Annales de la Société Géologique de Belgique, T. 103 - 1980, pp. 97-110 décembre 1980

SEDIMENTARY ENVIRONMENTS, CONODONT BIOFACIES AND PALEOECOLOGY OF THE BELGIAN FAMENNIAN (UPPER DEVONIAN) - AN APPROACH [1]

by

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(6 figures)

RESUME.- La succession verticale des formations sédimentaires qui sont diachroniques par rapport à la zonation standard des conodontes et des autres microfossiles, représente une mégaséquence régressive dans le Famennien belge, formée d'environnements marins s'étageant de milieux relativement profonds "offshore" à côtiers peu profonds à "backshore" confiné (THOREZ *et al.*, 1977).

Différentes associations de genre de forme de conodontes de plateforme (Biofaciès) reflètent des conditions écologiques différentes qui sont directement ou indirectement liées à la profondeur, la turbulence et la salinité de l'eau et la proximité de la côte. D'"offshore" à "backshore", nous identifions successivement des biofaciès à Palmatolepides, à Palmatolepides-Polygnathides, à Polygnathides-Icriodides, à Icriodides, et à Clydagnathides présumées.

De cette manière, le modèle de distribution des biofaciès de conodontes dans l'ensemble du Famennien représente une réponse normale aux mouvements d'oscillation d'une côte en progradation dans les bassins sédimentaires étudiés.

De plus, la présence de biofaciès de conodontes mélangés (ou thanatocoenoses) est aussi liée aux processus sédimentaires tels que l'action de tempêtes, les courants de turbidité et les dépôts de marée.

ABSTRACT.- The vertical succession of the sedimentary formations, which are diachronic with respect to the standard conodont and other microfossils zonation, represents a regressive megasequence in the Belgian Famennian, ranging from relatively deep, offshore open marine, shallow nearshore, to backshore restricted marine environments (THOREZ *et al.*, 1977).

Different associations of platform conodont form genera (Biofacies) reflect different ecological conditions, which are directly or indirectly related to water depth, turbulency, salinity and proximity to the coast ; from offshore to backshore we recognized successively a Palmatolepid, a Palmatolepid-Polygnathid, a Polygnathid-Icriodid, an Icriodid, and a supposed Clydagnathid biofacies.

In this way the distribution pattern of conodont biofacies throughout the Famennian, represents a normal response to the oscillating movements of a prograding "coast" in the studied sedimentary basins. The presence moreover of mixed conodont biofacies (or thanatocoenoses) is also related to sedimentological processes, such as storm wave action, turbidity currents and tidal inlets.

1.- INTRODUCTION

During the sixties, Upper-Devonian conodont research was almost completely focused on the establishment of stratigraphical zonation. This zonation was based on autochronological successions of closely related conodont genera such as *Polygnathus* and *Palmatolepis*.

In the early seventies, differences were observed in first occurences of zonal species within Upper-Devonian rock sequences. These differences seemed to be related to different, probably environmental controlled conodont habitats.

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[1] *Note présentée le 8 juillet 1980, manuscrit déposé le 23 septembre 1980.*

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MOURAVIEFF (1970, unpublished dissertation) was first to notice the absence of species belonging to the genus *Palmatolepis* in sediments of reefal origin, in the Frasnian type area of Belgium. He believed that *Palmatolepis* species did not live in the relatively shallow areas in and around the reefs, which was a supposed habitat for species of the genus *Ancyrognathus*. In the interreef basinal sediments however *Palmatolepis* seemed to occur normally.

SEDDON (1970) and DRUCE (1969) noticed differences in the faunal associations of the various facies of the reef complex of the Bonaparte Gulf Basin (Upper Devonian - Lower Carboniferous, West Australia). They recognized a back-reef *Icriodus* "sequence" and a fore-reef-inter-reef *Palmatolepis* "sequence" or biofacies. DRUCE (1969) also recognized a third *Belodella* biofacies, which he believed to occupy the extreme near-reef environments (Frasnian reef-complexes).

In their classical depth-stratified ecological model for conodonts, similar to that for recent Chaetognaths, SEDDON & SWEET (1971) referred to the biofacies boundary as a biological filter, which allowed elements of the *Icriodus* biofacies to pass into the underlying *Palmatolepis* biofacies, but not vice versa.

DRUCE (1970) on the other hand suggested lateral differentiated habitats for the conodont animal and underlined the relationship to distance from shore as well as the absence of the shallow-water fauna from the deep-water areas. DRUCE (1973) also constructed a possible biofacies model for each time interval of the Upper Paleozoic, using the criterion of similar morphology :

- Biofacies I is thought to occur at very shallow depths and is characterized by simple cone forms. If it existed after Famennian times, then it would be possibly characterized by asymmetrical units (Class IV of LANE, 1968).
- Biofacies II is thought to occur at intermediate depths, perhaps up to 50 metres, and is characterized by "simple" units, possibly LANE's Class I, but more likely Class II and complex units of Class IIIa or IV.
- Biofacies III is presumed to occur below a depth of about 50 metres and is characterized by complex genera of Class II and a few of Class IIIa.

In the Famennian, DRUCE assigned the following form genera (each of them belonging to a specific symmetry class) as being typical of the different Biofacies :

Biofacies I	**Biofacies II**	**Biofacies III**
simple cones	*Icriodus* (II)	*Palmatolepis* (II)
(*Acodina*)	*Pelekysgnathus* I or II)	*Polygnathus* of the *nodocostatus*-group (II)
(*Clydagnathus* IV ?)	simple *Polygnathus* (II)	*Polylophodonta* (II)
	Bispathodus (IIIa)	
	Scaphignathus (IV)	

The author also noted that, although the general morphology of "nodose" *Spathognathodus* (= *Bispathodus*) and *Scaphignathus* suggested a Biofacies II, they were also present in Biofacies III fauna of Australia and West Germany.

BARNES *et al.* (1973), BARNES & FAHRAEUS (1975), FAHRAEUS & BARNES (1975) emphasized a strong component of lateral segregation of Ordovician conodont fauna, from which they inferred a nektobenthic of benthic mode of life for many conodont genera. General application of the nektobenthic model was inferred to the majority of Paleozoic conodonts.

The laterally segregated associations were interpreted as communities related to paleotectonic setting and forming a lateral sequence extending from nearshore to deeper water environments. SANDBERG (1976) distinguished five laterally segregated associations of platform conodont genera (biofacies) in the Upper *styriacus*-Zone of the late Famennian in the Rocky Mountains and Great Basin (W. United States).

These biofacies occupy long relatively narrow belts, corresponding to five paleotectonic facies, parallel to a former east-west coastline in an equatorial region. The biofacies do not demonstrate any significant longitudinal changes in fauna and only slight latitudinal ecological "straggling" or postmortem mixing of conodonts from one biofacies belt to another. From the continental slope and rise to the hypersaline environments of offshore banks and associated lagoons, he distinguished successively the following biofacies : palmatolepid-bispathodid, palmatolepid-polygnathid, polygnathid-icriodid, polygnathid-pelekysgnathid, and clydagnathid biofacies. These conodont biofacies are named for the one or two predominant platform conodont element(s), which constitute at least 65 percent of the total population of platform elements.

SANDBERG & ZIEGLER (1979) added 3 new shallow-water biofacies (the pandorinellid, the scaphignathid and patrognathid biofacies) to the 5 previously proposed biofacies. These shallow-water biofacies may occupy very nearshore settings similar to that of clydagnathid biofacies, but the exact conditions for these biofacies remain uncertain ; they have been interpreted on the basis of associated biota and enclosing sediments, to have included nearshore and peritidal settings such as bays, estuaries, and lagoons, characterized by a wide range of salinities.

2.- CONODONT BIOFACIES AND THEIR PALEOECOLOGICAL SIGNIFICANCE

In a first attempt and following SANDBERG's (1976, p. 184) proposition, we have applied his biofacies model to the conodont fauna from the entire Belgian Famennian stage.

The paleoecological scheme for the Belgian Famennian so obtained, which is based on the conodont biofacies distribution, fits the paleogeographical reconstruction (J. THOREZ, 1977) of the different mega-environments very well (fig. 4.-5).

An important new environmental element is added to this scheme, namely the presence of crinoidal "mud mounds" on shoals near to the coast ; these "mud mounds", which delimit "fore-reef" and "back-reef" environments, occur at the transition of the Esneux and Souverain-Pré Formations (DREESEN, 1977, 1978).

After plotting the distribution of the most important platform conodont forms on this paleogeographical scheme, we noticed that the distribution pattern of conodont biofacies throughout the Famennian, represents a normal response to the oscillating movements of a prograding "coast", especially in the basins studied (Dinant Basin and Vesdre Basin).

However the different conodont biofacies often appear to be contaminated by elements of adjacent biofacies belts, a process which we relate to sedimentological mechanisms affecting the regressive basin evolution during the Famennian.

Discrepancies, with respect to the standard conodont zonation, in the first occurences and ranges of important species and subspecies, which were previously noticed by DREESEN & DUSAR (1974, 1975) and DREESEN (1976, 1978), are now explained by facies influences and the occurence of different conodont biofacies. Finally, we emphasize here that the calculated abundance ratios which typify the different conodont biofacies (classification of SANDBERG, 1976), must be interpreted very carefully : the comparative distribution charts of the most important platform conodont genera (figs. 4, 6) are based on countings of several hundred samples from different sections within the Famenne type areas ; these samples are not always equivalent - mainly due to unfavourable lithofacies - as the conodont frequencies range from a few hundred specimens to only ten or fewer specimens per kilogram of rock sample.

Five conodont biofacies - we prefer the term conodont thanatocoenoses - are recognized within the conodont faunas of the Belgian Famennian : a palmatolepid, a palmatolepid-polygnathid, a polygnathid-icriodid, an icriodid and a clydagnathid biofacies (figs 4-5).

The roman numerals refer to the conodont biofacies classification of DRUCE (1973) - note the presence of "transitional" conodont biofacies, initially attributed to lateral contamination by elements of adjacent biofacies belts (DREESEN, 1978, unpublished).

1) The open marine offshore sediments are characterized by a PALMATOLEPID biofacies, mainly and often exclusively composed of *Palmatolepis* species. *Ancyrognathus* species and species belonging to the group of *Polygnathus nodocostatus* represent rare or minor constituents (up to 1 or 2 o/o).

The form genus *Ancyrognathus* is almost exclusively represented in the Famennian by the species *A. sinelaminus.*

Very rare specimens of *A. cryptus* and *Ancyrolepis* (a related conodont genus) have been recorded from the lowermost Famennian deposits only (*triangularis*-Zone).

Although *Ancyrognathus* is generally considered as a common form in near-reef and relatively shallow water environments, the Famennian representatives of this genus have only been found in palmatolepid (and palmatolepid-polygnathid) biofacies. If we agree with the general concept that conodonts with similar ornamentation of their upper surfaces may have lived in similar depth zones, this would explain the presence of *Ancyrognatus, Polylophodonta* and members of the *Polygnathus nodocostatus*-group in the same conodont biofacies, which is the palmatolepid (-polygnathid) biofacies.

Within this palmatolepid biofacies some irregularities have been observed in the distribution of *Palmatolepis* species and subspecies :

The tiny smooth subspecies *P. delicatula delicatula* most probably represents a more offshore, basinal form, whereas the more robust and sculptured *P. delicatula clarki* is probably a nearshore form of the same species. This would explain the scarcity of *P.*

delicatula delicatula and the high frequency of *P. delicatula clarki* at the base of the Middle *triangularis*-Zone in Belgium.

An analoguous environmental control would also explain the scarcity or absence of *Palmatolepis rhomboidea* (which is also a tiny smooth *Palmatolepis* species) at the base of the *P. rhomboidea*-Zone in Belgium ; at this stratigraphical level, which more or less corresponds to the base of the Esneux Formation, the robust *Palmatolepis* species *P. klapperi* occurs in relatively large amounts.

2) The more nearshore, relatively shallow subtidal marine environments are inhabited by a PALMATOLEPID-POLYGNATHID biofacies. This biofacies is composed of *Palmatolepis* and *Polygnathus* species in more or less equal proportions (30 to 50 o/o of the whole platform conodont population).

The *Polygnathus* species belong to both the *nodocostatus*- and *semicostatus*-groups, the latter group (relatively slender and narrow *Polygnathus* species) becoming more important shoreward. SANDBERG (1976) noticed the same distribution pattern of *Polygnathus* during the Upper *styriacus*-Zone in the W. United States : the *nodocostatus*-group is most abundant on the continental shelf, while the population of the *semicostatus*-group attains its maximum on the outer cratonic shelf.

Species of the form genus *Polylophodonta* have only been encountered within this palmatolepid-polygnathid biofacies, but they seem to constitute a rather accessory element.

Icriodus species are present (up to 5 o/o) but they are more typical of the nearshore shallow marine environments.

Rare species of *Nothognathella* occur within this palmatolepid-polygnathid biofacies, but their distribution is not at present clearly understood.

In the uppermost part of the Upper Famennian, in the so-called "Strunian" deposits, a BISPATHODID-PSEUDOPOLYGNATHID biofacies replaces the palmatolepid-polygnathid biofacies of the former Famennian deposits, but apparently occupied a similar paleoecological niche.

3) The very shallow subtidal and intertidal marine environments and the immediate surroundings of the dispersed reef-like bio-accumulations, are characterized by a POLYGNATHID-ICRIODID biofacies.

This biofacies is mainly composed of *Polygnathus* species of the *semicostatus*-group and Icriodids. *Icriodus* shows a probably endemic morphological evolution consisting, of particular arrangements of the platform denticles, within these environments (DREESEN & HOULLEBERGHS, 1980, this volume).

Pelekysgnathus is not as frequent as is *Icriodus.*

Polygnathus ? pseudostrigosus DREESEN & DUSAR, *Scaphignathus ? subserratus* (BRANSON & MEHL) - both now considered as probable ancestors of *Siphonodella* and probably belonging to a new form genus - and *Scaphignathus velifer* HELMS, represent asymmetric shallow water genera (according to SANDBERG & ZIEGLER, 1979), possibly imported from an adjacent SCAPHIGNATHID biofacies.

Palmatolepis is becoming rare but is still present (as "intruder"?) and may reach up to 5 or even 10 o/o of the platform elements in some very rich conodont faunas of the *velifer*-Zone.

4) The following conodont biofacies, which we name the ICRIODID biofacies, most probably represents a mixed conodont biofacies (or thanatocoenosis) ; it is mainly composed of Icriodids, Pelekysgnathids, Scaphignathids, Polygnathids of the *semicostatus*-group and some asymmetrical or bizarre forms such as *Pandorinellina cf. insita* (STAUFFER) (= specimens of "*Spathognathodus*" *strigosus* with thickened or doubled denticles) and rare species of the new genus *Bouckaertodus* GAGIEV, 1979 (= "grerontic" specimens of *Icriodus ? raymondi* SANDBERG & ZIEGLER = *Icriodus platys* NICOLL & DRUCE, 1979). The latter probably represent conodont elements of the very shallow (?) pandorinellid biofacies. This ICRIODID biofacies is characteristic of the surroundings of sand barrier complexes, similar to recent longshore bars. Tidal inlets are responsible for mixing elements of a fore-barrier POLYGNATHID-ICRIODID biofacies with elements of a CLYDAGNATHID (or scaphignathid, pandorinellid biofacies), the latter we suppose to be present behind those sand bars, in the restricted marine or brackish environments of a tidal lagoon.

3.- SEDIMENTARY ENVIRONMENTS AND CONODONT BIOFACIES DISTRIBUTION

From the top of the Upper Frasnian (Matagne Shales) to the base of the Lower Carboniferous (Hastière Limestone), the following sedimentary environments have been recognized (THOREZ *et al.*, 1977). Their vertical and lateral succession - particularly in the eastern part of the Dinant Basin and in the Vesdre Basin - are symptomatic of a regression that started at the end of the Upper Frasnian and reached its maxi-

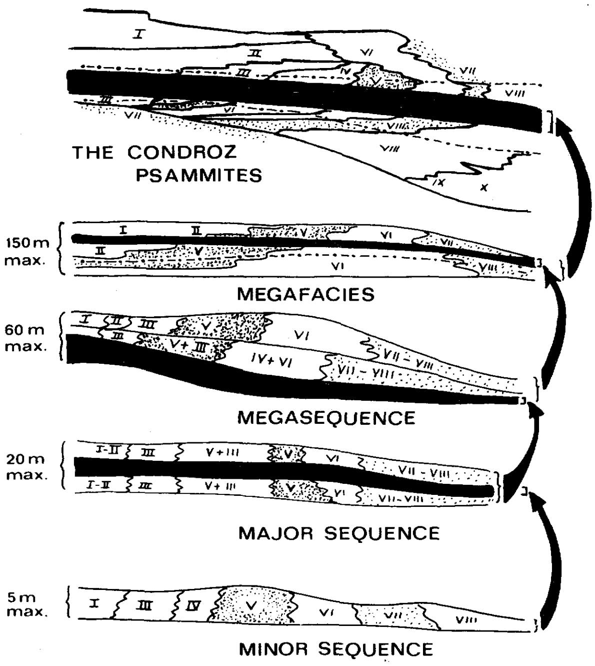


Figure 1

Relations between sedimentary environments (for the legend of the roman numerals see figure 2) and the different but integrated scales of the sedimentational pattern in the Group of the Condroz Psammites (Sandstones) : minor, major and megasequences, megafacies and the general sedimentological scheme.

mum during the Upper Famennian, with the deposition of the Condroz Psammites.
As presented in the regressive model of THOREZ *et al.*, (1977), different but integrated sedimentological scales characterize the Famennian sedimentation especially for the Group of the Condroz Psammites (figs. 1-3). From the Lower Famennian (Famenne Shales) to the Upper Famennian (including the "Strunian"), the following sedimentary mega-environments are recognized each of which is characterized by its conodont biofacies (which may or may not be mixed) (fig. 6).

1) The nodular, clayey to sandy crinoidal limestones, scattered within the Famenne Shales, yield a typical PALMATOLEPID biofacies ; they have been deposited during the *triangularis-* and *crepida-*Zones in an open marine, offshore environment ; a predominant infratidal clayey sedimentation characterizes the Lower Famennian Substage everywhere in the studied basins.

Of particular interest is the presence of goniatites (*Cheiloceratidae*) within a same stratigraphical interval (Middle *crepida-*Zone to lowermost *rhomboidea-*Zone, corresponding to the upper part of the Famenne Shales and the transitional beds to the following Esneux or Aye Formation) throughout the whole Vesdre Basin and at the southwestern border of the Dinant Basin ; in the latter area however these goniatites have been recorded from the shaly Aye Formation ; the conodont fauna indicated here an (Upper) *rhomboidea-*Zone (BOUCKAERT, DREESEN & DRIJKONINGEN, 1978). It is also worth noting the abrupt extinction of Conularidae and rugose corals at the Frasnian/Famennian boundary, a phenomenon already mentioned by DUSAR (1976).

This faunal break at the Frasnian/Famennian stages boundary, associated with a temporary outburst of Icriodids (up to 50 o/o of the conodont fauna), might, at the present stage of investigation, indicate a possible sedimentary gap and/or a sudden influx of shallower conodont biofacies, both related to some widespread intrabasinal tectonical disturbances (DUSAR, 1976, 1980). Another hypothesis to explain the high amount of Icriodids near the base of the Lower famennian, could relate this to the undulating palaeotopography of the offshore seabottom during the Lower Famennian : such irregularities could be generated, at small depths, by the presence of Upper Frasnian (F2j) bioherms (DREESEN & HOULLEBERGHS, 1980, this volume).

2) Lithostratigraphically speaking, the Upper Famennian starts with the thin-bedded micaceous sandstone series of the Esneux Formation. This formation is well developed at the northern borders of the Dinant Basin, and in the Namur and Vesdre Basins, whereas it passes laterally, but southwards - in an offshore direction - into the still highly shaly Aye Formation (THOREZ *et al.*, 1977). The arenaceous sediments of the Esneux Formation have been interpreted as subtidal marine deposits (BECKER *et al.*, 1974 ; THOREZ *et al.*, 1977).

Both the sandy and shaly sediments yield conodonts indicating a *rhomboidea-* and Lower *marginifera-*age ; these faunas are contained in thin lenticular coarse crinoidal limestone beds, interlayered in predominantly detrital sediments. Locally these coarse-grained limestone beds are enriched with iron oolites ; these oolites, which have been formed outside their actual paleo-settlement, are interpreted as storm layers deposited in the coastal sand-shelf mud transitional zone. Similarly, the presence of Fe-oolites and hematitized rounded skeleton debris in the nodular limestones of the underlying Famenne Shales, could be attributed to "débris-flows" characterizing a fluxo-turbiditic mechanism. Indeed, specific sedimentary structures such as slumping, flute and groove casts, have been observed within these limestone concentrations. They could support the hypothesis of a turbidity current removing material from a nearshore source to more offshore deeper areas of the basin.

The source of the Fe-oolites and Fe-stained debris is probably situated at the high-energetical seasides of crinoidal mud mounds, dispersed on shoals near the coastal area. These reef-like bio-accumulations are interpreted as the first barrier-system on the paleoshelf, at the limit of the turbidite generating slope ; a second, more pronounced and sandy barrier-complex is developed more inshore (figs. 2, 5).

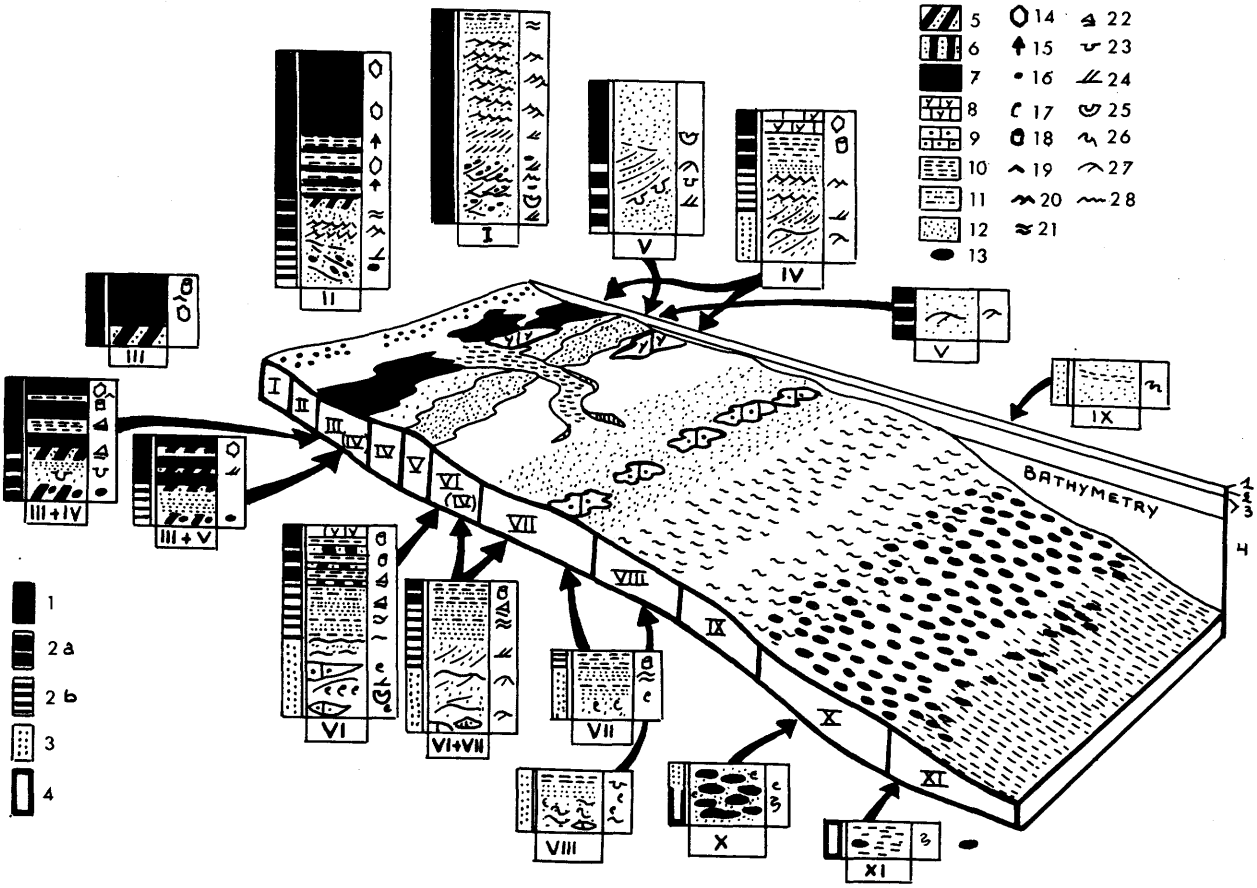


Figure 2.- Lateral relations between characteristical environments within a minor depositional sequence. Paleogeographical reconstruction of the lateral sequences based on rhythmical combined lithologies textures and structures, with regard to the paleobathymetry.

Environments : 1: supratidal ; 2a: high intertidal ; 2b: low intertidal ; 3: subtidal to offshore ; 4: offshore.

Lithologies : 5: dolomitic arkose ; 6: calcareous arkose ; 7: dolomite ; 8: calcareous micrite ; 9: calcareous bio-calcarenite ; 10: pelite ; 11: psammite ; 12: micro arkose ; 13: calcareous (organoclastic) nodule.

Sedimentary structures : 14: dessication fissure ; 15: plant drift ; 16: dolomitic pebble ; 17: Brachiopod test ; 18: burrow ; 19: ripple-mark ; 20: ripple-drift ; 21: ondulous stratification ; 22: flazer-bedding ; 23: load-cast ; 24: cross-stratification ; 25: tidal channel ; 26: convolute bedding-slumping ; 27: mega-ripple ; 28: erosion mark.

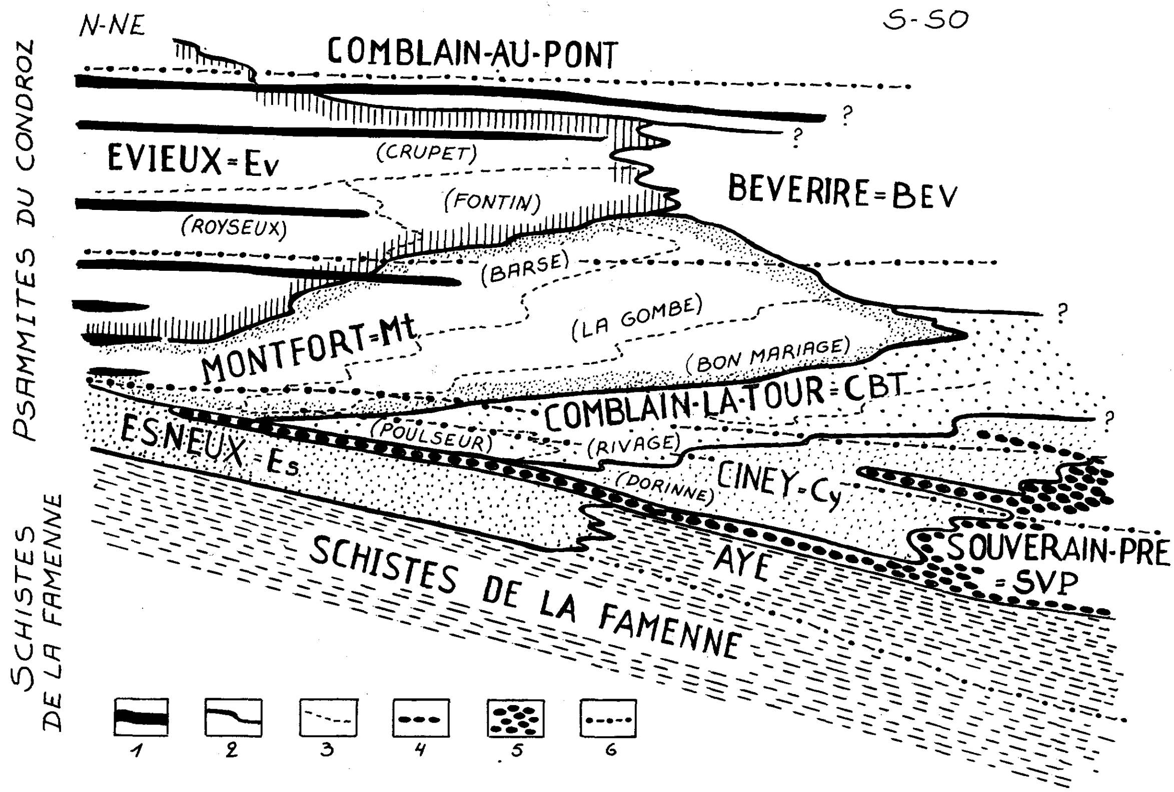


Figure 3a.- Lithostratigraphical framework of the Upper Famennian. Large capitals refer to the Formation names (Montfort, Evieux, etc.) small capitals correspond to (enclosed) Member names (Fontin, Poulseur, etc.).

1: Red beds; 2: Stratigraphical limit of a Formation ; 3: Stratigraphical limit of an integrated Member ; 4: Layer of calcareous nodules ; 5: Nodular limestones (cf. Souverain-Pré Formation) ; 6: Micropaleontological limit. (For more details see THOREZ et al., 1977).

Wave action and tidal currents around these mud mounds have been able to pick up elements from their accumulation area and allowed their subsequent transportation by turbidity currents into the infratidal and subtidal environments of the Famenne Shales and Esneux Formations.

The immediate surroundings of these reef-like bioaccumulations (with undissociated crinoid stems, brachiopods, "*stromatactis*"- structures and dwarfish solitary corals) seem to have been prolific for a POLYGNATHID-ICRIODID conodont biofacies. The conodont elements of the latter were regularly removed by (storm) wave action and transported seaward into the near-by (shallow) subtidal environments, which are normally inhabited by a PALMATOLEPID-POLYGNATHID biofacies.

3) The Souverain-Pré Formation consists of a sandy nodular limestone facies that caps the underlying arenaceous Esneux series. Nodular and lenticular limestones, containing crinoids, brachiopods, bryozoans and locally foraminifera (the first species of *Tournayellidae* and *Endothyridae* appear within this lithofacies, BOUCKAERT, CONIL & THOREZ, 1967), are embedded in either a sandy or a clayey matrix.

The sand fraction of this calcareous lithofacies has a similar petrographic character to the younger strata of the Condroz Psammites, i.e. the rather high but fresh feldspar content that makes the detrital sediments arkosic. The Souverain-Pré Formation is interpreted as a "back-reef" facies of crinoidal mud mounds. The reworking of these crinoid accumulations by waves and/or tidal currents enabled the dispersion and transport of the debris either inshore, towards the "continent" (or the coast-line) where the material became embedded in the subtidal-intertidal sediments (BELLIERE, 1953), or seaward, by turbidity currents, with subsequent accumulation and interlayering of subnodular limestones in a subtidal to infratidal, more clayey sediment. The limestone nodules contain a conodont fauna typical of a PALMATOLEPID-POLYGNATHID biofacies, often contaminated by elements of a rather POLYGNATHID-ICRIODID biofacies, which is typical of the more shoreward shallow subtidal to intertidal environments (*marginifera*- and Lower *velifer*-Zones).

4) The nodular limestones of the Souverain-Pré Formation pass laterally, in a more inshore direction, into a more sandy facies, in which limestone commonly occurs as thin crinoid-enriched layers at the very base of fluxo-turbiditic sequences (THOREZ *et al.*,

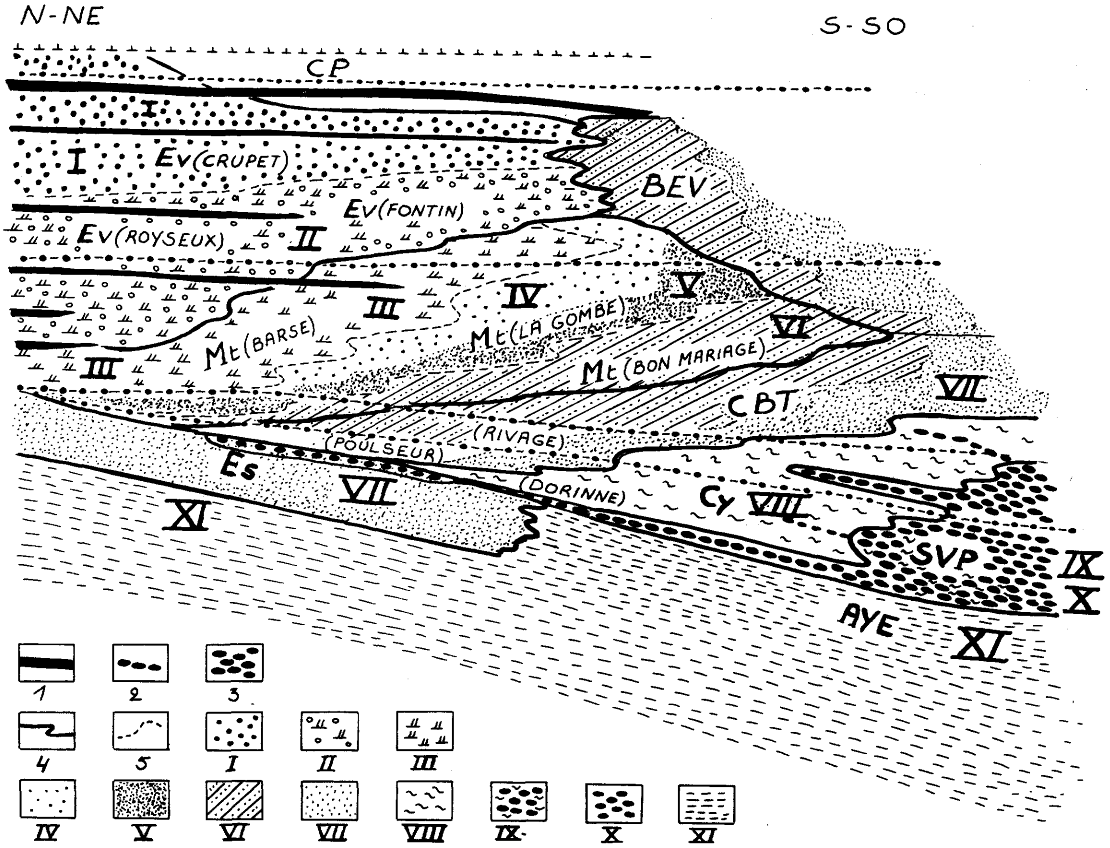
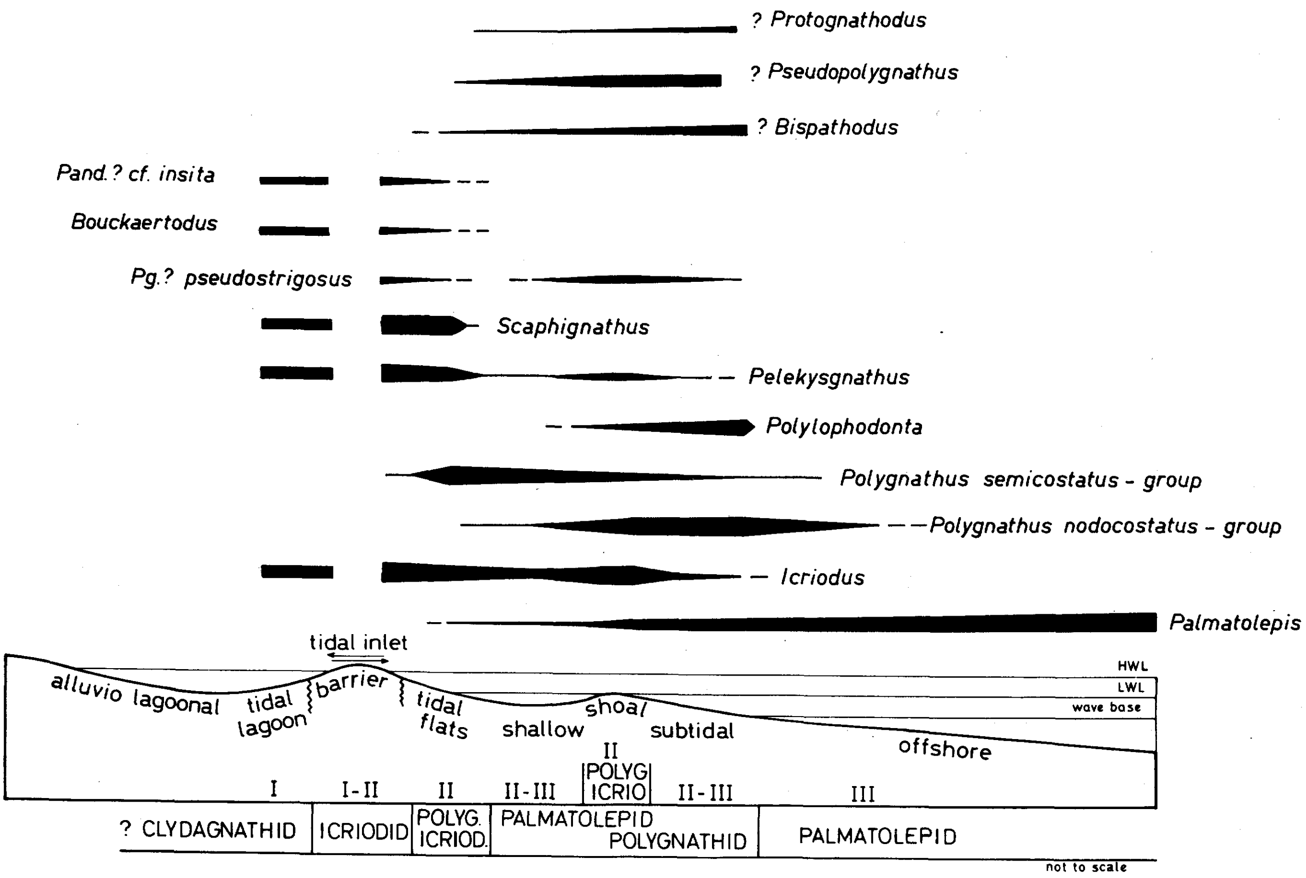


Figure 3b.- Generalized scheme of the Famennian mega-environments (resulting from detailed analysis of the sedimentological processes at different (but integrated) scales (from minor sequence to megafacies) (same lithostratigraphical framework as in Fig. 3a).

1: Red beds ; 2: Layer of calcareous nodules ; 3: Nodular limestones ; 4: Formation limit ; 5: Member limit - I = Distal alluvial mega-environment of the Evieux Formation (Ev) - II = Alluvio-lagoonal with local tidal-lagoonal environments (Ev) - III = Lagoonal environment (with evaporitic dolomites) within the Montfort Formation (Mt) - IV = Back-barrier tidal-lagoonal environment - V = Barrier complex within the Montfort Formation - VI = Fore-barrier environment with tidal flats in the Montfort and Comblain-la-Tour Formations - VII = Proximal subtidal environment in the Comblain-la-Tour and Esneux Formations - VIII = Distal subtidal environment with fluxo-turbidites (Ciney Formation) - IX = Subtidal to infratidal environment with fluxo-turbidites and nodular limestones - X = Distal subtidal to infratidal environment with typical nodular limestones - XI = Infratidal environments with predominantly pelites, characterizing the Aye Formation (Upper Famennian) and the Famenne Shales (Lower Famennian)



R. DREESEN _ J. THOREZ

Figure 4.- Comparative distribution table of platform conodonts in the Famennian (Belgium) with respect to the marine environments.

1977). This contemporaneous sandy formation is defined as the Ciney Formation, which is well-developed in the area of Dinant, but which lacks in the Famennian type-localities of the Ourthe Valley, south of Liège. Its depositional environment has been defined as distal subtidal (fig. 2 ; THOREZ, 1977).

The Ciney Formation wedges out northward, where it disappears between the Esneux Formation and the younger Comblain-la-Tour Formation.

Conodont faunas have been recorded from this rather arenaceous lithofacies, which are indicative of a POLYGNATHID-ICRIODID biofacies (*velifer*-Zone).

Sedimentological analysis of this formation however pointed out clearly that the limestone sediment is certainly not "in situ", but that it must have been reworked from more nearshore subtidal to intertidal environments.

5) The Comblain-la-Tour Formation is an essential sandy deposit with thin arkosic beds, interlayered with thin beds of more clayey micaceous material and occasional crinoidal limestones (mostly crinoidal "schlieren").

The depositional environment for this formation has been related to an open marine-proximal subtidal one. The type-locality of this formation is situated at Comblain-la-Tour, in the southern part of the Ourthe Valley.

In a previous study by BOUCKAERT & ZIEGLER (1965) the very occasional occurence of limestone

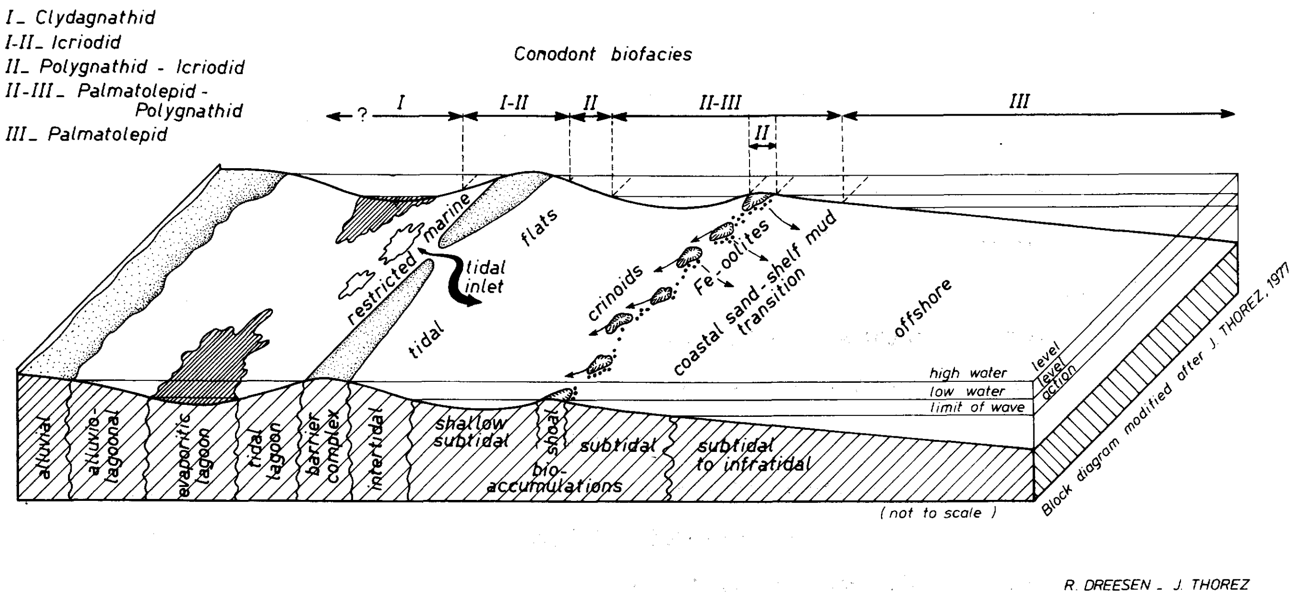


Figure 5.- Sedimentational model and conodont biofacies distribution for the Famennian Stage - Belgium.

beds within this lithofacies has been emphasized.
Rich conodont faunas however, typical of a POLYGNATHID-ICRIODID biofacies, have been recorded from nodular limestones of the Comblain-la-Tour Formation in the area of Hamoir-Ferrières (DUSAR, 1980) (*velifer*-Zone).

6) In the paleogeographical model for the Upper Famennian, the Montfort Formation represents a sand barrier complex (figs. 1-3). The Bon Mariage Member of this Formation represents the forebarrier environment of this sand barrier and exhibits sedimentary sequences (Rhythms) of a typical tidal-flat environment (with subtidal, intertidal and occasionally supratidal subenvironments). The latter subenvironment is characterized by the presence of micritic limestone beds containing very tiny bivalve ostracods (BECKER *et al.*, 1974), whereas rich conodont faunas have been recorded from crinoidal concentrations or lags at the extreme base of tidal channels.
This conodont fauna represents a mixed thanatocoenosis, composed of elements of both a POLYGNATHID-ICRIODID biofacies and an actually supposed CLYDAGNATHID (or scaphignathid, or pandorinellid) biofacies (*velifer*-Zone).
The sand barrier environment itself - which constitutes the La Gombe Member of the Montfort Formation - is virtually barren of limestone.

The strata are highly sandy (arkosic) and organized in beds at least one metre thick, exhibiting a systematic reverse grading. Clay material occurs occasionaly interlayered within the sandy beds and is always enriched with micas, the latter having been washed out by wave action from the original detrital material that now constitutes the sand barrier.
The La Gombe Member is devoid of any limestone or calcareous sediment. Even the brachiopod tests, often present in the sands of the Bon Mariage Member, are lacking here. The barrier itself is frequently crossed by shallow-water tidal inlets, linking the back-barrier lagoonal (dolomitic) environment of the Barse Member with the fore-barrier tidal flats of the Bon Mariage Member. At the extreme base of the La Gombe Member however, just beneath the barrier sandstones, and associated with load casts and submarine bars, some very thin sandy crinoidal limestone beds may occur, containing a relatively rich conodont fauna ; this fauna is also indicative of a mixed POLYGNATHID-ICRIODID and CLYDAGNATHID (?) thanatocoenosis (*velifer*-Zone). It is clear that these concentrations are not in situ, but have been brought accidentally inshore by tidal currents, may be due to storm activity, which has provoked the formation of ball-and-pillow structures and load casts on the flanks of the submarine bars, at the base of the La Gombe Member.

The more inshore Barse Member of the Montfort Formation finally represents a back-barrier environment with typical lagoon-evaporitic (Sabhka) sedimentary deposits. The carbonate material is always a "primary" dolomite, without any macro-

or microfossils content. Within the lagoon pans, the status of dolomite was reached very soon, resulting from a very early diagenetic process : intraclasts and pebbles of dolomite have been found in the younger sandy intercalations, which rhythmically interrupt the evaporation process. Some of these interlayering sandstones are red, the colour of which is due to chemical processes within this sabhka-environment.
More than 120 dolomite beds have been unsucessfully investigated for conodonts. It is therefore apparent that this lagoon-evaporitic environment was unfavourable for the conodont animal, despite the fact that sea-water was regularly brought in the lagoon by the mechanism of shallow-water tidal inlets that frequently crossed the sand barrier.

This hypothesis is supported by the richness of some dolomites in mica particles. These particles had been separated from the original detrital material during

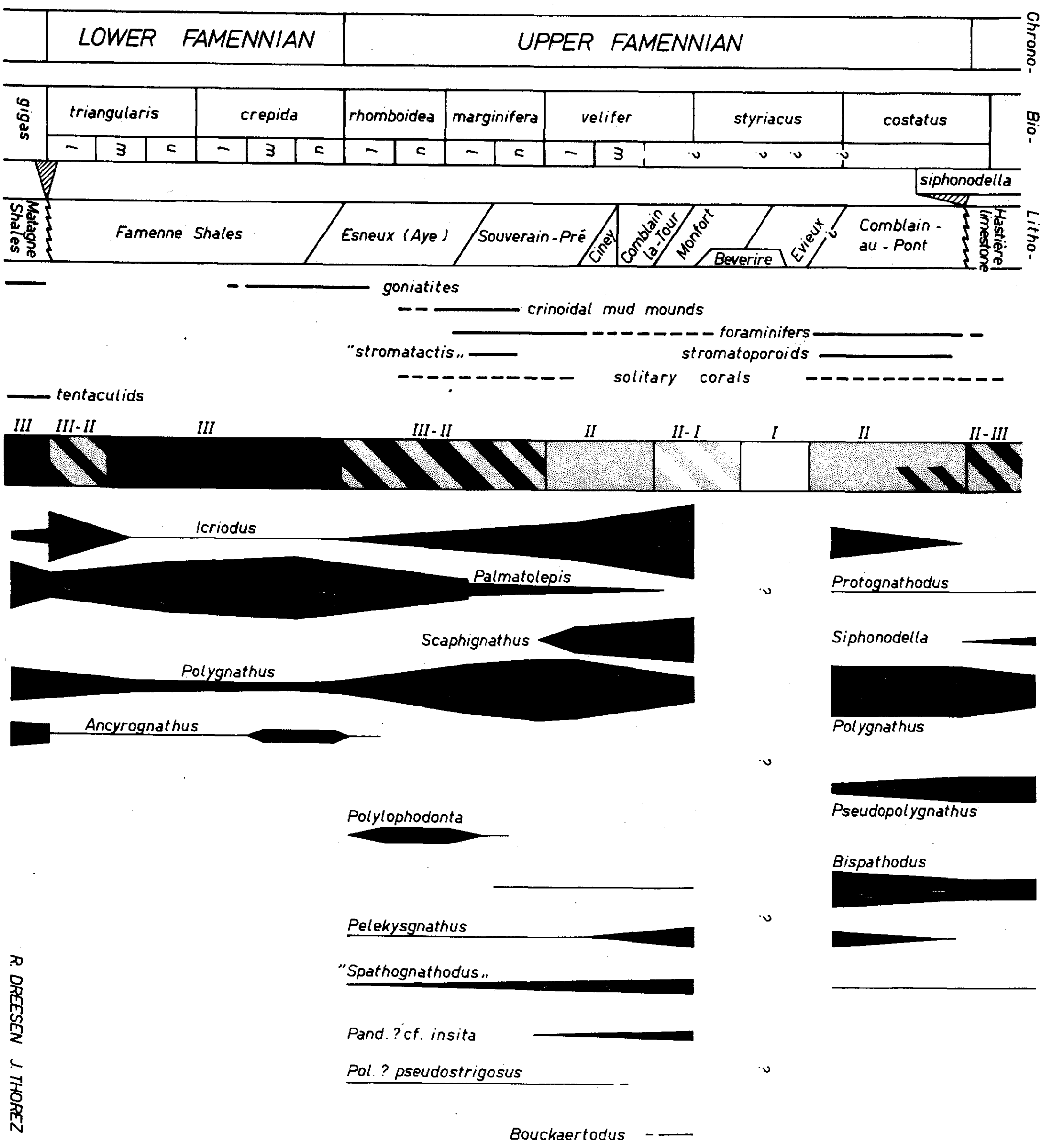


Figure 6.- Stratigraphical and paleoecological Scheme of the Belgian Famennian.

the development of the sand barrier itself : whilst the sand fraction accumulated into reverse graded beds, the micas floated and became concentrated for subsequent introduction into the lagoon by quiet waters. There, at the limit of barrier and lagoon, they were deposited together with carbonate mud within Mg-rich water and gave rise, after diagenesis, to the characteristic micaceous dolomites. Thus, as external elements only the micas were brought in from offshore through tidal inlets ; the currents were not strong enough to transport other relatively heavy materials such as conodonts, crinoid ossicles or brachiopod tests.

7) The Evieux Formation is composed of the following three members, the composing sediments of which were unfavourable to contain conodont elements : the Royseux Member with arenaceous red beds, related to sabhkas, interlayered with supratidal evaporitic dolomites ; the Fontin Member with dolomites and sublagoonal ostracod and oncolithic micrites ; the Crupet Member with "continental" red beds.
Because of the general alluvio-lagoonal facies of the Evieux Formation, the index conodonts for the *styriacus*-Zone have never been recorded in Belgium.

At the current state of micropaleontological research in the type-area of the Evieux Formation (a more "continental" facies at the northern border of the Dinant Basin, as well as in the Namur and Vesdre Basins), there appears no chance of recovering this "missing link" of the Belgian Famennian conodont zonation. However some favourable calcareous facies are present within the Fontin Member : the sediments of this member, deposited in a more supratidal-intertidal but still sublagoonal environment, yield some micritic limestone intercalations, with thin-shelled ostracods and oncoliths.
Although such a petrographic character usually not favours any conodont record (as proved until yet), further investigation is required to prove the existence of some shallow conodont biofacies which might indicate the presence of the *styriacus*-Zone in Belgium.

8) Facing but overlapping somewhat both the Montfort and Evieux Formations within a southern, more offshore position, a supplementary formation has been added by THOREZ *et al.*, (1977) to the Upper Famennian lithostratigraphical scale, namely the Beverire Formation. This formation, which is well developed in the southern part of the Ourthe Valley, seems to be restricted to this area ; it is absent from the other parts of the Dinant Basin because of a probable post-sedimentary erosion. Its presence however has been confirmed by field investigation and the study of boreholes in the Vesdre Basin.
Here again most of the limestones are micritic and, as a consequence, unfavourable for conodont-studies. Nevertheless two crinoidal limestone beds within the top layers of the Beverire Formation have been dissolved, which yield a conodont fauna indicating a (Lower ?) *costatus*-Zone.
The Beverire Formation appears to have been deposited as a rhytmically organized succession of high-intertidal to supratidal sediments. The supratidal deposits comprise micritic ostracod limestone (with thin-shelled ostracods) without crinoids.

9) The Comblain-au-Pont Formation is characteristic of the transition from a detrital sedimentation (Evieux Formation) to a more marine sedimentation, with rhytmically alternating sands, shales and limestones (containing Stromatoporoids and foraminifers) of the "Strunian" and the rich calcareous facies of the Carboniferous Hastière Limestone. This sedimentary sequence has been previously studied by many authors, in particular by CONIL and co-authors (1964, 1967, 1968, 1970).
The depositional environment for the Comblain-au-Pont Formation is more marine than for the Beverire Formation : all sedimentological features indicate a subtidal marine environment.
Conodonts have been described from the calcareous layers from these beds, typical of a BISPATHODID-PSEUDOPOLYGNATHID biofacies (which is equivalent, ecologically spoken, to the PALMATOLEPID-POLYGNATHID biofacies) contaminated by elements of a POLYGNATHID-ICRIODID biofacies (DREESEN, DUSAR & GROESSENS, 1976 ; BOUCKAERT & DUSAR, 1976) (Lower and Middle *costatus*-Zones).
The lithofacies and biofacies of the Comblain-la-Tour Formation are also indicative of the new transgression that reached its maximum during the Lower Carboniferous, and that ended the regression which has characterized the entire Famennian Stage.

To be noted, too, finally, that species of the form genus *Palmatolepis* have completely disappeared since the (Middle) *velifer*-Zone, which corresponds more or less with the establishment of the barrier complex of the Montfort Formation.

4.- CONCLUSIONS

The aim of this paper is to show the close relationships between conodont biofacies distribution and marine environments on the Famennian paleoshelf, and to explain the presence of mixed conodont biofacies (we prefer the term : mixed conodont thanatocoenoses) by the mechanism of sedimentological processes.

The paleoecological scheme here proposed, which is based on the distribution of conodont biofacies, fits the regressive sedimentational model of THOREZ *et al.* (1977) very well.

Conodont occurrences in the upper part of the Condroz Psammites are extremely rare, because of the presence of unfavourable facies for the nektobenthic conodont animal. Nevertheless, different sandy formations could be dated by conodonts, due to the accidental influx of conodont-bearing organoclastic marine sediments, by the mechanism of tidal inlets or storm wave action. The discrepancies in first occurrences of index conodonts ("retardations") that were previously noticed by DREESEN & DUSAR (1974, 1975) and DREESEN (1976) are probably due to the presence of different conodont biofacies.

Nevertheless, some problems concerning conodont distribution require further investigation, such as the Frasnian/Famennian boundary, and the subdivision of the *triangularis*- and *crepida*-Zones. Subdivisions of the *velifer*- and younger Zones should be based in the future, on the ranges of shallow-water conodont species (in Belgium).

An overall picture of the "facio"-stratigraphy and paleoecology of the entire Famennian stage in Belgium, will be published as a special issue (Mémoire) of the Belgian Geological Survey, with contributions by several specialists on sedimentological, micro- and macropaleontological topics.

ACKNOWLEDGEMENTS

The first author gratefully acknowledges financial support of the Nationaal Fonds voor Wetenschappelijk Onderzoek, for attending the Second European Conodont Symposium (ECOS II) in Vienna, August 1980.

We are very indebted to Prof. F. GEUKENS and Prof. J. BOUCKAERT of the Section Historical Geology, K.U. Leuven, in which laboratories all conodont-studies have been carried out. We thank Mrs. G. WILLEMS for her technical assistance in preparing the text figures. The manuscript was read and corrected by Prof. G. KING before being typed by Mrs. H. Van HOREBEEK.

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