Annales de la Société géologique de Belgique, T. 110 - 1987, pp. 261-269 Août 1988

DIAGENESIS, HISTORY OF POROSITY CREATION AND DESTRUCTION WITHIN KARSTIFIED VISEAN LIMESTONES OF THE NAMUR SYNCLINORIUM, BELGIUM[1]

by

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(6 figures and 1 plate)

RESUME.- La diagenèse des calcaires karstifiés du Viséen du synclinorium de Namur a été étudiée par des méthodes de pétrographie classiques et par cathodoluminescence.

L'agencement des minéraux et des séquences diagénétiques est décrit ainsi que leurs implications sur la porosité (création/destruction). Les principales séquences diagénétiques sont les suivantes :

1) Grainstones : cimentation précoce, lessivage précoce, cimentation, compaction, fracturation, cimentation tardive.
2) Boundstones : lessivage précoce, cimentation, compaction, fracturation, cimentation tardive.
3) Packstones et wackestones : lessivage précoce (faible), cimentation, compaction, fracturation, cimentation tardive.

Le développement de la porosité est fonction des textures spécifiques : une importante porosité primaire de grainstone est correlable avec une bonne porosité secondaire. Une porosité primaire moyenne de boundstone correspond à une amélioration de la porosité secondaire. Une porosité primaire très faible d'un wackestone ou d'un packstone est mise en relation avec une porosité secondaire quasi nulle. Le matériel étudié ne présente actuellement pas de porosité (occlusion par un ciment).

L'interprétation de l'effet d'une karstification tardive est la suivante : la karstification a créé un élargissement des fractures, puis un remplissage de ces fractures et des cavités associées par des argiles du Namurien. A l'échelle microscopique il est bien confirmé que la porosité secondaire, actuellement occluse, a été acquise lors du lessivage précoce et non lors de cette karstification tardive.

ABSTRACT.- Petrographic and cathodoluminescence methods were applied to study the diagenesis of karstified Visean limestones of the Namur Synclinorium. Diagenetic fabrics and sequences and also porosity creation and destruction are described. Diagenetic sequences for various limestone types consist of :

1) Grainstones : early cementation, early leaching, cementation, compaction, fracturation, late cementation.
2) Boundstones : early leaching, cementation, compaction, fracturation, late cementation.
3) Packstones and wackestones : early (minor) leaching, cementation, compaction, fracturation, late cementation.

1 Manuscrit déposé et communication présentée le 8 décembre 1987.

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Porosity development depends on texture : high primary porosity in grainstones is mostly related to good secondary porosity. Intermediate primary porosity in boundstones corresponds to improved secondary porosity. Zero to low primary porosity in wackestones and packstones is related to inferior secondary porosity. The investigated rock is non porous at present as a result of occlusion by cement.

Interpretation of the effect of late karstification on porosity distribution is as follows : karstification has caused enlargement of fractures and filling of fractures and caves by Namurian shales. At a microscale , the secondary (plugged) porosity was caused by early leaching and not by late karstification.

1.- INTRODUCTION

The objective of this study is to describe diagenetic fabrics and sequences, and to derive resultant porosity creation and destruction. The effects of late karstification on porosity distribution within Visean limestones of the Namur Synclinorium are also included. The upper parts of the Visean limestones which are unconformably overlain by Namurian were studied. The results have both a theoretical and practical value : they improve the understanding of porosity creation and final destruction within Visean limestone which is also of relevance to the oil industry.

2.- GEOLOGICAL SETTING

The study area is located in the Namur Synclinorium which is positioned between the Brabant Massif to the north and a major thrust fault (Midi fault) to the south (Fig. 1). The Dinantian stratigraphy of the Namur Synclinorium is shown in Figure 2. Dinantian overlies Devonian with a gradual contact and is in turn unconformably overlain by Namurian. A more gradual transition between uppermost Dinantian and Namurian is present in the western part of the basin. The upper parts of the karstified Visean limestone comprising the Seilles Formation, the non breccia equivalent of

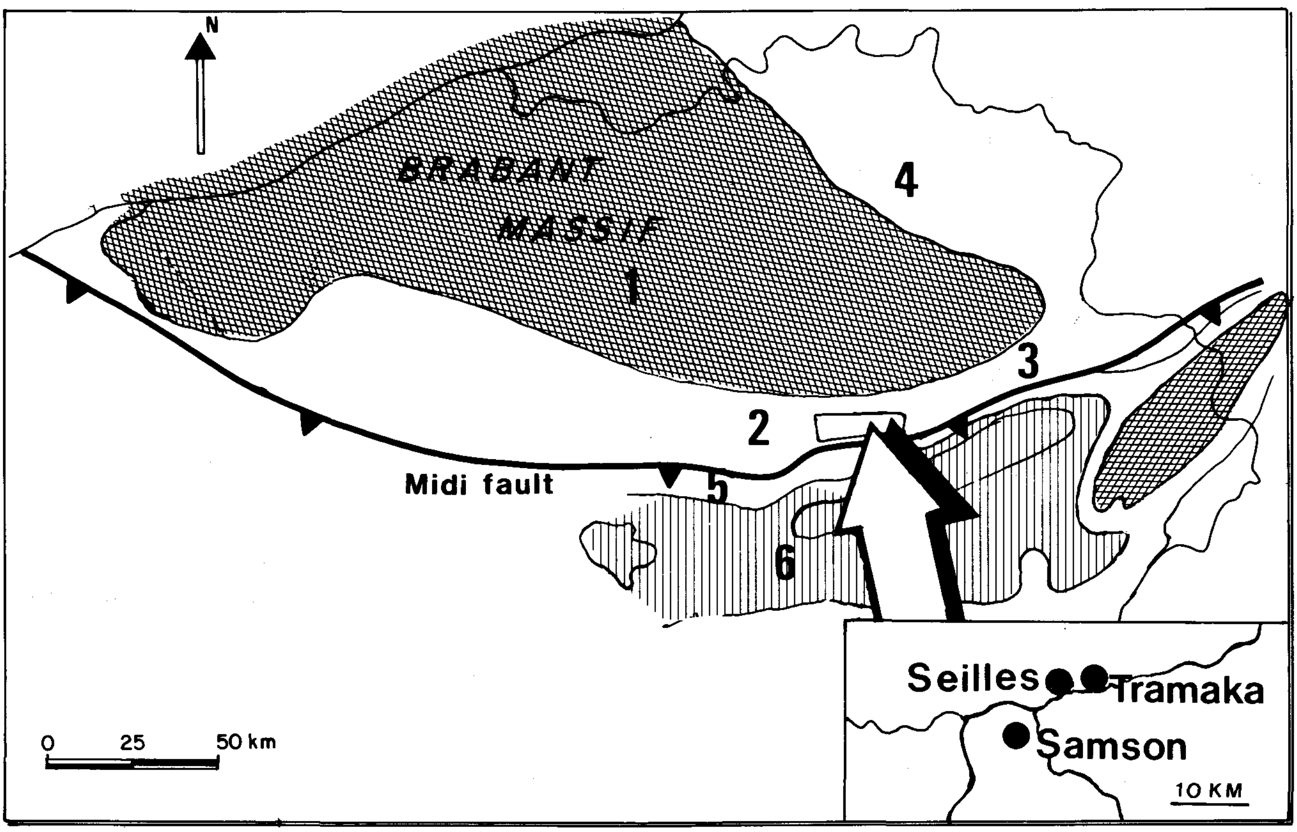

Figure 1.- Simplified structural map slightly modified after Michot (1980) showing location of study area within the Namur Synclinorium. Insert shows a location map of sections sampled.
(1. Brabant massif; 2. Namur Synclinorium; 3. Herve Synclinorium; 4. Campine; 5. Condroz Anticlinorium; 6. Dinant Synclinorium).

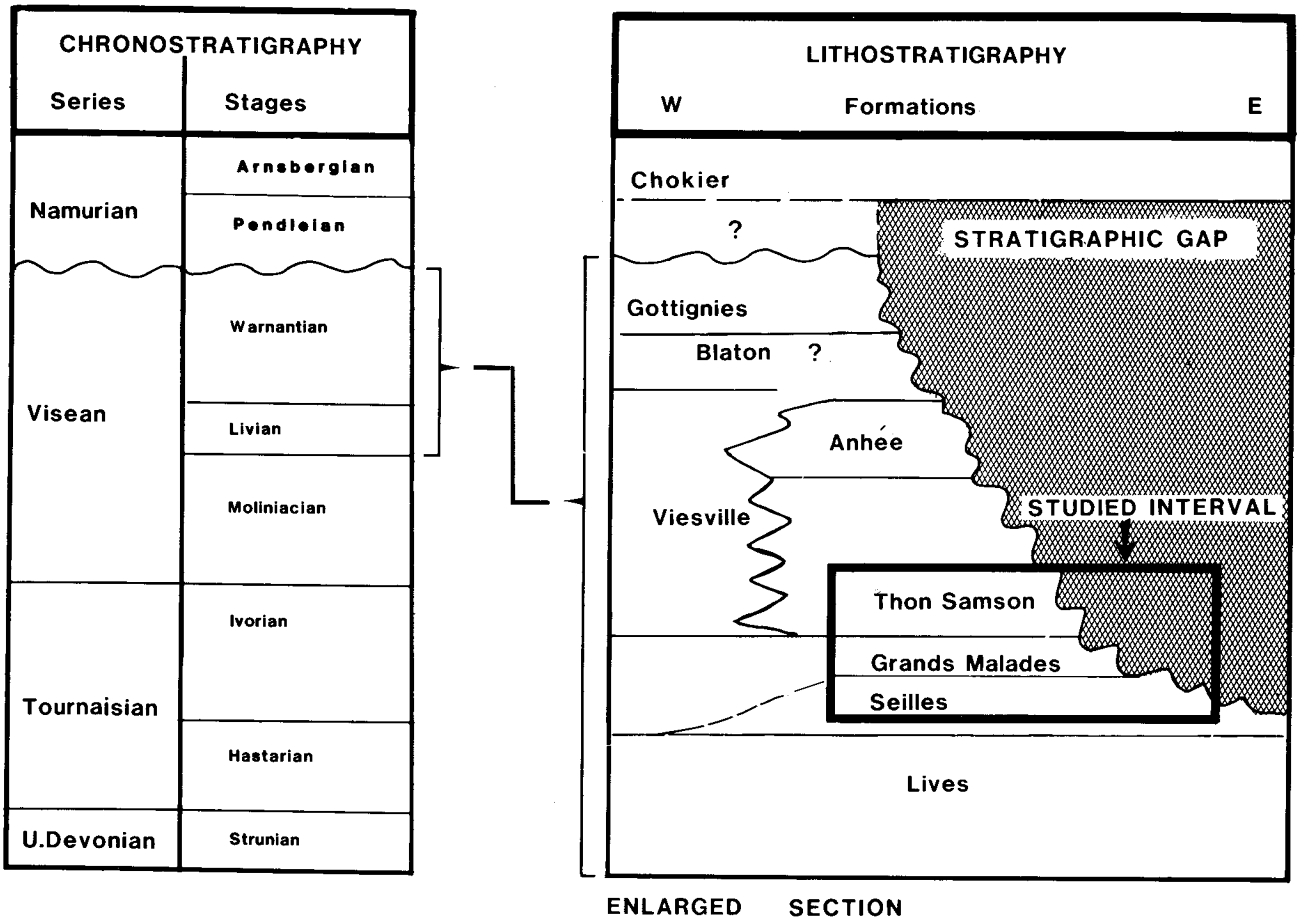

Figure 2.- Stratigraphic section of the Namur Synclinorium slightly modified after Paproth *et al.* (1983). The studied interval is indicated.

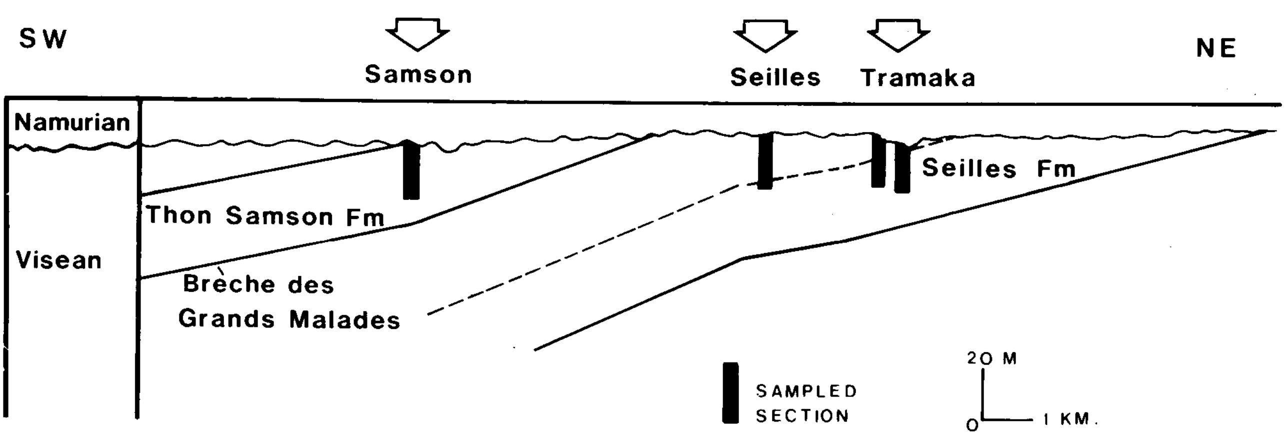

Figure 3.- Correlation section of the Seilles Formation, the Brèche des Grands Malades and Thon Samson Formation (after Pirlet, 1968). The upper 20 meters of the carbonates were sampled at locations Samson, Seilles and Tramaka).

the Brèche des Grands Malades and Thon Samson Formation, were investigated (Figs. 2-3).

The structural history of the Namur Synclinorium was presented in detail by Graulich (1963) and Michot (1980). Deposition and subsidence during the Visean was followed by uplift, erosion and karstification during the Sudetian orogeny (Graulich, 1963). Renewed subsidence and deposition of Upper Carboniferous predates the Hercynian orogeny which caused formation of the Namur Synclinorium (Michot, 1980). A reconstruction of the post Carboniferous subsidence history is uncertain due to lack of sufficient overburden.

3.- PREVIOUS WORK

No detailed description of the diagenetic fabric, diagenetic sequences, porosity creation and destruction or analysis of the effect of karsts on porosity distribution in Visean limestone was published before for the Namur Synclinorium. Previous work emphasized the sedimentology and stratigraphy (Pirlet, 1963, 1964, 1968, 1970; Paproth *et al.* 1983). The Seilles Formation consists of rhythmic sequences which comprise grainstones, mudstones, wackestones, packstones, boundstones and neomorphic limestones. This formation is overlain by the «Brèche des Grands Malades», which consists mainly of breccia and boundstone. The «Brèche des Grands Malades» is overlain by the Thon Samson Formation which consists of rhythmic sequences comprising grainstones, mudstones, wackestones, packstones, boundstones and neomorphic limestones with some intercalated kaolinite beds. The depositional environment is shallow to very shallow marine according to Pirlet (1968).

Features of karsts were described by Pirlet (1970) and Graulich (1963), but their effect on the distribution of porosity was not discussed in detail.

4.- METHODS

Four vertical sections (each twenty meters long) were sampled, just below the unconformity at the locations Samson, Seilles and Tramaka (Fig. 3). Some 50 thin sections were cut and partially stained with potassium ferricyanide and alizarin red-s for respectively Fe^{++} and calcite determination. Petrographic and cathodoluminescence methods were used to unravel the diagenesis. The rocks are generally classified after Dunham (1962). Neomorphic rock terminology was applied after Folk (1965).

5.- SEDIMENT PETROGRAPHICAL DESCRIPTION

The textural types comprise grainstones, packstones, wackestones, mudstones, boundstones and neomorphic limestones. Their distribution within sampled sections is shown in Figure 4. The rock consists of limestone without detectable quantities of iron as was shown by coloration for iron and calcite.

5.1.- GRAINSTONES

Allochems consist of oncoids, peloids and ooids. Additionally bioclasts such as forams, ostracods, crinoids, bryozoa and non determinable fragments are observed. Cements comprise fibrous, equant and bladed sparite. Some allochems and cements are partly converted to neomorphic calcite.

5.2.- PACKSTONES/WACKESTONES

Bioclasts, pellets, peloids and ooids are observed. Bioclasts comprise foraminifera, ostracods, crinoids, bryozoa and non determinable fragments. Allochems and matrix are partly neomorphic.

5.3.- BOUNDSTONES

Laminated, cryptalgal rock comprising bioclasts and pellets within a largely neomorphic matrix is observed.

5.4.- NEOMORPHIC LIMESTONES

Transitions from grainstones, packstones, wackestones and boundstones into neomorphic limestones are often noticed. The rocks comprise neomorphic calcite with relicts of allochems and matrix. Crystal sizes vary mainly from less than 5 μm to up to 100 μm.

Silica and pyrite is observed in some of the samples.

The observed sediment petrographic textures suggest deposition in a shallow marine to intertidal environment (according to a model of Wilson, 1975, p. 351). This interpretation is in agreement with the conclusion of Pirlet (1968) who interpreted the environment of the rhythmic sequences as shallow to very shallow marine.

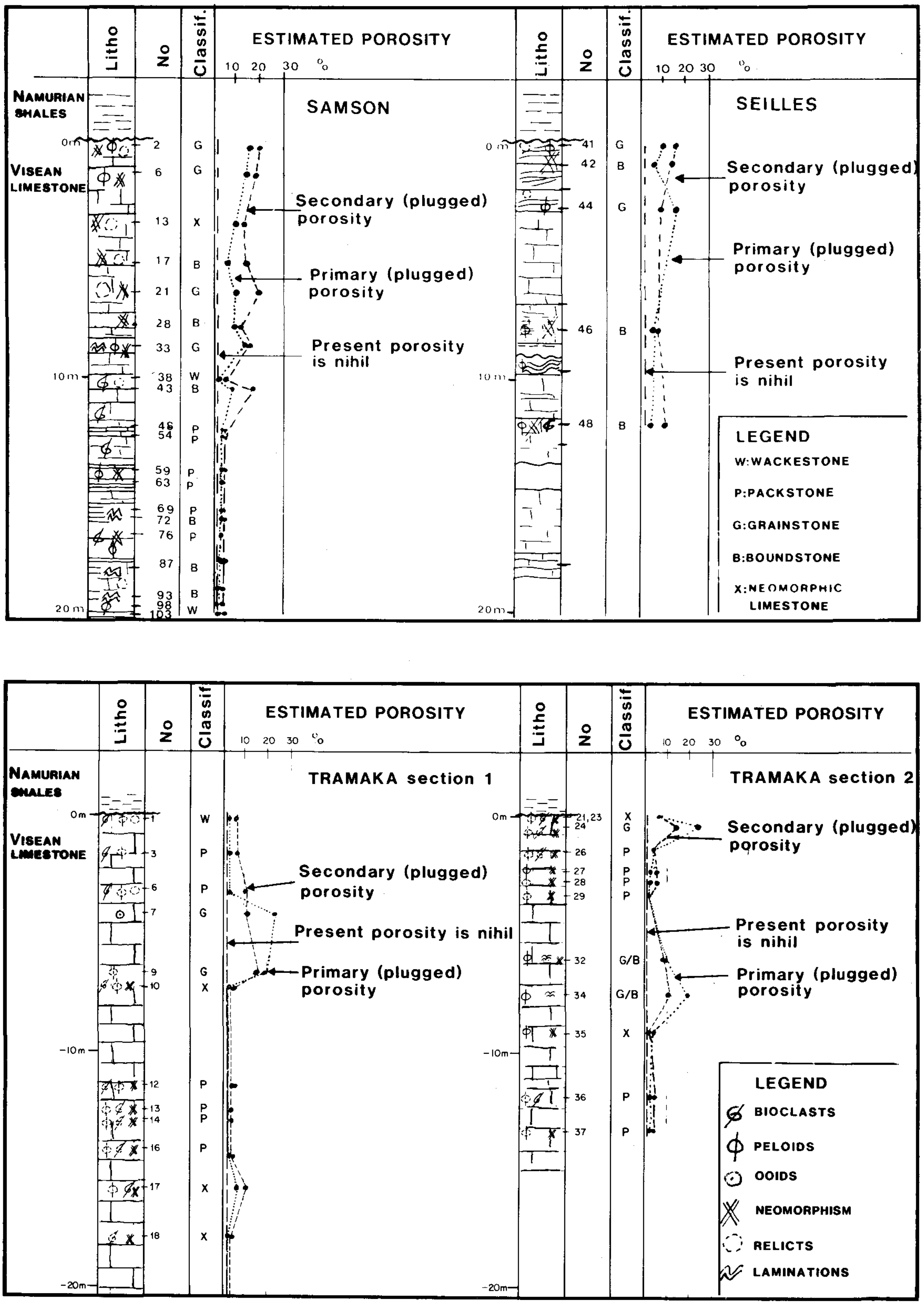

Figure 4.- Sampled sections at Samson, Seilles and Tramaka with estimated plugged primary and secondary porosity distribution. Highest (plugged) secondary porosities are found in grainstones and boundstones. Present porosity is nihil.

DIAGENETIC SEQUENCES			POROSITY	TIME
GRAINSTONES	PACKSTONES WACKESTONES	BOUNDSTONES	(increase) (+) (decrease) (–)	
Deposition	Deposition	Deposition		T
Cementation			–	I
Leaching	Minor leaching only	Leaching	+	M
			–	E
Cementation	Cementation	Cementation	–	
Compaction	Compaction	Compaction	–	
Fracturation	Fracturation	Fracturation	+	
Cementation	Cementation	Cementation	–	

Figure 5.- Diagenetic sequences illustrate that early leaching took place mainly in grainstones and boundstones. Due to later cementation all final porosity is nihil.

6.- DIAGENETIC OVERPRINTS

The diagenetic sequences within various textural types are shown in Figure 5. They are based on observation of certain «type samples» and on combinations of samples. Parts of the deduced diagenetic sequence may be missing within individual samples.

6.1.- GRAINSTONES AND BOUNDSTONES

After deposition of the allochems, cementation by fibrous isopachous cement took place. Subsequently a network of porosity was created by the partial leaching of allochems and cements. This gave rise to molds, enlarged voids, intergranular porosity, vugs and channels (Plates 1A, 1C, 1D, 1G). In a following stage, equant to bladed cement occluded all secondary porosity. This is followed by major compaction as can be deduced from interpenetrating grains with sutured contacts and from stylolites. In a following stage all sedimentary and diagenetic features were intersected by microfractures (Plates 1G, 1H) which created fracture porosity. Finally these microfractures were cemented by equant calcite which reduced the fracture porosity to nihil.

6.2.- PACKSTONES AND WACKESTONES

After deposition, minor leaching is difficult to assess as shells may have been inverted to calcite without going through a moldic stage. Leaching is assumed to have taken place if shells contain clear drusy cement. Also, early fracture porosity is locally observed. This type of porosity is probably an enlargement of shrinkage cracks. In a following stage, equant to bladed cement occluded the minor secondary porosity. This was followed by major compaction as can be deduced from interpenetrating grains and stylolites (Plates 1E, 1F). Subsequently all sedimentary and diagenetic features were intersected by microfractures, which caused fracture porosity. Finally, these microfractures were cemented by equant calcite which reduced the fracture porosity to nihil. The exact timing of neomorphism and silicification could be established in a few samples in which neomorphism predates compaction and silicification predates fracturation. The timing of neomorphism and silicification is not shown in Figure 5 for clarity reasons.

The data for grainstones, packstones, wackestones and boundstones show that the diagenesis is facies specific with regard to porosity formation and destruction.

7.- POROSITY

Leaching at a macroscale as a result of late karstification is visible in the field : man-sized shale filled dissolution caves, enlarged shale filled fractures and irregular unconformity surfaces are evident.

As previously described, porosity at a microscale is nihil in all samples as a result of occlusion by cement. Previous porosity values were determined by estimating porosities before pores were filled by calcite. Intergranular and shelter porosity are called primary porosity. This porosity was plugged afterwards by cement. Leaching created vug porosity, channels, enlarged intergranular porosity, moldic porosity and some early fracture porosity which were grouped as secondary porosity. Recognizable moldic porosity is not included in porosity estimates as its quantitative influence is limited. The late fracture porosity is not included in the term secondary porosity as it postdates all other porosity types.
Porosity values were estimated visually from thin sections and are expressed in percentages, using comparison charts as given by Flügel (1982, P247-257). No porosity corrections for compaction were applied. Previous primary, secondary and present day (plugged) porosities were plotted versus depth below the top of the karstified rock (fig. 4). It can be observed from this figure that the vertical distribution of secondary porosities do not show evidence of increased porosity towards the top.

The estimated primary porosity values were plotted versus secondary porosity for the different textural types (Fig. 6). High primary porosity in grainstones is mostly related with good secondary porosity. Intermediate primary porosity in boundstones corresponds to improved secondary porosity. Zero to low primary porosity in wackestones and packstones is related to low secondary porosity.

8.- DISCUSSION

The effect of late karstification and dissolution on the creation and distribution of the porosity can be explained as follows : Following a period of subsidence during the Dinantian, emergence and fracturation took place during the Sudetian orogenic phase. Macro fractures were enlarged by solutions. Both enlarged macro fractures and caves were subsequently filled by Namurian shales (Graulich, 1963). The minor fractures became plugged by calcite from descending solutions. The data for grainstones, boundstones, packstones and wackestones show that the diagenesis is facies specific with regard to porosity formation and destruction. High primary porosity in grainstones is mostly related to high secondary porosity. Intermediate primary porosity in boundstones corresponds to improved secondary porosity. Zero to low primary porosity in packstones and wackestones is related to low secondary porosity. Also the vertical distribution of secondary porosities do not show evidence of increased porosity towards the top. These results suggest that the (plugged) secondary porosity was not created by the late karstification, but that it resulted from earlier leaching of grainstones and boundstones during the eogenetic phase. It is likely that such leaching occurred in a freshwater vadose or phreatic environment near sealevel.
The leached porosity was plugged afterwards by equant, bladded drusy cement. It is suggested by

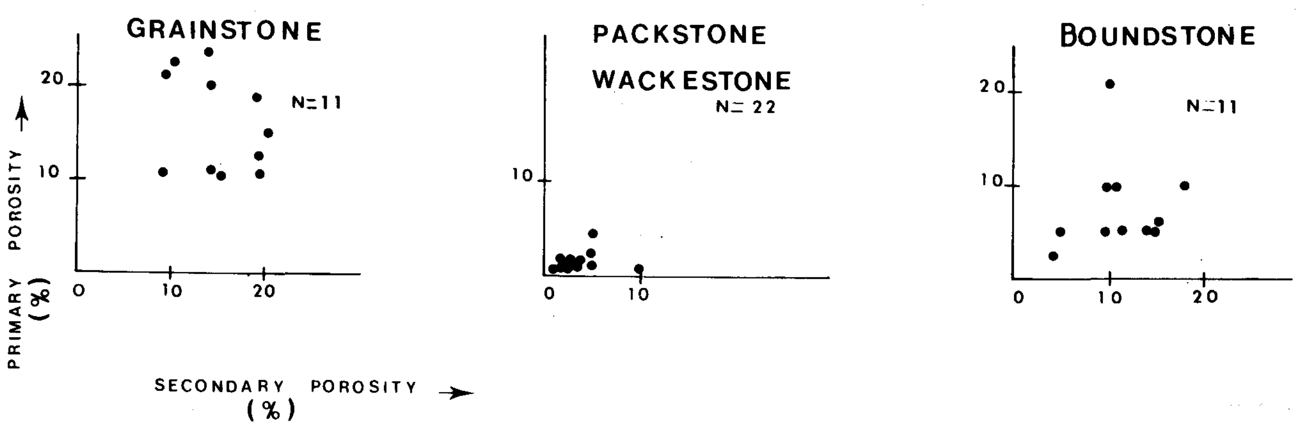

Figure 6.- Primary versus secondary porosity plots illustrating that the high secondary porosity developed especially within lithologies with initial intermediate to high primary porosity (grainstones, boundstones). (N = number of samples). The rocks are non porous at present as a result of occlusion by cement.

Longman (1980) that such a cement is found in a fresh water phreatic zone. Flügel however, mentions that these kinds of cement are also found in other diagenetic environments such as the subaerial, shallow marine and deep marine zones (Flügel, 1982, p. 74). Since we focussed on porosity enhancement, no additional isotope and geochemical data were analysed. However, these data are necessary to unravel the exact diagenetic setting of these cements.

9.- CONCLUSIONS

Diagenetic sequences for the various textural types consist of :

Grainstones : early cementation, partial leaching, porosity occlusion, compaction, fracturation and late cementation.

Boundstones : early leaching, porosity occlusion, compaction, fracturation, late cementation.

Packstones and wackestones : early (minor) leaching, cementation, compaction, fracturation, late cementation.

Porosity development depends on texture. This was documented by the fact that high primary porosity in grainstones is mostly related to high secondary porosity. Intermediate primary porosity in boundstones corresponds to high secondary porosity. Zero to low primary porosity in wackestones and packstones is related to low secondary porosity. The rock is non porous at present as a result of occlusion by cement.

Interpretation of the effects of late karstification on porosity distribution is as follows : karstification has caused enlargement of macrofractures and filling of caves and fractures by Namurian shale. The secondary porosity which was observed in thin sections was caused by early leaching of grainstones and boundstones and not by late karstification.

ACKNOWLEDGEMENTS

The author wishes to thank Prof. Dr. W. Viaene (Catholic University of Leuven) and Dr. R. Swennen for critically reading the manuscript. Dr. J.L. Deltombe (University of Liège) kindly provided rock material from the «Samson section».

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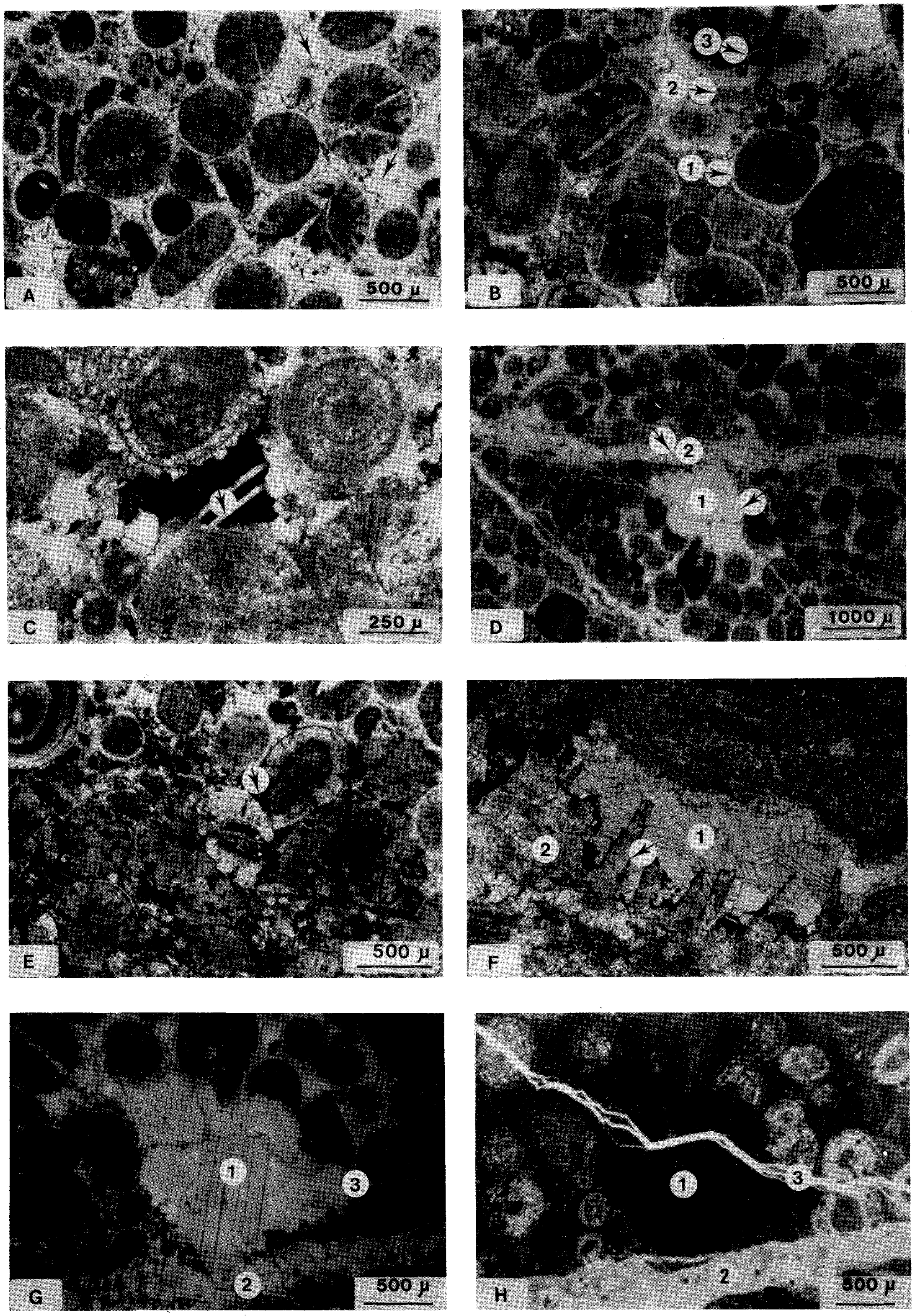
PLATE 1

Displayed photomicrographs were taken in polarised transmitted light unless indicated otherwise.

A. Ooid grainstone. Cracked ooids with pore filling calcite (arrows).
B. Ooid packstone with isopachous rim cement (1), infill by sediment (2) and idiotopic silica (3).
C. Ooid grainstone (crossed nickols). Enlarged interparticle porosity (arrow) is plugged by calcite.
D. Ooid grainstone. A vug (1) and a fracture (2) are plugged by cement.
E. Ooid pacstone. Sutured contacts between particles are present (arrow).
F. Peloid packstone. A stylolite (arrow) separates cement (1) from neomorphic limestone (2).
G. Ooid grainstone. A vug (1) and late fractures (2, 3). The diagenetic sequence is not evident here but is apparent in Plate 1H.
H. Cathodoluminescence photomicrograph of same thin section as in Plate 1G. Fractures 2 and 3 clearly postdate vug filling calcite (1).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