tournaisian) and Moliniacian + Livian + Warnantian (= Visean) is used here, as given in CONIL, GROESSENS & PIRLET, 1976 (p. 368-369) and again in PAPROTH *et al.*, 1983 (p. 188-189). In Great Britain, the Lower Carboniferous is subdivided into Courceyan (= Tournaisian) and Chadian + Arundian + Holkerian + Asbian + Brigantian (= Visean), see THOMAS, OWENS & RUSHTON, 1984 (fig. 29). In Germany, the sediments of the Kulm facies are subdivided into Balvian + Lower Erdbachien (= Tournaisian) and Upper Erdbachian + Aprathian (= Visean). The correlation of these three charts is given in CONIL, GROESSENS & PIRLET, 1976 (tab. 1) and again in PAPROTH *et al.*, 1983 (p. 186 - tab.). It is repeated here simplified in tab. 2. In Belgium, trilobites are spread from the base of the Hastarian up to the Lower Namurian. They are common in the Ivorian and the Warnantian, but they are extremely rare in the Moliniacian and the Livian. In tab. 3 are those taxa compiled, which are useful as index fossils. Complete charts of all taxa know from Belgium, subdivided stratigraphically, are given in G. HAHN, R. HAHN & BRAUCKMANN, 1988 - tabs. 4 (Hastarian), 5 (Ivorian), 9 (Moliniacian and Livian) and 10 (Warnantian).

Tab. 2. The stratigraphic subdivisions of the Lower Carboniferous in Belgium, Great Britain and Germany. From G. HAHN, R. HAHN & BRAUCKMANN, 1988, tab. 3.

Series	DEMANET 1958	recent subdivisions: Great Britain	Belgium	Germany
	V 3c	Brigantian	Warnantian	Aprathian
	V 3b	Asbian		
	V 3a	Holkerian	Livian	
Visean	V 2b			
	V 2a	Arundian	Moliniacian	
	V 1b			Erdbachian
	V 1a	Chadian		
	Tn 3c		Ivorian	
	Tn 3b			
	Tn 3a			
Tournaisian	Tn 2c	Courceyan	Hastarian	
	Tn 2b			
	Tn 2a			
	Tn 1b			Balvian

Hastarian assemblages

Text.-figs. 3-4.

In the succession of trilobites, the change from Devonian to Carboniferous is marked very distinctly by the extinction of the last Phacopidae and the beginning of the Cummingellinae, Phillipsiinae and other subfamilies of the Phillipsiidae. No species of *Phacops* enters the Carboniferous, as far as it is known today (following the Devonian/Carboniferous boundary between Tn 1a and Tn 1b).

The succession begins with the Tn 1b (Calcaire noir d'Avesnelles, Calcaire d'Hastière). Trilobites are rare. Only few specimens are known from Avesnelles, Hastière and Ermeton-sur-Biert. Two species are predominant : *Moschoglossis rhiannon* G. HAHN, R. HAHN & BRAUCKMANN, 1987 (text-figs. 3a-b) and *Piltonia (P.) balor* G. HAHN, R. HAHN & BRAUCKMANN, 1987 (text-figs. 4a-b). Both species are easily to distinguish : the first has a smooth carapace, the second is spinous. Only by a single cranidium know is *Archegonus (Phillibole) artaios* G. HAHN, R. HAHN & BRAUCKMANN, 1987 from Avesnelles. It is remarkable because it belongs to a subgenus bound usually to the Kulm facies.

In the Tn 2a (*peracuta* Shales) trilobites are more common than in the Tn 1b and known also from more finding places, especially in the Meuse Valley.

Limestone facies (Belgium)		
Warnantian	V 3c sup.	*P. (P.) maillieuxi*
Warnantian	V 3c inf.	*P. (P.) eichwaldi*
Warnantian	V 3b	*C. (C.) carringtonensis carringtonensis* *G. (G.) acanthiceps* *B. (Co.) ornatus*
Livian	V 3a V 2b	*Ling. matthewsi livesensis*
Moliniacian	V 2a V 1b V 1a	?
Ivorian	Tn 3c Tn 3b Tn 3a	*Phil. (Phil.) ornata* *C. (C.) belisama* *Pil. (Pil.) kuehnei* *P. (K.) arduennensis* *Ar. (Belg.) belgica* *B. (B.) maccoyi spinimarginatus*
Hastarian	Tn 2c Tn 2b	*M. decorata brevicauda*
Hastarian	Tn 2a Tn 1b	*M. rhiannon* *Pil. (Pil.) balor*

Kulm facies (Rhenish Slate Mountains)				
Aprathian	γ	*Ku. westphalica*		
Aprathian	β	*Ar. (Phb.) moravicus*		
Aprathian	α	*Ar. (Ar.) aequalis* *Ar. (Ar.) antecedens*	*Ar. (Phb.) aprathensis*	
Erdbachian	δ	*Ar. (Phb.) nehdenensis* *Li. (Li.) glabra bottkei*		ERDBACHER KALKE: *Ar. (Phb.) nitidus*, *Li. (Li.) glabra glabra*, *Li. (Li.) glabra hiemalis* (δ–β)
Erdbachian	γ	*Li. (S.) glabroides*		
Erdbachian	β			
Erdbachian	α	?		
Balvian		*Ar. (Phb.) drewerensis* *Liobolina*, *Diacoryphe*		

Tab. 3. The biostratigraphical subdivisions of the Lower Carboniferous by trilobites in the Belgian Limestone region and the German Kulm region (Rhenish Slate Mountains).

Abbrevations :

Ar. = *Archegonus*
B. = *Brachymetopus*
Belg. = *Belgibole*
C. = *Cummingella*
Co. = *Conimetopus*
G. = *Griffithides*
K. = *Kaskia*
Ku. = *Kulmiella*
Li. = *Liobole*
Ling. = *Linguaphillipsia*
M. = *Moschoglossis*
P. = *Paladin*
Phb. = *Phillibole*
Phil. = *Phillipsia*
Pil. = *Piltonia*
S. = *Sulcubole*

M. rhiannon and *P. (P.) balor* are further predominant : Tn 1b and Tn 2a are one unit biostratigraphically.

From Tn 2a to Tn 2b (Calcaire de Landelies) the trilobite fauna changes : *M. rhiannon* is substituted by *M. decorata brevicauda* GOLDRING, 1958, which has lost the long genal spines present in the older species. Otherwise, both taxa are very similar, and isolated pygidia (the most common part of the carapace found in the field) cannot be determined in each case with security. *Piltonia* is without importance in that time.

In the Tn 2c (Calcschistes de Maredsous) *M. d. brevicauda* continues to be the predominant taxon. A rare, but remarkable species of the Upper Hastarian is *Parvidumus maastrichtensis* (BRAUCKMANN, 1982) from a bore-hole of Kastanjelaan in Maastricht. *Parvidumus* is a genus originally confined to Japan. Its presence in Belgium demonstrates a free geographical interchange alongside the coast of the Palaeo-Tethys in that time.

A second species of *Parvidumus* is present in Belgium in the Ivorian

Ivorian assemblages

Text-figs. 5-15

From the Ivorian the richest trilobite faunas are known, in view of the number of species as well as in view of the number of individuals. They can be arranged very well bathymetrically, as is membered under "Ecology".

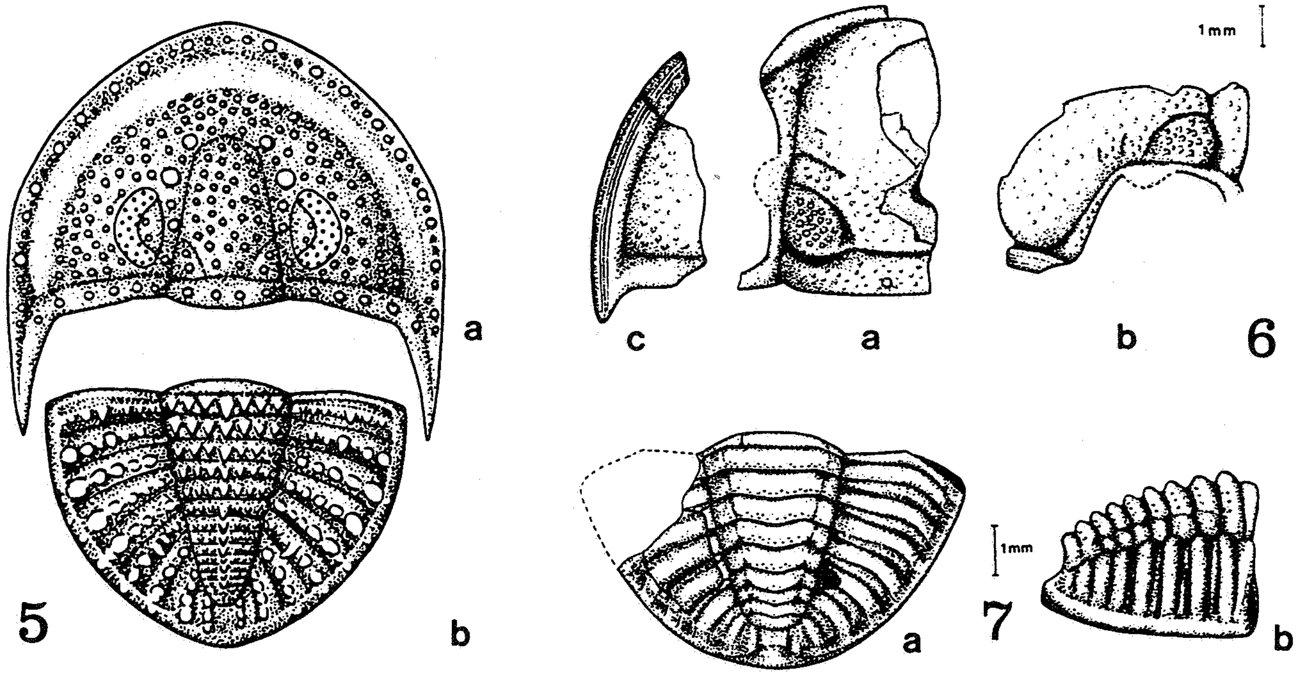
The most extreme shallow water assemblage is that of the "Waulsortian reefs", known from many outcrops in the Meuse Valley. Sixteen species are proved by their exuviae (moulting remains), but no complete specimen has been found. All taxa show large eyes which are placed on a socket and able to look upwards, forwards, backwards and sidewards. More than one thousand of lenses may compose one eye. The dominant genera are *Brachymetopus (Brachymetopus)* and *Pudoproetus*. *Brachymetopus* is widespread on the Carboniferous Limestone facies ; its most significant feature are the reduced facial sutures : fixed cheeks and free cheeks are melt. The glabella is small ; the surface of the carapace is spinous as in *Piltonia*. Among the three species known from the Waulsortian, the most important is *B.(B.) maccoyi spinimarginatus* G & R. HAHN, 1969 (text-figs. 5 a-b). *Pudoproetus* is known in West Europe only from Belgium, but in the Waulsortian it is proved by no less than five species. Diagnostic features are the large, highly vaulted glabella and the short pygidium with deeply incised rings and ribs (text-figs. 6-7). The carapace may be equipped with small nodes. Other, but rather rarely represented genera are *Bollandia*, *Cummingella*, *Griffithides* and *Phillipsia*. Today it is not possible to differ between the Ivorian and the Moliniacian parts of the Waulsortian complex by help of trilobites.

The "normal Carboniferous limestone", as known best from the Tournai region, is a characteristic example of the well enlighted, neritic zone. These platform carbonates represent usually remains of a soft ground, where trilobites were able to grub. This neritic trilobite community differs distinctly in its specific composition from that of the Waulsortian. The most abundant species are *Piltonia (P.) kuehnei* G. HAHN, 1964 (text-figs. 8 a-b), *Cummingella (C.) belisama* G. HAHN, R. HAHN & BRAUCKMANN, 1985 (text-figs. 9 a-d) (with three subspecies), *Phillipsia (Ph.) ornata* (PORTLOCK, 1843) (text-figs. 10 a-b) (with two subspecies) and *Paladin (Kaskia) arduennensis* G. & R. HAHN, 1968 (text-figs. 11 a-b). They all are more or less large-eyed, and from all completely preserved carapaces are present. This fauna was, from the region of Tournai, already known to de KONINCK. *Piltonia (P.) kuehnei* is a descendant of *P. (P.) balor* from the Lower Hastarian ; it differs from its ancestor chiefly by its larger pygidium with more rings and ribs. *Cummingella (C.) belisama* is characterized by its sand-glass shaped, in its middle part distinctly constricted glabella, its narrow fixed cheeks, very large, long eyes and reduced genal spines. The pygidium shows a distinctly separated border. The carapace is smooth. In *Phillipsia (Ph.) ornata* the glabella is parallel-sided, the pygidium is very long. Nodes on the carapace may be present (more distinct on the pygidium than on the cephalon), but they never are as coarse as in *Piltonia*. *Paladin (K.) arduennensis*, at last, differs from the other three taxa mainly by its pear-shaped glabella which is broadest anteriorly. The pygidium resembles that of *Cummingella*. It may be mentioned that, as a rarety, a second species of the Japanese *Parvidumus* is known from the Ivorian of Milieu near Tournai, *P. cernunnos* G. HAHN, R. HAHN & BRAUCKMANN, 1984. A subdivision of the Ivorian Limestone into Tn 3a-c is not possible by help of trilobites.

The third bathymetrical zone characterizes the transition from the neritic shelf region to the bathyal Kulm basin. The platform carbonates are replaced by limestones that were deposited by turbidity currents (FRANKE *et al.*, 1975). Geographically, the outcrops of this zone are confined to W-Germany (Velbert Anticline), at last as far as they have yielded trilobites. Stratigraphically, they are confined to the Middle Erdbachian (cu IIβ-γ).

This shelf slope region is characterized by its muddy water and decrease of light, and a decline of taxonomic diversity among trilobites should be expected. But, in contrast to this supposal, a very rich trilobite fauna has been found, composed of more than one dozen of species. This assemblage is a mixture of limestone taxa and Kulm taxa. Important representatives of the limestone fauna are several species of *Bollandia (Bollandia)* (text-figs. 12 a-g) and *Griffithidella (Rhenogriffides)* (text-figs. 13 a-c). *Bollandia* is easily to distinguish by its extremely vaulted glabella. *Griffithidella (Rhenogriffides)* is similar to *Paladin*, but its glabella is only little broadened anteriorly. Characteristic Kulm representants in this shelf slope fauna are *Archegonus (Belgibole)* (text-figs. 14 a-b) and *A. (Latibole)* (text-figs. 15 a-b). These Kulm trilobites differ from the limestone taxa above all by their flat glabella and small eyes with a reduced number of lenses. The eyes were sunk down more or less into the cheek, being able only to look upwards. Most of these animals have spent their days probably in the upper portion of the sediment. Unexpectedly, also few specimens of *B. (B.) maccoyi spinimarginatus* have come to light in Ratingen. They perhaps have sloped down from the adjacent neritic area. But it must be added that two other species of *Brachymetopus* are present in the Velbert Anticline, which have never been found in the neritic or the Waulsortian sediments.

An ecological problem represents the outcrop of Petit-Modave in the province of Liège. It is very rich in trilobites (see G.HAHN, R. HAHN & BRAUCKMANN, 1988 - tab. 5). Besides some endemic taxa, it shows a mixture of forms from different bathymetrical zones. *Brachymetopus (B.) mac-*



Text-figs. 5-7. Characteristic trilobites of the Waulsortian.
5. *Brachymetopus (Brachymetopus) maccoyi spinimarginatus* G. & R. HAHN, 1969. -- a) Cephalon. -- b) Pygidium. -- From G. & R. HAHN, 1975 (pl. 9 figs. 4 a-b).
6. *Pudoproetus teutates* G. HAHN, R. HAHN & BRAUCKMANN, 1980. -- a) Cranidium, dorsal view. -- b) Cranidium, side view. -- c) Free cheek, dorsal view. From G. HAHN, R. HAHN & BRAUCKMANN, 1980 (text-figs. 1-2).
7. *Pudoproetus incertus* G. HAHN, R. HAHN & BRAUCKMANN, 1980. -- a) Pygidium, dorsal view. -- b) Pygidium, side view. From G. HAHN, R. HAHN & BRAUCKMANN, 1980 (text-figs. 5 a-b).

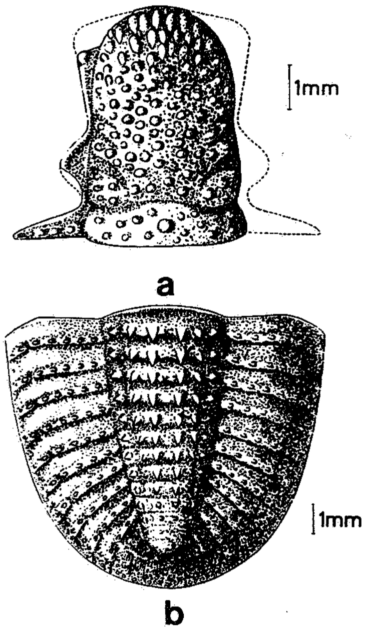
coyi spinimarginatus (very abundant) and *Phillipsia (Ph.) gemmulifera* are known from the Waulsortian. *Piltonia (P.) kuehnei, Paladin (K.) arduennensis* and *Cummingella (C.) belisama* are known from the neritic sediments of Tournai. And *Archegonus (B.) belt gicus* (the most abundant species of all, see text-figs. 14 a-b) is immigrated from the shelf slope region, representing a Kulm component. The reasons of this peculiar faunal mixture is unknown.

The fourth bathymetrical zone (not represented in Belgium) is that of the "Erdbacher Kalk". It is deposited amid the Kulm basin on sills mostly above older Devonian reefs ("Tiefschwellen"), and it is fossileferous. About twenty species of trilobites are known today. Typical Kulm taxa as *Liebole, Archegonus (Phillibole)* and *A. (Waribole)* are predominant, but three species of limestone trilobites are still present : *Cummingella (C.) auge* G. & R. HAHN, 1968, *Bollandia (B.) megaira* (G. & R. HAHN, 1970) and *B.(B.) persephone* (G. & R. HAHN, 1970) known each by relatively few specimens. These forms have immigrated the Kulm basin probably by drifting larvae. They were able to survive in that foreign habitat, evolving new species as a result of geographical isolation.

The last bathymetrical zone is that of the real Kulm shales. During the Erdbachian, these shales are hostile to benthonic life, because of the concentration of silicic acid. But at the beginning of the Aprathian, with reduction of silicic acid, a rich benthonic fauna evolves, among them many trilobites, especially of *Archegonus (Archegonus)* and *A. (Phillibole)*. In a dark mud, with only little oxygen in it, trilobites were flourishing, feeding on the masses of organic rubbish, accumulated in that mud. All these trilobites were flat animals with small eyes, but only very few of them were completely blind. This indicates that at least a little twilight must be left over also in this surrounding : the bottom of the Kulm sea was neither free of oxygen nor completely free of light, at least not in all its part.

Moliniacian and Livian assemblages

Text-fig. 16.



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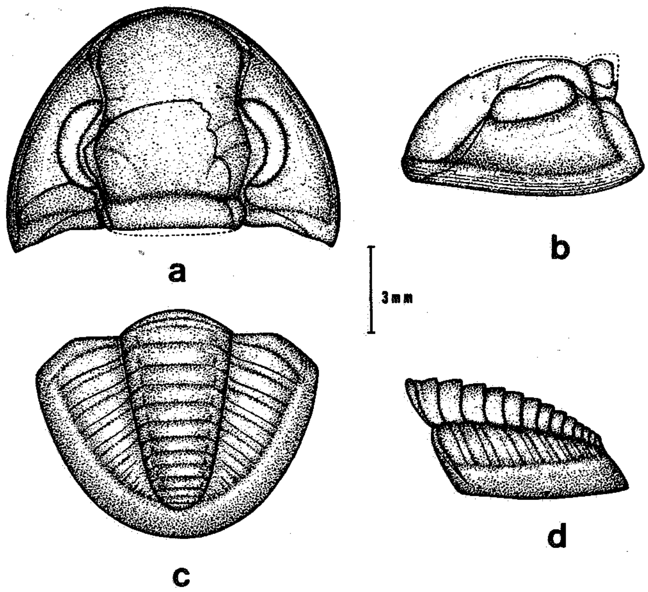

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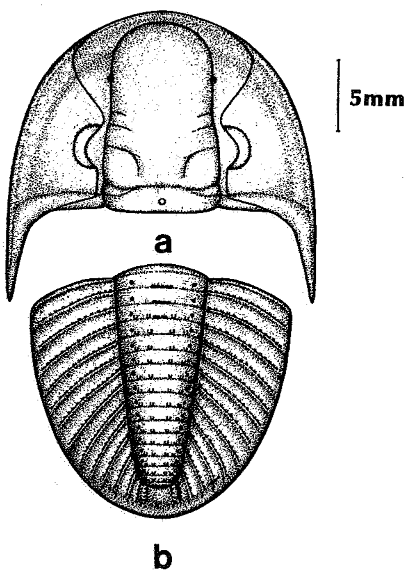

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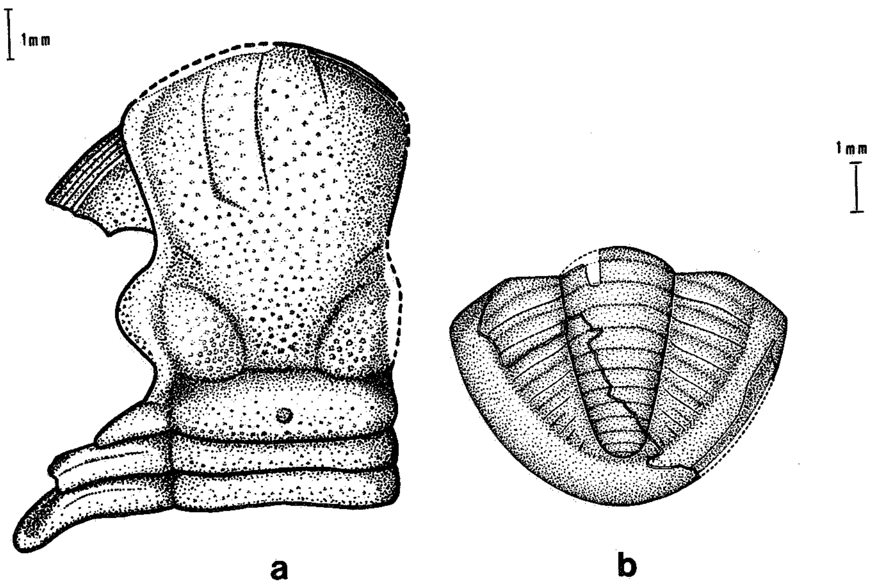

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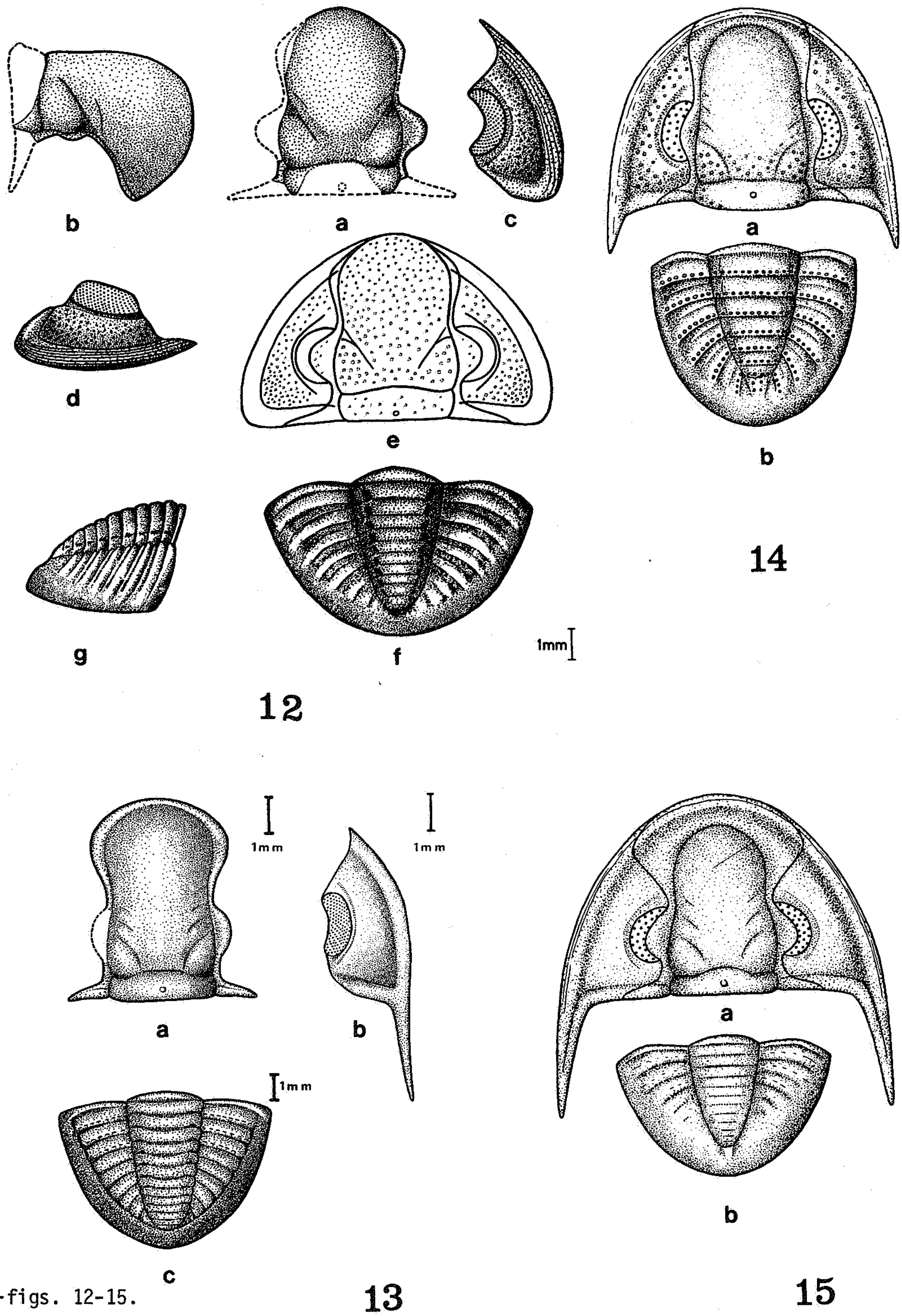
Text-figs. 8-11.

Characteristic trilobites of the neritic platform carbonates of the Ivorian.
8. *Piltonia (Piltonia) kuehnei* G. HAHN, 1964. -- a) Cranidium. -- b) Pygidium. From G. HAHN, 1964 (text-figs. 5 a-b).
9. *Cummingella (Cummingella) belisama belisama* G. HAHN, R. HAHN & BRAUCKMANN, 1985. -- a) Cephalon, dorsal view. --b) Cephalon, side view. -- c) Pygidium, dorsal view. -- d) Pygidium, side view. From G. HAHN, R. HAHN & BRAUCKMANN, 1985 (text-figs. 4 a-d).
10. *Phillipsia (Phillipsia) ornata ornata* PORTLOCK, 1843. -- a) Cephalon. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1982 (text-figs. 11 c-d).
11. *Paladin (Kaskia) arduennensis* G. & R. HAHN, 1968. -- a) Cranidium. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1986 (text-figs. 13, 14 a).

In the Moliniacian and the Livian, trilobites are extremely rare in Belgium. Only six species are known. It is very interesting to state, that at the same time (Chadian, Arundian, Holkerian) also in Great Britain only few species are present, in comparison with the rich faunas of the Upper Tournaisian and the Asbian (see THOMAS *et al.*, 1984 - text-fig. 29).

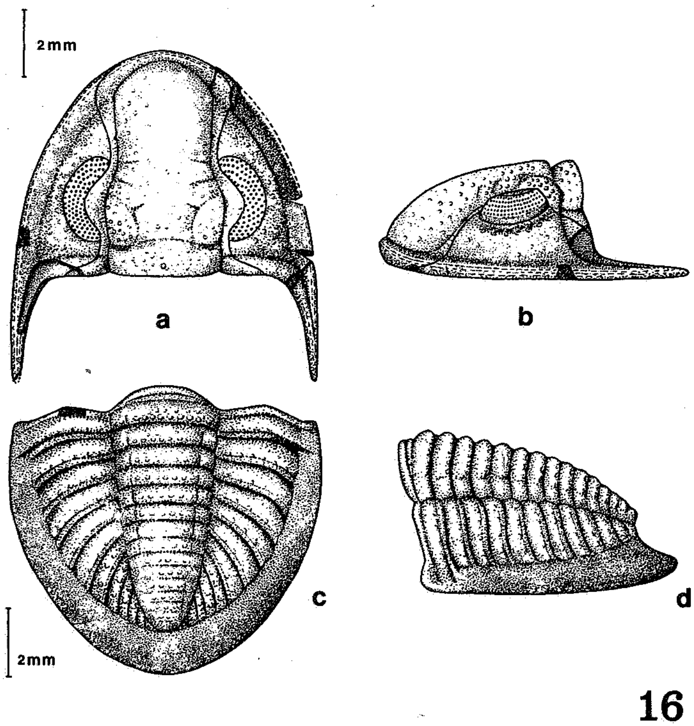
From the Lower Moliniacian (V 1a,



Text-figs. 12-15.

Characteristic trilobites of the "shelf slope" fauna from the Velbert Anticline and from Modave.
12. *Bollandia (Bollandia) tisiphone* (G. & R. HAHN, 1970). -- a) Cranidium, dorsal view. -- b) Cranidium, side view. -- c) Free cheek, dorsal view. -- d) Free cheek, side view. -- e) Cephalon, reconstruction. -- f) Pygidium, dorsal view. -- g) Pygidium, side view. From G. & R. HAHN, 1971 (text-figs. 4-7).
13. *Griffithidella (Rhenogriffides) dalmani* (EMMRICH, 1839). -- a) Cranidium. -- b) Free cheek. -- c) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1986 (text-figs. 4-6).
14. *Archegonus (Belgibole) belgicus* (G. HAHN, 1963). -- a) Cephalon. -- b) Pygidium. From G. & R. HAHN, 1975 (pl. 8 - figs. 6 a-b).
15. *Archegonus (Latibole) paprothae* G. & R. HAHN, 1969. -- a) Cephalon. -- b) Pygidium. From G. & R. HAHN, 1975 (pl. 8 - figs. 2 a-b).

Text-fig. 16. *Linguaphillipsia matthewsi livesensis* G. & R. HAHN, 1982, characterizing the Livian.
-- a) Cephalon, dorsal view.
-- b) Cephalon, side view.
-- c) Pygidium, dorsal view.
-- d) Pygidium, side view.
From G. & R. HAHN, 1982 (text-figs. 1-2).



Marbre noir) only one species is known, *Carbonocoryphe (Winterbergia) ogmios* G. HAHN, R. HAHN & BRAUCKMANN, 1980, from Walcourt From the Middle Moliniacian (V 1b, Calcaire de Sovet), two trilobite bearing outcrops are known : Leignon near Ciney with *Moschoglossis moccus* G. HAHN, R. HAHN & BRAUCKMANN, 1985 and Walzin in the Meuse Valley with *Bollandia (B.) frechi frechi* (SCUPIN, 1900). From the Upper Moliniacian (V 2a, Calcaire de Neffe), again only one taxon is known, *Cummingella (C.) jonesii jonesii* (PORTLOCK, 1843) from Heiligenhaus in W-Germany. With that, the trilobite fauna of the Moliniacian is so scanty that it is impossible for the present to designate an index fossil.

Linguaphillipsia matthewsi livesensis G. & R. HAHN, 1982, is the only trilobite taxon known from the Livian today (V 2b of Lives). The closely related type subspecies, *L. m. matthewsi* G. & R. HAHN, 1973, is present at the same time in Great Britain. A third subspecies, *L. m. damona* G. HAHN, R. HAHN & BRAUCKMANN, 1987, comes from the Meuse Valley. It has been found in an old collection, and the exact stratigraphical age and the finding place are unknown. With some reservation, *L. matthewsi* can be used as index fossil for the Livian (text-fig. 16 a-d).

Warantian and Upper Carboniferous assemblages

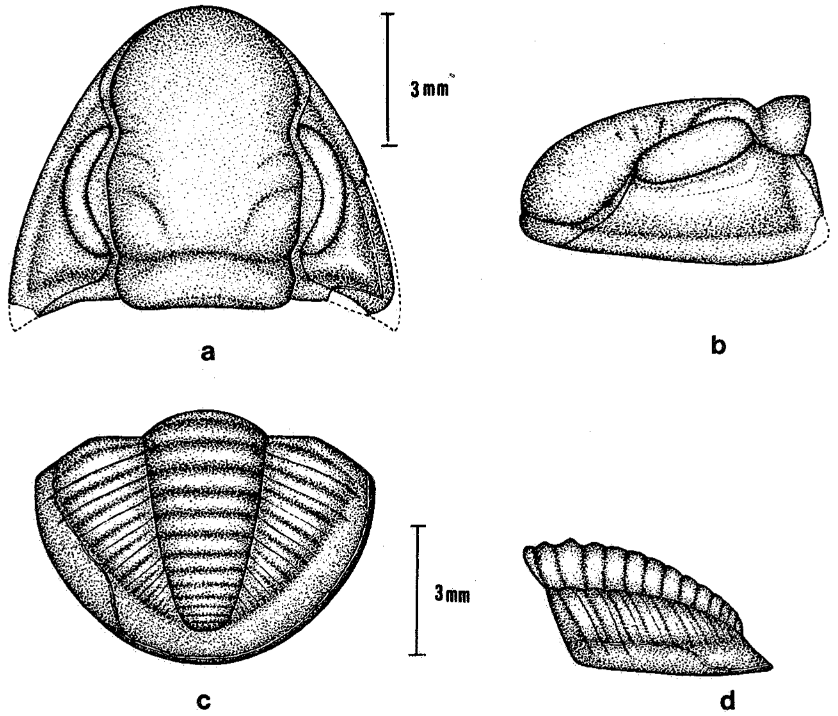
Text-figs. 17-22

In contrast to the Moliniacian and Livian trilobites are in the Warnantian abundant again. From the Lower Warnantian (V 3b, Calcaire de Visé) about a dozen of species is known (see G. HAHN, R. HAHN & BRAUCKMANN, 1988 - tab. 10). But most of them are known from only one small area, the quarries of Richelle south of Visé. As it is said under "Geographical distribution", these quarries are closed now, and it is impossible to collect there trilobites today. The rich old collections, stored in museums and institutes, do not allow to check up on their exact stratigraphical assigment in the field. Therefore, detailed discussions have happened about this question in the last decades (PIRLET, 1967). The trilobites themselves help to solve this problem !

The predominant taxa in Richelle are *Cummingella (C.) carringtonensis carringtonensis* (ETHERIDGE, 1884) (text-figs. 17 a-d), *Griffithides (G.) acanthiceps* WOODWARD, 1883 (text-figs. 18 a-b) and *Mahaiella belgica* (WEBER, 1937) (text-figs. 19 a-b). The first and the second of these taxa are well known from the Asbian reef facies of Great Britain. Other species, also known from the Asbian of Great Britain and the Visean of Richelle (but not predominant there) are *Brachymetopus (Conimetopus) ornatus ornatus* WOODWARD, 1884 (text-fig. 20), *Bollandia (B.) obsoleta* (PHILLIPS, 1836) and *Cyrtoproetus (C.) cracoensis* (REED, 1899). *Mahaiella belgica* as well as *Brachymetopus (Conimetopus) ouralicus esus* G. & R. HAHN, 1982 and *B.(C.) bormanus* G. HAHN, R. HAHN & BRAUCKMANN, 1987, are endemic taxa, known only from Richelle. One species shows geographical connection only to East Europe ; this is *Linguaphillipsia* cf. *silesiaca* (SCUPIN, 1900). The remaining taxa cannot definitely grouped taxonomically. This list shows clearly that the trilobite fauna of Richelle is very closely related to that of the British Asbian. It shows moreover that it is a shallow water community that has lived in Great Britain in reef-like environments. Similar ecological conditions must have been present at least for a short time also in Richelle, when our trilobite fauna was existing! By that it follows that in Belgium, as in Great Britain, two shallow water periods with reef-like environments were present locally, in the Upper Tournaisian and the Middle Visean.

The frequent trilobite taxa of Richelle are easily to distinguish. *Cummingella (C.) carringtonensis carringtonensis* is again characterized by its sand-glass shaped glabella, narrow fixed cheeks and long eyes. Eyes and palpebral lobes are longer than in *C. (C.) belisama,* the constriction of the glabella is situated more anteriorly. *Griffithides (G.) acanthiceps* shows a heavily vaulted anterior part of the glabella, distinctly expressed lateral preoccipital lobes, relatively small eyes and, on the pygidium, reduced posterior bands of the pleural ribs. The most characteristic feature of *Mahaiella belgica* are its tiny dimensions. The whole carapace is not longer than 2 cm. The glabella is nearly parallel-sided, the pygidium is short, the surface of the carapace is occupied by small nodes. The type species of *Mahaiella* has been found in the Visean of China (province of Guangxi). This proves that in the Visean as in the Tournaisian trilobites were able to move from Europe to East Asia (or vice versa) alongside the coasts of the Palaeo-Tethys. *Brachymetopus (C.) ornatus ornatus* at last, is characterized above all by its very small, conical glabella and crescentic eyes. The facial sutures are, as usually in *Brachymetopus*, coalesced ; they were no longer, as normal in trilobites, a help in moulting.

In the Upper Warnantian (V 3c, Cou-



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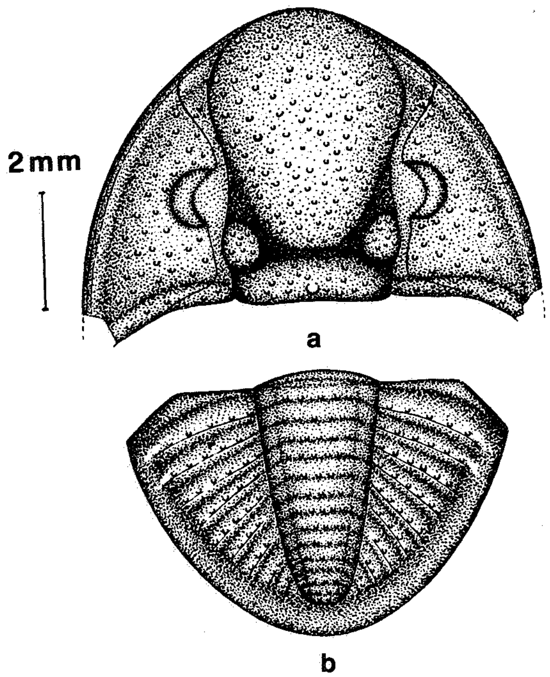

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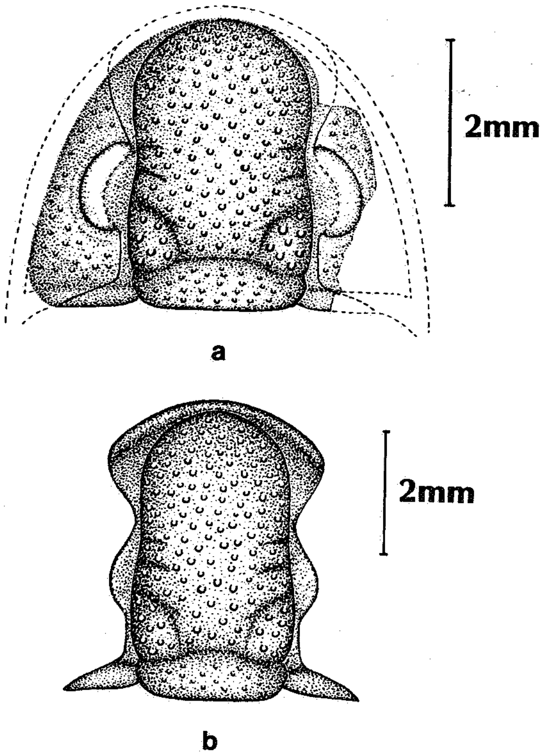
Text-figs. 17-18. Characteristic trilobites of the Lower Warnantian.
17. *Cummingella (Cummingella) carringtonensis carringtonensis* (ETHERIDGE, 1884). -- a) Cephalon, dorsal view. -- b) Cephalon, side view. -- c) Pygidium, dorsal view. -- d) Pygidium, side view. From G. HAHN, R. HAHN & BRAUCKMANN, 1985 (text-figs. 12-13).
18. *Griffithides (Griffithides) acanthiceps* WOODWARD, 1883. -- a) Cephalon. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1983 (text-figs. 3a, 3c).



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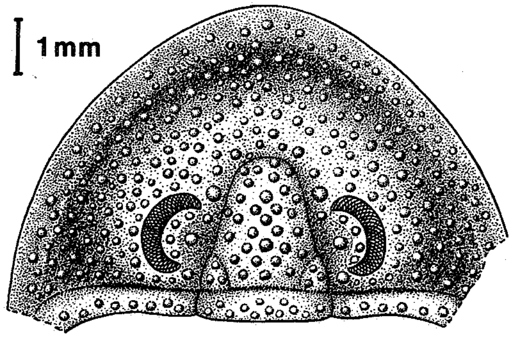

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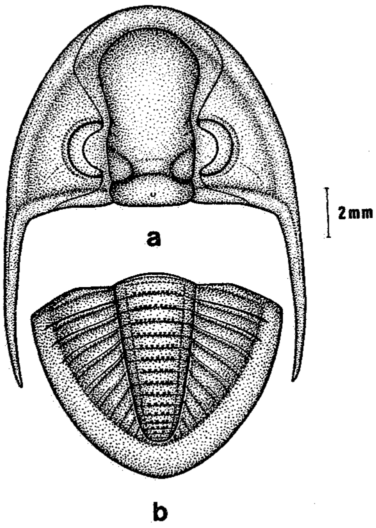
Text-figs. 19-20. Characteristic trilobites of the Lower Warnantian. 19. *Mahaiella belgica* (V. N. WEBER, 1937). -- a) Cephalon. -- b) Cranidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1986 (text-figs. 2-3). 20. *Brachymetopus (Conimetopus) ornatus ornatus* WOODWARD, 1884. -- Cephalon. From G. & R. HAHN, 1982 (text-fig. 3).

ches de passage) and the Lowermost Namurian, the character of the sediments alters slowly. Slaty rocks become more and more frequent, and in correlation with that the trilobite fauna changes markedly. The diversity of genera, known from the Lower Warnantian, disappears, and a monotonous assemblages of *Paladin* species occurs. In the lower part of the Upper Warnantian (V 3c inf.) *Paladin (P.) eichwaldi* (FISCHER de WALDHEIM, 1825), known only by isolated pygidia, is present. In the upper part of the Warnantian (V 3c sup.) *P. (P.) maillieuxi* (DEMANET, 1938) (text-figs. 21 a-b) dominates, and in the Lowermost Namurian (Lower Arnsbergian, Nm 1b moyen) *P. (P.) serotinus* (DEMANET, 1941) (text-fig. 22 a-b) is the last member of the trilobite succession. The species of *P. (Paladin)* are characterized by a relatively flat, anteriorly broadened glabella, broad anterior part of the fixigenae and long genal spines ; their pygidium is more or less triangular in shape and shows a very well marked border. Finding places of Upper Warnantian trilobites are confined to the eastern part of Belgium : regions of Bioul, Warnant, Clavier, Modave and Yvoir. *P. (P.) serotinus* is confined to Anhée in the region of Bioul.

In strata younger than the Lower Namurian, only one finding place of trilobites is known : the coal-pit "Emma" in the province of Limburg, southern Netherlands. It has yielded some remains of a species described as *"Griffithides* sp.*"* in the older literature, but better grouped with *Ditomopyge* now. These remains have been found in the Westphalian C ("Wn 3a = Horizon marin de Petit-Busson à *Anthracoceras aegiranum*"). Perhaps the same species is known from strata of the same age from Great Britain.



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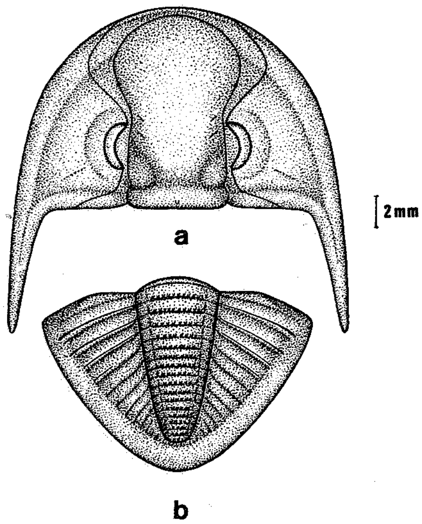

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Text-figs. 21-22. Characteristic trilobites of the Upper Warnantian and the Lowermost Namurian.
21. *Paladin (Paladin) maillieuxi* (DEMANET, 1938), Upper Warnantian (V 3c sup.) -- a) Cephalon. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1986 (text-figs. 8 a-b).
22. *Paladin (Paladin) serotinus* (DEMANET, 1941), Lowermost Namurian (Nm 1 b moyen). -- a) Cephalon. -- b) Pygidium. From G. HAHN, R. HAHN & BRAUCKMANN, 1986 (text-figs. 9 a-b).

COMPARISONS WITH KULM ASSEMBLAGES

Tab. 2-3

As it is discussed under "Ecology", Carboniferous trilobites are bound facially. The assemblages of the limestone facies and those of the Kulm shales differ completely of each other, and in no stratigraphical unit the index-fossils are identical. This should be explained by a comparison with the assemblages of the Rhenish Slate Mountains, that region, where the trilobite succession is best known of all Kulm areas. In tab. 2 this comparison is presented graphically.

The stratigraphical oldest trilobite community of the Rhenish Slate Mountains is that of the Balvian Hangenberg-Kalk. It corresponds to the Lower Hastarian (Tn 1b) of Belgium. The Balvian fauna is much reacher in species than that of the Tn 1b. Among a dozen of species, *Archegonus (Phillibole) drewerensis* RUD. & E. RICHTER, 1951 and species of *Liobolina* are predominant. *Piltonia* and *Moschoglossis* are completely missing. Only in *Archegonus (Phillibole) artaios* from Avesnelles, a weak connection is given, not enough for a stratigraphical correlation.

The Upper Hastarian and the Ivorian correspond to the Lower Erdbachian (cu II α - β). In that time lydites and other silicious sediments are sedimentated in the Kulm basin which are free from trilobites. At the end of that time the first Erdbacher Kalke occur. These sediments reach the maximum of their distribution in the cu II γ which corresponds to the Moliniacian. The Erdbacher Kalke have yielded a very rich Kulm assemblage with species of *Liobole* and *Archegonus* as most important representants, but with few limestone taxa also present (see :). A detailed comparison with the limestone assemblages is again difficult, because of the fact that the trilobites of the Moliniacian are very inadequately known. In the silty sediments of the Erdbachian the SiO_2 slowly decreases now, and the first trilobites come back, but being very rare for the present. *Liobole (Sulcubole) glabroides* (RUD. & E. RICHTER, 1949) is dominating.

The Upper Erdbachian (cu IIδ) corresponds mainly to the Livian. The Erdbacher Kalke are declining, but in the now only little silicious schists and limestones, a new trilobite assemblage begins to flower. It is a typical Kulm fauna with no one representative of the limestone facies in it. Predominant taxa are *Archegonus (Phillibole) nehdenensis* G. & R. HAHN, 1969, *Liobole (Liobole) glabra bottkei* G. & R. HAHN, 1969, and *Spinibole (Sp.) ruethenensis* G. & R. HAHN, 1969. *Linguaphillipsia* is not present in this assemblage.

In the Lower Aprathian a maximum of trilobite taxa is present in the limestone facies as well as in the Kulm facies. Again we see that no correspondance exists. In the V 3b species of *Cummingella*, *Griffithides* and *Brachymetopus* are dominating, in the "*Posidonia* Shales" species of *Archegonus (Archegonus), A. (Phillibole)* and of the Cystispininae with swollen genal spines are the most important taxa. In the Middle Aprathian (cu $II\beta$) as well as in the corresponding V 3c the trilobite fauna declines and has become very poor specifically in comparison with the Lower Aprathian and the Lower Warnantian. *Paladin (P.) eichwaldi* respectively *Archegonus (Phillibole) moravicus* (PŘIBYL, 1950) are the only common species each. They belong to different subfamilies and have nothing else in common.

At the end of the Lower Carboniferous and at the beginning of the Namurian, both facies areas get closer to each other, as far as trilobites are compared. They do not correspond completely, but at first closely related genera (in the Upper Warnantian = Upper Aprathian) and then even species of the same genus (in the Lowermost Namurian) occur. *Kulmiella westphalica* (NEBE, 1911) = *K. leei* (WOODWARD, 1884), the index fossil of the Upper Aprathian, differs from *Paladin* by lost of its eyes. *Paladin (P.) pitzi* G. & R. HAHN, 1968, the index fossil of the Lowermost Namurian in the Rhenish Slate Mountains, differs from *P. (P.) serotinus* only by details of the glabella shape and the course of the facial sutures. With that, trilobites disappear in both facial regions.

SUMMARY

The Carboniferous trilobites of Belgium and Germany can be grouped in five communities which depend above all on bathymetrical conditions in the sea (RAMSBOTTOM 1978) : 1) the shallow water community, known from reefs and reef-like structures ; 2) the "normal" neritic shelf community ; 3) the shelf slope community ; 4) the community of the Erdbacher Kalke, deposited on sills in the Kulm basin and 5) the bathyal community of the Kulm shales. The communities 1 and 2 represents the "limestone trilobites", which are characterized by large eyes and a more or less heavily inflated glabella ; important genera are *Brachymetopus, Phillipsia, Cummingella, Griffithides* and *Paladin*. The community 5 represents the typical Kulm trilobites with a flat glabella and small eyes ; the most important taxa are *Archegonus, Liobolina, Liobole* and the Cystispininae. The community 3 is mixed by about 50 % limestone taxa and 50 % Kulm taxa. In community 4 Kulm taxa are predominant, but limestone taxa are not completey missing.

The first community is represented in Belgium by the reef-like sediments of the Waulsortian in the Ivorian and again in the Middle Visean (Lower Warnantian = Asbian) in the succession found in Richelle near Visé. The trilobites of the second community are wide spread on the whole Belgian limestone area ; they are the base of the biostratigraphical diagram given in tab. 2 Both communities consist only of limestones trilobites as characterizes above. The third community is restricted geographically to the region of the Velbert Anticline in W-Germany and stratigraphically to the Middle Erdbachian (cu $II\beta$-γ). Community 4 and 5 are not represented in Belgium. With trilobites of community 5 the Kulm sediments are subdivided biostratigraphically (see tab. 2).

In the Carboniferous Limestone of Belgium, maxima of trilobite occurrence are found in the Ivorian and in the Lower Warnantian. Less abundant are trilobites in the Hastarian and the Upper Warnantian, and very rare they are in the Moliniacian and the Livian. By help of species belonging to *Piltonia, Phillipsia, Mochoglossis, Cummingella, Linguaphillipsia, Paladin* and *Brachymetopus*, a biostratigraphical subdivision can be elaborated, as given in tab. 2. The long known genera *Phillipsia* and *Griffithides* are, restricted in a modern sense, confined to only few species, which are important in the Ivorian respectively the Lower Warnantian biostratigraphically.

In tab. 2, the biostratigraphical subdivision of the Kulm sediments (Rhenish Slate Mountains) is confronted with that of the limestone facies. It is shown that no correspondance exists. The main trilobite assemblages differ completely in both regions. Only in the shelf slope area they are mixed : some of the limestone taxa were crawling down the slope, whereas others from the Kulm basin, as *Archegonus (Belgibole)*, were crawling it up, till both groups met one another.

Besides this one exception, immigrations from one region into the other have happened very seldom. In the Ivorian, crawling up the shelf slope, *Archegonus (Belgibole)* was penetrating the neritic region and spread geographically up to the region of Modave, where *A. (B.) belgicus* is abundant. Reversally, the larvae of few *Bollandia* and *Cummingella* species have been drifted into the Kulm basin, where they were able to settle on the Erdbacher Kalke in the midst of the Kulm trilobite fauna.

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