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THE OCCURRENCE OF A MICROBIAL BUILDUP AT POEDERLEE (CAMPINE BASIN, BELGIUM): BIOSTRATIGRAPHY, SEDIMENTOLOGY, EARLY DIAGENESIS AND SIGNIFICANCE FOR EARLY WARNANTIAN PALEOGEOGRAPHY[1]

by

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(4 figures, 2 tables and 2 plates)

ABSTRACT.- The Poederlee borehole is situated in the Campine Basin and has been drilled in the center of a domal structure at the top of the Visean, identified by reflection seismic studies. The Visean limestones in this borehole have an Early Warnantian (Late Visean) age. They belong to the Carboniferous foraminifer 6γ subzone and to the rugose coral 7α and β subzones.

Two types of lithofacies, namely microbial boundstones and bioclastic packstones and grainstones, are present in these limestones. The first type represents the core of a reef mound, which developed below and near the wave base. The second type occurs above the boundstones, forms the flank and top facies of the reef mound and has been deposited above wave base. Five superimposed reef mounds have been recognized in the Lower Warnantian and are interpreted as a reef complex. A comparison of the Lower Warnantian reef mounds in the Campine Basin indicates that the paleogeographical position is a factor which influences their evolution.

Diagenesis started with the precipitation of isopachous fibrous and fibrous radiaxial calcites under oxidizing conditions in marine pore-waters. After the precipitation of the fibrous calcites, dissolution of these cements and of the host limestone possibly occurred in meteoric waters. Rim cements around crinoids and blocky calcites developed in a pore fluid which evolved from oxidizing to reducing.

RESUME.- Le sondage de Poederlee (bassin de Campine) a été implanté dans une structure en dôme affectant le sommet du Dinantien, reconnue par des études de réflexion sismique. Il a recoupé des calcaires attribués sur base des foraminifères et des coraux au Warnantien inférieur (biosubzones Cf6γ et RC7α,β).

Deux types de lithofaciès ont été déterminés. Le premier consiste en des bindstones cyanobactériens développés immédiatement sous le niveau d'agitation des vagues et formant le corps d'une construction biohermale; le second type de lithofaciès comprend des packstones et des grainstones bioclastiques déposés dans la zone d'agitation des vagues et qui, surmontant le précédent lithofaciès, forment les flancs et le sommet de l'édifice. Cinq séquences biohermales ont été reconnues dans le sondage et suggèrent l'existence d'un complexe récifal. La comparaison de ces édifices biohermaux avec d'autres connus dans le Warnantien du bassin de Campine fait ressortir l'influence de leur position paléogéographique sur leur développement.

La diagenèse a commencé avec des calcites fibreuses isopaques et fibro-radiaxiales, qui ont été précipitées à partir d'eaux marines oxydées. Des ciments syntaxiaux (rim cements) se sont développés à partir d'échinodermes dans un fluide capillaire, oxydant à réducteur, ainsi que le montrent leurs caractéristiques en analyse par cathodoluminescence.

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1.- INTRODUCTION

The Poederlee borehole (DzP1) was drilled near Antwerp (northern Belgium) in 1984 as a joint venture of Distrigaz and the Belgian Geological Survey. As in the Heibaart boreholes (Bless *et al.*, 1981; Muchez *et al.*, 1987b), it allows to investigate the reservoir qualities of the karstic zones of the Visean carbonates for underground gas storage. The Poederlee borehole has been drilled in the center of a domal structure at the top of the Visean, previously identified by reflection seismic studies. Carboniferous rocks occur between 769 m and 1689 m. Visean limestones are present between 1521 m and 1689 m. Drilling was stopped at 1689 m. A detailed report and a description of the borehole is available at the Belgian Geological Survey (Bouckaert *et al.*, 1987). The borehole has been listed on the Geological Survey files as 30W/371.

The Visean of the Campine Basin is only known from boreholes (fig. 1), except at its southeastern part, where several outcrops occur near Visé. In the Upper Visean limestones of the Heibaart borehole, which also penetrated a domal structure, a reef mound has been recognized (Muchez *et al.*, 1987b). Near Visé, a domal structure in the Richelle quarries corresponds with a small buildup (Muchez & Peeters, 1986). Macroscopical features which are at first sight comparable with those occur in the Late Visean buildups recognized in the Poederlee borehole. Therefore, a more detailed study of this borehole has been undertaken. In addition, it penetrates a part of the Campine Basin in which the Visean is poorly known. Important cementation of small and large interconnected cavities is present in the Poederlee limestones. The chemical evolution of the pore-water in which cementation took place has also been investigated.

2.- LITHOLOGY AND BIOSTRATIGRAPHY OF THE VISEAN IN THE POEDERLEE BOREHOLE

2.1.- LITHOLOGY

The Poederlee borehole was deviated in the Visean interval by 17 to 20 degrees. Depositional stratification has an average dip of 54 degrees with respect to the core margin (fig. 2). In the same sample low amplitude stylolites, which likely represent the horizontal planes, have a dip of 19 degrees. This pressure solution occurred as a response to overburden stress. So, these data point to a local depositional dip of 35 degrees.

Fine-grained limestones constitute the major part of the Visean. They are intercalated with packstone and grainstone intervals. Shaly intraclasts and thin black shale horizons occur at different levels in the lithological succession. Tectonic deformations created a network of fractures. Some of these are still open or have even been widened. Additionally, the limestones has been dissolved along the fractures. This resulted in a typical fracture type reservoir. The fractures occur at a depth of 1635 m and deeper.

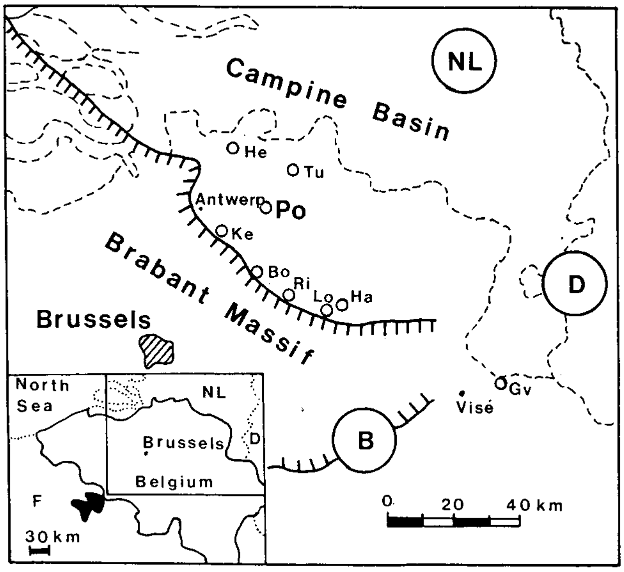

Fig. 1.- Location of the boreholes, which penetrated Visean limestones in northern Belgium. The barbed lines mark the northern and southern border of the Dinantian strata (Bo: Booischot; Gv: 's Gravenvoeren; Ha: Halen; He: Heibaart; Ke: Kessel; Lo: Loksbergen; Po: Poederlee; Ri: Rillaar; Tu: Turnhout).

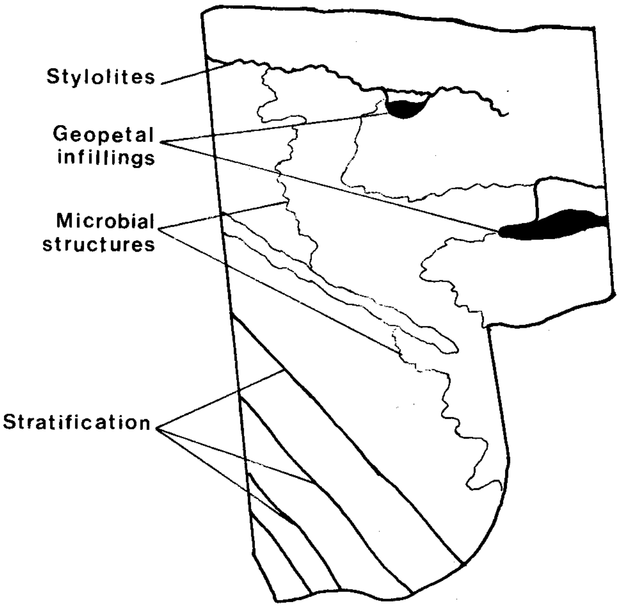

Fig. 2.- Rock slab showing depositional stratification and low amplitude stylolites.

The major distribution of the fractures can be recognized on the sonic, density, neutron and GR logs. The study of the dissolution phases and of the fractures forms part of a separate paper (Muchez *et al.*, in prep.).

2.2.- BIOSTRATIGRAPHY

The foraminifers, algae and problematica, which occur in the Visean limestones of the Poederlee borehoie are presented in table 1. The presence of **Paleotextulariidae** with a double wall at 1657m and 1573m, of *Scalebrina* at 1573m and of *Asteroarchaediscus* at 1535 m indicates that the sequence between 1657 m and the top of the Visean has a Lower Warnantian age. The association of these foraminifers appears in the subzone Cf6γ.

Table 1.- Foraminifers, algae and problematica present in the Visean strata of the Poederlee borehole.
X : presence; cf : probable presence

Depth (m)	Rugose corals	Coral subzones
1536	Axophyllum cf lonsdaleiforme	RC7 ß
1539	Axophyllum sp.B	
1572	Siphonophyllia aff. siblyi	
1583	Axophyllum cf. lonsdaleiforme	
1591	Lithostrotion araneum	RC7 α
1591.5	Lithostrotion araneum (colony)	
1592	Lithostrotion araneum (colony)	
1622.9	Axophyllum sp.A	
1635	Siphonodendron pauciradiale	
1635	Clisiophyllum cf. delicatum	

Table 2.- Rugose coral distribution in the Poederlee borehole and their biostratigraphical interpretation.

Foraminifers, algae, problematica / Depth	1657 m	1613 m	1573 m	1566 m	1540 m	1535 m
Koninckopora tenuiraunosa		X				
Quasiumbella				X		
Diplosphaerina inaequalis	X	X	X		X	X
Earlandia moderata	X		X		X	X
Pseudoammodiscus	X		X		X	
Scalebrina			X			
Palaeotextulariidae (single wall)		X				
Palaeotextulariidae (double wall)	X		X			
Asteroarchaediscus			cf			X
Archaediscus	X		X		X	
Tetrataxis	X	X	X		X	
Endothyranopsis		X	X		cf	cf
Globoendothyra		X				
Endothyra	X	X		X	X	X
Omphalotis minima	X	cf				
Pojarkovella		X				
Eostafella	X	X				
Loeblichia				cf		cf
Interpretation	Cf6γ					

The study of corals allow a subivision of the limestones in two Rugose coral subzones (table 2). The RC7α subzone here is characterized by the concurrent range of *Lithostrotion araneum, Siphonodendron pauciradiale* and *Axophyllum* sp. *A. Axophylum* cf. *lonsdaleiforme, Axophyllum* sp. *B* and *Siphonophyllia* aff. *siblyi* are typical for the RC7α, subzone (Poty, 1985; Conil *et al.*, 1990).

3.- SEDIMENTOLOGY OF THE VISEAN

3.1.- SEDIMENT PETROGRAPHICAL DESCRIPTIONS

Two lithofacies types have been recognized in the Lower Warnantian limestones (fig. 3). They occur as cyclic deposits.

Macroscopically, spotted darker and lighter areas occur in the first type (Pl. I: 1). They are very irregular and can clearly be distinguished from sedimentary structures caused by processes such as currents, waves. . . A common aspect of the rocks are the patches of light-coloured micrite (Pl. I: 2), in which peloids can be recognized. A few spheroidal cryptalgal structures (oncolites) and lithoclasts have been observed. Stromatactoid cavities are abundant.

Microscopically, peloidal and clotted textures are the main feature of this lithofacies (Pl. I: 3). The biota include foraminifers, crinoids, algal tubes, echinoid and brachiopod spines, pelecypods,

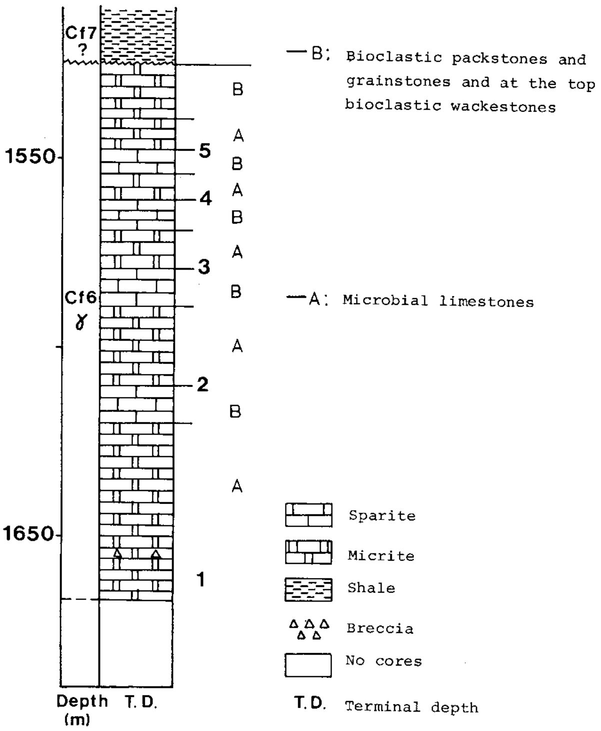

Fig. 3.- Sediment petrographical log of the Visean limestone in the Poederlee borehole. The cycles are numbered 1 to 5.

ostracodes, brachiopods, gastropods, bryozoa, trilobites, calcispheres, corals and spongespicula. The characteristics of the first lithofacies point to a microbial origin (sensu James & Macintyre, 1985) of the limestones.

The second lithofacies type (B) consists of bioclastic packstones and grainstones (Pl. I: 4). The limestones are massif. Foraminifers, crinoids, brachiopods, corals, pelecypods, moravamminids, gastropods, ostracods, algal tubes, bryozoa, brachiopod and echinoid spines have been found. The crinoids and the foraminifers are often micritised (Pl. I: 5). Lithoclasts up to 15 mm occur regularly in the second lithofacies. At the top of the Lower Warnantian, wackestones occur in association with bioclastic packstones.

3.2.- FACIES INTERPRETATION

Microbial structures, stromatactoid cavities and important depositional dips occur in the Lower Warnantian buildups of the Campine Basin (Muchez & Peters, 1986; Muchez *et al.,* 1987a,b). Comparable Late Visean reef mounds developed in Great Britain (Orme, 1970; Walkden, 1970; Broadhurst & Simpson, 1973; Grayson & Oldham, 1987). The small number of oncolites and lithoclasts in lithofacies A indicate a temporary turbulence in the depositional environment. This suggests that the microbial lithofacies formed mostly below and sometimes near wave base.

The bioclastic packstones and grainstones were deposited in an open marine environment as indicated by the open marine biota. Water turbulence and circulation rates were high enough to prevent considerable accumulation of mud. This suggests a deposition above wave base. The absence of desiccation cracks and of other indications for subaerial exposure are consistent with a subtidal sedimentation.

The evolution from lithofacies A to lithofacies B represents a shallowing upward cycle. Wilson (1975, p.369) interpreted the transition from boundstones to packstones and grainstones as an evolution of the depositional environment below or just at the wave base to a sedimentation above wave base. Five such cycles have been recognized in the Lower Warnantian of the Poederlee borehole. One such cycle can be regarded as a simple reef mound (sensu James & Macintyre, 1985) with its core (lithofacies A) and its flank and top facies (lithofacies B). The superimposed cycles can be interpreted as a reef complex (sensu James, 1984, p.239).

Early Warnantian cycles also occur extensively in southern Belgium (Pirlet, 1968) and in Great Britain (Ramsbottom, 1973, 1981; Somerville, 1979). The origin of the cycles has been related to epeirogenic movements by Pirlet (1968). Ramsbottom (1973) attributed most importance to periodic eustatic changes in sea-level. However, George (1978) disagreed with this model, because it diminishes the role of contemporary tectonism. Recent investigations showed that both tectonism and eustatic factors influenced the Early Warnantian cycles (Walkden, 1987; Horbury, 1989).

3.3.- PALEOGEOGRAPHICAL IMPLICATIONS

The Dinantian subcrop of the central part of the Campine Basin in Belgium can be structurally divided into two main zones: a western zone in which the strike grades from WNW-ESE in the north to NNW-SSE in the south, and an eastern zone with a dominant NNW-SSE strike (Dreesen *et al.,* 1987). An important NNW-SSE oriented fault system characterizes the transition between both structural areas. The Poederlee and the Heibaart reef mound (Muchez *et al.,* 1987b) occur in the western zone.

A north-south paleogeographical section, north of the Brabant Massif, with the deposition of the buildups is sketched in figure 4. The Heibaart reef mound is located to the north of the Poederlee buildup. It is characterized by a thick reef core and by the absence of cycles (Muchez *et al.,* 1987a,b). The buildup developed at a greater water depth than at Poederlee. This allowed the formation of a large reef core. At the southeastern part of the Campine Basin, an Early Warnantian reef mound (near Visé) developed near some localized highs at the eastern end of the Brabant Massif (Poty, 1982). Under conditions of only slight subsidence, the original mound core at Visé was soon buried by the flank beds, which accumulated on all sides of the core (Muchez & Peeters, 1986).

Another explanation for the observed differences between the Heibaart and Poederlee reef mound could be related to a different position of the boreholes with respect to the reef core. The Poederlee borehole would have penetrated the outer part of the reef core, where interfingering with the flank facies occurs and where variations of the relative sea-level are easily observed. The Heibaart borehole on the contrary would have intersected the inner part of the reef core. However, variations in the sedimentation depth also influence the characteristics of the inner part of a reef core (e.g. fig. 20 *in* James, 1984). Such features have not been recognized at Heibaart. In addition, both boreholes penetrate the central part of the domal structure, which likely represents the inner part of the reef mound.

On the isochron map of the top of the Dinantian (Dreesen *et al.,* 1987), the position of the reef

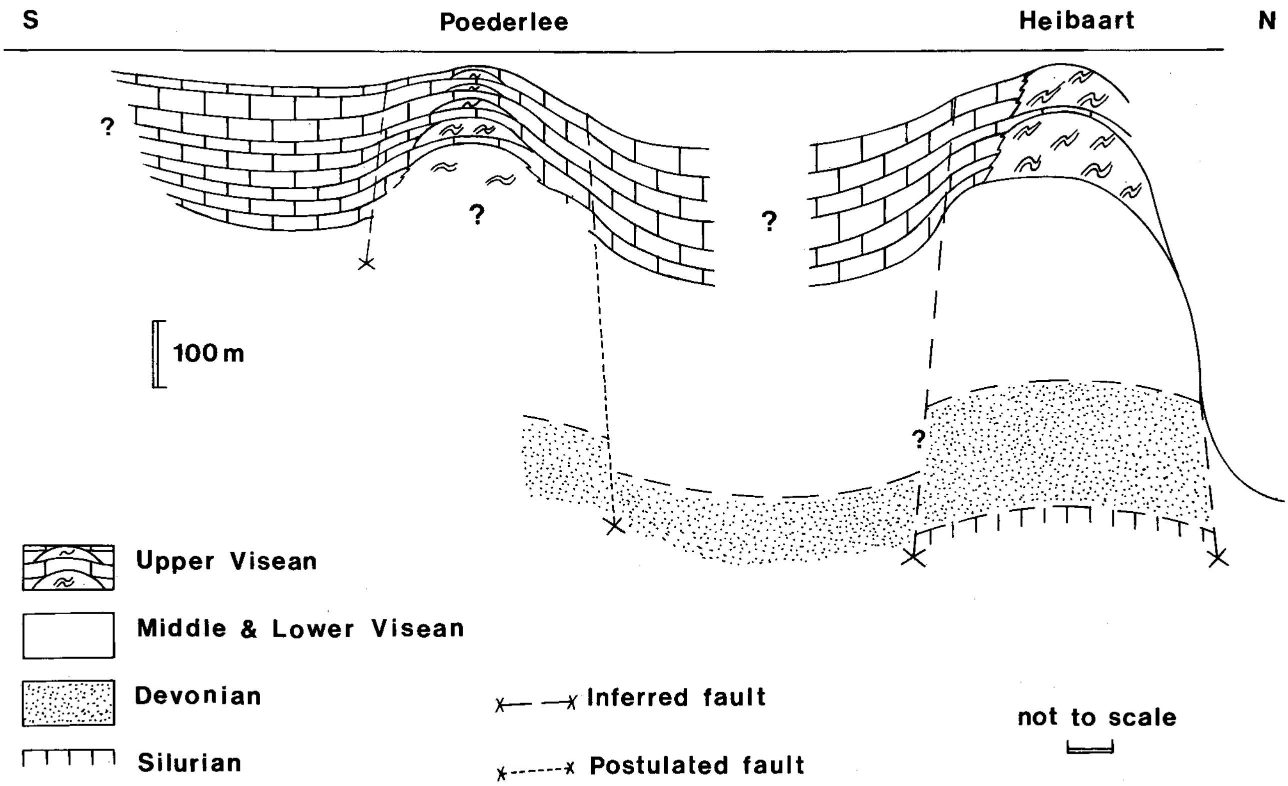

Fig. 4.- N-S paleogeographical section through the Lower Carboniferous and Devonian of the Campine Basin. The dashed lines are hypothetical. The distance between Poederlee and Heibaart is approximately 20 km.

mounds of Poederlee and Heibaart corresponds with fault-bounded domal structures. The Devonian and the Upper Carboniferous strata at the Heibaart high are reduced (Bless *et al.,* 1981). Geometrical considerations on a geological cross-section (fig. 2 *in* Vandenberghe *et al.,* 1986) prove that the Devonian under the Heibaart area must be faulted north and south of its domal structure. The precise geometry, however, is not known. Based on the analogy of the Poederlee and Heibaart domal structure, a similar fault system underlying the Poederlee area as under the Heibaart area is supposed. These data suggest that the reef mounds preferentially developed on fault-bounded, periodically uplifted domal structures. The regional area where the Heibaart and Poederlee reef mounds developed was characterized by an important subsidence during the Early Warnantian (Muchez *et al.,* 1987a).

From the discussion above, it is obvious that the paleogeographical position of a reef mound is a factor, which influences its evolution.

4.- EARLY DIAGENESIS OF THE VISEAN

4.1.- DESCRIPTION OF THE DIAGENETIC PRODUCTS

Eighty samples have been examined by conventional petrography and under cold cathodoluminescence. Although various trace and rare earth elements are capable of influencing calcite luminescence (Machel, 1985), it is well known that the major control exerted by is the manganese and iron concentration and the Mn/Fe ratio (Mason, 1987; Hemming *et al.,* 1989). Manganese (Mn2+) is the most important activator and iron (Fe2+) the main inhibitor of luminescence (Sommer, 1972; Pierson, 1981; Fairchild, 1983).

The pores in the microbial framework and the stromatactoid cavities are filled with isopachous fibrous (Pl. I: 6), fibrous radiaxial and blocky calcites. In the fibrous calcites, the long axis of the crystals is perpendicular to the boundaries of pore walls. Radiaxial fibrous calcites (Bathurst, 1959; Kendall & Tucker, 1973) are composed of crystals which possess curved twin lamellae and glide planes, optic axes that converge from cavity walls and subcrystals that diverge from cavity walls. They show an undulose extinction and intercrystalline boundaries are non-planar. Pyrite is present between different zones of fibrous calcites. The fibrous and fibrous radiaxial calcites show a cloudy aspect. This aspect is caused by minute organic and fluid inclusions. Bioclasts, intraclasts and peloids can be completely surrounded by fibrous calcites (Pl. I: 7). Sediment clasts with a rim of fibrous calcites fill cavities which already display a first fibrous calcite generation. A neomorphism has taken place between the development of the fibrous and the blocky calcites (Pl. I: 8). Neomorphic microspar and spar replace the earlier fibrous cement. Dissolution occurred after the precipitation of the fibrous calcites. Layers of this cement type are truncated. Even the host limestone has been partly dissolved. The resulting cavities have been filled by blocky calcites. Crinoids are surrounded by a rim cement. Neomorphic microsparites and the two types of fibrous calcites are originally non-luminescent.

The rim cement (Pl.II: 1,2) can be divided into a series of stages representing a pronounced change in crystal habit, mineralogy or cathodoluminescence characteristics (Miller, 1986). The first stage of the rim cement is non-luminescent. It may contain bright luminescent zones. Between the first and the second stage an irregular surface is observed. The second stage is bright luminescent. Also this stage may be zoned. An alternation of yellow and orange luminescent zones or of yellow and non-luminescent zones is present. Between the different zones, dissolution occurred as indicated by the truncation of zones and by the pitted surface and depressions between the zones (Pl. II: 3). The number and the thickness of the zones varies between different samples and within one thin section (Pl. II: 4,5,6). a dissolution occured after the development of the second stage. The third stage is ubiquitous and shows a brown-orange dull luminescence. Parts of the crinoids dissolved before the development of the second and third stage and even possibly before the first (Pl. II: 7). The resulting voids have been filled by a bright luminescent zone of stage 2, by the brown-orange luminescent stage 3 and probably by the non-luminescent stage 1.

The blocky calcites may show the same compositional zonation under cathodoluminescence. However, the first and second stage are often absent (Pl. II : 8).

4.2.- INTERPRETATIONS

The presence of sediment clasts with a rim of fibrous calcites in cavities which already display a first fibrous calcite generation suggests a synsedimentary origin of these calcites. The non-luminescent character and the synsedimentary precipitation conditions indicate that this cement precipitated under oxidizing conditions (Meyers, 1974; Frank *et al.,* 1982; Grover & Read, 1983). The exact timing of the development of the pyrite in the fibrous calcites is unknown due to the possibility of diffusion processes along micropores. Locally reducing conditions produced by the degradation of the organic material in these calcites, could have occurred at very shallow burial depths (Carpenter *et al.,* 1988). Microbial reduction of marine sulphates in the presence of $Fe2^+$ in the pore fluids would have yielded a small amount of pyrite. Carbonate dissolution and neomorphism which preceeded the formation of the blocky calcites could have taken place in meteoric waters, which infiltrated in the subsurface during a continental period at the end of the Visean (Dreesen *et al.,* 1987).

The evolution in the rim cements from the non-luminescent first stage to the bright luminescent second stage most likely reflects a change in the redox conditions. Changes in luminescence may be due to variations in the Mn^{2+} concentration of the precipitating solution (Meyers, 1974, 1978) or to differences in crystal growth rate (ten Have & Heijen, 1985). However, strong and abrupt variations in luminescence in growth experiments occur only after changes in the Mn^{2+} concentrations of the solution (ten Have & Heijen, 1985). In the oxidizing zone, Mn^{3+}, and Mn^{4+} ions could not be incorporated into the calcite lattice and no luminescence can be created. Under slightly reducing conditions Mn^{2+} and Fe^{3+} are present in the pore waters (Garrels & Christ, 1965; Frank *et al.,* 1982; Grover & Read, 1983; Barnaby & Rimstidt, 1989). Mn^{2+} can be incorporated into the calcite lattice and luminescence is produced. The source of Mn^{2+} in the bright zone of the rim cements may be marine (Stow & Miller, 1984; Hurley & Lohmann, 1989) or meteoric (Meyers, 1974; Grover & Read, 1983). If the rim cements have a meteoric origin, precipitation occurred during the continental period at the end of the Visean. The third, dull stage in the rim cements represents more reducing precipitation conditions, allowing the incorporation of Fe^{2+} in the calcite lattice and quenching the luminescence. The number and the thickness of the zones and of the stages may differ in the same sample and even within a thin section. This suggests besides a general evolution in the redox conditions, the existence of local (pore volume) geochemical and crystallographic variations (sector zoning). The fact that the first and the second stage in the rim cements around the crinoids are often absent in the blocky calcites indicates a substrate selectivity of the precipitates.

A similar evolution in the redox potential of the pore fluids occurred in the Frasnian «F2j» mudmounds of Belgium (Boulvain, 1989).

5.- CONCLUSIONS

The Visean limestones of the Poederlee borehole have an Early Warnantian age. They belong to the Carboniferous foraminifer 6γ subzone (Conil *et al.,* 1977, 1979). Rugose coral stratigraphy allowed a subdivision of the rocks in a RC7α subzone and a RC7β subzone (Poty, 1985; Conil *et al.,* 1990).

Two alternating lithofacies have been recognized in the Lower Warnantian: microbial boundstones and bioclastic packstones and grainstones. The microbial limestones formed below and near wave base. The packstones and grainstones occur on top of the boundstones and were deposited in an open marine environment above wave base. The association of both lithofacies is regarded as a reef mound with its core, flank and top facies. Five superimposed reef mounds have been recognized and are interpreted as a reef complex. From the comparison of the Lower Warnantian reef mounds in the Campine Basin, it is obvious that the paleogeographical position is a factor which has a major influence on the evolution of a reef mound.

Isopachous fibrous and fibrous radiaxial calcites occur between the microbial framework and precipitated from marine pore-waters under oxidizing conditions. After the precipitation of the fibrous calcites, dissolution of these cements and of the host limestone possibly took place in meteoric waters. Rim cements around crinoids show an evolution in their luminescence which reflects increasing reducing conditions of the pore-water. However, very local geochemical and crystallographic variations occurred during early diagenesis.

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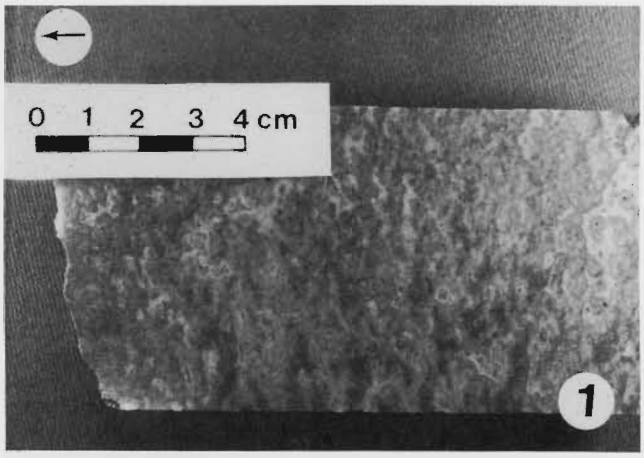
PLATE I

1. DzP1 1599 m. Boundstone with microbial structures. The microbial structures appear as spotted darker and lighter areas. The arrow points towards the sample top.
2. DzP1 1628 m. Microbial structures characterized by cloudlets of light coloured micrite (a). The vertical arrow indicates the top of the sample. Scale bar is 1 cm.
3. DzP1 1645.5 m. Peloidal (a) and clotted(b) textures in a microbial boundstone. Scale bar is 360 μm.
4. DzP1 1583 m. Bioclastic grainstone. Note the authigenic quartz crystal in the middle of the microphotograph. Scale bar is 275 μm.
5. DzP1 1613 m. Micritized crinoids (a) and foraminifers (b) in a grainstone. Scale bar is 275 μm.
6. DzP1 1649 m. Voids in the microbial framework are filled with isopachous fibrous calcites (a) and blocky calcites (b). Scale bar is 150 μm.
7. DzP1 1649 m. Foraminifer (a) and intraclast (b) surrounded by fibrous calcites. Scale bar is 150 μm.
8. DzP1 1655,9 m. The fibrous calcites are recrystallized. Patches of fibres occur in the blocky calcites. Scale bar is 150 μm.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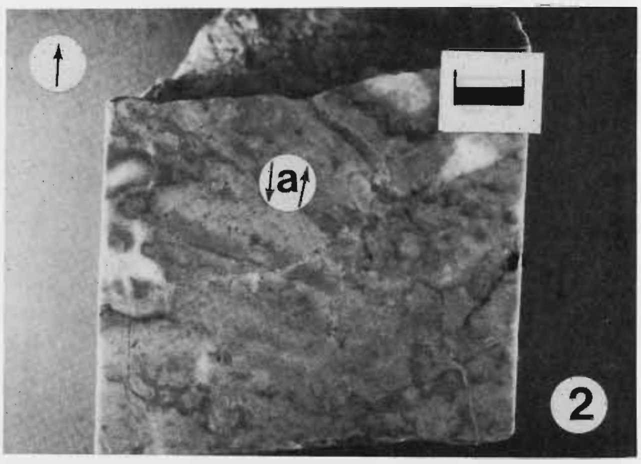
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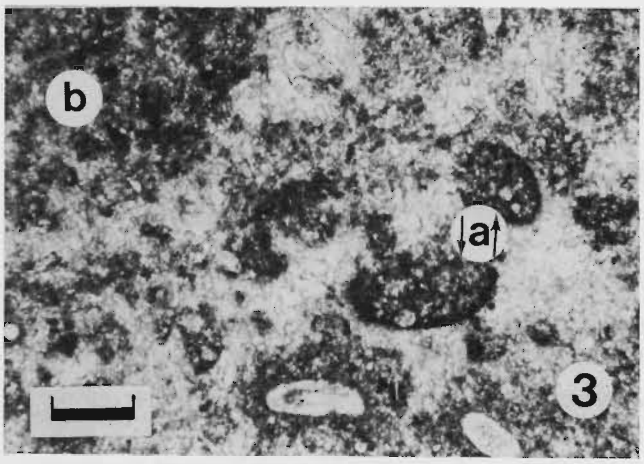
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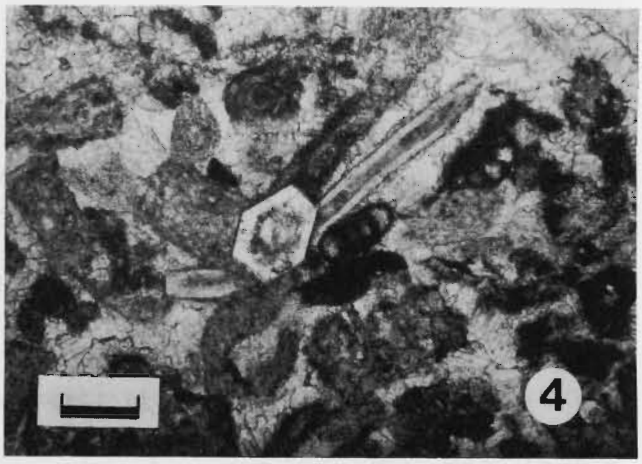
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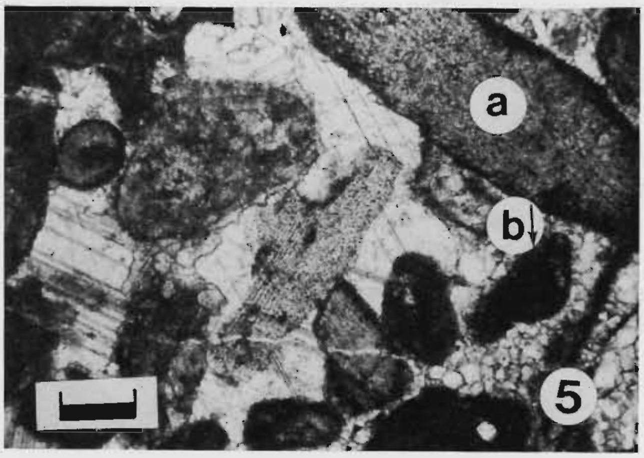
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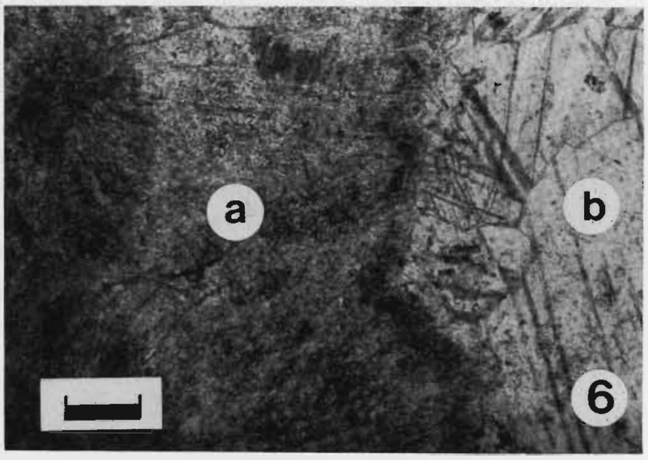
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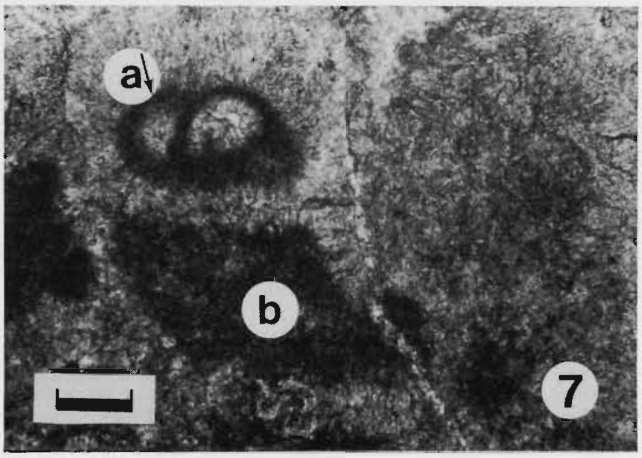
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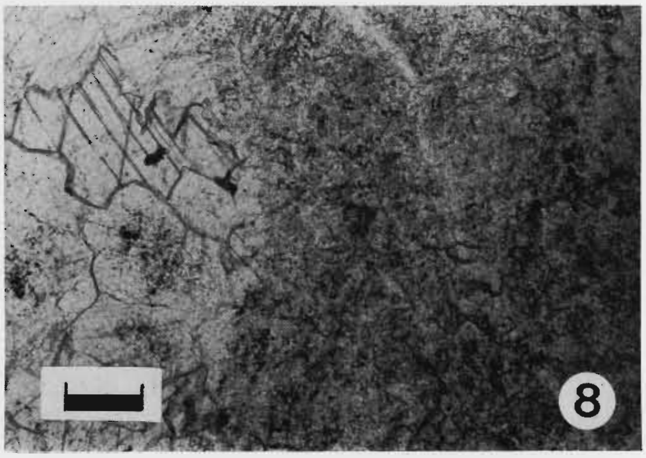
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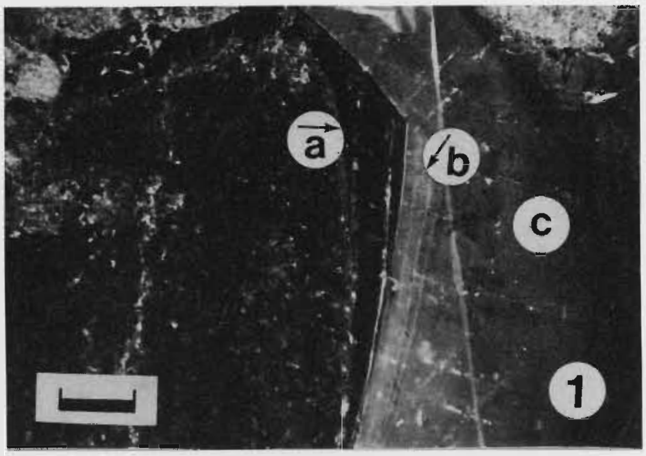
PLATE II

1. DzP1 1613 m. Cathodoluminescence (CL) microphotograph of a rim cement. Three stages can be recognized : a mainly non-luminescent stage (a), a bright luminescent stage (b) and a brown-orange luminescent stage (c). Scale bar is 150 μm.
2. DzP1 1613 m. Same photograph as figure 1 under transmitted light.
3. DzP1 1566 m. CL microphotograph of irregular dissolution surfaces (arrows). The second stage ends with a bright luminescent yellow zone (a) has not been recognized at 1633 m. Scale bar is 150 μm.
4. DzP1 1613 m. CL microphotograph of stage 1 and 2, which show an irregular development around a crinoïd ossicle (arrows). Scale bar is 150 μm.
5. DzP1 1613 m. CL microphotograph of the irregular development of a rim cement around a crinoid ossicle. Stages 1 and 2 are absent at the right sight of the ossicle (a). The number of thin yellow zones in stage 1 is variable (b). Scale bar is 150 μm.
6. DzP1 1566 m. CL microphotograph. Irregular development of a rim cement (a) around a crinoid ossicle. Scale bar is 150 μm.
7. DzP1 1613 m. CL microphotograph of a rim cement with the three stages. However, parts of the crinoid have been dissolved before the development of the second and third stage and even possibly before the first. Voids have been filled by a bright luminescent zone of stage 2, by the brown-orange luminescent stage 3 and probably by the non-luminescent stage 1. Scale bar is150 μm.
8. DzP1 1613 m. CL microphotograph of blocky calcites (a) which show a brown-orange luminescence. Stage 1 and 2 are absent around the peloids (b). Scale bar is 150 μm.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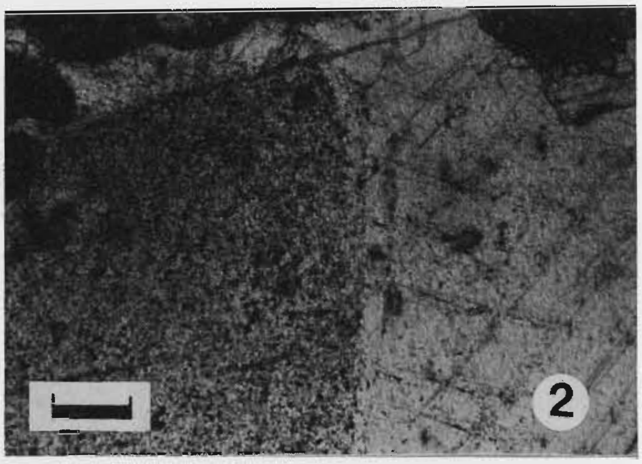
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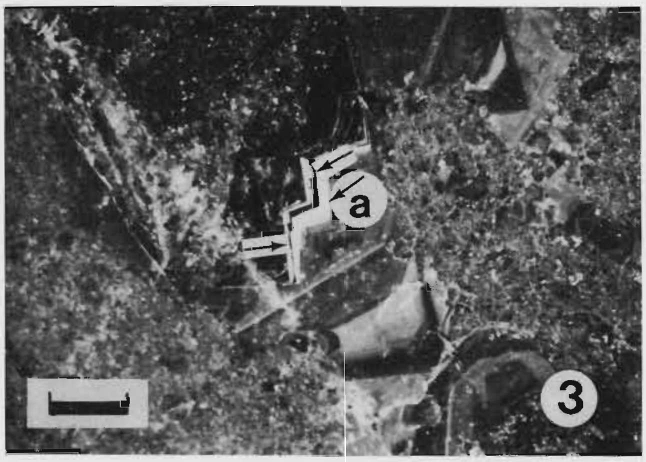
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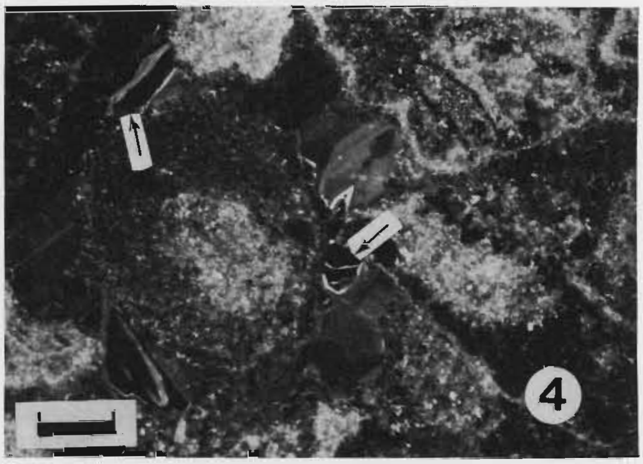
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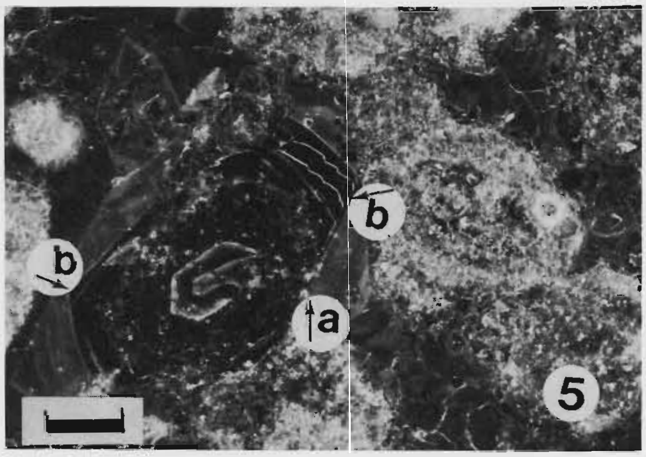
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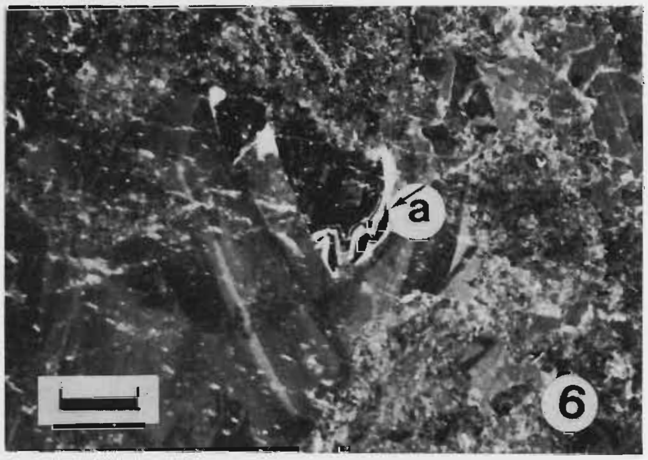
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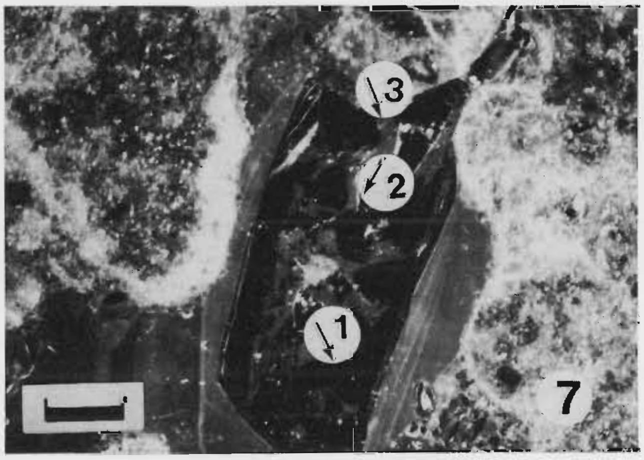
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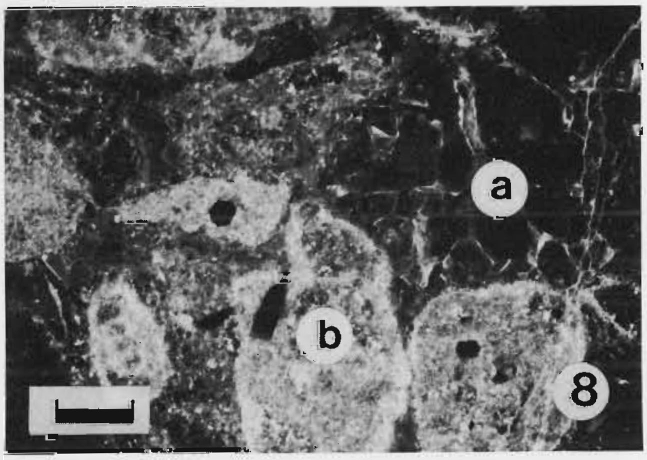
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