BIO- AND LITHOSTRATIGRAPHIC SUBDIVISIONS OF THE SILESIAN IN BELGIUM, A REVIEW[1]

by

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(12 figures, 6 tables and 1 plate)

RESUME.- Un regain d'intérêt pour l'étude du Silésien (Namurien et Westphalien) en Belgique a entraîné une révision des échelles bio- et lithostratigraphiques. Il en résulte de nouveaux tableaux stratigraphiques. Ils représentent l'état actuel des connaissances et peuvent être considérés comme une base de développement futur des recherches. Un raffinement ultérieur des différentes zonations est aussi possible.

Les corrélations avec les stratotypes britanniques du Namurien sont basées sur les goniatites. La succession des goniatites du Namurien inférieur montre des lignées de nature phylogénétique. De tels lignées ne peuvent être identifiés si facilement dans le Namurien supérieur où les goniatites sont présentes seulement pendant des incursions marines de courte durée.

La microfaune marine (conodontes et foraminifères) est moins bien développée dans les dépôts belges du Silésien. On peut la comparer avec la biozonation en usage international mais une subdivision détaillée basée sur les conodontes, les foraminifères ou les ostracodes va au-delà des intentions du présent travail.

Généralement, les corrélations avec les stratotypes allemands du Westphalien sont fondées sur l'existence d'horizons marins `isochrones" qui constituent la trame des subdivisions de la série westphalienne, même quand les faunes ne sont pas très typiques (à l'exception de la base de l'étage Westphalien D qui est défini par la première apparition d'une plante fossile).

Des `tonsteins" supposés d'origine volcanique peuvent fournir un autre moyen de corrélations isochrones entre les bassins.

Des zones d'`assemblage" (parfois nouvellement définies) basées sur les lamellibranches non-marins, la mégaflore, les mégaspores et les miospores permettent d'utiliser les groupes fossiles les plus abondants dans des environnements sédimentaires paraliques, aux fins de corrélations et comparaisons avec les zonations standards. Des groupes fossiles moins importants pour cet objectif tels que les ostracodes, les arthropodes et les poissons sont brièvement cités.

Le développement lithologique des séquences silésiennes est illustré par une série de coupes qui se recouvrent partiellement. Elles ont été sélectionnées à cause de leur lithologie et/ou parce que leurs contenus en fossiles ont été étudiés récemment, et/ou parce qu'il reste des échantillons en nombre suffisant pour des recherches ultérieures.

Une nouvelle subdivision lithostratigraphique est proposée qui devrait se substituer aux `zones" actuellement en usage et dont les limites coïncident avec des limites d'étages et de sous-étages mais sont souvent employées dans un sens lithostratigraphique. La subdivision lithostratigraphique proposée est basée sur des changements sédimentaires majeurs et ses limites correspondent à des événements bien décrits.

ABSTRACT.- Renewed interest in the Silesian (Namurian-Westphalian) deposits in Belgium has prompted a revision of the bio- and lithostratigraphic scales. This has resulted in new stratigraphic charts. These represent the actual state of knowledge and may be considered as a basis for further research. There is no doubt that these will be improved by further exploration. Also a refinement of the different zonations may be possible.

Correlations with British Namurian stratotypes are based on goniatites. The lower Namurian goniatite succession shows phylogenetical lineages. Such lineages cannot be recognized so easily in the upper Namurian where goniatites appear only during short-lived marine incursions. The marine microfauna (conodonts and foraminifera) is less well developed in the Belgian Silesian deposits. Comparison can be made with international biozonations. But a detailed biozonal subdivision based on conodonts, foraminifera or ostracodes is beyond the scope of the present paper.

Generally, correlations with German Westphalian stratotypes are based on `` isochronous" marine horizons which form the basic framework for the subdivision of the Westphalian series even when marine faunas are rather untypical (with the exception of the base of the Westphalian D stage, defined by the first appearance of a plant fossil). Presuma-b bly volcanic tonsteins may provide an additional way of isochronous interbasin correlations.

Assemblage-zones (sometimes newly defined) of non-marine lamellibranchs, megaflora, megaspores and miospores allow the utilisation of the most abundant fossil groups in paralic sedimentary environments for correlation and comparison with the standard zonations. Less important fossil groups for this tool such as ostracodes, arthropodes and fishes are briefly commented.

The lithological development of Silesian sequences is illustrated by a number of stratigraphically overlapping sections. These have been selected because their lithology and/or fossil contents had been investigated recently and/or because of the fact that sufficient rock samples are available for further research.

A new lithostratigraphic subdivision is proposed, which should substitute the actually used `` zones" whose limits coincide with stage and substage limits but are often used in a lithostratigraphic sense. The proposed lithostratigraphic subdivision is based on major sedimentary changes, its boundaries on well-described events.

1.- INTRODUCTION

In Belgium, the Silesian subsystem comprises the Namurian and Westphalian series. In the present review the limits of these series and their subdivision into stages follow the decisions of the first Carboniferous Congress at Heerlen in 1927 (Jongmans, 1928) and those of the second Carboniferous Congress at Heerlen in 1935 (Jongmans & Gothan, 1937) eventually refined at later congresses (Ramsbottom, 1969) (Tab. 1).

Lithologically, the Visean-Namurian boundary is characterized by a distinct change in the rock type which consists of carbonates in the Visean and fine siliciclastics in the Namurian, except in the westernmost part of the Namur Synclinorium where a more gradual transition exists. This lithological change marks a stratigraphical hiatus covering at least the Pendleian stage (lowermost Namurian ; Fig. 1).

Lower Westphalian D strata form the youngest Silesian deposits recognized so far in Belgium (Fig. 2). They are unconformably overlain by Zechstein beds in central parts of the Campine basin or even by much younger deposits elsewhere. It is hoped that future exploration boreholes in the Campine may contribute to fill this gap. New lithostratigraphic terms are proposed herein in addition to those indicating particular, well-defined beds such as coal seams or coal seam groups, coal tonsteins, lenticular sandstone bodies, limestone beds or marine horizons. The zonal subdivision of the Silesian deposits (Demanet, 1941 ; Delmer, 1963, Tab. 2-3) does not correspond to lithologically distinguishable units. Their limits are mostly based on goniatite sequences or marine horizons and they are as such concurrent with the internationally used stages. For these reasons they are not withheld as formation names.

The lithology of the Silesian in Belgium is illustrated by a number of stratigraphically overlapping sections (Fig. 1, 2, 3). These have been selected because they had been investigated recently and/or because sufficient rock samples are available for further research. Some of these sections are surface exposures which usually are accessible ; borehole samples are kept at the Royal Institute for Natural Sciences and the Belgian Geological Survey in Brussels or at the Campine Collieries.

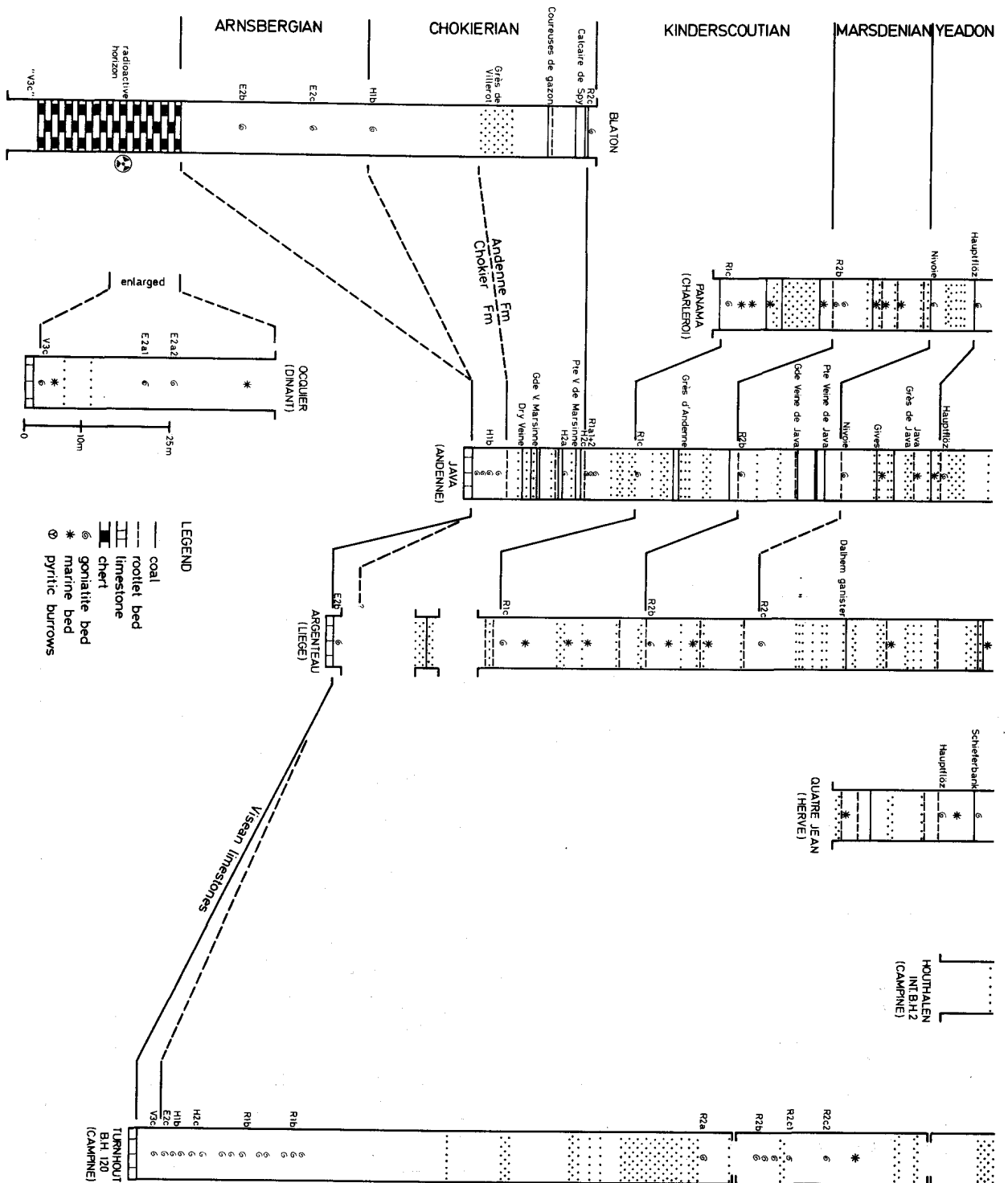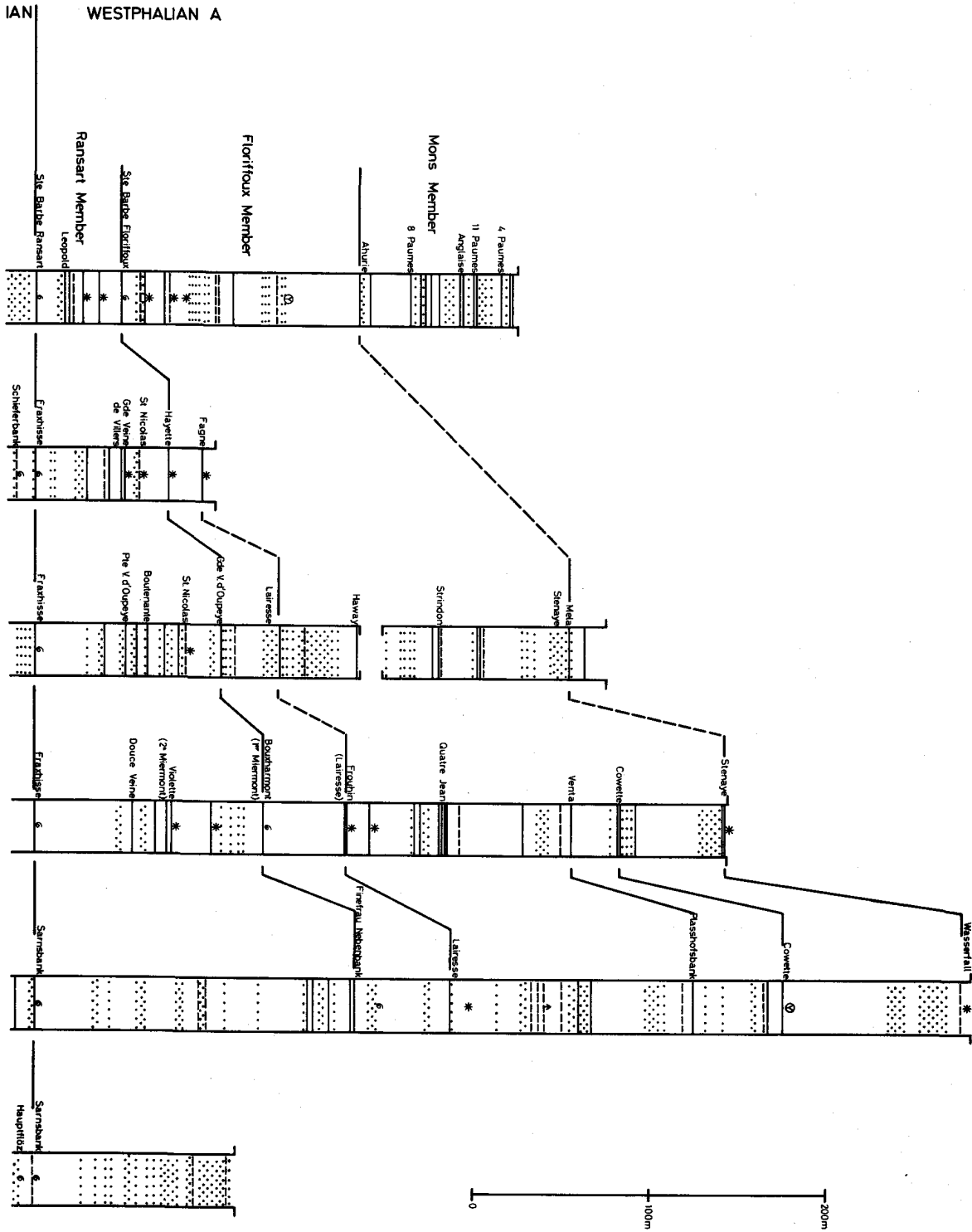The composite log of the Silesian sequence in the

Table 1.- Stratigraphic chart of the Silesian subsystem in Belgium

stages	tonsteins	litho formations-members	marine horizons / eulittoral horizons	goniatites	(subzone)	conodonts	foraminifera	non-marine lamellibranchs	macroflora	miospores	megaspores
WESTPHALIAN D / N. ovata		Neeroeteren						A.pseudostellata / E. striata / N. ovata		T. obscura / T. thiessenii / 117-820 OT / 117-875	T. tuberculatus / 117-846 MG IV / S. pseudotenuispinosus / 117-1025 MG III
WESTPHALIAN C / A. aegiranum	KS61 Nibelung / KS84/4 Hagen 1 / KS19 Hagen 4 / KS20 Erda / KS24 Z 1	Maurage	117-1153 Palaeestheria / 117-1234 Palaeestheria / Maurage = Aegir	A. aegiranum			Phillipsii / Maurage Aegir	Phillipsii / Hagen 1 / upper Similis-Pulchra / Maurage Aegir	L. subbrongniarti / A. sphenophylloides / S. emarginatum / N. rarinervis / N. loshi / N. scheuchzeri / Lanklaar	117-1153 SF / P granifer / T sculptilis / KS21 GS	Z. brasserti / R. dentatus / 117-1216 MG II / S. praetextus MG I
WESTPHALIAN B / (A. vanderbecki)	KS35 P4 or O2 / KS45/1 Zollv 2 / KS47 Zollv 3/6? / KS49 Zollv 8	Eisden / Quaregnon	Lanklaar / "raindrops" E2 / "raindrops" E1 / Eisden=Domina / KS45 Wijshagen Leaia / "raindrops" A2 / "raindrops" A1 / Quaregnon=Katharina					lower Similis-Pulchra / KS44 / Modiolaris / Quaregnon	P. pseudogigantea / N. hollandica / K. daviesi / P. gigantea / L. rugosa	M. nobilis / E. globiformis / KS43 NG / V. costata / V. pseudoreticulata / KS56 CP	
WESTPHALIAN A	KS70 Karl / KS75 Wilhelm / KS82	Mons / Floriffoux / Ransart	KS57/2 Schelpenbed / KS71a Voort Palaeestheria / "pyritic burrows" / Mons=Wasserfall / KS82 Cowette"pyritic burrows" / Lairesse / Floriffoux=Finefrau Nebenbank / Ransart=Sarnsbank	G. listeri / G. subcrenatum		sulcatus-parvus CC9	Wasserfall / Lairesse / Ransart Sarnsbank	KS70 / Communis / KS82 / Lenisulcata / Sarnsbank	L. hoeninghausi / A. lonchitica / K. acuta / N. schlehani / Ransart=Fraahisse	R. aligerens RA	
YEADONIAN / Gastrioceras		Schieferbank / Hauptflöz / Nivoie		G. crenulatum / G. cancellatum / G.sp+R. superbilingue	R2c1+2		Pseudostaffella antiqua CF9	Ventricosa-Perlongata	Transitional flora		
MARSDENIAN / R. gracile				R. superbilingue / R. bilingue / R. gracile	R2b2 / R2b1 / R2a				R gracile		
KINDERSCOUTIAN / H. magistrorum +Reticuloceras		Andenne		R. reticulatum / R. nodosum / R. circumplicatile	R1c2 / R1c1 / R1b2 / R1b1 / "R1a3" / "R1a2" / "R1a1"	sinuatus-corrugatus-sulcatus CC8		E. hollandica / K. laciniata / P. aspera / H. magistrorum		
ALPORTIAN / H. smithi + Hd. proteum				Ht. prereticulatus / (H2b not recorded) / Hd. proteum	H2c / H2a		Millerella-Seminovella			
CHOKIERIAN / Homoceras		Chokier		H. beyrichianum / H. subglobosum	H1b / H1a	noduliferus-lateralis CC7 / CC6 minutus	CF8			
ARNSBERGIAN / E. bisulcatum				N. nuculum / Ct. nitidus / E. bisulcatum s.s.	E2c / E2b3 / E2b2 / E2b1 / E2a2 / E2a1	bilineatus bollandensis-naviculus	Eosigmoilina CF7 / E2		E. waldenburgense / S. tenerrinum / E2	
(PENDLEIAN) (C. leion) / **WARNANTIAN**		(carbonates)		(E1 not recorded) / N. spiralis	V3c	CC5				

Figure 1.- Namurian and Lower Westphalian A sections

IAN | WESTPHALIAN A

Ransart Member

Ste Barbe Ransart
Leopold
Ste Barbe Floriffoux

Floriffoux Member

Mons Member
8 Paumes
11 Paumes
Anglaise
4 Paumes
Ahurie

Schieferbank
Frahisse
St Nicolas
Gde Veine de Villers
Hayette
Fagne

Frahisse
Pie V d'Oupeye
Boulonnaise
St Nicolas
Gde V d'Oupeye
Lairesse
Haway
Strindon
Mela
Stenaye

Frahisse
Douce Veine
Violette (2e Miermont)
Boutharmont (1er Miermont)
Froidpin (Lairesse)
Quatre Jean
Venia
Cowette
Stenaye

Sarnsbank
Finefrau Nebenbank
Lairesse
Passhofsbank
Cowette
Wasserfall

Sarnsbank
Hauptflöz

0 — 100m — 200m

Campine basin is based on borehole sections described by Delmer (1948, 1958, 1962) and Tricot & Claus (1980-1982, unpublished). This log is representative for the eastern part of the Campine for Westphalian C - D rocks, for the central part of the same area for Westphalian A - B rocks, and for the western Campine for Namurian rocks (Fig. 4). Biostratigraphic data obtained from other boreholes or subsurface exposures can be transferred to the figured borehole suite because of seam to seam correlations (Bouckaert & Delmer, 1962 in Delmer, 1963 ; most recently reviewed by Tricot & Claus, 1982, unpublished).

The Silesian rocks in the Dinant-Namur Synclinoria have not been the subject of similar recent (bio) stratigraphic investigations. Important lateral facies and thickness variations, as well as intricated tectonic structures need to be reviewed before an updated compilation of stratigraphic sections can be published (Fig. 1).

In the Namurian the most complete section is that of the Java roadway in the Andenne-Huy district (Ancion *et al.*, 1947, Van Leckwijck *et al.*, 1952, Hodson, 1957 ; Lambrecht & Van Leckwijck, 1960) whereas the most complete outcrop is situated at Argenteau in the northern part of the Liège district (Lambrecht, Charlier *et al.*, 1956). This section has not yielded many fossils. Moreover some crucial limits are not exposed. Upper Namurian strata and the contact with the overlying Westphalian strata are well described in the Herve coalfield (NE Liège district) by Chaudoir *et al.* (1951) (goniatite succession revised by Delmer & Graulich in 1959) and in the Charleroi coalfield by Van Leckwijck *et al.* (1951).

The contact with the underlying Visean strata has been described in most detail from the Bioul-Warnant and Ocquier sections in the Dinant Synclinorium (Demanet, 1938 ; Ronchesne, 1955 ; Bouckaert & Higgins, 1963) and from sections in the Basècles-Blaton area in the western part of the Namur Synclinorium (Bouckaert & Delmer, 1960 ; Bouckaert, Delmer & Overlau, 1961).

2.- MACROFAUNA

2.1.- GONIATITES

The stratigraphical framework of the Upper Carboniferous - and especially of the Namurian - in Western Europe is mainly based on a well-known succession of goniatite faunas (Tab. 1). The basis for a subdivision

of the Upper Carboniferous into superzones, zones and subzones has been made available by the work of o.a. W.S. Bisat in Great Britain and H. Schmidt in Germany since 1924.

The scheme of goniatite biozones has been refined by later workers (a.o. Ramsbottom, 1969). This zonation is also applicable for the Upper Carboniferous of Belgium (Bouckaert, 1961, 1971 ; Van Leckwijck, 1964).

Goniatites are especially useful markers in the early Namurian where several phylogenetic lineages have been distinguished. They also provide an excellent tool for the correlation of the more isolated marine bands in the late Namurian and Westphalian rock sequence.

It is unfortunate that the early literature on goniatites - especially on those of the Arnsbergian, and Westphalian A stages - includes unreliable species identifications. Therefore a new range chart of index species has been added (Tab. 4).

2.1.1.- E1 Superzone (Pendleian)

Thus far, no Pendleian rocks have been recorded in Belgium. Bouckaert & Higgins (1963) rejected the correlation of the " Zone de Bioul" beds in the Dinant Synclinorium with the E1 superzone. This correlation was based on incorrect goniatite determinations by Demanet (1938, 1941).

The oldest Namurian deposits in the Dinant Synclinorium are of early Arnsbergian (E2a) age. However in the Mont des Groseilliers section near Blaton (western part of Namur Synclinorium), beds dated V3c (" Couches de passage") with *Neoglyphioceras spirale,* and lower E2b beds are separated by a predominantly cherty (80 m thick) sequence without characteristic fossils which may be partly of E1 age (Bouckaert, Delmer & Overlau, 1961) (fig. 1).

2.1.2.- E2 Superzone (Arnsbergian)

The base of the Arnsbergian stage is defined by the first appearance of *Eumorphoceras bisulcatum.* All the goniatite zones and subzones established in the Arnsbergian have been recognized in Belgium, though not everywhere. The stratigraphic gap separating Visean and Namurian sequences - which comprises only the E1 in the Dinant Synclinorium - increases gradually in the Namur Synclinorium, where this includes most of the E2 as well.

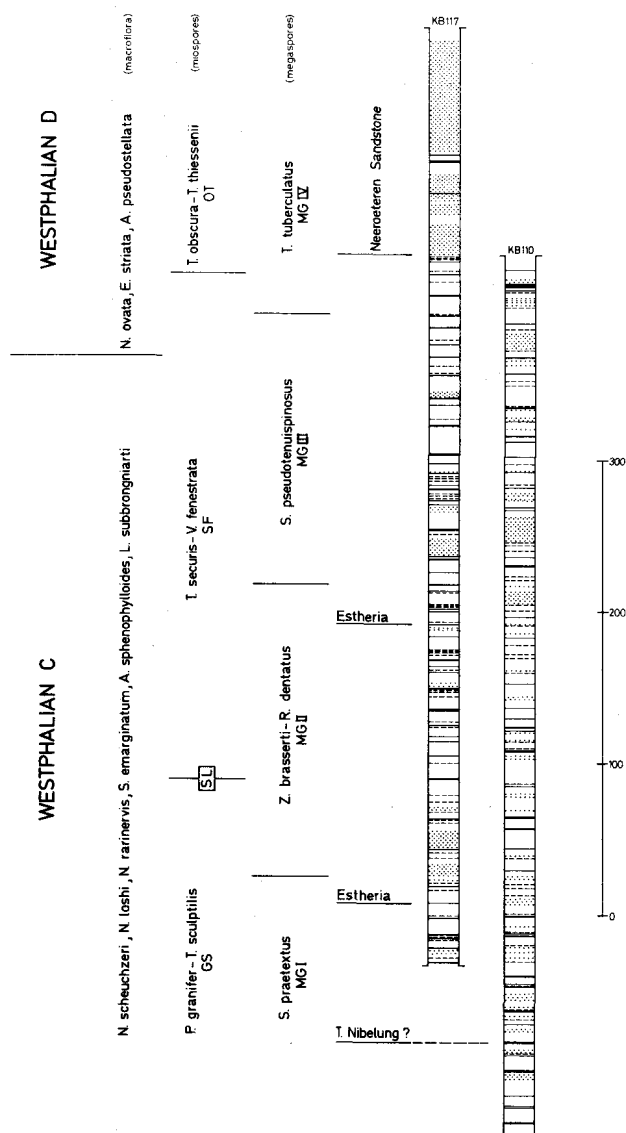E2a goniatites are only described from the central

Figure 2

Westphalian C-D sections in the Neeroeteren area (NE Campine)

synclines of the Dinant Synclinorium (Bouckaert, 1961 ; Bouckaert & Higgins, 1963). E2b goniatites are also known from the western and eastern margins of the Namur Synclinorium and from the Theux Massif (Demanet, 1941 ; Lambrecht & Charlier, 1955 ; Delmer & Graulich, 1959 ; Bouckaert, Delmer & Overlau, 1961 ; Bouckaert, 1962, 1963 ; Van Leckwijck, 1964).

E2c goniatites are described from at least 25 localities in the Dinant and the Namur Synclinoria ; in the

latter from its western to its eastern extension (Van Leckwijck, 1964). They are also known from the Campine basin (Delmer, 1962) and thus indicate a continuous transgression in the lower Namurian. Furthermore, karstic dissolution pockets in Visean limestones may have been filled with Arnsbergian sediments (dated by goniatites). This has been observed at Thon-Samson, Engis (both locations in Namur Synclinorium), and in the Soiron borehole (Vesdre Massif ; cf. Van Leckwijck *et al.*, 1955 ; Bouckaert, 1971).

The discrimination between the ``Zone de Malonne`` (Nm1b) and ``Zone de Bioul`` (Nm1a) by means of goniatites is not possible. Both ``zones`` of Demanet (1941) contain *Eumorphoceras bisulcatum* (Bouckaert & Higgins, 1963).

2.1.3.- H1 Superzone (Chokierian)

The base of the Chokierian stage is correlated with the base of the first faunal band containing *Homoceras.* Occurrences of *Homoceras subglobosum* without *H. beyrichianum,* characterizing the H1a zone are limited, but *H. beyrichianum* (H1b) marine bands have been recorded throughout the Namur Synclinorium thus indicating the acme the Lower Namurian transgression (Delmer & Graulich, 1959 ; Hodson, 1959 ; Lambrecht & Van Leckwijck, 1959 ; Bouckaert & Delmer, 1960 ; Bouckaert *et al.,* 1961 ; Bouckaert, 1962, 1967a, b ; Bouckaert & Lambrecht, 1967).

Whereas the eastern synclines in the Dinant Synclinorium and the Theux Massif already contained coal seams during the middle Arnsbergian, a marine ampelitic (= aluniferous shale) facies prevailed in the Namur Synclinorium until lower Chokierian times. The Namur Synclinorium probably represented a coal measure swamp area of typically paralic character with the first exploitable thin coal seams in the interval between the *H. beyrichianum* (upper Chokierian) and *Hudsonoceras proteum* (base Alportian) marine bands (Hudson, 1959).

At first, this temporary but widespread facies change from a marine ampelitic to a paralic coal measures sedimentary environment has been selected for tracing the limit between the ``Assise de Chokier`` (without coal) and the ``Assise d'Andenne`` (with coal). This facies change was used also as the boundary between the ``Zone de Spy`` (Nm1c) and the ``Zone de Sippenaeken`` (Nm2a ; Demanet, 1941). In the Campine basin, Chokierian beds containing both *H. subglobosum* and *H. beyrichianum* are about 10 m thick and completely marine, suggesting a con-
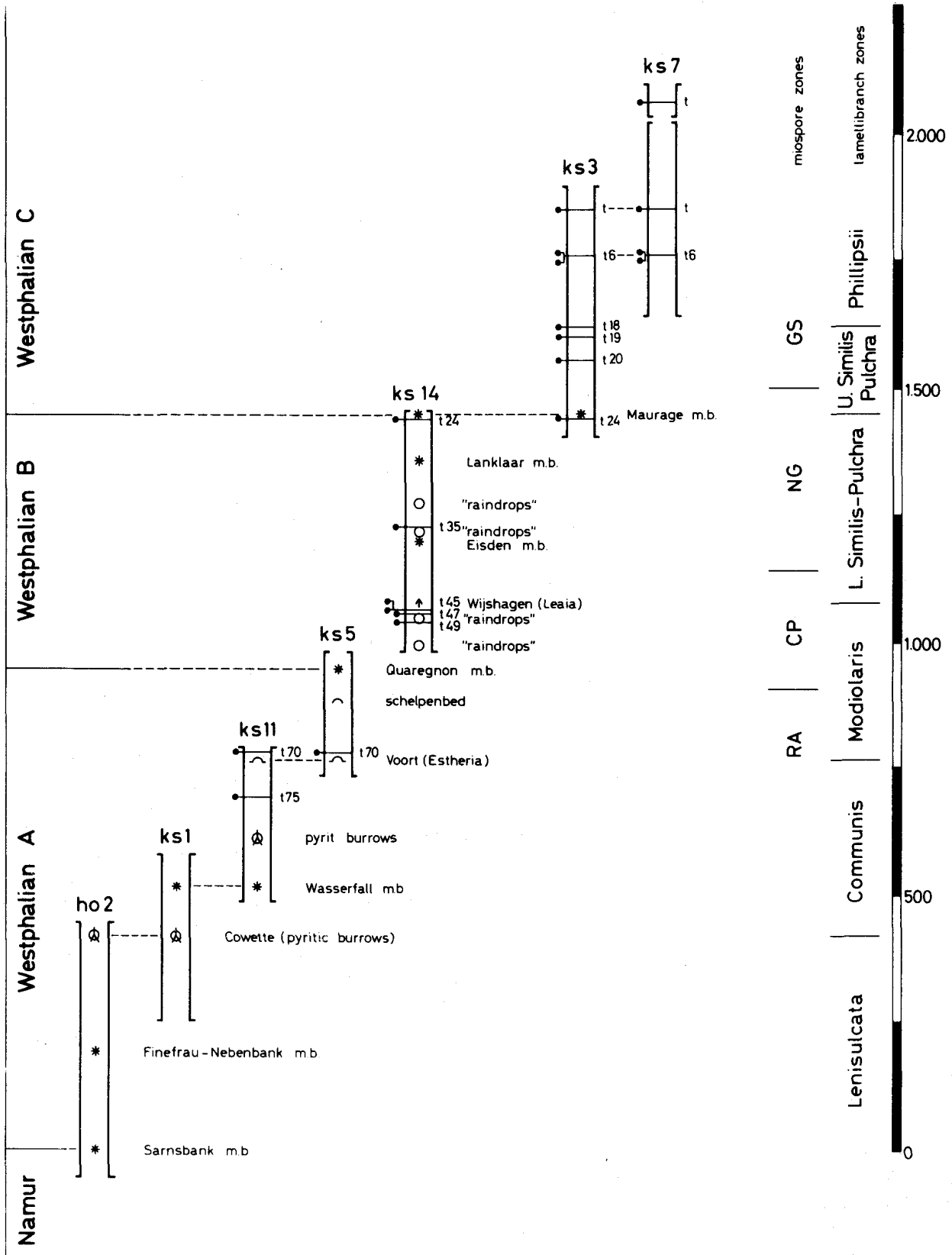
Figure 3.- Composite log of Westphalian A to C in the Campine mining district.

Table 2.- Correlation chart between stratigraphical legends used for the subdivision of the Namurian in Belgium

WESPHALIAN A	WESTPHALIAN A		Châtelet	
		(Wn1a)		
YEADONIAN (G1)	NAMURIAN C	Gilly (Nm2c)		H2 (Westphalien)
		R2c		
MARSDENIAN (R2)	NAMURIAN B	Baulet (Nm2b) R2b		
		Sippenaeken sup (Nm2a sup) R1c	Andenne	H1c (Poudingue)
KINDERSCOUTIAN (R1)		Sippenaeken mid (Nm2a mid) H2c		
ALPORTIAN (H2)	NAMURIAN A	Sippenaeken inf (Nm2a inf)		H1b
CHOKIERIAN (H1)		Spy (Nm1c)		H1a
			Chokier	
ARNSBERGIAN (E2)		Malonne (Nm1b) Bioul (Nm1a)		
PENDLEIAN (E1)				
WARNANTIAN	VISEAN			
stages	Heerlen 1935	Demanet 1941, 1943 (zones)	Stainier 1901 Renier 1938 (assises)	Legend geol. map 1892

Table 3.-   *Correlation chart between stratigraphical legends used for the subdivision of the Westphalian in Belgium*

STAGES	BEDS	FORMER NAMES (ASSISES AND ZONES)		LITHO. PROPOSED FORMATION, MEMBERS
WESTPHALIAN D				NEEROETEREN
WESTPHALIAN C	Tonstein Hagen 1	FLENU — Neeroeteren	Wn3	BELGIAN COAL MEASURES FORMATION
	Maurage = Aegir = Petit Buisson	Meeuwen		MAURAGE
WESTPHALIAN B	Eisden = Domina	CHARLEROI — Eikenberg	Wn2	EISDEN
	Quaregnon = Katharina	As		QUAREGNON
WESTPHALIAN A	Wasserfall = Stenaye = Gros Pierre = Faux	Genk	Wn 1c	MONS
	Finefrau Nebenbank = Bouxharmont = Gd. Veine d'Oupeye = St Barbe Floriffoux	CHATELET — Beyne / Beringen	Wn 1b	FLORIFFOUX
	Sarnsbank = Fraxhisse = St Barbe Ransart	Oupeye	Wn 1a	RANSART
YEADONIAN	Hauptflöz	ANDENNE	Nm 2c (Gilly)	ANDENNE
	Nivoie			

Demanet
1941 - 1943

tinuous existence of a land mass on part of the Brabant Massif.

2.1.4.- H2 Superzone (Alportian)

The base of the Alportian stage is correlated with the base of the *Homoceras smithi - Hudsonoceras proteum* faunal band (H2a). This marine band can be followed from W. Ireland into the Ruhr basin, and has been identified also in the Andenne (Hodson, 1957) and Liège (Lambrecht, 1958a) coalfields.

The *Homoceratoides prereticulatus* (H2c) band, which overlies the " Calcaire à crinoïdes de Spy " in the central and western parts of the Namur Synclinorium, constitutes an excellent marker bed (Hodson, 1957 ; Delmer & Graulich, 1959 ; Demanet & Van Leckwijck, 1959 ; Bouckaert & Delmer, 1960 ; Bouckaert, 1960, 1961, 1962 ; Delmer, 1962). The *Homoceratoides prereticulatus* band was placed at the base

of the " Zone de Sippenaeken, partie moyenne " (Nm2 moyen) by Demanet (1941). No marine band characterized by *Homoceras undulatum* (H2b) has yet been found between the H2a and H2c horizons.

2.1.5.- R1 Superzone (Kinderscoutian)

The base of the Kinderscoutian stage corresponds with the first appearance of *Reticuloceras*. The *Homoceras magistrorum* (R1a1) band contains, besides the index species, rare *Reticuloceras* aff. *compressum*. Although not as widespread as·the underlying *Homoceratoides prereticulatus* band, the *H. magistrorum* band has been recorded from west to east in the Namur Synclinorium after its first description by Hodson in 1957 (Lambrecht, 1958b,; Demanet & Van Leckwijck, 1959 ; Bouckaert & Delmer, 1960 ; Bouckaert, 1960, 1961, 1962). Six goniatite-bearing faunal bands have been recorded in the   Kinderscoutian strata of the
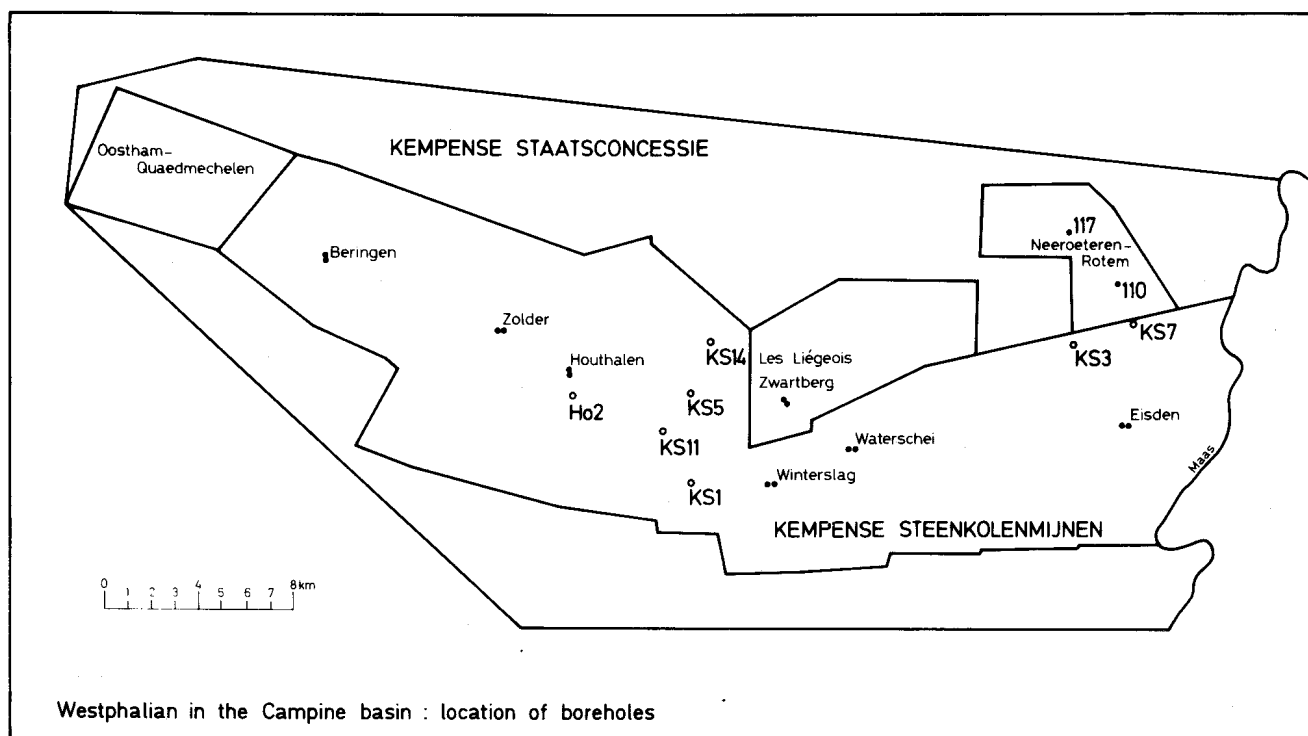
Figure 4.- Campine mining district map showing borehole locations

N.E. Liège district of the Namur Synclinorium within a condensed interval of about 10 m (*Ht. magistrorum, R. circumplicatile, R. todmordenense, R. subreticulatum, R. nodosum* and *R. reticulatum* bands : Bouckaert, 1960). In other regions (with only few marine beds in relatively thick sequences) some of these horizons have not been recorded, because the corresponding marine facies or guide species are absent, so that correlations are not always precise (Ancion *et al.*, 1947 ; Lambrecht, 1958b ; Bouckaert & Delmer, 1960 ; Bouckaert, 1961, 1962).

In the Andenne type area the "Andenne Sandstones" which have been mapped as "H1c" on the Geological map of Belgium, are in between the *Reticulocera circumplicatile* (R1a) and *R. bilingue* (R2b) horizons. Correlations with adjoining areas which are richer in goniatite bands suggest their stratigraphical position as top Kinderscoutian. However these and similar sandstones have originated as separate fluvial deposits which may occur at any stratigraphic level within the paralic facies realm. Previous stratigraphic correlations based on a supposed correlation with "Andenne Sandstone" beds should be treated with caution (Lambrecht, 1958b).

The *Reticuloceras reticulatum* (R1c) band has been placed at the base of the "Zone de Sippenaeken, partie supérieure" (Nm2a supérieur) by Demanet (1941).

2.1.6.- R2 Superzone (Marsdenian)

The base of the Marsdenian stage is correlated with the base of the *Reticuloceras gracile* band. The *R. gracile* horizon is the best known in the Campine basin and NE Liège district of the Namur Synclinorium (Bouckaert, 1960). The *R. bilingue* and *R. superbilingue* bands occur throughout the Namur Synclinorium and the Campine Basin. These bands may attain considerable thickness (up to 15 m) or be split into several thin horizons (Fiege & Van Leckwijck, 1964). The *Reticuloceras bilingue* (R2b) band has been placed at the base of the "Zone de Baulet" (Nm2b) by Demanet (1941). In the Campine basin, several horizons containing *Donetzoceras sigma* have been recorded between the *R. superbilingue* and *G. crencellatum* marine bands (Delmer, 1962).

2.1.7.- G1 Superzone (Yeadonian)

The base of the Yeadonian stage is defined by the

Table 4.- Goniatite index sequence of the Silesian strata in Belgium

WESTPHALIAN C	Aegir (= Maurage) horizon : *A. aegiranum, A. hindi, Ht. jacksoni, G. depressum*
WESTPHALIAN B	
WESTPHALIAN A	Finefrau Nebenbank (= St. Barbe de Floriffoux) horizon : *G. listeri, G. circumnodosum, G. coronatum, G. weristerense, Ht. divaricatus.* Sarnsbank (= St. Barbe de Ransart) horizon : *G. subcrenatum*
YEADONIAN	Schieferbank horizon : *G. crenulatum, G. cumbriense, Ht. divaricatus, A. arcuatilobum* Hauptflöz horizon : *G. cancellatum, G. crencellatum, A. carinatum* Nivoie horizon : *Gastrioceras* sp., *R. superbilingue*
MARSDENIAN	R2c2 : *D. sigma* R2c1 : *R. superbilingue, R. metabilingue, Ht. divaricatus* R2b2 : *R. metabilingue, R. wrighti* R2b1 : *R. bilingue, R. wrighti, R. gracile, Hd. ornatum, Ht. divaricatus* R2a : *R. gracile, H. striolatum, Hd. ornatum*
KINDERSCOUTIAN	R1c2 : *Hd. ornatum,* (*R. coreticulatum* index fossil not recorded) R1c1 : *R. reticulatum, R. davisi, Hd. ornatum, H. striolatum* R1b2 : *R. nodosum, R. regularum, R. hodsoni, R.* aff. *stubblefieldi, H. striolatum ; H. moorei, Ht. divaricatus* R1b1 : *R. subreticulatum, H. moorei* (*R. dubium* index fossil not recorded) R1a3 : *R. todmordenense, R. umbilicatum, R. paucicrenulatum, R. gulincki, R. adpressum, R.* aff.*pulchellum, R.* aff.*subreticulatum, Ht. divaricatus,Ht. mutabile* R1a2 : *R. circumplicatile, R. pulchellum, R. compressum, R.* aff. *umbilicatum , Ht. varicatus, H. henkei* R1a1 : *H. magistrorum, H. henkei, R.* aff. *compressum, D. looneyi*
ALPORTIAN	H2c : *Ht. prereticulatus, H.* aff. *eostriolatum, H. henkei* H2b : not recorded H2a : *Hd. proteum , H. smithi*
CHOKIERIAN	H1b : *H. beyrichianum, H. subglobosum, H. diadema, D. discrepans, D.* cf. *gilbertsoni* H1a : *H. subglobosum*
ARNSBERGIAN	E2c : *N. nuculum, N. tenuistriatum, E. bisulcatum, Ct. fragilis* E2b3 : *Ct. nititoides, Ct. fragilis, Ct.* cf. *stellarum, E. rostratum* E2b2 : *C. holmesi, Ct. nitidus, D. looneyi,* cf. *D. ribblense, E. bisulcatum varicatum, A. paucilobum, A. tenuispirale, C. rugosum* E2b1 : *Ct. edalensis, Ct. bisati, E. bisulcatum* E2a2 : *E. bisulcatum bisulcatum, E. bisulcatum erinense, E. bisulcatum ferrimontanum, C.* cf. *C. kettlesingense, A. glabrum* E2a1 : *E. bisulcatum bisulcatum, E. bisulcatum ferrimontanum, E. bisulcatum grassingtonense, C. cowlingense, K. scaliger*

first appearance of *Gastrioceras.* However the lowest marine band (containing rare and indiscrimate *Gastrioceras* which show some affinities to *G. cancellatum*) is generally very rich in *Reticuloceras superbilingue* especially in the central and eastern part of the Namur Synclinorium (Nivoie horizon, Lambrecht & Van Leckwijck, 1960). Two more marine bands are known within the Yeadonian : the "Hauptflöz" horizon with *G. cancellatum, G. crencellatum, Agastrioceras carinatum* and *Reticuloceras superbilingue* and the "Schieferbank"horizon with *G. crenulatum* and *G. cumbriense* (Delmer & Graulich, 1959 ; Lambrecht & Van Leckwijck, 1960).

The "Zone de Gilly" (Nm2c) of Demanet (1941) is characterized by the presence of *Reticuloceras superbilingue* which may occur together with *Gastrioceras* (Nivoie Horizon and locally also Hauptflöz Horizon). Demanet (1941) suggested that the base of the Westphalian "Assise de Châtelet" (Wn1a) was the Hauptflöz Marine Band with *Gastrioceras cancellatum* and *Reticuloceras superbilingue*. At that time, the Sarnsbank Marine Band, with *G. subcrenatum,* had been adopted already as the base of the Westphalian by the First Carboniferous Congress at Heerlen in 1927. However, in practice the top of the "Zone de Gilly"has been placed at the base of the Sarnsbank Marine Band. In the Namur Synclinorium, *R. superbilingue* is usually restricted to the Nivoie Horizon. Therefore, the "Zone de Gilly" more or less coincides with the Yeadonian.

2.1.8.- Westphalian

The base of the Westphalian coincides with the base of the *Agastrioceras subcrenatum* or "Sarnsbank" Marine Band (Delmer & Graulich, 1959 ; Lambrecht & Van Leckwijck, 1960 ; Delmer, 1962 ; Bouckaert & Molitor, 1962). In the Westphalian A of Belgium, only one other marine band, the Finefrau Nebenbank Marine Band, has yielded identifiable goniatites belonging to *Gastrioceras* group *listeri* (Demanet, 1948 ; Bouckaert & Molitor, 1962). The Quaregnon or Katharina horizon, marking the base of the Westphalian B, does not contain goniatites in the Belgian coal measures.

The youngest marine band in Belgium is Maurage (= Aegir) at the base of the Westphalian C. This horizon contains *Anthracoceras aegiranum* and *A. hindi* (Demanet, 1943, 1949 ; Van Leckwijck, 1948).

Note

Though useful as facies indicators other marine faunas do not possess a notable biostratigraphic value. The most exhaustive studies on Belgian Upper Carboni-

ferous marine fossils have been published by Demanet (1936, 1938, 1941, 1943).

2.2.- NON-MARINE LAMELLIBRANCHS

The non-marine faunas are dominated by the lamellibranchs which attain their greatest abundance and variety in the upper part of the Westphalian A and lower part of the Westphalian B, a section also particularly rich in coal seams.

The first stratigraphical subdivision of the Silesian based on non-marine lamellibranch assemblage zones has been established in the Pennine region of Great Britain. The subdivision now in use follows the definitions of the assemblage zones by Trueman & Weir (1946) (Tab. 1). This subdivision was further refined for the Westphalian A and B by Calver (1955) who described subzones ("Faunas") based on dominant lamellibranch associations. However zonal boundaries are not precise. They may partly overlap or may be separated by barren interzones. Already Trueman & Weir (1946, p. XXVIII) emphasized that "the names given to these zones, based upon index fossils, do not indicate that the species so selected are of universal occurrence within the zone, or that the absence of any particular index fossil implies the absence of the zone. The zones are recognized on the basis of assemblages of species, different assemblages (possibly reflecting different environments) being present at different horizons throughout a single zone . Furthermore index fossils may occur outside the zone denominated after them."

"Ces coquilles sont de près, toutes semblables et, de très près toutes différentes par la variabilité de leurs formes résultant des actions du milieu" (Deleers & Pastiels, 1947, p. 4). Because of the high morphological diversity of the non-marine lamellibranchs, greatly influenced by the environment in which they existed as shown by Eagar (1960), single specimens can be identified only when the horizontal distribution and vertical succession of the faunas is well known. Otherwise only faunal groups can be distinguished. Furthermore all identifications depend on the stratigraphic framework provided by marine horizons in the Silesian in NW Europe, because of a recurrent homeomorphism in the non-marine lamellibranchs. Therefore the specific name is limited to forms which are practically identical with the holotype of the species (Trueman & Weir, 1946, p. XX). In this way the Linnean classification in use has become artifical as has been amply demonstrated by Deleers & Pastiels (1947) who have tried to establish firm biometric criteria for species

determinations. However, they discovered that this approach was very unfruitful : high diversity and poor preservation make exact measurements nearly impossible.

The value of the non-marine lamellibranchs in zonal correlation has been established only as a result of experience. It has been noticed that the zonation can be recognized in all the coalfields of Northwestern Europe (Paproth, 1956-1962 ; Pastiels, 1951-1975) (Fig. 3). The faunal succession reflects changes in facies rather than phylogenetic trends. This explains why marine horizons or important widespread coal seams may mark major divisions in the non-marine lamellibranch zonation (Trueman & Weir, 1946 ; p. XXIV-XXV).

The main features of the non-marine lamellibranch succession are shown on Fig. 5. The genus *Carbonicola*, appearing in the Kinderscoutian, predominates between the Sarnsbank and Katharina Marine Bands and thus characterizes the Westphalian A. The genus *Anthracosia* appears at the time when *Carbonicola* disappears, and apparently it extends to the Aegir Marine Band and thus characterizes the Westphalian B. Unfortunately this transition from faunas dominated by *Carbonicola* to faunas dominated by *Anthracosia* does not clearly perspire from the biostratigraphic zonation.

2.2.1.- *Ventricosa-Perlongata* Assemblage Zone (erected herein)

Lower limit : provisionally at the first appearance of paralic facies conditions wherein non-marine lamellibranchs could flourish.

- in the Dinant and Vesdre allochthonous basins during the Arnsbergian

- in the autochthonous Namur and Campine basins during the upper Chokierian or Alportian.

Upper limit : the *Gastrioceras subcrenatum* (Sarnsbank) Marine Band, base of the Westphalian A.

Although the *Lenisulcata*-Zone, as defined by Trueman & Weir (1946) was limited to Westphalian A strata above the *Gastrioceras subcrenatum* horizon, a practice followed in the Rhein-Ruhr basins (Paproth, 1962), Pastiels (1960 a) included all Namurian nonmarine lamellibranch occurrences in the *Lenisulcata* Assemblage zone because of the absence of a clear paleontological break coinciding with the Sarnsbank horizon. However the *Anthraconaia angulosa-perlongata-ventricosa* group, first described by Pastiels (1960a,

p. 147) appears in the Arnsbergian and characterizes the Namurian strata (even if *A. perlongata* persists into the *Lenisulcata*-Zone s.s.). This group probably forms the ancestral stock for forms such as *A. lenisulcata* which appear in the Yeadonian.

Occurrences

- Ruhr basin ; Sprockhöveler Schichten (Yeadonian), between the Hauptflöz *(Gastrioceras cancellatum)* and Schieferbank *(G. crenulatum)* Marine Bands : *Anthraconia angulosa-perlongata-ventricosa* (Michelau *et al.*, 1967).

- Belgium, (Pastiels, 1960a) Figured specimens : Dinant allochthonous basin : Bois-et-Borsu : type locality for *Anthraconaia angulosa* (Pastiels, 1960a, p. 39, 149) ; associated with *A.* cf. *ventricosa, Curvirimula* sp. and ampelitic goniatite beds dated E2b and the first paralic coal seams (Delmer & Graulich, 1959). Because of the complicated tectonic style and insufficient outcrops, no detailed section through these beds has been made.

Herve subautochthonous basin : Charbonnage d'Argenteau, Siège Marie at Blegny, Ravalle du puits no. 1 (Pastiels 1960a, p. 82, 147, 151) - Section in Chaudoir *et al.* (1951) : type locality for *Anthraconaia ventricosa* and *A. perlongata,* associated with *A. angulosa* and Naiadites. Section 30-43 m below Fraxhisse = Sarnsbank, in between Veinette Double (= Schieferbank with ``Gastrioceras cumbriense" and 1ere passée sous Veinette double (= Hauptflöz with *G. cancellatum)* ; age Yeadonian (Delmer & Graulich, 1959).

Liège autochthonous basin : Cheratte-Argenteau outcrop (Pastiels 1960a, p. 75). Section in Lambrecht, Charlier *et al.* (1956). Toit de la 2ème veinette sous Fraxhisse (= Sarnsbank), age Yeadonian. Association of *Anthraconaia* aff. *perlongata, A.* cf. *ventricosa, Carbonicola,* Naiadites.

Campine basin : Borehole 120 Turnhout (Pastiels, 1960a, p. 97). Section in Delmer (1962) : Depth 1645 m : *Anthraconaia perlongata,* age Yeadonian.

2.2.2.- *Lenisulcata* Assemblage Zone

Lower limit : *Gastrioceras subcrenatum* (Sarnsbank) Marine Band.

Upper limit : At the base of a coaly sequence overlain by a horizon with pyritized burrows (``tubulations pyriteuses"), separating the sequence between the Plasshofsbank and Wasserfall eulittoral horizons (Pas-
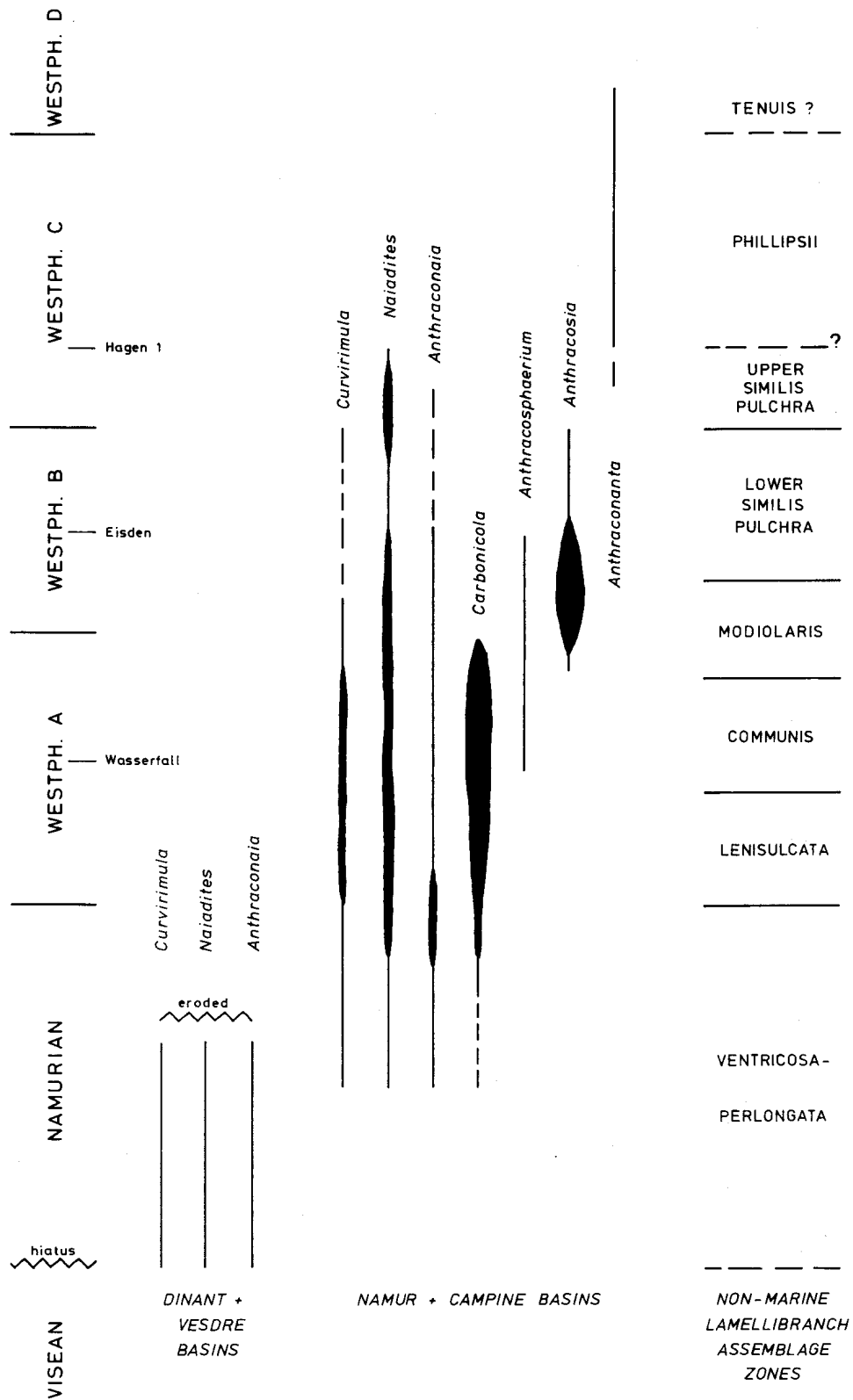
Figure 5.- Range and relative abundance of non-marine lamellibranch genera in the coal measures of Belgium

tiels, 1964a, b). This limit coincides with the base of the `Grande Stampe stérile" in the Belgian basins, the Schöttelchen Gruppe in the Rhein-Ruhr basin, the Elland Flags in Yorkshire and the Upholland Flagstones in W. Lancashire.

The *Lenisulcata* Assemblage Zone includes practically all the marine bands recorded from the lower part of the Westphalian A. The genus *Carbonicola* predominates. *Naiadites* and *Curvirimula* are common, indicating brackish-water conditions. *Anthraconaia lenisulcata* which was originally designated for naming this assemblage zone is rare. This species is also present in the underlying Yeadonian strata. Two subzones can be recognized (Calver, 1955) : 1.- *Carbonicola protea / fallax* fauna, and 2.- *Carbonicola proxima* Fauna. A transition between these subzones may be found above the Finefrau Nebenbank *(Gastrioceras listeri)* Marine Band (Pastiels, 1960a, p. 164).

2.2.3.- *Communis* Assemblage Zone

Lower limit : `Tubulations pyriteuses" horizon (= Cowette), about halfway between the Plasshofsbank and Wasserfall eulittoral horizons.

Upper limit : hard to define because of overlapping faunal assemblages ; recognized by Pastiels (1964) in the Campine and Liège basins at ± 40 m above the Voort (Estheria) Horizon which possibly corresponds to the `Low Estheria Band" in the East Midlands. The upper limit corresponds to the Albert 4 - Wellington coal seam group in the Rhein-Ruhr area (Paproth, 1962).

This assemblage zone is dominated by the genus *Carbonicola* (large specimens in upper subzone), whereas *Curvirimula, Naiadites* and (rare) *Anthraconaia* persist. *Anthracosphaerium* appears within the *Communis* Assemblage zone but is rare and localized. Two subzones can be recognized (Calver, 1955) : 1.- *Carbonicola bipennis* Fauna, and 2.- *Carbonicola pseudorobusta* Fauna. Pastiels (1964a, b) recognized three faunal associations within the latter subzone. The transition between both subzones possibly occurs at ± 25 m (Liège basin) to ± 60 m (Campine basin) above the eulittoral Wasserfall (= Arley Mine) horizon. Pastiels (1964b) recognized two biogeographic provinces in the Belgian autochthonous and subautochthonous coal measures for the *Communis* Assemblage Zone. During the lower and middle part of the zone, the western province was characterized by a predominance of the genera *Curvirimula, Naiadites* and to a lesser extend *Anthraconaia,* whereas the eastern province contained a more diverse

fauna characterized by a predominance of *Carbonicola*. The limit between both provinces went through the Charleroi district (fig. 6). During the upper part of the zone, the genus *Carbonicola* completely disappeared in the western province, which in turn extended slightly more to the east including the eastern part of the Charleroi and Basse Sambre districts (Pastiels, 1964b).

2.2.4.- *Modiolaris* Assemblage Zone

Lower limit : ± 40 m above the Voort (Estheria) Horizon = `Low Estheria Band", in the Liège and Campine coal basins.

Upper limit : coal seam overlying a very arenaceous sequence at ± 30 m above the Wijshagen (Leaia) Horizon in the Campine basin ; the Wijshagen Horizon overlies Tonstein Zollverein-2 in the Campine and Rhein-Ruhr basins and is probably equivalent to Tonstein Faidherbe in the Pas-de-Calais coalfield (Scheere, 1956).

The *Modiolaris* Assemblage Zone can be subdivided into a lower *Carbonicola*-dominated fauna and an upper *Anthracosia*-dominated fauna. The transition occurs slightly below the Katharina (= Quaregnon) Marine Band.

Four subzones can be recognized (Calver, 1955) : 1.- *Carbonicola cristagalli* Fauna, 2.- *Anthracosia regularis* Fauna, 3.- *Anthracosia ovum* Fauna, and 4. *Anthracosia phrygiana* Fauna.

The distinction between the latter two subzones is not always clear.

The biogeographic provinces (Hainaut - Basse Sambre region or western part of the Namur synclinorium, and Liège-Campine region or eastern part of the Namur synclinorium and Campine, Fig-6) observed already in the *Communis* Assemblage Zone continue in the *Modiolaris* Assemblage Zone. The western province is characterized by a *Curvirimula-Naiadites* association, whereas the more diverse eastern province is characterized by respectively, a *Carbonicola* and a *Anthracosia* with subordinate *Anthracosphaerium* association (Pastiels, 1972).

The substitution of *Carbonicola* by *Anthracosia,* the appearance of *Anthracosphaerium* and the gradual disappearance of *Curvirimula* suggest that the limnic facies becomes more important during Westphalian A-B time (Pastiels, 1964a).

The `Schelpenbed" musselband found throughout the Campine basin at ± 65 m below the Katharina (=
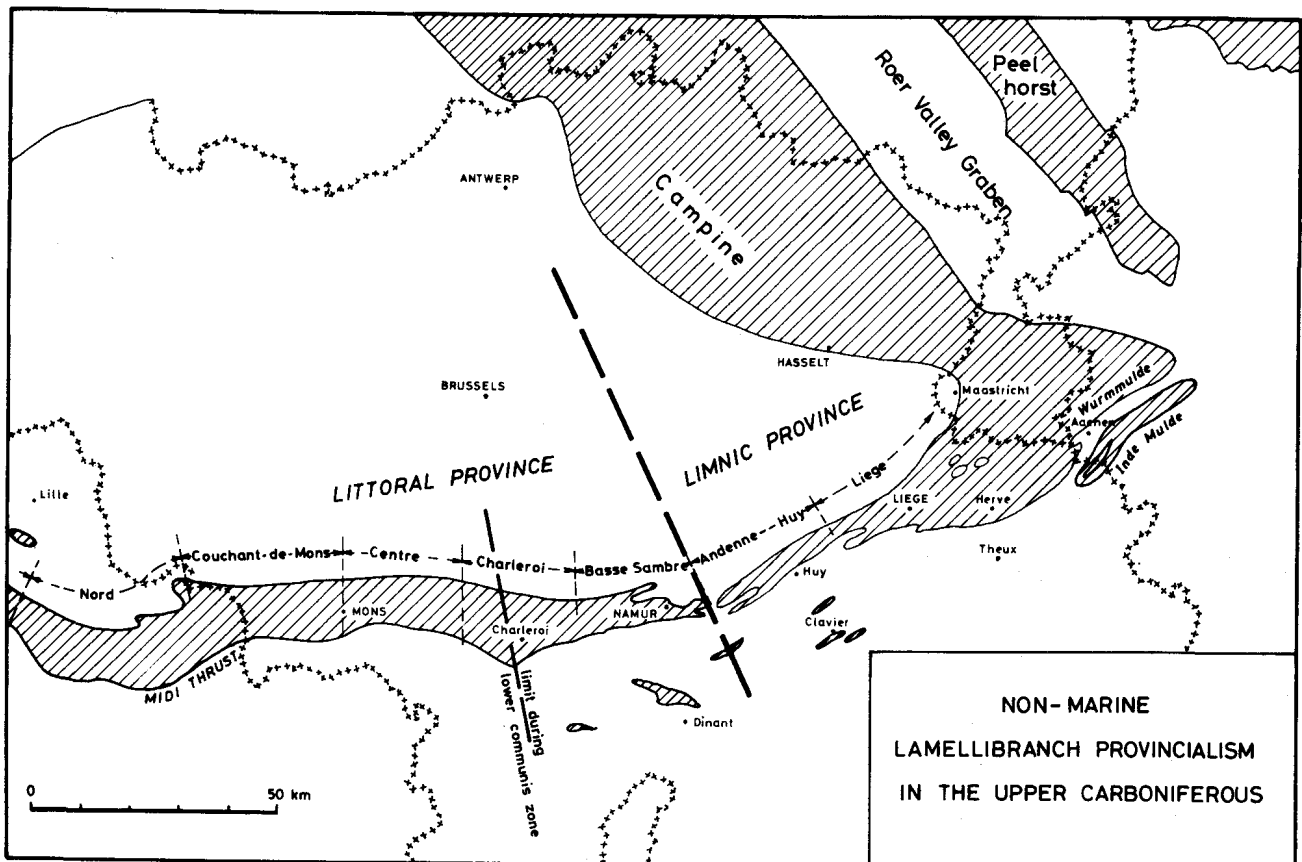
Figure 6.- Non-marine lamellibranch provincialism in the Upper Carboniferous

Quaregnon) Marine Band (Delmer, 1963) does not show any distinct faunal features, although it is approximatively situated at the base of the *Anthracosia regularis* Subzone (Pastiels, 1972).

2.2.5.- Lower *Similis-Pulchra* Assemblage Zone

Lower limit :   coal seam at ± 30 m above Wijshagen (Leaia) Horizon, overlying Tonstein Zollverein-2.

Upper limit : Aegir (= Maurage, = Rimbert, = Mansfield) Marine Band with *Anthracoceras aegiranum* and *A. hindi.*

The increasing limnic character of the faunal associations (predominance of *Anthracosia,* associated with *Anthracosphaerium*) already observed in the *Modiolaris* Assemblage Zone, is maintained up to the Domina (= Eisden) marine bed.   Between the Eisden Horizon and the Aegir Marine Band, *Anthracosphaerium* and also *Anthracosia* disappear.

Two subzones can be recognized (Calver, 1955) : 1.- *Anthracosia caledonica* Fauna,   and 2.- *Anthra-*

cosia atra Fauna. The transition between the two subzones is situated at the P4 (or O2) tonstein, ± 40 m above the Eisden Horizon (Pastiels, 1975).   The biogeographic distinction between a western province dominated by *Naiadites* with *Curvirimula,* and an eastern province dominated by *Anthracosia* with *Anthracosphaerium* and subordinate *Naiadites-Curvirimula* faunas, is maintained during this assemblage zone (Pastiels, 1975).

2.2.6.- Upper *Similis-Pulchra* Assemblage Zone

In the British Coal Measures, the Upper *Similis-Pulchra* Assemblage Zone is characterized by a *Naiadites-Anthraconaia* association.   *Anthraconauta phillipsii* appears in the upper part.

The lower limit coincides with the Aegir (= Mansfield) Marine Band, which represents the most important of all marine incursions in the Westphalian of the NW European paralic sedimentary basin.   The upper limit coincides with the Top Marine Band, which represents the last widespread marine incursion in the paralic

basin. In the Rhein-Ruhr basin, the non-marine lamelli-branch fauna is scarce and poorly preserved. The Upper *Similis-Pulchra* assemblage zone has been recognized in the lower Horstener Schichten (Aegir-Hagen sequence). Above the Hagen horizon the fauna is less well defined (Paproth, 1962).

In the Belgian Coal Measures (Campine basin, Borinage and Masse allochthonous massifs) no non-marine lamellibranch faunas have been described but it is assumed that some similarity with the Rhein-Ruhr or Pennine basins may exist.

2.2.7.- *Phillipsii* Assemblage Zone

In the British Coal Measures, an assemblage zone characterized by the predominance of *Anthraconauta phillipsii* occurs between the Top Marine Band (mid-Westphalian C) and the Westphalian C - D boundary.

In the Upper Westphalian C beds of the Campine basin (borehole 146), a recurring *Anthraconauta phillipsii* fauna has been noted, often associated with smooth-shelled ostracodes of the genus *Carbonita* (Dusar & Houlleberghs, 1981).

2.2.8.- *Tenuis* Assemblage Zone

In the British Coal Measures, an assemblage zone characterized by *Anthraconauta tenuis* associated with the older *A. phillipsii* indicates the Westphalian D.

In the Campine basin (borehole 146) the lowermost Westphalian D strata have been recognized. However, only *Anthraconauta phillipsii* was found. *A. tenuis* has not been observed.

2.3.- FISH REMAINS

Remnants of fossil fish in the Silesian strata of Belgium mainly consist of teeth, scales and egg-capsules. A summary of the discoveries was published in 1930 by Pruvost, whereas additional information was made available by Demanet in 1941.

These data may be compared with those for northern France (Pruvost, 1919), the Netherlands (Van der Heide, 1943) and the Ruhr coal field (Keller, 1938). The stratigraphic range of most of the species seems to be controlled by environmental factors. Many species show a tolerance for both marine and non-marine environments. This suggests a life-cycle which may be comparable somehow to that of the present-day eel or salmon. The varying stratigraphic range of a fish species in the different coal-basins of northwestern Europe may be interpreted in terms of the local (or regional) nearness of delta- or river-mouth complexes, which show rela-

tively high numbers of species (in Belgium, this is the case during the late Namurian and Westphalian A to lower Westphalian B).

The number of fish species is distinctly lower in the predominantly marine environment of the early Namurian and in the predominantly non-marine environment of the Westphalian C-D.

2.4.- ARTHROPODS

Non-marine ostracodes represent the most common group of arthropods in the Silesian of Belgium.

Amongst the other fossil arthropods, the phyllopod genera *Estheria* and *Leaia*, as well as the malacostracan genus *Anthrapalaemon* show some value for local or regional correlations, since these are usually concentrated in relatively thin bands (or a sequence of thin horizons) which can be traced throughout a smaller or larger part of a coalfield or coalmine. This suggests that the presence of the same is controlled by (largely unknown) paleoenvironmental factors.

Anthrapalaemon may have preferred the river-mouth complex, since this genus occurs both in marine and non-marine strata of typically paralic sequences. *Anthrapalaemon* tends to become rare or absent in predominantly marine, respectively predominantly non-marine sequences.

3.- MICROFAUNA

3.1.- FORAMINIFERS

The foraminifer assemblages of the Western European Silesian are incompletely known. Only the carbonate deposits of the Cantabrian Mountains in Northern Spain have yielded rich foraminifer faunas, which have been used for stratigraphic purposes by a.o. Van Ginkel (1965, 1971) and Martinez Diaz (*in :* Garcia-Loygorri, 1974).

3.1.1.- Namurian

Conil *et al.* (1977, 1979) have recognized three foraminifer zones in the Namurian of Western Europe. These can be roughly correlated with the foraminifer zones established by Mamet & Skipp (1970, modified by Brenckle *et al.*, 1977) (Tab. 1).

Usually, foraminifers are studied in thin sections from carbonates. However, carbonates are rare in the Belgian Namurian, especially in the upper part, where paralic (clastic) deposits predominate. Agglutinating foraminifers have been recorded from lower Namurian

shales (de Dorlodot & Delépine, 1930).

3.1.1.1.- Foraminifer zone Cf7

The foraminifer zone Cf7 with *Eosigmoilina* more or less corresponds to the Pendleian and Arnsbergian, and may be correlated with the zones 17, 18 and 19 of Mamet & Skipp (1970, modified by Brenckle *et al.,* 1977). This zone is characterized by the appearance of *Eosigmoilina, Howchinia* with axial tubulations, *Monotaxinoides, Eolasiodiscus, Bradyina cribrostomata, Eostaffella pseudostruvei, Pseudoendothyra* ex. gr. *globosa.* "*Biseriammina*" is abundant. *Asteroarchaediscus,* or *Archaediscus* and *Ammarchaediscus* (stage *tenuis*) may predominate depending on the environment. Attached foraminifers with an irregular (partly coiled and often zig-zagging chambers), tubular test are frequent in many Silesian sediments, this in contrast to the upper Visean strata. In the literature, these foraminifers are often considered as primitive *Miliolina.*

This foraminifer zone shows many affinities with the underlying late Visean zone Cf6. The discrimination between these two zones is not always so easy. The guide form *Eosigmoilina* has only been recognized in Great Britain (from the Arnsbergian onwards ; cf. Brady, 1876 ; Cummings, 1963 ; Brenckle *et al.,* 1977 ; Fewtrell *et al.,* 1981), and in the Central Pyrenees (Perret, 1973). In these areas, the Cf7 zone is represented by well-developed assemblages. Elsewhere these show however an endemic character, and can only be identified by the predominance of *Asteroarchaediscus, Archaediscus* and *Ammarchaediscus* (stage *tenuis*). These criteria seem only valid if they are matched by other paleontological arguments (e.g. conodont or goniatite assemblages).

In Belgium, the foraminifer assemblage from the Tramaka Limestone (situated in between V3c and E2 deposits ; Austin *et al.,* 1974) is assigned to the Cf7 zone. Groessens (1983) has attributed this limestone to the E2a.

In Great Britain, the Cf7 zone has been described from the Central Province and Scotland (Cummings, 1963 ; Mamet *et al.,* 1966 ; Hallet, 1970 ; Brenckle *et al.,* 1977 ; Mamet & Roux, 1980 ; Fewtrell *et al.,* 1981 ; Laloux unpublished data based on material collected thanks to Ramsbottom.

In Ireland, the Cf7 zone has been recognized in Northwest Clare (Laloux unpublished data based on material collected thanks to Macdermott).

In France, the Cf7 zone is known to occur in the Central Pyrenees (Perret, 1973) and at Morlaix (Pelhate, 1973).

In Spain, the Cf7 zone has been described from Menorca (Bourrouilh & Lys, 1977) and Cordoba (Crousilles *et al.,* 1976).

3.1.1.2.- Foraminifer zone Cf8

The foraminifer zone Cf8 with *Millerella* and *Seminovella* more or less corresponds to the Chokierian, Alportian and Kinderscoutian, and may be correlated with zone 20 of Mamet & Skipp (1970, modified by Brenckle *et al.,* 1977). This zone is characterized by the abundant presence of *Millerella,* and by the appearance of *Seminovella.*

In Belgium, endemic faunas with *Asteroarchaediscus* and *Biseriella* from the limestones at Spy (H2c according to Higgins & Bouckaert, 1968) and at Baudour (Marlière, 1977) have been attributed to the foraminifer zone Cf8 (Laloux, unpublished data).

In Great Britain, no foraminifer assemblages from this zone are known from Chokierian and Alportian deposits. Fewtrell *et al.,* (1981) have reported some beds with *Archaediscidae* and *Millerella* of Kinderscoutian age.

In Northern France, Lys *et al.* (1962) have described a poor foraminifer assemblage without stratigraphic value from some limestones, which have been attributed to the H2c and R1.

3.1.1.3.- Foraminifer zone Cf9

The foraminifer zone Cf9 with *Pseudostaffella antiqua* more or less corresponds to the Marsdenian to basal Westphalian A, and might be correlated with zone 21 of Mamet & Skipp (1970, modified by Brenckle *et al.,* 1977). This zone is characterized by the appearance of *Pseudostaffella antiqua.* However, the recognition of this zone may be problematic since many paleobiotopes have not been suited for the foraminifers.

In Belgium, the guide species *P. antiqua* is absent in the thin limestone beds of the Marsdenian R2b deposits (*R. bilingue* zone) in the Epinois borehole (Delmer, 1968 ; Laloux unpublished data). These beds have yielded a.o. *Millerella* and *Seminovella.*

In Northern France, Marsdenian limestone beds have yielded the guide species *P. antiqua,* but not the genera *Millerella* and *Seminovella* (Lys, 1976).

In Great Britain, Fewtrell *et al.* (1981) have reported a few beds with small *Archaediscidae* from Marsdenian deposits.

In the Cantabrian Mountains of Northern Spain, foraminifer assemblages of this zone have been reported a.o. by Van Ginkel (1965) and Laloux (unpublished

data based on material collected thanks to Mrs. Villa).

3.1.2.- Westphalian

The marine bands of the Westphalian in Belgium have yielded large numbers of foraminifers (Pastiels, 1956). Usually, the foraminifer faunas are monotonous and characterized by only a few genera and species. The same holds for the Westphalian marine bands in Great Britain, the Netherlands and the Federal Republic of Germany.

Several Westphalian A marine bands (Sarnsbank, Lairesse and Wasserfall) contain benthonic foraminifers with agglutinating test (*Textulariina*, frequently misidentified as silicified bilocular *Fusulinina*) and *Miliolina*. These foraminifers have been interpreted as possible brackish-water indicators. Silicified specimens of *Fusulinina* have been reported from Westphalian A strata of the western Pyrenees in Spain (Requadt *et al.*, 1977).

Foraminifers are rare in the Westphalian B, C, D. An exception is the Aegir (= Maurage, = Mansfield) Marine Band at the base of the Westphalian C, which has yielded foraminifers with a calcareous test (`Endothyra`; Van Leckwijck, 1948 ; Demanet, 1949 ; Bless & Winkler Prins, 1972). The youngest Westphalian foraminifers in the Federal Republic of Germany have been reported from the Westphalian D (Knauff *et al.*, 1971).

Fusulinids of Bashkirian, Moscovian and Kasimovian age are common in the Cantabrian Mountains of Northern Spain (Van Ginkel, 1965, 1971 ; Bless & Winkler Prins, 1973 ; Wagner, 1977 ; Villa, 1982 ; Laloux, unpublished data based on material collected thanks to Mrs Villa). Fusulinids of Moscovian age occur in the Oslo Graben of Norway (Olausen, 1981).

3.2.- CONODONTS

The presence of conodonts in the Carboniferous was first mentioned by Demanet (1938, 1941, 1943, 1948), who recorded them from the `Couches de Passage` (V3c), from ampelitic beds in the `Assise de Chokier` (Arnsbergian-Chokierian), from the Sarnsbank (= Ransart), Finefrau Nebenbank (= St. Barbe de Floriffoux) and Aegir (= Maurage) marine bands in the Westphalian. The faunas however, were treated as natural assemblages.
Conodonts were described by Bouckaert & Higgins (1963, 1968) from various marine environments and lithologies (mainly carbonates). The association of conodonts and goniatites allows an accurate correlation of the conodont succession with the standard zonation of the Namurian, even if the conodont succession is incomplete (Higgins, 1975) (Tab. 1). Gaps in the conodont succession are either due to absence of strata (e.g. Pendleian) or to the difficulty of obtaining suitable samples (e.g. Yeadonian).

Austin & Rhodes (1970) and Austin *et al.* (1974) have described a conodont assemblage from the Tramaka Limestone (Namur Synclinorium). An early Arnsbergian (E2a) age has been suggested for the Tramaka Limestone (Higgins, 1981 ; Groessens, 1983). The conodont faunas described by Higgins & Bouckaert (1968) exhibit major changes within the Namurian between the Upper Arnsbergian (E2c) and Lower Kinderscoutian (R1a) substages. The importance of the faunal breaks occuring within this interval has been discussed by Higgins (1982a). A major change in the conodont sequence occurs in the Chokierian stage (H1b in the Namur basin vs. H1a in the Pennine area, where a more complete conodont record is available) with the first appearance of the genera *Declinognathodus* and *Neognathodus* together with *Rachistognathus minutus* (which is limited to the Chokierian). At the same level *Gnathodus* and *Paragnathodus* disappear. This limit probably matches the Mississippian-Pennsylvanian boundary in the U.S.A. Another major change is found at the base of the Kinderscoutian, and is marked by the massive appearance of the genus *Idiognathoides*. No *Idiognathus* species have been recorded from Marsdenian strata in Belgium. This reduces the possibilities for a further zonal subdivision. A tentative correlation with the more complete British conodont zonation (Higgins, 1975) is based on the conodont distribution charts of Higgins & Bouckaert (1968) (Tab.5).

3.3.- OSTRACODES

Ostracodes have not yet been described from the Namurian strata of Belgium, although they may occur at several horizons.
Ostracodes from the Westphalian deposits in Belgium should be divided into three groups : non-marine ostracodes belonging to the genera *Carbonita* and *Radiicypridina*, brackish-water ostracodes belonging to the genus *Geisina*, and a highly diversified group of marine ostracodes.

Non-marine ostracodes belonging to the genus *Carbonita* occur throughout the Westphalian of Belgium. A sample list of locations and horizons has been published by Pruvost (1930). The genus has been frequently observed in the Carboniferous coalbasins of

Table 5.- Conodont Distribution Chart

Species	Arnsbergian					Choki-erian	Alpor-tian	Kinderscoutian				Marsdenian		Yeado-nian	Westph. A
	V3c	E2a1	E2b2	E2b3	E2c	H1b	H2c2	R1a3	R1b2	R1c1	R1c2	R2a2	R2b1	G2a	G2b
Cavusgnathus naviculus	x	x	–	–	–	–	–	–	–	–	–	–	–	–	–
Paragnathodus commutatus	x	x	x	x	–	–	–	–	–	–	–	–	–	–	–
Paragnathodus cruciformis	x	–	x	x	–	–	–	–	–	–	–	–	–	–	–
Paragnathodus nodosus	x	x	–	x	x	–	–	–	–	–	–	–	–	–	–
Adetognathus unicornis	–	x	–	–	–	–	–	–	–	–	–	–	–	–	–
Gnathodus girtyi	x	x	–	x	–	–	–	–	–	–	–	–	–	–	–
Gnathodus bilineatus bilineatus	x	x	–	x	x	x	–	–	–	–	–	–	–	–	–
Gnathodus bilineatus bollandensis	–	x	x	x	x	x	–	–	–	–	–	–	–	–	–
Declinognathodus noduliferus noduliferus	–	–	–	–	–	x	x	–	x	–	–	–	–	–	x
Declinognathodus noduliferus japonicus	–	–	–	–	–	x	x	x	–	–	–	x	–	–	–
Rachistognathus minutus	–	–	–	–	–	x	–	–	–	–	–	–	–	–	–
Neognathodus bassleri	–	–	–	–	–	x	x	–	–	–	–	–	–	–	–
Declinognathodus lateralis	–	–	–	–	–	–	x	x	x	x	–	x	x	x	x
Idiognathoides corrugatus	–	–	–	–	–	–	–	x	–	–	–	x	–	x	x
Idiognathoides sinuatus	–	–	–	–	–	–	–	x	–	–	x	x	x	x	x
Idiognathoides sulcatus	–	–	–	–	–	–	–	x	–	–	x	x	–	x	x
Idiognathoides attenuatus	–	–	–	–	–	–	–	–	–	–	–	x	x	x	x
Idiognathoides convexus	–	–	–	–	–	–	–	–	–	–	–	–	–	x	x
Idiognathoides sulcatus parvus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	x
Zones	bilineatus bollandensis - naviculus					noduliferus lateralis minutus		corrugatus - sulcatus - sinuatus							sulcatus parvus

Great Britain (e.g. Pollard, 1966, 1969 ; Anderson, 1970), France (e.g. Pruvost, 1919 ; Waterlot, 1934), the Netherlands (e.g. Van der Heide, 1951 ; Bless & Pollard, 1973), Federal Republic of Germany (e.g. Kremp & Grebe, 1955 ; Vangerow, 1970), Spain (e.g. Bless, 1973), Canada (Copeland, 1957), United States of America (e.g. Scott & Summerson, 1943 ; Scott, 1944), and the U.S.S.R. The genus *Carbonita* seems of little value for stratigraphic purposes.

The non-marine ostracode genus *Radiicypridina* (= "*Cypridina*" *radiata*) is extremely rare in the Westphalian of Belgium. Only one specimen has been mentioned from the Upper Westphalian A of the Campine coalfield (Pruvost, 1930). This genus has also been observed once in the Upper Westphalian A of the neighbouring South-Limburg area (Van der Heide, 1951). Although this genus ranges throughout the Westphalian, it shows its greatest frequency in the Westphalian A.

The brackish-water ostracode genus *Geisina* (in the literature frequently described as *Jonesina* or *Beyrichia arcuata*) is restricted in Belgium, the southern Netherlands and the Federal Republic of Germany to the Westphalian A and lower part of the Westphalian B (e.g. Bless, 1967). It is a facies-fossil that undoubtedly will be recognized in the Namurian deposits of these countries. In Great Britain, the genus ranges into the Westphalian C (e.g. Calver, 1969).

Thus far, marine ostracodes in the Silesian of Belgium have only been described from the Aegir or Maurage Marine Band at the base of the Westphalian C. More than 25 species are known. These have been observed also in the Aegir Marine Band and its equivalents of Great Britain, the Netherlands and the Federal Republic of Germany (Bless & Winkler Prins, 1972). However, one should be aware of the fact that these species may occur in other marine horizons under favourable circumstances. Marine ostracodes have been described from several marine bands in Great Britain (e.g. Bless & Calver, 1970 ; Calver, 1973 ; Bless, 1974).

4.- MACROFLORA

Plant macrofossils constitute the most spectacular fossil group of the Silesian strata. They have been frequently used for stratigraphical purposes, long-distance correlations, and regional studies of areas with a complex tectonic structure. A general account of the most important publications on this subject has been made by Stockmans (1962) who also emphasized the problems and bias related to a macrofloral biozonation.

The macrofloral zonation proposed here is based on a survey by M. Fairon-Demaret and E. Houlleberghs of the published data in combination with first-hand observations by E. Houlleberghs. It summarizes mainly the wealth of data accumulated by Y. Willière, who examined and determined a tremendous amount of plant remains within the framework of the publications and documents of the "Association pour l'étude de la Paléontologie et de la Stratigraphie houillères" and the "Centre National de Géologie Houillère" (1947-1975).

Few plant fossils are cited here. They are mentioned because they are regarded as typical representatives in successive range associations. As single element determinations are of little or no biostratigraphical value, only correlations based on form associations result in meaningful interpretations.

4.1. *Sphenophyllum tenerrimum - Eleutherophyllum waldenburgense* **Zone. (Arnsbergian/Chokierian/ Alportian)** (Tab. 1, Fig. 7).

Arnsbergian to Chokierian macrofloral successions have been studied in great detail in the Dinant Synclinorium and Vesdre Massif by Stockmans & Willière (1955) and by Van Leckwijck & Stockmans (1956). Alportian floras in the Namur Synclinorium have been described by Stockmans & Willière (1953).

Eleutherophyllum waldenburgense and *Sphenophyllum tenerrimum* have been selected as representative species ; the first one has not been recorded from younger strata ; the second is rare in the Kinderscoutian. They are both locally abundant together with representatives of stratigraphically long-ranging *Stylocalamites, Calamostachys* and *Palaeostachya, Mariopteris* with dissected pinnules, a few *Neuropteris schlehani* etc.

Apart from those elements which have a wide geographical distribution, the associations of this zone show peculiar elements with a restricted regional or even local occurrence *(Gulpenia limburgensis, Sphenopteris gulpeniana, Neuropteris condrusiana . . .)*. Such endemic elements should not be used for a definition of an assemblage zone.

Moreover, the transitional aspects of the floral assemblages described from various localities are obvious (Stockmans, 1962). Dinantian genera *(Adiantites, Sphenopteridium)* are found together with typical Westphalian ones *(Neuropteris, Pecopteris, Mariopteris, Lepidodendron, Lepidophloios)*. There are no criteria based on plant macrofossils which would allow a definition of the base of this biozone.

4.2.- *Pecopteris aspera - Karinopteris laciniata - Eusphenopteris hollandica* **Zone.   (Kinderscoutian).** (Tab. 1, Fig. 7).

Macrofloral assemblages from this zone appear to have been less influenced by local facies conditions than those from the Lower Namurian stages. In the lower part of the zone, two types of associations are found - an autochthonous one, characterized by the occurrence of coal seams and/or rootlet beds ; and an allochthonous one, composed of smaller fossil plant fragments, mainly Sphenopterideae and Calamariaceae.

The flora of Gives - Groynne (Stockmans & Willière, 1953, p. 343 ; 1954, p. 123), and the flora of Flawinne (Stockmans & Willière, 1953, p. 344), are considered typical of respectively, the first and the second types. In the upper part of the Kinderscoutian, with less marine influence and sequences increasing in thickness, several horizons with a diverse macroflora are recorded : e.g. the floral assemblage of `Carrière Kévret-Nord (Andenne)` (Stockmans & Willière, 1953, p. 344).

The biozone is characterized by the abundance of *Pecopteris aspera* (also known from at least one locality of the underlying zone : Stockmans & Willière 1954), and by the appearance of *Eusphenopteris hollandica* and *Karinopteris laciniata. K. laciniata* is restricted to this zone, but *Eusphenopteris hollandica* ranges into the lower Westphalian A.

4.3.- *Transitional flora* **(Marsdenian and Yeadonian)** (Tab. 1, Fig. 7).

The macrofloral assemblages of these two stages are increasingly cosmopolitan. These are characterized by the last representatives of Dinantian genera and by the massive appearance of Westphalian species. These associations have been found throughout the Belgian coal basins.

4.4.- *Neuropteris schlehani - Karinopteris acuta - Alethopteris lonchitica - Lyginopteris hoeninghausii* **Zone (Westphalian A)** (Tab. 1, Fig. 7).

The lower part of this stage (up to the Wasserfall horizon) and especially the Ransart member still yield characteristic pre- Westphalian species ; *Eusphenopteris hollandica* is a good example (Lambrecht & Charlier, 1956 ; Stockmans & Willière *in* Lhoest, 1958 ; Van Amerom & Lambrecht, 1979). On the other hand, some species which appeared already in the Namurian, reach their maximum abundance, e.g. *Neuropteris schlehani, Karinopteris acuta* and *Alethopteris lonchitica. Lygi-*

nopteris hoeninghausii, amongst other new Sphenopterideae, appears in the Westphalian A.

In the western area of the Liège District the Bouxharmont coal seam (= Saurue = Première Mièrmont = Grande Veine d'Oupeye (e.g. Lambrecht, *et al.,* 1962b) contains numerous coal balls (Fig.1).The permineralized peat allowed detailed studies of plant anatomy (e.g. Leclercq, 1925 ; Schumacker-Lambry, 1966). Biostratigraphical analysis of the included fossil plants raises renewed interest (Phillips, 1980).

Above the Wasserfall horizon (in the Mons member), *Lyginopteris hoeninghausii* is locally very abundant, particularly in the Liège District (niveau de Liège of Lohest, 1958). This species disappears together with *Neuropteris schlehani* and *Karionopteris acuta* just below the Quaregnon Marine Band. The sporadic occurrence of *Alethopteris lonchitica* has been recorded from Westphalian B strata (Chaudoir, 1950). *Lonchopteris neuropteroides, Neuropteris heterophylla, Neuropteris hollandica, Lonchopteris rugosa* and *Karinopteris daviesi* appear for the first time in the Mons member. These are, however, typical elements of the Westphalian B floral assemblage.

4.5.- *Lonchopteris rugosa, Paripteris gigantea, Karinopteris daviesi, Neuropteris hollandica, Paripteris pseudogigantea* **Zone. (Westphalian B, up to the Lanklaar horizon)** (Tab. 1, Fig. 8).

Maximum abundance of *Lonchopteris rugosa* characterizes the lower part of this zone (Quaregnon member). *L. rugosa* is not recorded above the Eisden Marine Band. The distribution of *Karinopteris daviesi,* although a very rare species, is similar (e.g. Stockmans & Willière, 1962, Van Amerom & Lambrecht, 1979).

Neuropteris bourozi is regarded a `guide fossil` for the Westphalian B by Van Amerom & Lambrecht (1979), but this species is not taken into account here because it is only rarely recorded in the literature (in the `Couchant de Mons` District , Laveine, 1967, and in the Liège District, Van Amerom & Lambrecht, 1979) ; its vertical range is limited to the Lower Westphalian B.

Sphenopteris baumleri has been cited as typical of the Lower Westphalian A in the Ruhr basin (Josten, 1962a), but this species has been collected from Westphalian B strata below the Eisden horizon in the Namur synclinorium (Aderca *et al.,* 1961 ; Lambrecht *et al.,* 1962a), as well as in Northern France (Stockmans, 1962).
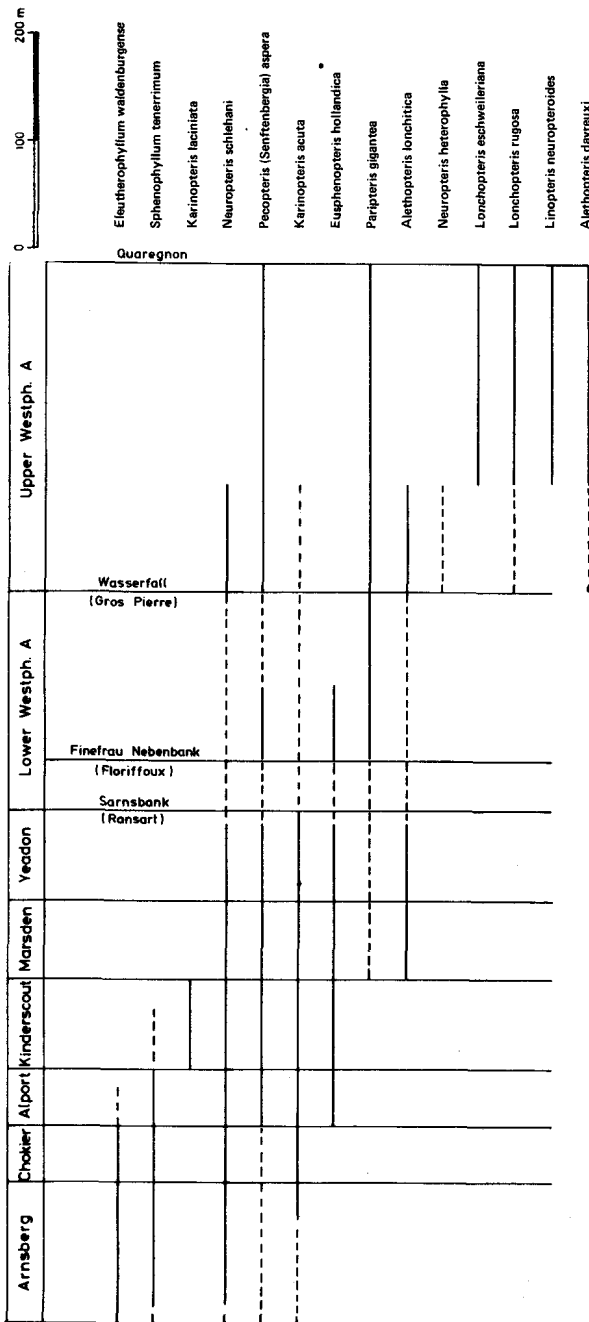
Figure 7

Range chart for important plant species during Namurian to upper Westphalian A time (based mainly on data from the Puits Panama, S-E area of the Charleroi basin)
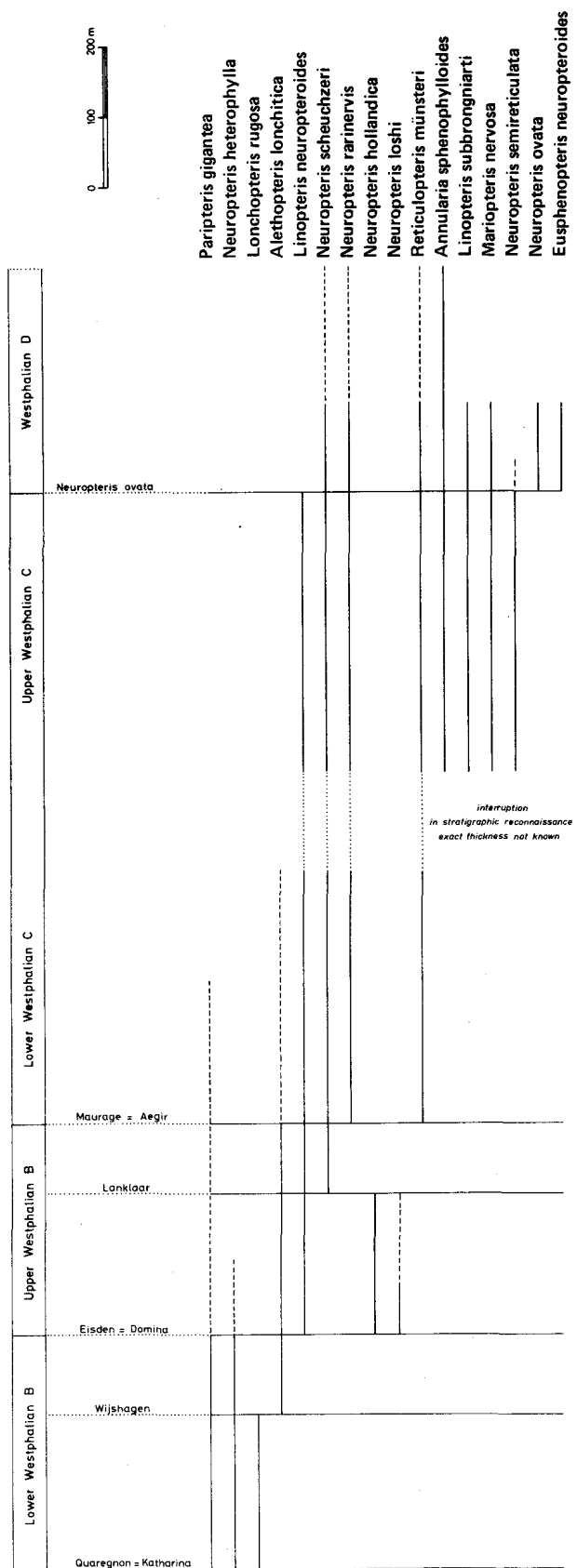
Figure 8   →

Range chart for selected plant species in the Campine basin during Lower Westphalian B to Westphalian D time

Neuropteris hollandica, Paripteris gigantea, which occur already in the Upper Namurian (Stockmans & Willière, 1954), are abundant. Also *Paripteris pseudogigantea* is typical for this zone. *Neuropteris abbreviata* Stockmans 1933 is considered here as a synonym of *P. pseudogigantea* according to Laveine (1967). The distribution of *P. pseudogigantea* is not affected by the marine transgressions of the Eisden and Lanklaar horizons. The same is true for *Neuropteris obliqua* which is a very long-ranging species (from the Upper Namurian to the upper part of Westphalian C) ; it is particularly well represented below the Lanklaar horizon (Chaudoir *et al.,* 1950). *Neuropteris hollandica, N. loshi, Sphenopteris obtusiloba* and *Annularia microphylla,* amongst other have not been recorded above the Lanklaar horizon. The influence of this marine transgression on the paralic swamp flora is marked by several extinctions.

The floral assemblage typical of the next zone is foreshadowed in the upper part of this zone by sporadic records of *Neuropteris scheuchzeri* and *Alethopteris serli* (Chaudoir *et al.,* 1950).

4.6.- *Linopteris subbrongniarti, Neuropteris rarinervis, Neuropteris scheuchzeri, Sphenophyllum emarginatum, Annularia sphenophylloides* **Zone. (From the Lanklaar horizon up to the base of the Westphalian D)** (Tab. 1, Fig. 8).

In this zone, many species already recorded from the above zones become very abundant. A widely distributed monotonous floral assemblage consists of *Neuropteris tenuifolia* (which is known from the upper part of the Westphalian A ; e.g. Chaudoir, 1953), *Neuropteris parvifolia* (already present in the Quaregnon member of the Westphalian B ; Van Amerom & Lambrecht, 1979), *Eusphenopteris striata* and *Eusphenopteris neuropteroides* (both species recorded at least from the Quaregnon Marine Band upward ; cfr. Van Amerom, 1975). Apart from these long-ranging species (which are so frequently collected in this zone that they are called ``Weeds" by Stockmans & Willière, 1975), more typical Westphalian C forms are recorded : *Linopteris subbrongniarti, Neuropteris scheuchzeri* and *Neuropteris rarinervis.* This last species disappears below the upper limit of the zone. Following Laveine (1967) and in agreement with Stockmans & Willière (1975) a specific distinction between *Linopteris subbrongniarti* and *Linopteris neuropteroides,* is maintained although this is not yet unanimously accepted. *Linopteris neuropteroides* has not been recorded from strata above the Westphalian C-D limit.

Sphenophyllum emarginatum and *Annularia sphenophylloides* show their maximum abundance in the upper part of the Westphalian C.

The phyletic series *Neuropteris obliqua - Neuropteris semireticulata - Reticulopteris münsteri* (Josten, 1962b) deserves special attention. *R. münsteri* occurs throughout the Westphalian C, becoming very abundant in the upper part of this zone ; it continues into the Westphalian D (Pl. 1). The last specimens of the long-ranging *Neuropteris obliqua* have been collected from the uppermost Westphalian C in the Campine (Stockmans & Willière, 1975 ; Dusar & Houlleberghs, 1981) ; these occur in association with *N. semireticulata,* which is still rarely present above the base of the Westphalian D (Neeroeteren borehole 117 ; Stockmans & Willière, 1975). The simultaneous occurrence of these three forms as observed in the Campine and in Northern France (Laveine, 1967) could allow an evaluation of their relative abundance in order to precise the position of the observed, otherwise ordinary, assemblage within the zone.

A cyclic alternation of associations is particularly obvious for the Westphalian C deposits of the Campine (Dusar & Houlleberghs, 1981).

4.7.- *Neuropteris ovata, Eusphenopteris striata, Annularia pseudostellata* **Zone. (Westphalian D)** (Tab. 1, Fig. 8).

As decided in 1963 at the Congress on Carboniferous stratigraphy, the lower limit of the Westphalian D is defined by the lower limit of the biozone (acrozone) of *Neuropteris ovata.* Therefore, the first occurrence of *Neuropteris ovata* has been accepted as the base of the Westphalian D in the Campine.

In this area, correlations between borehole 146 (Neerglabbeek ; Dusar & Houlleberghs, 1981) and borehole 117 (Neeroeteren ; Stockmans & Willière, 1975) are not based solely on the presence of *Neuropteris ovata.* The lower Westphalian D deposits of these two boreholes offer in addition two other remarkable horizons. The first one, some ten metres above the Westphalian C-D limit is a plant fossil horizon with an assemblage consisting of up to 80 °/o of *Eusphenopteris striata.* The second horizon, some 25 m above the limit, mainly consists of *Annularia sphenophylloides* (75 °/o). These two plants might be new elements for the definition of the Westphalian C-D limit in order to overcome the problems of the many ``*Neuropteris* aff. *N. ovata",* so often recorded in the literature (Pl. 1). Both species are already abun-
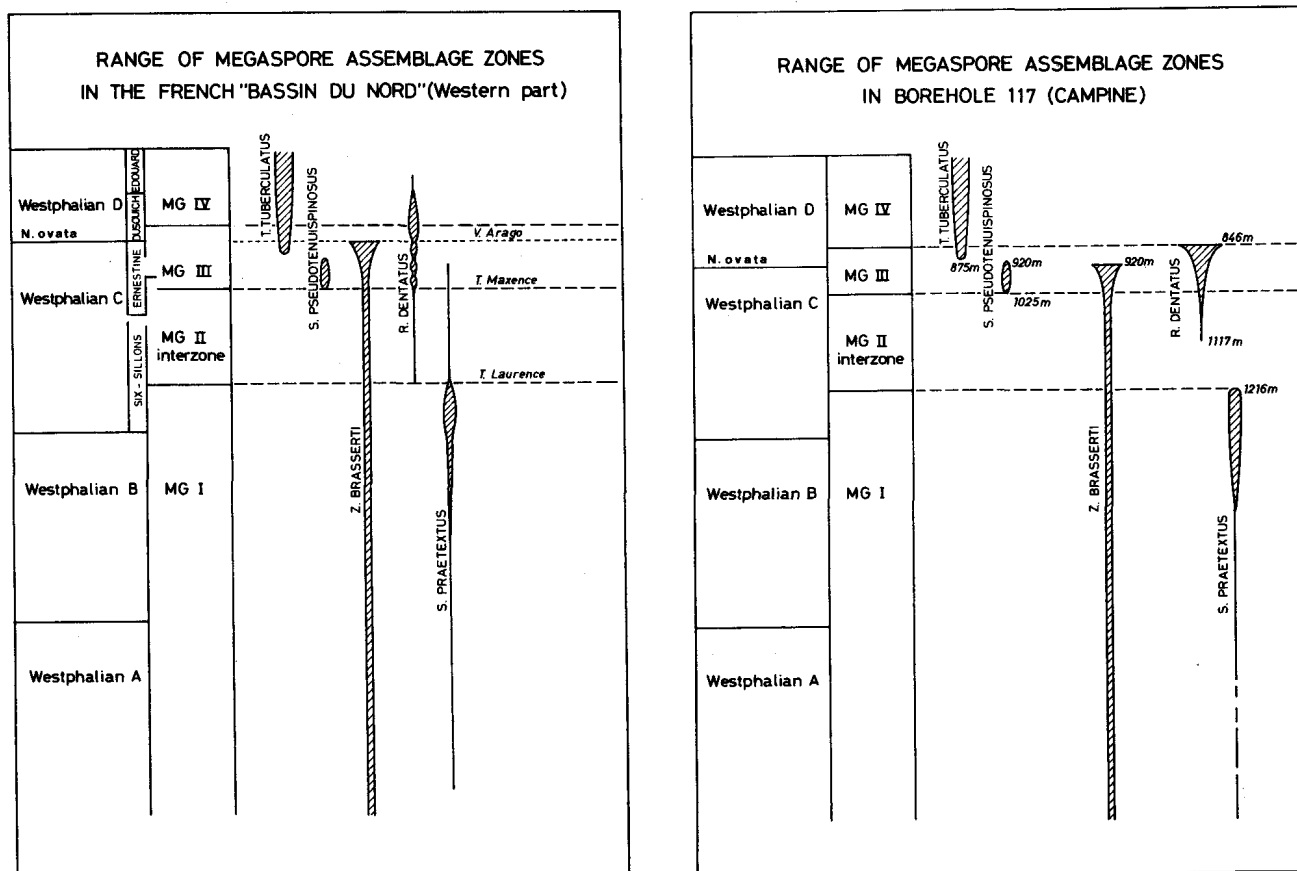
Figure 9.- Range of megaspore assemblage zones in Northern France and Campine

dant in the upper part of the previous zone. Nevertheless, *Eusphenopteris striata,* which is so widely distributed here, has been selected to characterize the base of this Westphalian D zone. It is accompanied by *Annularia pseudostellata,* a distinctive species, which is rarely mentioned in the literature.

In the succeeding Neeroeteren Sandstone, the plant fossils are scarce and, when present, they are badly preserved and of limited value for precise determinations.

5.- MICROFLORA

5.1.- MEGASPORES

The distribution of megaspores in the Westphalian A-B shows only quantitative fluctuations. These permit to trace individual coal seams over several kilometers. However, a zonal subdivision of the Westphalian A-B is not possible. A different situation exists for the Westphalian C-D, where a number of megaspore species appear and/or disappear. This allows the recognition

of four megaspore zones in the Westphalian, or rather three zones and one interzone, which have been recognized in the boreholes117 and 146 (1) of the Belgian Campine, as well as in Northern France : Megaspore zone I or MG I, Megaspore Interzone II or MG II, Megaspore zone III or MG III and Megaspore zone IV or MG IV. The lowermost zone (MG I) includes the Westphalian A and B plus Lower Westphalian C, the second and third zones (MG II and MG III) include more or less the Upper Westphalian C and the fourth one (MG IV) comprises more or less the presently known portion of the Westphalian D.

Megaspore assemblage zone I or MG I (*Setosisporites praetextus* **Zone**) (Syn. Westph. A, B + WC1) (2)

This zone starts somewhere in the Westphalian A or B, i.e. as early as it is possible to macerate the mega-

(1)PIERART, P. , en préparation. Premiers résultats stratigraphiques et palynologiques de l'étude du sondage 146 de Neerglabbek).

(2)Zonation in Piérart, 1962.

spores from the coal, and ends with the end of the epibole of *Setosisporites praetextus* (at a depth of 1216 m in the 117 borehole ; Jonguelleresse seam at Sentinelle in the Borinage). This zone is also characterized by *Setosisporites hirsutus* which disappears at the same level as *S. praetextus*. Moreover, zone I is characterized by *Lagenicula horrida* and *L. subpilosa*. *Rotatisporites dentatus* is absent in the zone I of the 117 boring. Loboziak (1971) cited this last species from his Six-Sillons zone (Fig. 9). The thickness of zone I is min. 300 m in the Westphalian C in the Campine and 575 m in the Westphalian C of the Borinage.

Megaspore Interzone II or MG II (interzone with *Z. brasserti* **and** *R. dentatus* **located between the zone with** *S. praetextus* **and the zone with** *S. pseudotenuispinosus***) (Syn. : WC2)**

This interzone starts just above the upper limit of *Setosisporites praetextus* and finishes at the lower limit of *Setosisporites pseudotenuispinosus*. This interzone is also characterized by *Zonalesporites brasserti* which is present in MG I, MG II and an important part of MG III, and in addition by *Rotatisporites dentatus* which appears in the 117 borehole at a depth of 1117 m, i.e. about the middle of Interzone II.

The top of Interzone II is characterized by the first appearance of *Setosisporites pseudotenuispinosus* (at a depth of 1025 m in the 117 boring). The thickness of interzone II is 200 m in the boring 117.

Megaspore assemblage zone III or MG III (*Setosisporites pseudotenuispinosus* **Zone) (Syn. : WC3)**

This zone starts with the appearance of *Setosisporites pseudotenuispinosus* and ends a little higher than the upper boundary of this taxon. *Setosisporites pseudotenuispinosus* is reported from the 117 boring between 1025 and 920 m. *Zonalesporites brasserti* disappears at the same point i.e. 920 m. This sudden and simultaneous disappearance of these two taxons *(S. pseudotenuispinosus* and *Z. brasserti)* is obvious in the 146 boring of Neerglabbeek at a depth of 1098 m.

The second event is the appearance of *Triletisporites tuberculatus* (in the 117 borehole at 875 m and in the 146 borehole at 1056 m) in the upper part of MG III. Finally, a third event (20 to 30 m higher) is the sudden disappearance of *Rotatisporites dentatus,* preceded by an important maximum of the same species (in the 117 borehole at 846 m and in the 146 borehole at 1036 m). The disappearance of *Densosporites* is more or less synchrone with that of *R. dentatus.* Thus, in the time interval corresponding to a sediment thick-

ness of a few tens of meters, three important changes occur in the megaspore assemblages. The appearance of *Triletisporites tuberculatus* is not important. Therefore, the boundary between MG III and MG IV is placed at the maximum of *Rotatisporites dentatus,* just before its sudden disappearance.

The first event (disappearance of *Setosisporites pseudotenuispinosus* and *Zonalesporites brasserti*) is also very clear because it is preceded by a maximum of specimens, but with a sharper boundary for the level characterized by the top of the *Zonalesporites brasserti* range.

The base of zone III corresponds in Northern France with the Tonsteins Maxence and Maurice . The thickness of MG III varies between 125 and 175 m.

Megaspore assemblage zone IV or MG IV (*Triletisporites tuberculatus* **Zone) (Syn. : WC4)**

The base of this zone is at the maximum of *Rotatisporites dentatus* (found at the depth of 1036 m in the 146 borehole, 846 m in the 117 borehole, 745 m in the 113 borehole and 630 m in the 110 borehole. The lower boundary of MG IV is just above the base of the Westphalian D. The appearance of *Neuropteris ovata,* discovered by F. Stockmans at a depth of 875 m in the 117 borehole, i.e. exactly at the level where *Triletisporites tuberculatus* appears, is considered to be the base of the Westphalian D. This boundary corresponds to the Arago seam, accepted as the base of the Westphalian D in Norther France (Fig. 9). The upper boundary of zone IV is not known (not yet explored).

5.2.- MIOSPORES

5.2.1.- Introduction

The inventory of miospores of the Neeroeteren "zone" in the Campine basin was the first paper on the Westphalian miospores of Belgium (Pierart, 1958). In the same basin, Somers (1971, unpublished) (3), studied the miospore assemblages from the 117 borehole and from the main mined coal seams above the Wasserfall horizon. The high coalification of the seams below this horizon did not favour palynological investigations. Somers distinguished four miospore zones and eleven subzones.

Concerning the whole Northwestern Europe, the first palynological studies dealt only with coals and

(3) SOMERS, Y., 1971. *Etude palynologique du Westphalien du Bassin de Campine et révision du genre* Lycospora. *Thèse Doct. Sci. Bot. Univ. Liège, 472 p.*
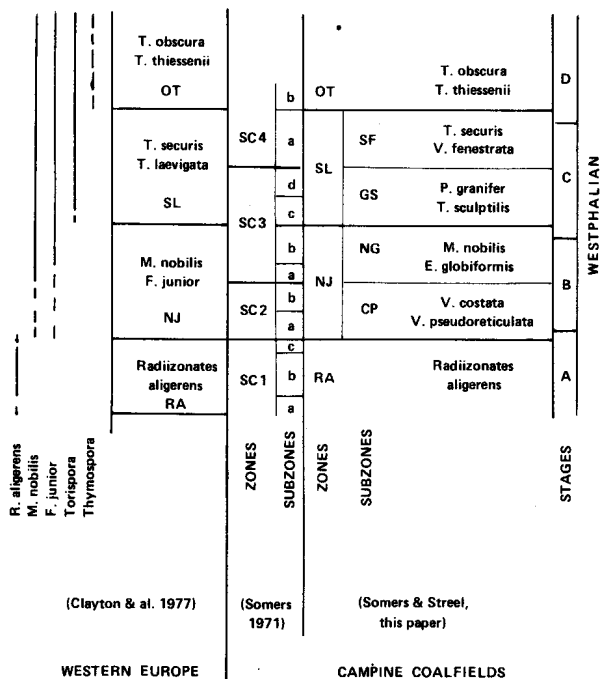
T. obscura T. thiessenii OT				OT	T. obscura T. thiessenii	D	
			b				
T. securis T. laevigata	SC4	a		SF	T. securis V. fenestrata	C	
		d	SL				
SL	SC3	c		GS	P. granifer T. sculptilis		
M. nobilis F. junior		b	NJ	NG	M. nobilis E. globiformis	B	
		a					
NJ	SC2	b		CP	V. costata V. pseudoreticulata		
		a					
		c					
Radiizonates aligerens RA	SC1	b	RA		Radiizonates aligerens	A	
		a					

R. aligerens / M. nobilis / F. junior / Torispora / Thymospora   ZONES   SUBZONES   ZONES   SUBZONES   STAGES   WESTPHALIAN

(Clayton & al. 1977)   (Somers 1971)   (Somers & Streel, this paper)

WESTERN EUROPE   CAMPINE COALFIELDS

Figure 10

Comparison of the miospore zonation in the Westphalian of the Campine basin and the whole Northwestern Europe

consisted essentially in establishing a descriptive monograph of the miospore species (Potonié, 1932 ; Potonié *et al.*, 1932 in the Ruhr coalfield).

One of the first palyno-stratigraphic zonations of the Silesian in Northwestern Europe has been published in 1967 by Smith & Butterworth, who investigated the coal basins of Great Britain. Simultaneously, a miospore zonation for the Upper Westphalian and Stephanian of the Saar-Lorraine coal basin was published (Alpern & Liabeuf, 1966 ; Alpern *et al.*, 1967, 1969).

Subsequently, miospore zonations for the Westphalian deposits of other regions have been established, a.o. Northern France (Loboziak, 1969, 1971 ; Coquel, 1976), the Ruhr coal basin (Grebe, 1971, 1972), the Campine (Somers, 1971, unpublished) and the Netherlands (Van Wijhe & Bless, 1974). Some of these zonations are based on the miospore assemblages from coal seams only, others from both coal seams and clastic material.

Many authors have proposed correlations between these regions (a.o. Alpern, 1970 ; Somers, 1971, unpublished ; Loboziak, 1974 ; Butterworth & Smith, 1976). A synthesis of all the data available from the Western European Carboniferous has been made in 1977

by a working group of the Commission Internationale de Microflore du Paléozoïque (CIMP). This working group (Clayton *et al.*, 1977) has proposed a standard zonation based on miospore assemblages. Four of these ˇassemblage zones˝ have been recognized in the Campine coal basin (Fig. 10), where also several subzones can be distinguished.

5.2.2.- Miospore zonation of the Westphalian in the Campine basin

The four palynological zones and eleven subzones established by Somers (1971, unpublished) are indicated by the characters ˇSC˝ (S = sporology, the discipline used for the zonation ; C = Campine, the area concerned), according to the CIMP usage of that period. In order to harmonize with the standard CIMP zonation of Clayton *et al.* (1977), the nomenclature of the 4 zones defined by these authors for the Westphalian in Europe is used here for the zonal division of the Westphalian in the Campine and the subzones are also indicated by the first character of the guide species.

The Westphalian microflora is quite diverse, but only those species which are used for stratigraphic purposes in other Western European basins are shown on Figure 11. The stratigraphic range of the miospores in the Campine basin has been largely determined through the study of coal seams (Somers, 1971, unpublished, also recent unpublished data), but also of shales (Streel, unpublished data). The discontinuous presence of spores is indicated by a dotted line. An uninterrupted line is used for the epibole or for the continuous presence of a species. The relative abundance of a species has not been taken into account since this may depend on facies rather than on the age of the deposits.

5.2.2.1.- *Radiizonates aligerens* (RA) zone

- **base** : not identified in the Campine basin because of the high coalification of the coal seams.

- **age** : Middle to Upper Westphalian A.

- Characterized by the presence of *R. aligerens, P. sinuatus* and *S. rara* in practically all coal seams. These species are associated with several others which are more useful to define the next zones, such as *C. connexus, R. striatus, A. guerickei, C. loricatus, D. bireticulatus* and *Densosporites* spp., and - less frequently - also by *R. tenuis* and *S. nux.* In the upper portion of this zone *Vestispora* appears, first *V. costata* and subsequently *V. pseudoreticulata.* The first specimens of *C. indignabundus* appear at the very top of the RA zone.
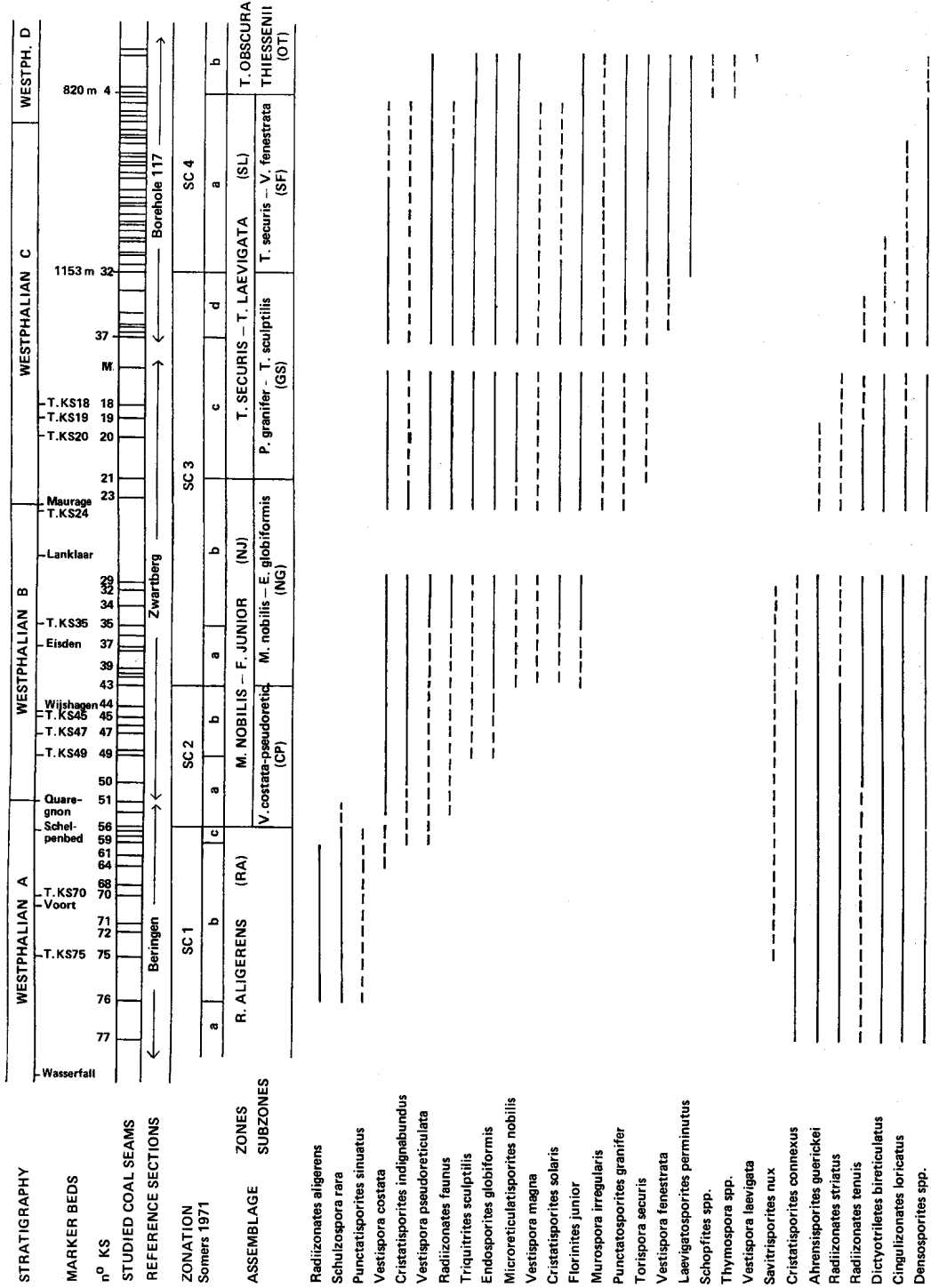
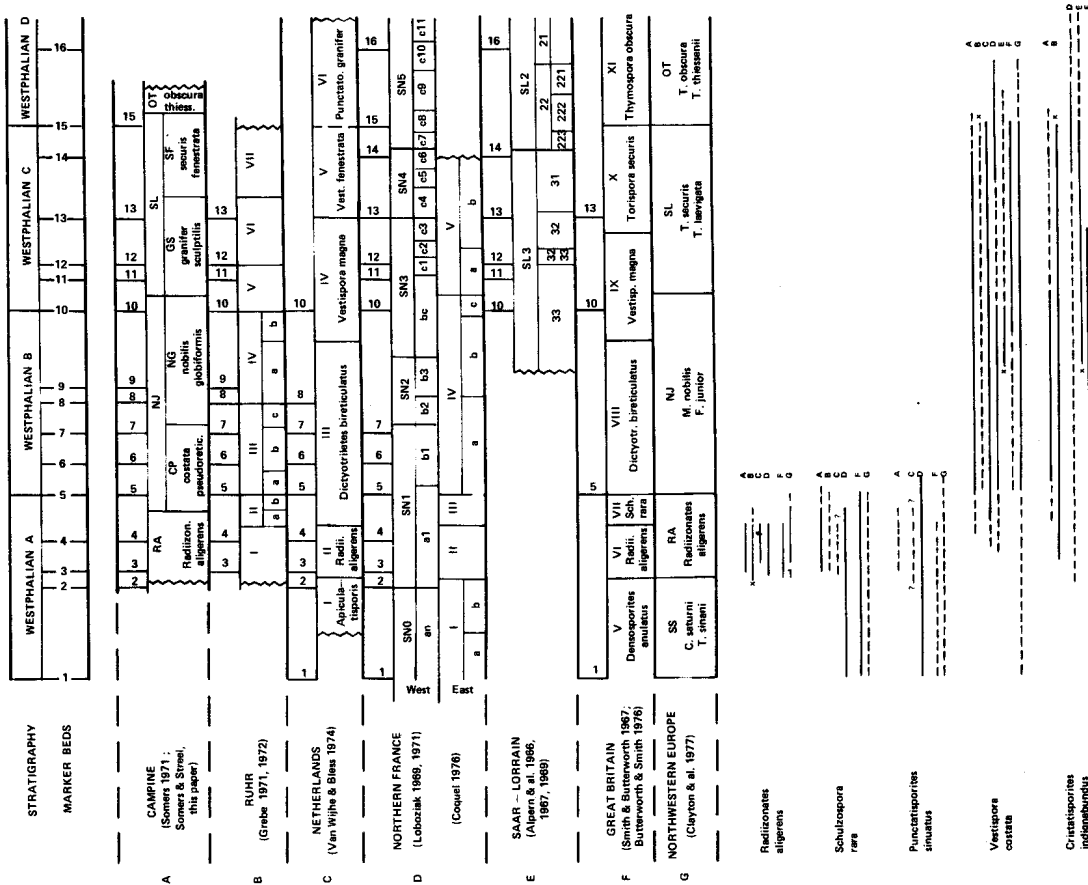*Figure 11.- Stratigraphic range of miospore guide species in the Campine basin*

Figure 12

Miospore zonations and comparative stratigraphic range of selected species of the Westphalian in Northwestern Europe. Marker Beds after Tricot (this paper), Bouroz, 1967 ; Burger, 1982/3 ; Kimpe, 1969 ; Scheere, 1956 : 1.- Ransart ; 2.- Mons ; 3.- tonstein KS-75 ; 4.- tonstein KS-70 ; 5.- Quaregnon ; 6.- tonstein KS-49 ; 7.- tonstein KS-45 ; 8.- Eisden ; 9.- tonstein KS-35 ; 10.- Maurage ; 11.- tonstein KS-20 ; 12.- tonstein KS-18 ; 13.- tonsteins KS-6 ; 14.- (tonstein Patrice) ; 15.- N. ovata ; 16.- (tonstein Valence). x = limit of investigation ; ? = doubtful limit.

5.2.2.2.- *Microreticulatisporites nobilis - Florinites junior* (NJ) zone

According to Clayton *et al.* (1977), the lower limit of this zone is defined by the appearance of *M. nobilis* and *F. junior,* as well as by the disappearance of *S. rara* and *P. sinuatus.* The NJ zone is characterized a.o. by the continuous presence of *V. costata* and *D. bireticulatus.*

In the Campine basin, the two species used to name the NJ zone *(M. nobilis* and *F. junior)* appear at a higher level, but otherwise the microflora is indicative of the assemblage zone as defined by Clayton *et al.* (1977).

5.2.2.2.1.- *Vestispora costata - Vestispora pseudoreticulata* (CP) subzone

- **base** :   last occurrence of *P. sinuatus* in KS-56[*] coal seam. (*S. rara* becomes discontinuous).

- **age** :   uppermost Westphalian A and Lower Westphalian B.

[*] *Coal seam number of Kempense Steenkolenmijnen.*
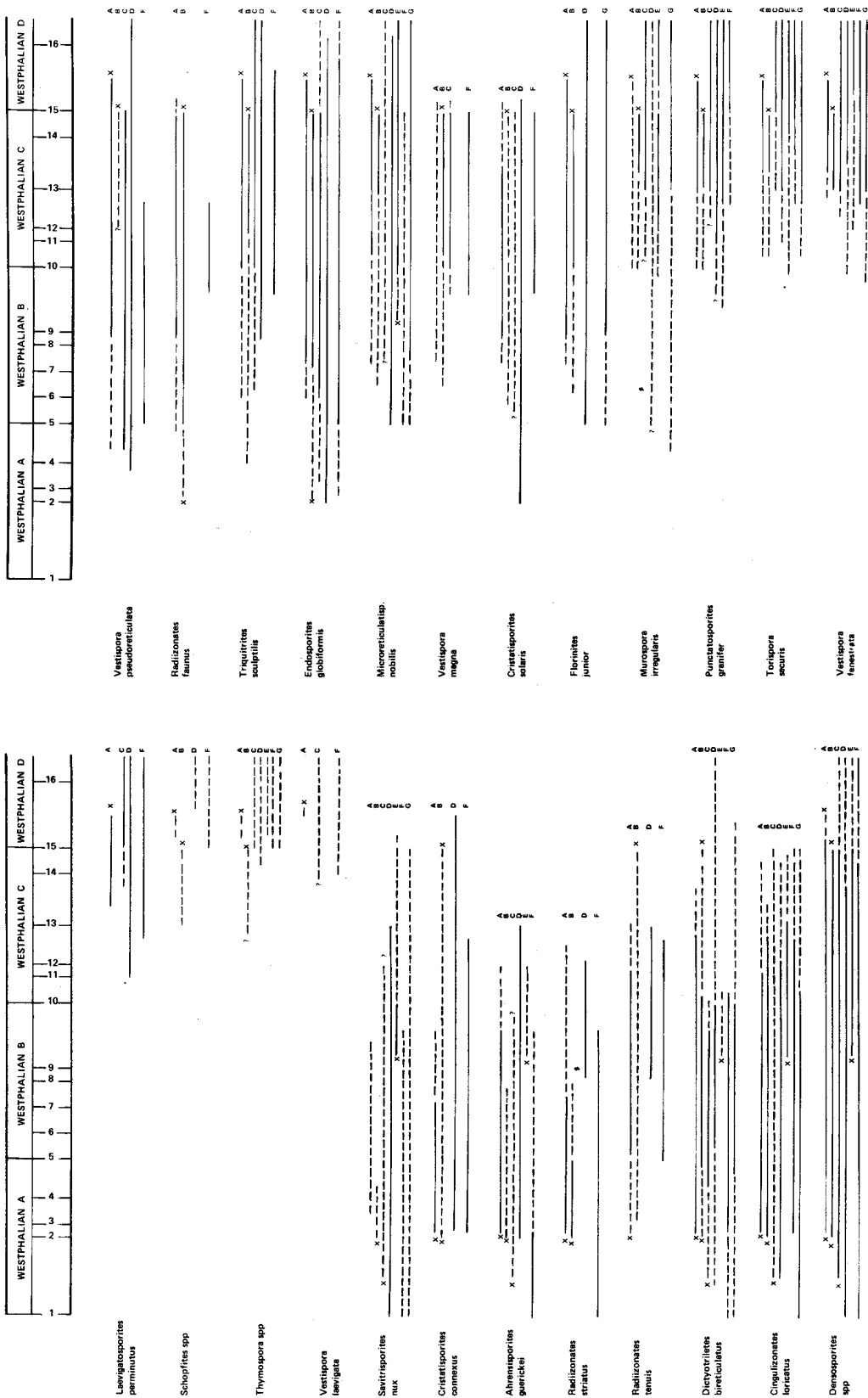
- Characterized by the base of the epibole of *V. cos-tata*, *R. tenuis* and *C. indignabundus,* appearance of *V. pseudoreticulata* and *R. faunus. S. rara* disappears in the lowermost part of this subzone. *T. sculptilis* and *E. globiformis* appear in the middle portion of the subzone.

5.2.2.2.2.- *Microreticulatisporites nobilis - Endosporites globiformis* (NG) subzone

- **base** : appearance of *M. nobilis,* in KS-43 coal seam, base of epibole of *E. globiformis* (top of epibole of *C. connexus* and *R. striatus*).

- **age** : Middle to Upper Westphalian B and basal Westphalian C.

- Characterized in the lowermost part by the appearance of *M. nobilis, V. magna, C. solaris* and *F. junior,* and by the base of the epibole of *E. globiformis.* Slightly higher, the base is found of the epiboles of *V. pseudoreticulata, R. faunus, C. solaris* and *F. junior,* and then the top of the biozone of *S. nux* and *C. connexus. A. guerickei* becomes infrequent. *R. striatus* is less frequent than in the CP subzone.

5.2.2.3.- *Torispora securis - Torispora laevigata* (SL) zone

For the definition of this zone, the reader is referred to Clayton *et al.* (1977).

5.1.2.3.1.- *Punctatosporites granifer - Triquitrites sculptilis* (GS) subzone

- **base** : appearance of *T. securis* in KS-21 coal seam, development of epibole *T. sculptilis,* top of epibole of *C. indignabundus.*

- **age** : Lower Westphalian C.

- Characterized by the relative abundance of *T. sculptilis* and *M. nobilis,* absence of *C. connexus,* appearance of *P. granifer, T. securis* and *M. irregularis. C. indignabundus* becomes infrequent.
The middle portion of the GS subzone is characterized by the disappearance of *A. guerickei* and *R. striatus,* by the top of the epibole of *R. tenuis, C. loricatus,* and subsequently by the top of the epibole of *D. bireticulatus.* In the upper part of the subzone, *V. fenestrata* appears, *P. granifer* becomes more abundant, whereas *R. tenuis* disappears.

5.2.2.3.2.- *Torispora securis - Vestispora fenestrata* (SF) subzone

- **base** : base of epibole of *T. securis* and *V. fenestrata* in No 32 coal seam (depth 1153 m) of 117 borehole.

- **age** : Upper Westphalian C.

- Characterized by the base of epibole of *P. granifer, T. securis* and *V. fenestrata,* regular occurrence of *L. perminutus. D. bireticulatus* and subsequently *C. loricatus* disappear. Also the top is observed for the epiboles of *C. solaris,* then of *V. costata* and subsequently, *R. faunus.* These species disappear at the top of this subzone. The top of the subzone is also characterized by the top of the epibole of *Densosporites,* and by the disappearance of *C. indignabundus* and *V. magna.*

5.2.2.4.- *Thymospora obscura - Thymospora thiessenii* (OT) zone

- **base** : appearance of *Thymospora* in No 4 coal seam (depth 820 m) of 117 borehole.

- **top** : not determined.

- **age** : Lower Westphalian D.

- Characterized by the appearance of *Thymospora, Schopfites* and *V. laevigata,* and by the absence of *C. indignabundus, V. magna, C. solaris, V. costata* and *R. faunus.*

N.B. : Stockmans & Willière (1975) noticed that some rare specimens of *Thymospora* had been observed by Loboziak in a shale sample at 875 m in the 117 borehole.

5.2.3.- Comparison with other Western European basins

The miospore zonations and the stratigraphic ranges of selected miospore species in the Westphalian of various Western European basins is shown in Figure 12. As far as possible, the stratigraphic range of these species has been determined by using a number of more or less synchronous reference horizons (marine bands and tonsteins).

Miospores which are produced in enormous quantities are easily dispersed through large distances. In the course of a palynological study, thousands of specimens are available. This makes that the zonations established for the different regions may be often very similar. Therefore, miospores have proved to be one of the most successful tools for stratigraphic investigations and correlations of the Westphalian in Western Europe.

6.- COAL TONSTEINS

Coal tonstein horizons constitute the best chronostratigraphic markers available in the Carboniferous. At least 12 coal tonstein horizons have been recorded in the Westphalian of the Campine. A tentative correlation with the German coal tonstein succession has been successively proposed by Scheere (1955, 1956, 1958), Kimpe (1969) and Burger (1982).

Westphalian A coal tonsteins were also described from the Liège and Charleroi coalfields (Biot & Scheere, 1961 ; Lhoest & Scheere, 1958).

A sequence of 6 Westphalian C coal tonstein horizons has been recorded from the " Massif de Masse" in the Centre coalfield. Correlations with stratigraphically better studied areas (Northern France, Ruhr) lack precision (Delmer, 1971).

A new tonstein find in borehole KS-16 (Campine basin) possibly corresponds to tonstein Baldur (Lower Westphalian C) in the Ruhr basin (personal communication, J. Tricot).

Table 6
Proposed correlation scheme between tonstein horizons in the Campine and Ruhr, based on Scheere, Burger, emended by Tricot. (correlations with Couchant de Mons coalfield between brackets).

T x	=	x
T 6$\frac{u}{l}$	=	Nibelung $\frac{u}{l}$ (Bechié)
T 18	=	Hagen 1 (Hanas)
T 19	=	Hagen 4 (Veine à Terre)
T 20	=	Erda (Soumillarde)
T 24	=	Z1 (Grand Buisson)
T 35	=	P 4 or O2
T 45 $\frac{u}{l}$	=	Zollverein 2 $\frac{u}{l}$
T 47	=	Zollverein 3 or 6 $\frac{u}{l}$
T 49	=	Zollverein 8 (V.H.)
T 70	=	Karl
T 75	=	Wilhelm

7.- LITHOSTRATIGRAPHY

7.1.- NAMURIAN

Usually, the Namurian strata in Belgium are subdivided in two "assises", based on lithological criteria : the "Assise de Chokier" without coal, and the "Assise d'Andenne" with coal. These may be considered as formations. This subdivision, first noticed by Dumont (1832), corresponds to the original description by Purves who established the name Namurian in 1881 (we refer to Van Leckwijck, 1957 and 1964 for the history of the stratigraphical nomenclature).

7.1.1.- Chokier Formation

The Chokier Formation is composed of calcareous shales, aluniferous shales (ampelites) and cherts, with a rich marine fauna, devoid of coal seams or rootlet beds. The original name was "Ampélite de Chokier" (d'Omalius, 1853), and was equivalent to the "Houiller sans houille" of Dumont (1832) and to the "Shales with *Posidoniellas* and goniatites" of Purves (1881).

base : the top of the Dinantian carbonates ; normally corresponding to a sharp boundary at the place of a stratigraphic gap of varying importance. In the western part of the Namur Synclinorium (Blaton area) a gradual transition consisting of chert beds persists between V3c dated beds (Warnantian) and E2b dated beds (Arnsbergian (Bouckaert *et al.* 1961). A radioactive márker horizon discovered in the chert sequence by R. Legrand probably corresponds to similar horizons occurring at a few meters below the top of the Visean limestones at many localities in the Dinant and Namur Synclinoria. This marker horizon may be a practical indicator for the Visean-Namurian limit (Ndziba, 1982, unpublished) (Fig. 1).

top : the base of the Andenne Formation.

7.1.2.- Andenne Formation

The Andenne Formation consists of sandstones, coal seams, rootlet beds and non-marine shales which are intercalated by a few thin marine shales (paralic facies). The cyclic nature is the most characteristic feature of the paralic sediments (Fiege & Van Leckwijck, 1964). The original name was "Schistes et psammites avec houille maigre" of Purves (1881), and included the Andenne grit (see Java section, Fig. 1). This was the equivalent of the "Houiller avec houille" of Dumont (1832). Many grits and ganister beds have been distinguished locally at different stratigraphic levels within this formation.

base : the top of the Chokier Formation. Development of paralic facies conditions ; with thin coal seams which have been widely exploited. In the Namur Synclinorium, the sediments of the Andenne Formation have been deposited since late Chokierian times. However in the

(4) NDZIBA, M., 1982. Anomalies radiométriques des couches du passage du Viséen-Namurien dans le Bassin de Dinant. Thèse Univ. Sc. Techn. Lille (unpublished).

eastern part of the Dinant Synclinorium and the Vesdre Synclinorium (including the Theux Massif) paralic facies conditions already appeared in Arnsbergian times, whereas in the Campine basin these conditions did not appear before Alportian times ("facies de stampe stérile", without coal).

top : the base of the Coal Measures.

7.2.- WESTPHALIAN

In the Westphalian, paralic facies conditions persisted without interruption. Nevertheless, the sequence of thick largely exploited coal seams is limited to the Westphalian and allows a distinction between the Andenne Formation and the Coal Measures in Belgium (Fig. 1). No further formations can be distinguished within the Coal Measures although a succession of coal seam groups ("faisceaux") separated by barren intervals ("stampes stériles") has been recognized which represent megacyclothems starting with a marine band (Van Leckwijck, 1949 ; Van Leckwijck & Fiege, 1963). The framework for further lithostratigraphic subdivisions is provided by marine bands selected as boundaries between the successive members in the Coal Measures. These bands allow firm (practically isochronous) correlations between different basins. Unfortunately, this has resulted in a confusion between chrono-, bio- and lithostratigraphic zonation (Table 3). Therefore, a simple lithostratigraphic subdivision is proposed here. This is based on the most important marine bands and named after the generally well known basal marine band.

7.2.1.- Belgian Coal Measures Formation

base : the top of the Andenne Formation : St. Barbe de Ransart (= Fraxhisse, = Sarnsbank) Marine Band ; transition between paralic sequences poor and rich in thick coal seams.

top : limited to the explored part of the Westphalian in Belgium.

7.2.1.1.- Ransart Member

base : St. Barbe de Ransart (= Fraxhisse, = Sarnsbank) Marine Band ; first accepted by Stainier (1930) as a marker for the base of the Westphalian, designated as the base of the "Zone d'Oupeye" (Renier, 1930) ; first described as a marine band by Stainier (1901).

top :   base of St. Barbe de Floriffoux Marine Band.

7.2.1.2.- Floriffoux Member

base :   St. Barbe de Floriffoux (= Grande Veine d'Oupeye,   = Beaujardin,   = Bouxharmont,   = Finefrau Nebenbank) Marine Band ; first described by Stainier (1901), its importance as a marker bed emphasized by Renier (1928), designated as the base of the "Zone de Beyne" by Renier (1930).

top : base of Wasserfall Marine Band.

7.2.1.3.- Mons Member

base :   Wasserfall (= Stenaye,   = Gros Pierre) Marine Band ; first recognized as a marine band on top of the Albert coal seam in the Bruyères borehole in Mons by Stainier (1928), more fully described from the Bois-du-Luc colliery (Stainier, 1941), its importance as a marker bed emphasized by Renier (1928), designated as the base of the "Zone de Genck" by Renier (1930).

top : base of Quaregnon Marine Band.

7.2.1.4.- Quaregnon Member

base : Quaregnon (= Katharina) Marine Band ; first recognized as a marine band by Stainier (1912), its importance as a marker bed emphasized by Renier (1928), designated as the base of the "Zone d'Asch" by Renier (1930).

top : base of Eisden Marine Band.

7.2.1.5.- Eisden Member

base :   Eisden (= Domina) Marine Band ; first recognized as a marine band by Grosjean (1929), designated as the base of the "Zone d'Eikenberg" by Renier (1930).

top : base of Maurage Marine Band.

7.2.1.6.- Maurage Member

base : Maurage (= Petit Buisson, = Aegir) Marine Band ; first recognized as a marine band by Fourmarier & Stainier (1911), its importance as a marker bed emphasized by Renier (1928), designated as the base of the "Zone de Maurage" in the Couchant de Mons and Centre coalfields by Renier (1930), designated as the base of the "Zone de Meeuwen" in the Campine coalfield by Delmer & Ancion (1954).

top : base of Neeroeteren Member.

7.2.1.7.- Neeroeteren Member

base : onset of massive, partly coarse-grained to con-

glomeratic, kaolinitic sandstones in the Neeroeteren area, first described by Renier (1944-1945) (Fig. 2) ; this limit does not correspond to the base of the ``Zone de Neeroeteren´´, placed at the Hagen-1 Tonstein (Delmer & Ancion, 1954).

top : not yet explored.

7.2.2.- Westphalian marker beds in the Campine mining district

The stratigraphical subdivision of the Westphalian in the Campine basin is based on the recognition of a sequence of marker beds, such as marine bands and tonsteins. These marker beds allow correlations between the different boreholes as shown on Fig. 3 , except for the correlation between boreholes KS 5 and KS 14 which is based on the identification of the first coalseams above the Quaregnon marine band.

The proposed sequence of marker beds does not alter the sequence previously described by Delmer (1963), which is completed by new tonstein finds in the Westphalian C and ``raindrops´´ horizons in the Westphalian B. These ``raindrops´´ have been identified as trace fossils (Plate 1). Although these characterize certain horizons, they may also occur (usually more discretely) from basal Namurian strata onwards.

Tonsteins KS-75 and KS-35 have not been recorded from the boreholes KS-11 and KS-14. Tonstein KS-75 is only known from subsurface workings at Zwartberg (Scheere, 1956). Tonstein KS-35 has been recognized in boreholes in the Zwartberg, Waterschei and Zolder collieries (Delmer, 1963) as well as in subsurface workings at Waterschei (Tricot, unpublished).

Recent exploration boreholes indicate that the actual list of tonsteins and eulittoral horizons in the upper part of the Westphalian B and in the Westphalian C may be incomplete. Correlations with the standard German tonsteins succession are shown on Table 6.

7.2.2.1.- Westphalian A, Ransart Member

(thickness 200 m)

- Sarnsbank Marine Band *(G. subcrenatum).*

7.2.2.2.- Westphalian A, Florrifoux Member

(thickness 330 m)

- Pyritized burrows horizon, above coal seam KS-82, ± 100 m below Wasserfall Marine Band.
- Finefrau Nebenbank Marine Band (pyritized burrows).

7.2.2.3.- Westphalian A, Mons Member

(thickness 510 m in the eastern part of the mining basin, 410 m in the western part).

- Schelpenbed, musselband on top of coal seam KS-57/2, ± 60 m below Quaregnon Marine band.
- Tonstein KS-70, in coal seam group KS-70, ± 150 m below Quaregnon Marine Band.
- Voort Horizon *(Estheria)* above rootlet bed, ± 20 m below coal seam KS-70.
- Tonstein KS-75, below first coal seam below KS-75.
- Pyritized burrows horizon, thickness 20-30 m, ± 80 m above Wasserfall Marine Band.
- Wasserfall Marine Band *(Lingula).*

7.2.2.4.- Westphalian B, Quaregnon Member

(thickness 335 m in the eastern part of the mining basin, 310 m in the western part).

- Wijshagen Band *(Leaia),* above coal seam KS-45.
- Tonstein KS-45 U/L, 2 tonsteins in coal seam KS-45.
- Tonstein KS-47, in coal seam KS-47.
- ``Raindrops´´ horizon A2, thickness 10 m, above coal seam KS-48.
- Tonstein KS-49, in coal seam KS-49.
- ``Raindrops´´ horizon A1, thickness 70 m.
- Quaregnon Marine Band *(Lingula).*

7.2.2.5.- Westphalian B, Eisden Member

(thickness 320 m in the eastern part of the mining basin, 260 m in the western part).

- Tonstein KS-24, in coal seam group underlying Maurage Marine Band.
- Lanklaar Marine Band *(Lingula, Orbiculoidea),* 90-100 m below Maurage Marine Band.
- ``Raindrops´´ horizon E2, thickness 20 m.
- Tonstein KS-35, in between two coalseams, 35 m above Eisden Marine Band.
- ``Raindrops´´ horizon E1, thickness 10 m.
- Eisden Marine Band *(Lingula).*

7.2.2.6.- Westphalian C, Maurage Member

Explored over 100 m in the western part of the mining basin (borehole KB-124), 330 m in the central part (Zwartberg subsurface workings), 600 m in the eastern part (boreholes KS-3, KS-6, KS-7).

- Tonstein, ± 425 m above base Westphalian C (Maurage Marine Band):

- Tonstein KS-6 U/L, 2 tonsteins in coal seam KS-6, ± 330 m above Maurage Marine Band.

- Tonstein KS-18, in coal seam KS-18/4, ± 180 m above Maurage Marine Band.

- Tonstein KS-19, in coal seam KS-19, ± 160 m above Maurage Marine Band.

- Tonstein KS-20, in coal seam KS-20, ± 120 m above Maurage Marine Band.

- Maurage Marine Band *(A. aegiranum)*.

7.2.2.7.- Westphalian C, Neeroeteren area

Explored over 525 m in the northeastern part of the Campine basin (boreholes KB-110, KB-113, KB-117), possibly partly overlapping with the Westphalian C recognized in the eastern part.

- *Estheria* band, ± 175 m below base Westphalian D.

- *Estheria* band, ± 350 m below base Westphalian D. referred to in Bless *et al.* (1977) ; lateral extent beyond Neeroeteren area not known.

- Tonstein, ± 450 m below Westphalian D, identified as Tonstein Nibelung by Burger (1982), possibly equivalent to upper tonstein in boreholes KS-3 or KS-7.

7.2.2.8.- Westphalian D

Explored over 200 m in borehole KB-117 and over 350 m (possibly faulted) in borehole KB-146 in the northeastern part of the Campine basin. Because of the preponderance of sandy sediments and the lack of information on the lateral extent of faunal and floral horizons, no marker beds have been established within these strata.

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PLATE 1

1-4   " Raindrops"

    1.   KS- 1 - 635,70 m.

    2-4. KS-14 - 1094,20 m, positive (3) and negative (4) impressions.

    5.   *Neuropteris* aff. *ovata*

        KB-146 - 840 m.

    6.   *Reticulopteris munsteri*

        KB-146 - 840 m.

KS : Kempense Steenkolenmijnen (Campine Collieries).
KB : Kempens Bekken (Campine basin).