Bulletin de la Société belge de Géologie	98-2	pp.149-154	Bruxelles 1989
Bulletin van de Belgische Vereniging voor Geologie	98-2	pp.149-154	Brussel 1989

SEDIMENTOLOGY, FACIES AND DEPOSITIONAL ENVIRONMENT OF THE HANONET (UPPER EIFELIAN) AND TROIS-FONTAINES (LOWER GIVETIAN) FORMATIONS IN COUVIN AREA (DINANT BASIN, BELGIUM)

by

Alain PREAT [1]

ABSTRACT

During Middle Devonian (Eifelian) times a major sea-level rise led to the development of an extensive siliciclastic-carbonate ramp over the Dinant and Namur basins. Differential subsidence and sea-level changes resulted in distinct facies sequences with various bioconstructions. The evolution of this continental margin leads to a good understanding of shelf evolution from Eifelian to Frasnian times.

An initial mixed ramp (Eifelian) consisting mainly of organic buildups and shoal-water complexes evolved into a carbonate progradational accretionary platform (Givetian ; Préat & Mamet, 1989). This latter consists of shallowing-upward subdital to supradital cycles that grade locally into evaporite-carbonate cycles along an arid coastline (Préat & Rouchy, 1986). This cyclic sedimentation was interrupted during a major event of incipient shelf drowning associated with backstepping of the rim and development of algal-sponge bioherms on a low-ramp continental slope environment (Frasnian ; Préat & Boulvain, 1988).

Microfacies analysis ("MF i" to "MF vi") of the Hanonet and Trois-Fontaines formations shows that the transition from Eifelian to Givetian times is marked by an entire regressive progradational megasequence partly interrupted by minor transgressive phases. Three distinct zones can be recognized : (1) an outer-ramp zone below storm wave base ("MF i" and "MF ii"), (2) a mid-ramp zone below normal wave base and strongly storm-influenced ("MF iii" and "MF iv") and (3) a landward inner-ramp zone within or above normal wave base ("MF v" and "MF vi"). According to sequential analysis the different infered water depths are the following ones : zone (1) up to 60 m, zone (2) between 60 m and 25 m and zone (3) between 25 m and 0 m.

RESUME

Suite à une élévation du niveau marin au cours du Dévonien moyen, une rampe siliciclastique-carbonatée s'étendait à l'Eifélien dans les bassins de Dinant et de Namur. Son évolution sera alors soumise aux variations relatives du niveau marin et de la subsidence, et se traduira par la succession de séquences sédimentaires renfermant de nombreuses bioconstructions à signification génétique précise. L'évolution de cette marge continentale à partir de l'analyse des séquences permet déjà d'en fixer les grandes lignes dès la fin de l'Eifélien : on observe en effet la transition d'un système de rampe mixte de faible pente, peu structurée, à une plate-forme carbonatée très stable sous le contrôle de rythmes régressifs élémentaires traduisant au Givétien le passage progressif des milieux subtidaux aux milieux intertidaux à supratidaux (Préat & Mamet, 1989) parfois à tendance évaporitique (Préat & Rouchy, 1986). Cette plate-forme est ensuite brutalement inondée au Frasnien, période pendant laquelle de nombreux monticules à algues et spongiaires s'installent sur une rampe plus profonde que celle de l'Eifélien mais de pente modérée à faible (Préat & Boulvain, 1988).

L'analyse des microfaciès ("MF i" à "MF vi") des formations d'Hanonet et de Trois-Fontaines montre qu'au passage de l'Eifélien au Givétien correspond une mégaséquence régressive de progradation. Cette mégaséquence est interrompue à plusieurs reprises par de petites évolutions à caractère transgressif. Trois zones géomorphologiques sont présentes : (1) une zone de rampe externe sous le niveau de base des tempêtes, (2) une zone médiane sous la zone d'action des vagues et

[1] Laboratoires Associés de Géologie-Pétrologie-Géochronologie, Université Libre de Bruxelles, avenue F.D. Roosevelt 50 - B-1050 Bruxelles.

fortement influencée par les tempêtes et (3) une zone de rampe interne dans ou au-dessus de la zone d'action des vagues. L'analyse séquentielle permet de fixer un ordre de grandeur approximatif des paléoprofondeurs dans chacune des zones : nous avons ainsi plus de 60 m pour la première zone, entre 60 m et 25 m pour le seconde et enfin entre 25 m et 0 m pour la troisième.

KEY WORDS

Microfacies, ramp evolution, rhythmite, Eifelian-Givetian, Dinant Basin, Belgium.

MOTS-CLES

Microfaciès, rampe mixte, rythmite, Eifélien-Givétien, Bassin de Dinant, Belgique.

1. INTRODUCTION

The "Assise de Bure" (Lower Eifelian) and the "Assise de Couvin" (Upper Eifelian) were firstly described by Gosselet (1874), and the specific locality and type of section by Roemer in 1850 and later by Gosselet (1860) at Couvin (figure 1). Because this stratigraphic unit is a shallow-basin, transitional mixed clastic-carbonate lens sandwiched by well-established Givetian rocks above, and clastic sediments of the Lower Devonian below, considerable interest and differences of opinion have resulted concerning its systematic boundaries. It has gradational contacts (Préat, 1984 ; Préat *et al.*, 1984 ; Mamet & Préat, 1985) with the overlying "Trois-Fontaines Formation" (Lower Givetian *sensu* Errera *et al.*, 1972) and shows a prominent change from the silty shales of the underlying "Assise de Hierges" (Upper Emsian).

The "Eifelian" was redefined in 1982 by Bultynck *et al.* (at that time the "belgian" Eifelian was called "Couvinian"), on the basis of its lithology and contained fauna and subdivided into four formations which are from the bottom to the top the following : "Saint-Joseph Formation", "Eau Noire Formation", "Jemelle Formation" and "Hanonet Formation". The Eifelian, although described early in the "Couvin" history geology, has been little studied in term of its depositional history. It is relatively homogeneous in lithology (mainly shales, argillaceous limestones and "reefal" biostromes and patch-reefs which generally seem to lack sedimentological features useful for environmental reconstruction. Moreover, no previous studies have rigourously considered the possibility of cyclic patterns of facies distribution and no comprehensive paleoenvironmental studies exist.

Vertical sequences of litho- and microfacies observed in the Couvin and Wellin areas, both located in the southern part of Dinant Basin, evidently reflect fluctuations in depositional environments. We are starting this study in the Upper Eifelian on a multidisciplinary approach, including paleoenvironment analysis in depositional analysis,

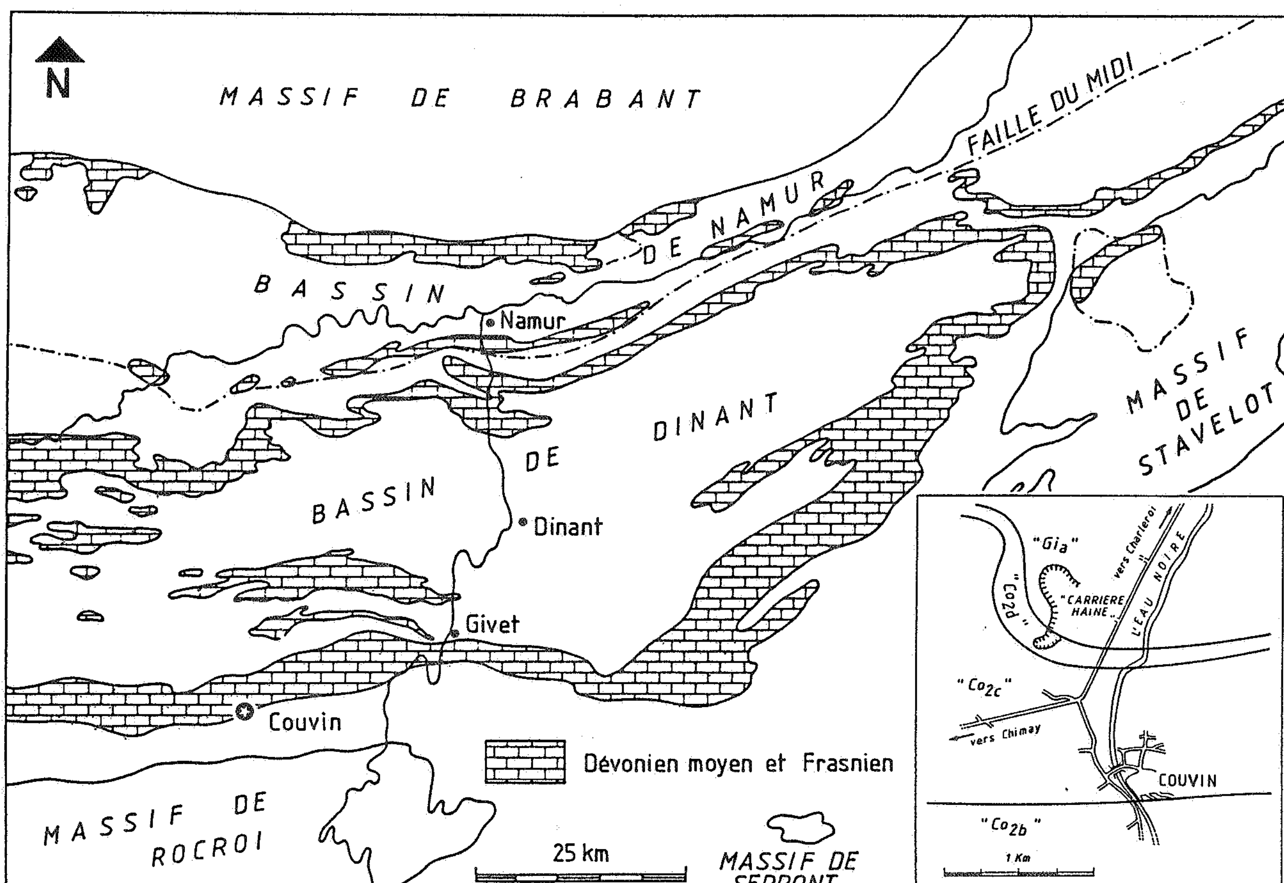


Figure 1. : Location map of studied profile and outcrop belts of Middle Devonian limestones in Belgium.

paleoecological and stratigraphic studies of algae, rugosa and tabulate. We hope to involve process-orientated analysis of sedimentary sequences and to develop in the future a dynamic stratigraphy for the Eifelian.

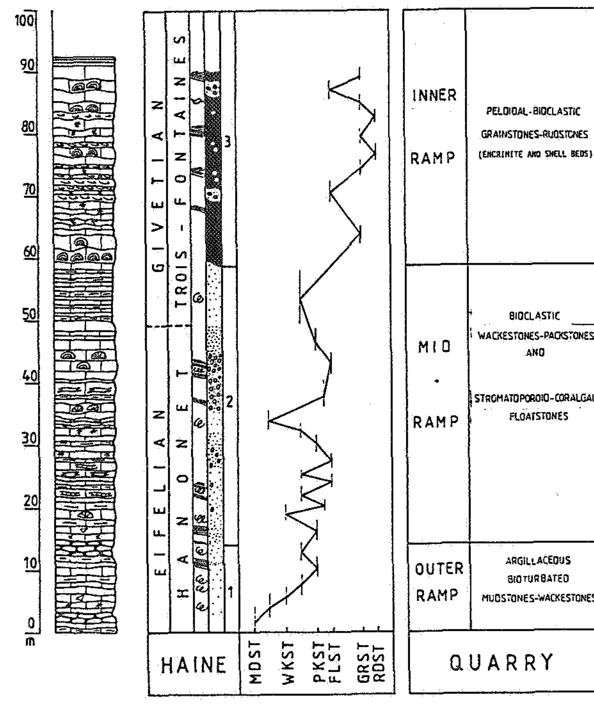
Meanwhile, we have studied the Upper Eifelian of several quarries and outcrops in the Couvin and Wellin areas. As mentionned above, the marine conditions during this period were established by an initial transgression which drowned underlying peritidal, deltaic and continental Lower Devonian sediments. Its upper part reflects gradual shoaling and the open-marine ramp depositional setting was ultimately supplanted by shoreline and peritidal sedimentation represented by the overlying Trois-Fontaines Formation (Lower Givetian). Now we will describe the Eifelian-Givetian transition from the Haine quarry and propose an environmental synthesis (fig. 2).

2. MICROFACIES ANALYSIS

The Haine (ancient name)) or "La Couvinoise" quarry is situated 1 km NNW of Couvin and 200 m from the road Couvin-Philippeville on Km 33,650 (fig. 1). On over more than 80 meters this quarry exposes the upper part of the Hanonet Formation (Upper Eifelian) and the lower part of the Trois-Fontaines Formation (Lower Givetian). The limit between these two formations has been established in the quarry by Bultynck (1970) by conodont analysis. For this author the "Gia" and "Gib" zones (or "Lower Givetian" *pro parte*) do not exhibit any *hiatus* with the underlying "Co2d" zone ("or Upper Eifelian" *pro parte*). The Hanonet Formation consists of thin calacareous claystones interbedded with nodular and well-stratified argillaceous limestones. The sediments were deposited in an open-shelf or ramp setting and are characterized by an abundant and well-diversified autochtonous and para-autochtonous benthic marine fauna and algal microflora. These communities consist of brachiopods, mollusks, pelmatozoans, ostracods, trilobites, corals, stromatoporoids, tentaculites, bryozoans, sponges and algae (porostromats, palaeoberesellids, codiaceans). The Trois-Fontaines Formation (lower part) is formed of irregularly thin- to medium bedded bioclastic packstones to floatstones containing crinoids, brachiopods, corals and bryozoans and thickly bedded bioclastic grainstones to rudstones (with massive stromatoporoids) interbedded with coquina levels of disarticulated and broken *Stringocephalus burtini*. Using the nomenclature of Embry & Klovan (1971, 1972) six major microfacies ("MF i" to "MF vi") are recognized within this profile, their succession from (i) to (vi) constitutes a standard sequence recording shallowing upward evolution of sedimentation (fig. 2a & 2b) :

(i) : very fine-grained argillaceous mudstones exhibiting excellent preservation of fossil (very few mollusks, crinoids, trilobites, brachiopods and tentaculites). Bioturbation is discrete and the facies has a pseudo-lenticular aspect. The micritic matrix has generally recrystallized in the form of a fine homogeneous calcitic microspar (up to 6μ). Fine pyrite crystals are common,

(ii) : moderately of heavily bioclastic argillaceous wackestones. Same organisms as before but with a few bryozoans, ostracods, pteropods and well-preserved trilobites and brachiopods exhibiting articulated and closed shells. As for the preceding microfacies, shell material is excellently preserved and the degree of *post-mortem* reworking is very weak and probably due to bioturbation



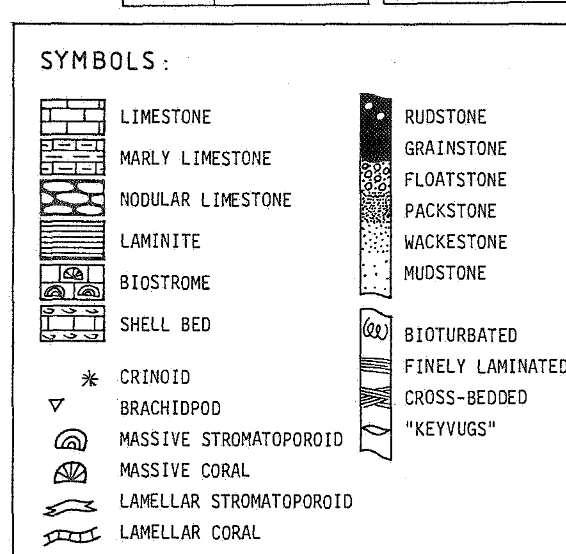


Figure 2a : Stratigraphic column of Upper Eifelian - Lower Givetian transition at "Haine" quarry. The right column shows the vertical transitions of microfacies types from "MF i" to "MF vi". Facies code is MDST = mudstone, VKST = wackestone, PKST = packstone, FLST = floatstone, GRST = grainstone, RDST = rudstone.

Figure 2b : Explanation of symbols used in figure 2a.

processes. Such observations suggest that little particle movement has affected the bioclasts, implying weak currents at the time of deposition and-or rapid burial,

(iii) several types of packstones composed of a few laminated silty packstones and a great variety of bioclastic packstones displaying mixing of distinctive taphocoenoses. They were dominated by bryozoans, mollusks, trilobites, brachiopods, crinoids with a few solitary corals and lamellar stromatoporoids. A few sponge nodules and calcispherids may be also observed.

With these facies appear the algal microflora dominated by *Girvanella* and by the palaeoberesellids with a very few encrusting *Sphaerocodium.* Encrustations between the large organisms by trachyporidae corals, lamellar stromatoporoids, bryozoans and algae are common. Most bioclastic beds composed of this facies contain a mixture of articulated and disarticulated unmicritized skeletal material : fragile fossils are fragmentated but are rarely abraded or corroded. Size sorting is common and grading occasional. This facies does not exhibit strong evidence for erosion of older sediments : a few mud-filled shells are present but intraclasts have never been observed. This indicates that the fossils have not been transported a significant distance and that lateral transport was rather weak. For example, palaeoberesellid packstones-bafflestones are common and could reflect the proximity of algal banks similar to those described by Mamet (1976) and by Mamet & Préat (1987). Moreover, *Girvanella* generally occur as small millimetric fragmented bushes composed of thin delicate and well-preserved tubules. These microfacies represent both longer term accumulation of skeletal material during calm-water and slow deposition periods with episodic reworking and burial during storm events.

The laminated silty packstones-siltstones are composed of fine skeletal and algal (palaeobersellids) fragments and peloids (*Girvanella*-origin), and display inframillimetric internal planar laminations. They occur as isolated beds within the previous mudstones and wackestones and could correspond to distal storm silt layers analogous to those reported by Reineck & Singh (1971) from the North Sea Basin. The fine- to medium-grained bioclastic packstones show well-defined internal stratification. However, these, which are generally coarser, are for the most part destroyed by infaunal organisms. They have quickly colonized the new sediment pavement after the storm event suggesting that the "new" environment was as before i.e characterized by more nearly continuous sedimentation with a generally slow sediment accumulation rate,

(iv) : coarse- to very coarse-grained stromatoporoid and coralgal floatstones with a matrix composed of disarticulated, fragmented pieces of bioclastic debris ("shell hash") comprising codiacean-udoteacean algal fragments. Skeletal material ranges in size between 20 µ and several centimeters. Biological abrasion (mainly due to boring) is as evident as mechanical abrasion in most fabrics. The resulting grains are relatively angular and display little evidence of prolonged current battering, indicating more or less in-place accumulation. Furthermore, most of grains have feature characteristic of long term reworking and minimal deposition including abrasion, bioencrustation, oncoidization, and weak micritization in intermittently agitated waters. As for the preceding microfacies these features firstly record the influence of episodic reworking by storm processes which have affected an area dominated by scattered carbonate bioconstructions?

(v) : very fine - to medium-grained peloid-bioclast grainstones and medium- to coarse-grained crinoid grainstones (encrinites) with some complex internal cross-bedding, centimeter-sized intraclasts, large brachiopods, *Ortonella* oncoids, superficial ooids, codiacean-udoteacean fragments of *Paralitanaia* and *Pseudopalaeoporella* (Mamet & Préat, 1985). Size sorting is well developped indicating multiple reworking and persistent winnowing. Graded bedding associated with coarse skeletal lag deposits may also be observed. Sparry laminoid fenestrae (keyvugs?), asymetric cements? and internal truncated surfaces suggest shallow environments associated with subaerial events and vadose diagenesis.

(vi) : coarse- to very coarse-grained stromatoporoid-coral rudstones constituying biostromal units. Same diagenetic characteristics as for the grainstone microfacies. Interbedded with this facies are thick shell beds (brachiopods) displaying infiltration fabrics.

3. ENVIRONMENTAL SYNTHESIS

Microfacies (i) to (iv) contain remains of a fully marine biota. Microfacies (i) and (ii) lacks any very shallow organisms as algae. Their mud-supported nature and the presence of well-preserved benthic fossils with a few hemi-pelagic forms such as tentaculites suggest an environment of relatively deep, low energy and probably poorly oxygenated water in the subphotic zone and at depths below significant wave or current activity. The excellent preservation of the organisms imply rapid burial. Interbeds of laminated silty packstones and siltstones ("MF iii") are irregularly distributed. They occur as isolated layers, typically a few centimeters thick, within the argillaceous mudstones-wackestones sequences and may represent distal storm layers. According to Hayes (1967) and Reineck & Singh (1971) such "storm layers" are found as far as 30 km from the land and in water depths of up to 40 m in the Gulf of Mexico or up to 300 m in the Mediterranea.

Microfacies (iii) and (iv) have a high faunal diversity with abundant shelly and "reefal" organisms and different algal taxa. Most part of the grains are reworked and it is difficult to reconstitute the original communities. We can just underline the presence of at least four biofacies successions, each of them dominated by (1) shelly material with abundant *Girvanella*, (2) pelmatozoan meadows, (3) reefal organisms (mainly stromatoporoids and corals) with palaeoberesellid meadows and (4) codiacean-udoteacean banks. All the grains are broken, show grading and size sorting indicating episodic reworking and burial. Wave-formed structures and micritized grains are absent suggesting deposition at depths below normal wave base (greater than 25 m), probably in the storm wave base zone in well aerated waters and in the photic zone.

Microfacies (v) and (vi), composed of fine to very coarse sands with a few reworked clasts of the underlying facies ("MF iii") represent shoal environments. These sediments which contain a rich and fully marine fauna, record multiple reworking and presistent winnowing. Their sequences display a few subaerial exposure surfaces indicating nearshore settings. The cross-bedding (encrinites) suggests that the original sediment was arranged in dunes and sandwaves, the bottoms being constantly and rapidly shifting. Coquina beds (winnowed shell beds of *Stringocephalus*), composed of whole fossil valves parallel to bedding and interbedded with the well-bedded grainstones may correspond to storm-induced high energy events in shallow waters (proximal tempestites). They are restricted to a zone of direct scouring of the sea floor by storm waves.

The global cyclic succession of the microfacies (fig. 2) shows evidence of shallowing from deeper settings, unaffected by storm-reworking ("MF i" and "MF ii") into "proximal", above storm wave base settings near a shoreline coast ("MF v" and "MF vi"). The megasequence shows gradual transition from mud-dominated "deep" water to grain-supported nearshore environments.

These features indicate that deposition could have occured on a ramp setting without any kind of continuous rims and-or typical lagoonal facies behind them. Three different zones can be recognized which are very similar to those reported by Wright (1986) from the carbonate ramp of the Carboniferous of South Wales :

(1) an outer-ramp zone below storm wave base ("MF i" and "MF ii") ;
(2) a mid-ramp zone below normal wave base and strongly storm-influenced ("MF iii" and "MF iv") ;
(3) a landward inner-ramp zone within or above normal wave base in very shallow waters ("MF v" and "MF vi).

The fact that these various zones are easily distinguishable may indicate low depositional slopes and that, at time of deposition and before mixing by storm-induced currents, various "relays" existed between the different biocoenoses. The general lack of turbidite slumps or important truncated surfaces support also the idea of low slope on the ramp which inhibited gravity flow and favoured storm-generated sequences over wide areas.

It appears clearly from figure 2 that the upper part of the Hanonet Formation and the lower part of the Trois-Fontaines Formation represent an entire regressive progradational megasequence partly interrupted by minor transgressive phases. If the rate of subsidence was low to moderate during the succession, the thickness of this sequence corresponds approximatively to the paleobathymetry of the latest "deep" outer-ramp sediments deposited at the base of the megasequence i.e. approximatively 60-70 meters. According to this point we can infer the different water depth ranges for each ramp zone as follows :

(1) most of the floor of the outer-ramp is deeper than 60 m ;
(2) the mid-ramp zone ranges in depth from 60 m up to 25 m ;
(3) the inner-ramp zone depth varies between 25 m and 0 m.

This general upward-coarsening progradational evolution may correspond to a phase of reduced sea-level rise or stillstand. We have to extend the study to other areas within the Dinant Basin in order to correlate more precisely this shallowing phase and to verify if there was a differential subsidence across the ramp.

4. CONCLUSION

The vertical succession of lithologies and communities within the Hanonet and Trois-Fontaines formations suggests an upward shallowing sequence underlining the Eifelian-Givetian transition. The lower regressive cycle, consisting of argillaceous mudstones-wackestones, begins with a quiet offshore, probably dysaerobic setting, below storm wave base at depths up to 60 m and was followed by the deposition of bioclastic wackestones and stromatoporoid coralgal floatstones within storm wave base at depths varying between 60 m and 25 m. It culminates with the deposition of high energy grainstones and rudstones within and above normal wave base in very shallow waters (between 25 m and 0 m). In general terms the succession shows gradual transitions from mud-dominated deeper water facies to grain-supported very shallow water facies across a mixed ramp or open shelf setting displaying a low depositional slope.

From this study it is difficult to precise the cause of this general progradational regression. This latter may correspond to phases of reduced sea level rise or stillstand or to localized tectonic base-level changes at the Eifelian-Givetian transition. Future studies have to determine the details of this regressive sequence on a regional scale in order to differenciate their causes.

REFERENCES

BULTYNCK, P., 1970 - Révision stratigraphique et paléontologique de la coupe type du Couvinien. *Mém. Inst. géol. Univ. Louvain, XXVI*, 152 p.

BULTYNCK, P., GODEFROID, J. & SARTENAER, P., 1982 - Brachiopods and conodonts from the beds near the Emsian/Couvinian boundary in the belgian Ardennes. *In* : Biostratigraphie des dépôts à la limite du Dévonien inférieur. *Akad. Nauk. SSSR Geol., Geofiz, Geox Tv. Pol. Sess. Mejd. Podk. Strat. Dev*, Samarkand, 31-37 (en russe).

EMBRY, A.F. & KLOVAN, J.E., 1971 - A late devonian reef tract on the northeastern Banks Island, Northwest Territories. *Canad. Petrol. Geol. Bull.*, *19*: 730-781.

EMBRY, A.F. & KLOVAN, J.E., 1972 - Absolute water depths limits of Late Devonian paleoecological zones. *Geol. Rdsch.*, *61*: 672-696.

ERRERA, M., MAMET, B. & SARTENAER, P., 1972 - Le Calcaire de Givet et le Givétien à Givet. *Bull. Inst. r. Sci. nat. Belg.*, *48*: 1-59.

GOSSELET, J., 1860 - Mémoire sur les terrains primaires de la Belgique, des environs d'Avesnes et du Boulonnais. Paris.

GOSSELET, J., 1874 - Carte géologique de la bande méridionale des calcaires dévoniens de l'Entre-Sambre-et-Meuse. *Bull. Acad. r. Sci. Belg.*, *2è série*, 37 p.

HAYES, M.O., 1967 - Hurricanes as geological agents, South Texas Coast. *Am. Assoc. Petrol. Bull.*, *51*: 937-942.

MAMET, B., 1976 - An atlas of microfacies in Carboniferous carbonates of the Canadian Cordillera. *Bull. geol. Surv. Canada*, *255*, 131 p.

MAMET, B. & PREAT, A., 1985 - Sur quelques Algues vertes du Givétien de la Belgique. *Rev. Micropal.*, *28*: 67-74.

MAMET, B. & PREAT, A., 1987 - Algues givétiennes du bord sud du Bassin de Dinant et des régions limitrophes. *Ann. Soc. géol. Belg.*, *109*: 431-454.

PREAT, A., 1984 - Etude lithostratigraphique et sédimentologique du Givétien belge (Bassin de Dinant). Thèse Doct., Université Libre de Bruxelles, 466 p.

PREAT, A., COEN-AUBERT, M., MAMET, B. & TOURNEUR, F., 1984 - Sédimentologie et paléoécologie de trois niveaux récifaux du Givétien Inférieur de Resteigne (bord sud du Bassin de Dinant). *Bull. Soc. belge Géol.*, *93*: 227-240.

PREAT, A. & ROUCHY, J.M., 1986 - Faciès pré-évaporitiques dans le Givétien des Bassins de Dinant et de Namur. *Bull. Soc. belge Géol.*, *95*: 177-189.

PREAT, A. & BOULVAIN, F., 1988 - Middle and Upper Devonian carbonate platform evolution in Dinant and Namur Basins (Belgium, France). *I.A.S. 9th European Regional Meeting, Excursion Guidebook*, Leuven, 1989, 1-25.

PREAT, A. & MAMET, B., 1989 - Sédimentation de la plate-forme carbonatée givétienne franco-belge. *Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine*, *13/1*: 47-86.

REINECK, H.E. & SINGH, I., 1971 - Genesis of laminated sand and graded rhythmites in storm-layers of shelf mud. *Sedimentology*, *18*: 123-128.

ROEMER, F.A., 1850 - Coupe du terrain dévonien de Couvin. *Bull. Soc. géol. Fr.*, *8*: 87-89.

WRIGHT, V.P., 1986 - Facies sequences on a carbonate ramp : the Carboniferous Limestone of South Wales. *Sedimentology*, *33*: 221-241.