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UPPER CRETACEOUS NANNOFOSSILS AND PALYNOMORPHS IN SOUTH LIMBURG AND NORTHERN LIEGE : A REVIEW

by

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(4 figures, 3 plates)

I. INTRODUCTION

Upper Cretaceous nannofossils and palynomorphs have been described from several localities in South Limburg and northern Liège provinces. These are indicated on figure 1.

We intend to compare all these data in order to select the most useful criteria as stratigraphic tools in this region.

Nannoplankton now clearly yields a rather accurate biostratigraphic scheme compared to the Belamnite zonation. It is compared with Hofker's regional Foram zonation that is used since 1966.

The palynomorphs are briefly reviewed and the distribution of a few selected species is compared with the other biostratigraphic subdivisions.

2. NANNOPLANKTON

Four nannoplankton zones have been recognized in the CPL Quarry of Halembaye by Manivit (*in* Robaszynski *et al.*, 1985). These are in ascending order :
Broinsonia parca constricta Zone comprising the (exposed portion of the) Vaals Formation and the lower two thirds of the Zeven Wegen Chalk. In contrast to the opinion of Bick (*in* Streel *et al.*, 1977) no major break in the nannoflora could be observed at the boundary between the Vaals Formation and Zeven Wegen Chalk.
Prediscosphaera stoveri Zone (base defined by appearance of index species) comprising the upper third of the Zeven Wegen Chalk.
Lithraphidites praequadratus Zone (base defined by appearance of index species) comprising Vijlen Chalk to Lixhe-2 Chalk (between Froidmont and Boirs horizons). At Beutenaken, this zone also comprises the Beutenaken Chalk. Thus the base of this zone in South Limburg and environs coincides with the lithological boundary between the Upper Campanian and the Lower Maastrichtian. It should be noticed (Manivit *in* Robaszynski *et al.*, 1985) that three species, which in the Tethyan realm disappear at the Campanian/Maastrichtian boundary, are found in the Lower Maastrichtian Beutenaken Chalk at Beutenaken and in the Cadier en Keer Borehole, and in the Upper Maastrichtian Vijlen Chalk at Halembaye.
Lithraphidites quadratus Zone (base defined by appearance of index species) above the Boirs Horizon in the Lixhe-3 Chalk.

Three nannoplankton zones are distinguished in the ENCI Quarry at Maastricht by Cepek & Moorkens (1979), namely :
- *Lithraphidites quadratus* Zone comprising the Lixhe and Lanaye Chalks.
- *Nephrolithus frequens* Zone (base defined by

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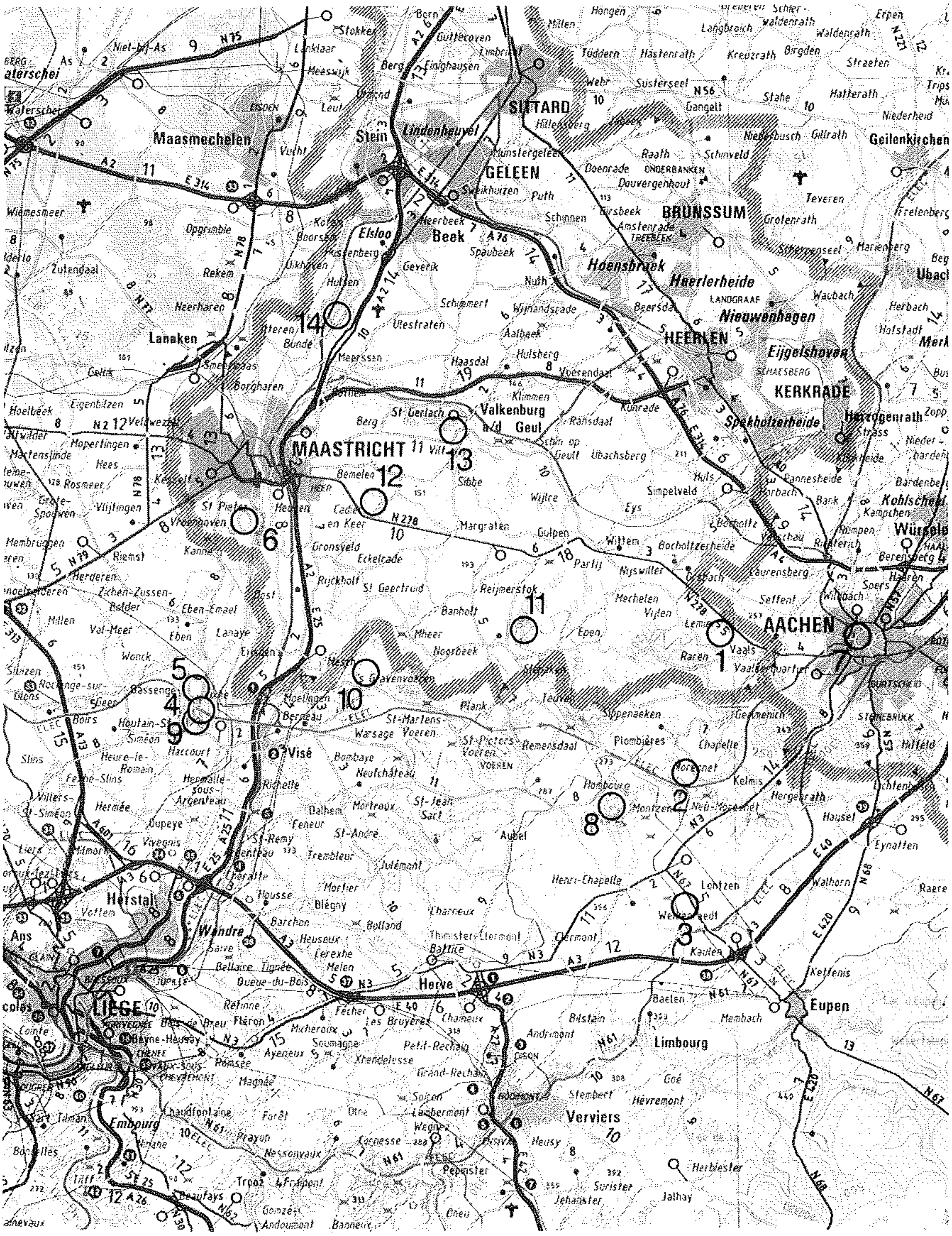


Figure 1 - Localities from where palynomorphs have been described

1. Lemiers section
2. Montzen section
3. Dickenbush Quarry at Welkenraedt
4. Lixhe viaduct
5. North Quarry
6. ENCI Quarry
7. Aachen borehole 4 (RWTH Maschinenhaus)
8. Gulpen boreholes
9. Halembaye Quarry
10. 's Gravenvoeren borehole
11. Beutenaken section
12. Cadier and Keer borehole
13. Thermae 2002 borehole
14. Bunde borehole

appearance of index species) presumably starting at the Lichtenberg Horizon (= base of Maastricht Formation) and reaching somewhere in the lower half of the "Mb" or Hofker's (1966) foram zone H-I.

- Post *Nephrolithus frequens* interval without *N. frequens*. However, Manivit (1970) mentioned *N. frequens* from the foram zones K and L/M (this is "Mc" to "Md") in the ENCI Quarry. Bramlette & Martini (1964) found *N. frequens* (called *N. barbarae* by these authors) in Hofker's foram zone H in the ENCI. Most likely, the post *N. frequens* interval of Cepek & Moorkens (1979) belongs to the *N. frequens* zone, at least in the ENCI Quarry.

3. PALYNOMORPHS

3.1. Quantitative approach

Scarcity of palynomorphs in chalk has been discussed by various authors in this region.

Vanguestaine (1966) made a first quantitative approach by using a volumetric method (Streel, 1965). He discovered that samples from the same beds of the lower Vijlen Chalk (taken in two quarries some 2 kilometers apart) contain different concentrations of palynomorphs : seven times more miospores and about two times more dinoflagellates in North Quarry (fig. 1, loc. 5) than in Halembaye Quarry (fig. 1, loc. 7). He emphasized a direct relationship between the percentages of a coarse (siliciclastic) detritical fraction present in the chalk and the amount of angiosperm and bisaccate gymnosperm pollen grains. He concluded that both the siliciclastic detritus and the pollen had been introduced in the area by water currents.

Reappraisal of the concentration of palynomorphs using a different method (introduction of exotic pollens, Stockmarr, 1971) in the lowermost part of the Vijlen Chalk in another section of North Quarry yielded very similar results (fig. 2, locality 5 : sample 12) to those of Vanguestaine (1986).

The very low concentrations of miospores in the Vijlen Chalk (up to 150 miospores per gram at North Quarry, only less than 20 at Halembaye) may have been interpreted as a complete absence by other authors (e.g. Legoux *in* Robaszynski *et al.*, 1985) due to differences in maceration techniques. Another explanation might be that the miospore content changes very quickly from one layer to the next one. Up to now, Vanguestaine (1966) is the only one who realized a continuous sampling of chalk, subdividing a meter high chalk column in ten 30 cm samples. Smaller samples for maceration were taken after careful homogeneisation. Other authors only analized spot samples. This may produce quite different or even contrasting results.

For example, a spot sample, taken by the present authors some 125 cms below the Lichtenberg horizon in the ENCI Quarry (fig. 2, locality 6: sample 14) yielded a rather rich assem-blage of miospores (more than 2000 angiosperm pollen grains in one gram of chalk) in a part of the Lanaye Chalk that appeared to be barren in another section of the same quarry (Kedves & Herngreen, 1980).

The suggestion of Herngreen *et al.* (1986) that miospores might be selectively destroyed (compared to dinoflagellates) by oxydation and microbial activity in chalk situated above the actual ground-water level does not explain the differences in miospore content of the lower Vijlen Chalk at Halembaye and North and of the Upper Lanaye Chalk in two sections at the ENCI. In all cases, the samples were taken well above the ground-water level.

On the other hand, these chalks are almost entirely composed of coccolith debris and some forams and therefore often have a rather high porosity (fide plate 1) but at the same time these chalks also show a strong capillary action.

Rather than accepting selective destruction of miospores, we prefer to emphasize the possibility that siliciclastic detritus and miospores may be irregularity distributed in a lithofacies dominated by planktonic organisms (coccoliths and dinoflagellates).

It is obvious that in the Vaals Formation, the Vijlen Member of the Gulpen Formation and the Valkenburg Member of the Maastricht Formation, the dinoflagellates are rather abundant ranging from 4000 to 7000 in one gram of chalk.

Dinoflagellates are less abundant in the "craie blanche" Zeven Wegen Member of the Gulpen Formation (fig. 2, locality 4, samples 9 and 10 and locality 5, sample 11). This argument is used here for proposing a correlation between the glauconitic marl observed at Lemierserberg (fig. 3, locality 1, sample 3) and the Zeven Wegen Chalk at Lixhe (fig. 2, locality 4, samples 9 and 10).

3.2. Pollen and spores (Miospores)

3.2.1. Santonian

Miospores from the Santonian Hergenrath Clay have been described by Pflug (1953) and Weyland & Krieger (1953) from the Aachen borehole 4 (RWTH Maschinenhaus), by Batten *et al.* (1987) from Thermae 2002 borehole at Valkenburg a/d Geul and 's Gravenvoeren borehole, and Batten *et al.* (1988) from the Dickenbush Quarry at Welkenraedt and the Gulpen boreholes.

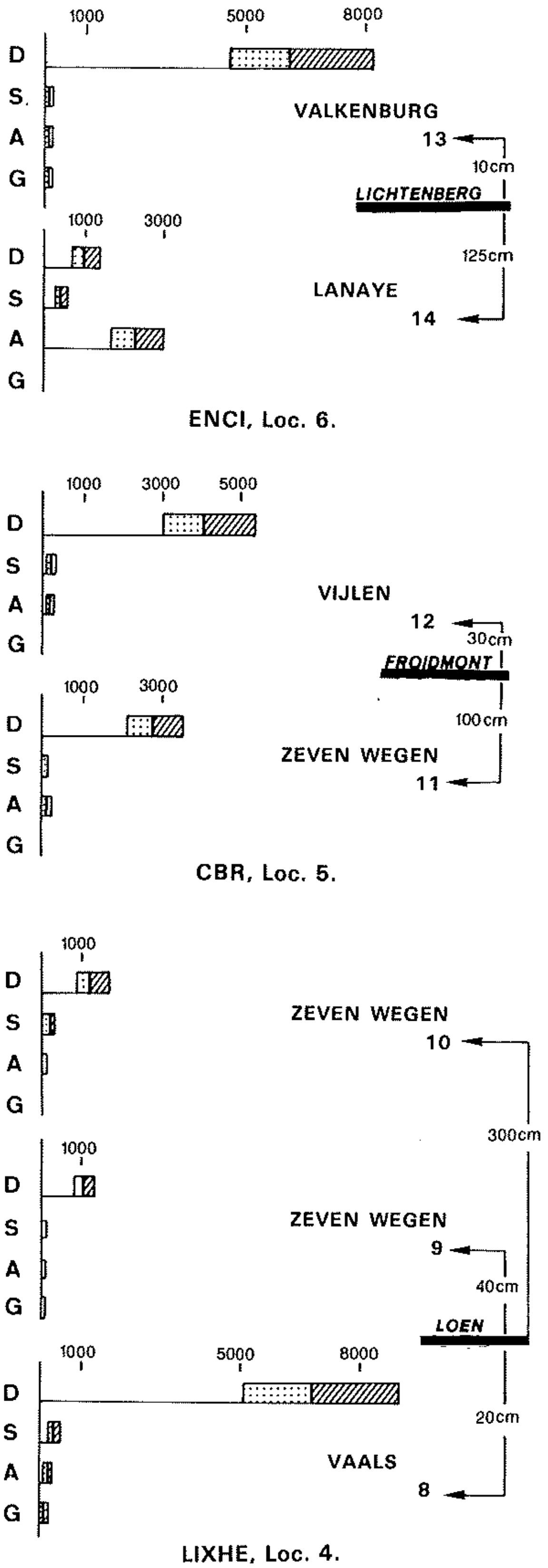


Fig. 2- Concentrations of palynomorphs in seven samples from Santonian to Maastrichtian in South Limburg and northern Liège (Localities 4, 5 and 6 on fig. 1).

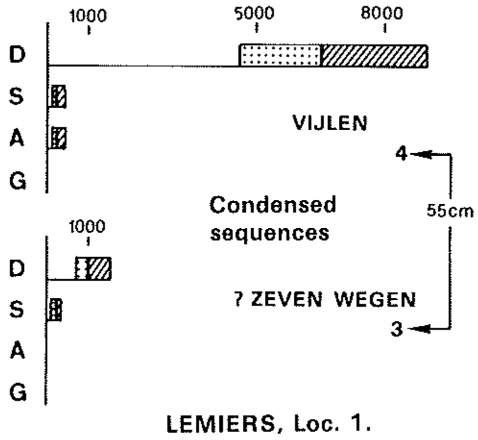


Fig. 3- Concentrations of palynomorphs in two samples from Lemierserberg in South Limburg (Locality 1 on fig. 1).

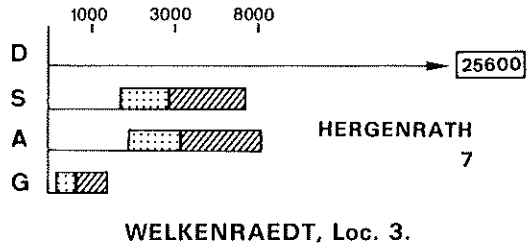


Fig. 4- Concentrations of palynomorphs in one sample from the Dickenbush Quarry at Welkenraedt in northern Liège (Locality 3 on fig. 1).

D = dinoflagellates,
S = spores,
A = angiosperm pollen,
G = gymnosperm pollen.
Concentration in number of specimens per gram of sediment.
Horizontal bars represent confidence limits (0,95) and mean for palynomorph concentration measurements using samples spiked with marker grains.

One sample, taken by the present authors from the Hergenrath Clay in Welkenraedt Quarry (fig. 4, locality 3, sample 7), 10 cms below the Aachen sands, yielded spores and angiosperm pollen grains in more or less comparable amounts (3000 specimens per gram of sediment). Gymnosperm pollen grains are less abundant (500 per gram of sediment).

3.2.2. Campanian

Our knowledge on the subject is still very limited. Vanguestaine & Streel (*in* Streel *et al.*, 1977) and Legoux (*in* Robaszynski *et al.*, 1985) investigated samples from Halembaye and Beutenaken. Spores and pollen are extremely rare at Beutenaken (Legoux *in* Robaszynski *et al.*, 1985). The best preserved and diverse assemblages have been found in the marly clays of the Lower Campanian Vaals Formation at Halembaye. These contain large numbers of pollen and spores which have been reworked from older strata, e.g. the Jurassic and Lower Cretaceous sediments on the then uplifted Rur Valley block. The *in situ* microflora is dominated by bisaccate pollen (a.o. *Alisporites* and *Pityosporites)*. Remarkable is the presence of *Felderipollenites triangulus* Kedves & Herngreen 1980, a species occurring also in the Upper Maastrichtian of ENCI Quarry and Bunde borehole (Kedves & Herngreen, 1980; Herngreen *et al.*, 1986). Legoux (*in* Robaszynski *et al.*, 1985) suggested that the presence of the genera *Semioculopollis, Santonipollis* and *Extrapollis* "is generally indicative of a Santonian to Lower Campanian age". However, *Semioculopollis* is common also in the Upper Maastrichtian of ENCI and Bunde.

3.2.3. Maastrichtian

The Lower Maastrichtian Beutenaken Chalk has only yielded pollen and spores in the section of the Cadier en Keer borehole (Legoux *in* Robaszynki *et al.*, 1985). The assemblages contain several reworked forms. Among the *in situ* sporomorphs dominate bisaccate pollen (a.o. *Alisporites*). The rather poor associations do not allow recognition of the Lower Maastrichtian age (based in this section of benthic foraminifera).

Data on Upper Maastrichtian spores and pollen are available from Vanguestaine (1966; base of Vijlen Chalk in Halembaye and North Quarries), Legoux (*in* Robaszynski *et al.*, 1985; Vijlen Chalk in Cadier en Keer Borehole), Kedves & Herngreen (1980; Lixhe to Meerssen Chalks in ENCI Quarry at Maastricht) and Herngreen *et al.* (1986; Maastricht Formation in Bunde Borehole).

Legoux (*in* Robaszynski *et al.*, 1985) mentioned an extremely poor sporomorph assemblage from the Vijlen Chalk of the Cadier en Keer borehole. Bisaccate pollen dominate. Reworked pollen occur. Amongst the three *in situ* species is *Kriegeripollenites retigressus* (Weyland & Krieger) Kedves & Herngreen, also mentioned by Kedves & Herngreen (1980) from the base of the Lixhe-3 Chalk of ENCI Quarry. Maybe, this is a marker for the early Upper Maastrichtian in this area ?

The papers by Kedves & Herngreen (1980) and Herngreen *et al.* (1986) are complementary for the middle to late Upper Maastrichtian. The information for the ENCI Quarry (Kedves & Herngreen, 1980) is mainly limited to the Lixhe-3 and Lanaye Chalks, because the data of the Maastricht Formation are incomplete. In the Bunde Borehole (some 10 km to the north) only samples from the Maastricht Formation have been analysed. The following remarks may be made :

- Three taxa which are suggested as characteristic for the Gulpen Formation by Herngreen *et al.* (1986) have been found each in only one sample in ENCI Quarry. This is the case for *Druggipollis cretaceus, Pecakipollis bohemiensis* and *Maestrichtipollenites concavus.*

- Two taxa which are considered as characteristic for the Gulpen Formation by Herngreen *et al.* (1986) have been cited by the same authors from the Maastricht Formation. These are *Semioculopollis maestrichtiensis* (in 2 samples) and *S. granulosus* (in 5 samples).

- Three Late Maastrichtian sporomorphs which first appear in the Maastricht Formation (*Extremipollis oebisfeldensis, Nudopollis endangulatus* and *Pompeckjoidaepollenites daniensis*) each occur in only one sample in the Bunde borehole (Herngreen *et al.*, 1986). Therefore their practical value for regional correlations seems limited.

- Bisaccate pollen also abound in the middle to late Upper Maastrichtian. The relative abundance of two species may have some value for regional correlations (Herngreen *et al.*, 1986) : *Abietiineaepollenites microreticulatus* (10 % or more in 7 out of 10 samples in Lixhe-3 and lower third of Lanaye Chalks of ENCI, common in higher part of Lanaye up to base of Gronsveld Chalk in ENCI, also present in Valkenburg Chalk of Bunde borehole) and *Pityosporites constrictus* (abundant in Valkenburg to Schiepersberg Chalks of Bunde borehole - more than 10 % in 6 out of 7 samples; present in Nekum Chalk of same borehole; absent in Lixhe-3 and Lanaye Chalks of ENCI).

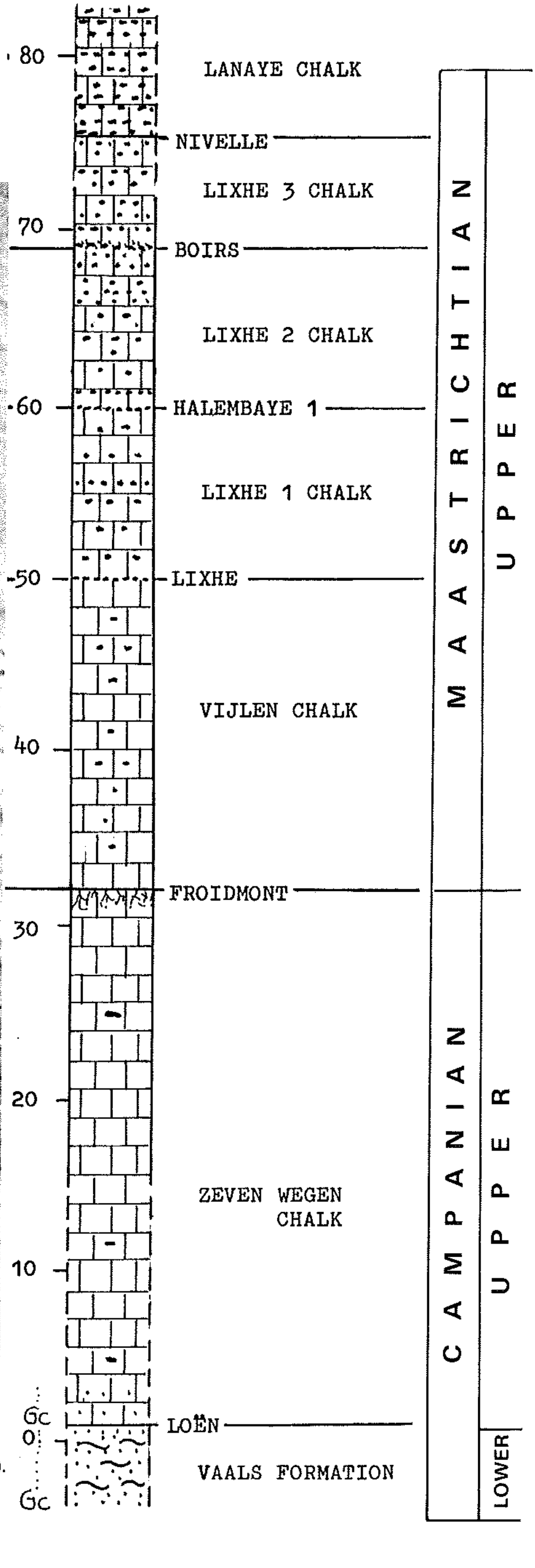
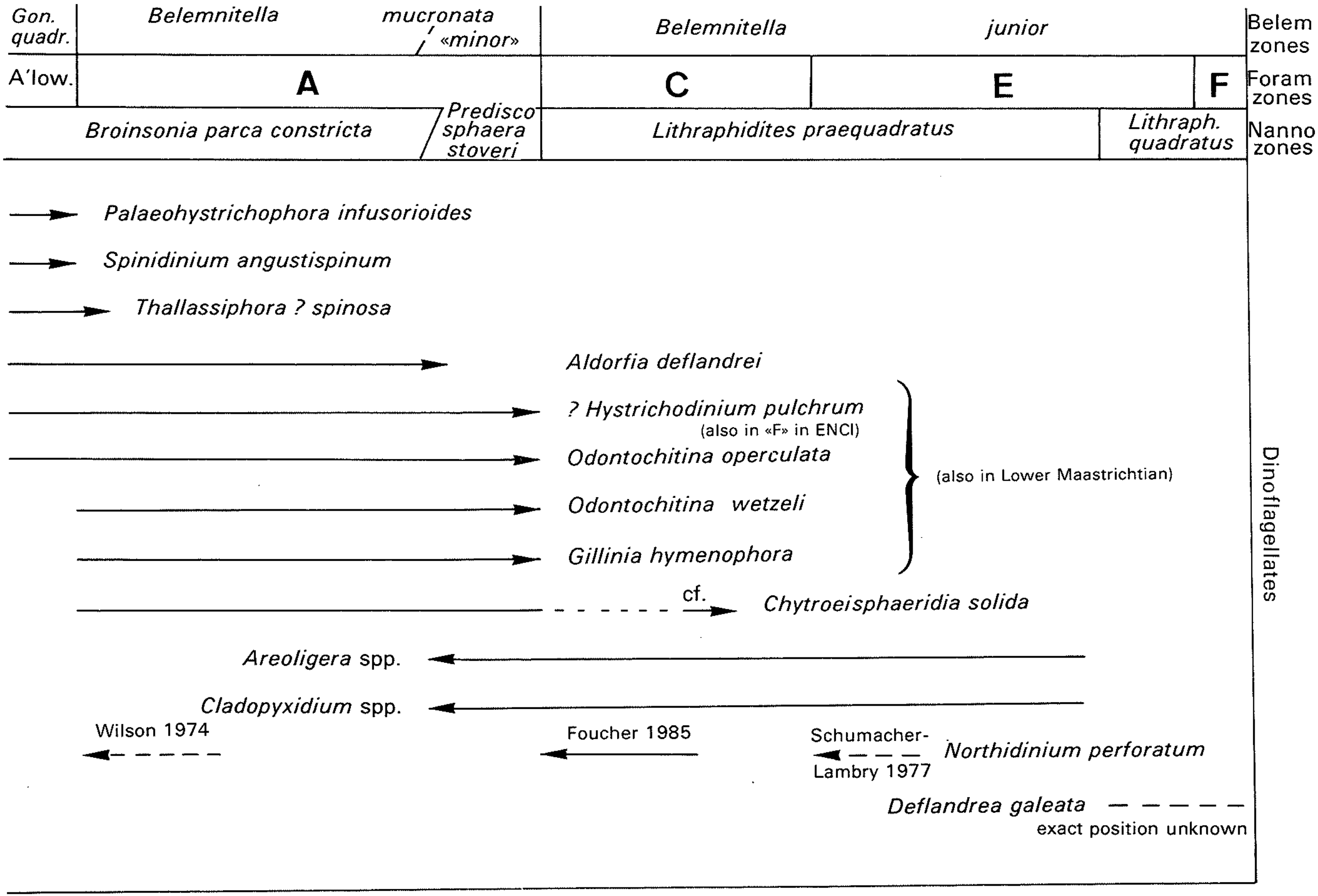


Plate 1 - Biostratigraphy and extension of selected dinoflagellates in the Halembaye Quarry (Locality 9 on fig. 1).



Gon. quadr.
Belemnitella
mucronata
«minor»
Belemnitella
junior
Belem zones
A'low.
A
C
E
F
Foram zones
Broinsonia parca constricta
Prediscosphaera stoveri
Lithraphidites praequadratus
Lithraph. quadratus
Nanno zones
Palaeohystrichophora infusorioides
Spinidinium angustispinum
Thallassiphora ? spinosa
Aldorfia deflandrei
? Hystrichodinium pulchrum
(also in «F» in ENCI)
Odontochitina operculata
Odontochitina wetzeli
Gillinia hymenophora
(also in Lower Maastrichtian)
cf.
Chytroeisphaeridia solida
Areoligera spp.
Cladopyxidium spp.
Wilson 1974
Foucher 1985
Schumacher-Lambry 1977
Northidinium perforatum
Deflandrea galeata
exact position unknown
Dinoflagellates

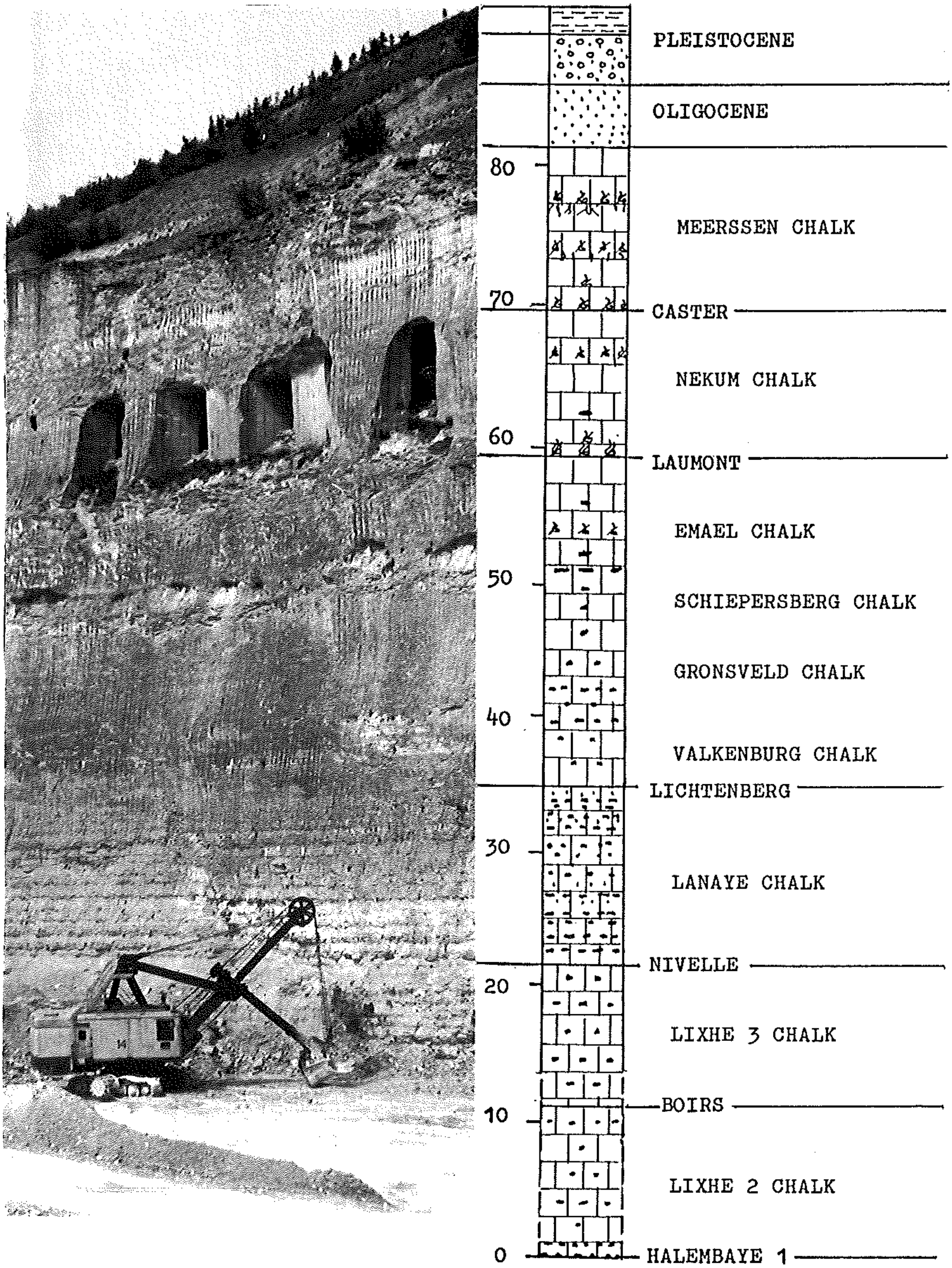
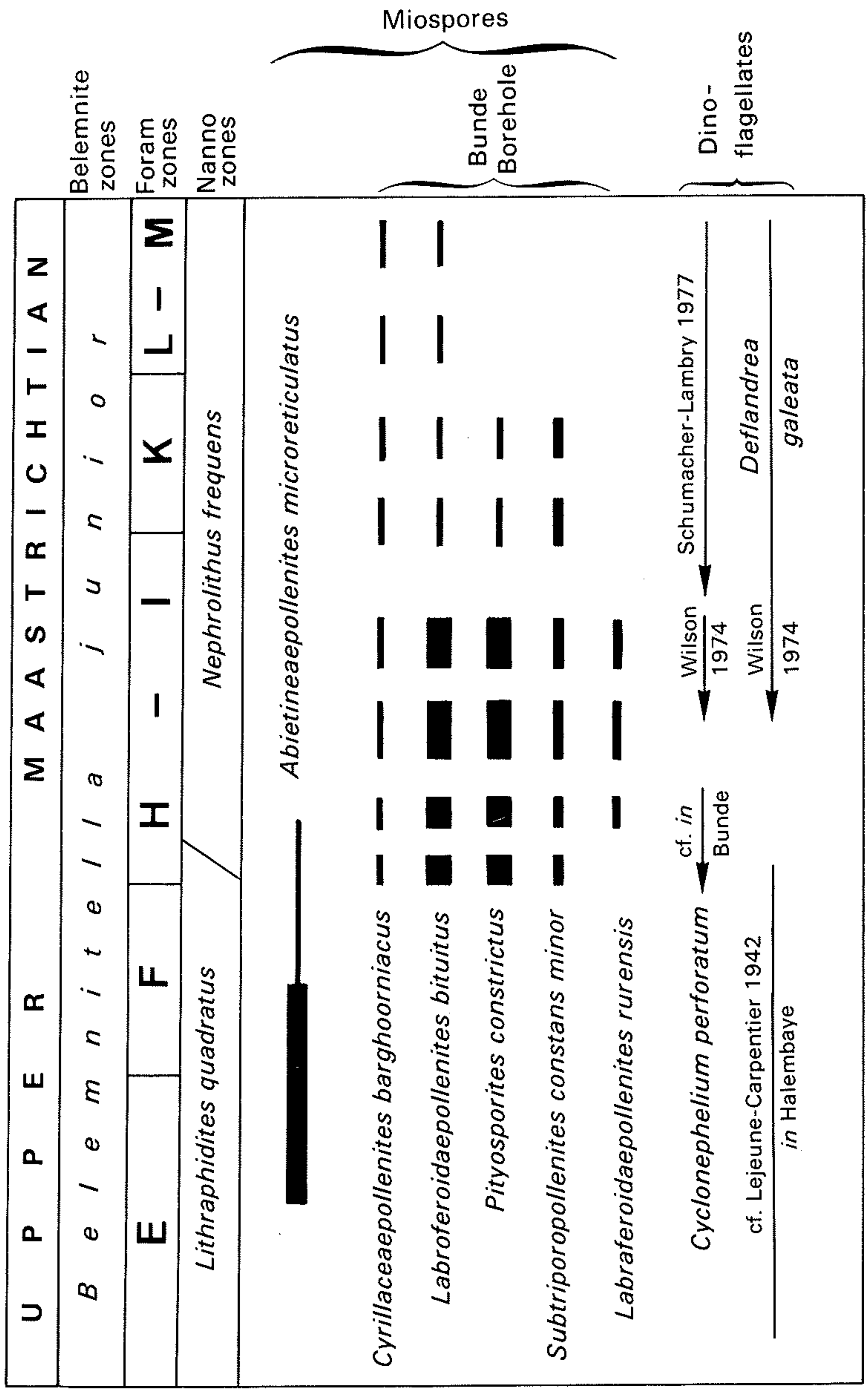


Plate 2 - Biostratigraphy and extension of selected palynomorphs in the ENCI Quarry (Locality 6 on fig. 1) and Bunde borehole (Locality 14 on fig. 1).



Miospores
Belemnite zones
Foram zones
Nanno zones
Bunde Borehole
Dino-flagellates
UPPER MAASTRICHTIAN
Belemnella junior
E F H – I K L – M
Lithraphidites quadratus
Nephrolithus frequens
Abietineaepollenites microreticulatus
Cyrillaceaepollenites barghoorniacus
Labroferoidaepollenites bituitus
Pityosporites constrictus
Subtriporopollenites constans minor
Labraferoidaepollenites rurensis
Cyclonephelium perforatum
cf. in Bunde
Schumacher-Lambry 1977
Wilson 1974
Deflandrea galeata
Wilson 1974
cf. Lejeune-Carpentier 1942
in Halembaye

- Four pollen species appearing at or near the base of the Maastricht Formation in the Bunde borehole may have some value for regional correlation, since these have not been found in the Gulpen Formation of the ENCI and occur frequently and in large numbers in the studied samples from Bunde. These are :
  Cyrillaceaepollenites barghoorniacus (in 7 out of 10 samples, and in 4 with 1-5 %), *Subtriporopollenites constans minor* (6 out of 10, in 5 with 2-5 %), *Labraferoidaepollenites bituitus* (6 out of 10, in 5 with 2-10 %), and *L. rurensis* (5 out of 10, in 3 with 2-5 %).
- Reworked spores and pollens have been mentioned from the Upper Gulpen and Maastricht Formations in the ENCI (Kedves & Herngreen, 1980).

3.3. Dinoflagellates

Research on Upper Cretaceous dinoflagellates in South Limburg and northern Liège was started by Lejeune-Carpentier (1937-1951), who worked mainly on flints, as did later on Conrad (1941), De Wit (1943, 1944) and Rademakers (1974). Part of her material has been restudied recently (Lejeune-Carpentier & Sarjeant, 1981, 1983). The most complete work was realized by Wilson (1971, 1974). Wilson's partly unpublished data (his 1974 paper is a Ph. D. thesis with limited distribution only) were reviewed and complemented by Schumacker-Lambry (*in* Streel *et al.*, 1977). The most recent publications are those by Foucher (*in* Robaszynski *et al.*, 1985) and by Herngreen *et al.* (1986). All these papers are based on spot samples and not on continuous sampling series. This makes any conclusions only preliminary.

3.3.1. Santonian

Although several dinocyst species are mentioned by Batten *et al.* (1988), none of these is restricted to the Santonian. However *Senoniasphaera protrusa* is not found in strata older than the Santonian and *Pervosphaeridium truncigerum* appears to have its acme in the Santonian. It should be noticed that both species are found in the Upper Campanian Zeven Wegen Chalk of Halembaye (Foucher *in* Robszynski *et al.*, 1985, fig. 20).

3.3.2. Campanian

Most of the data are based on samples from CPL Quarry at Halembaye in northern Liège.

The boundary between the Lower and Upper Campanian (boundary between Vaals Formation and Zeven Wegen Chalk) is marked by the disappearance of e.g. *Palaeohystrichophora infusorioides* and *Spinidinium angustispinum*, and by the appearance of e.g. *Odontochitina wetzeli*, *Gillinia hymenophora* and *Chytroeisphaeridia solida* (Foucher *in* Robaszynski *et al.*, 1985). However, several species occurring in the Lower Campanian are also found at the base of the Zeven Wegen Chalk in the "craie glauconifère" (e.g. *Thalassiphora ? spinosa*). Whether this is due to reworking or not has not yet been demonstrated. However, it should be noticed that the boundary between Wilson's (1974) biozones Ia and Ib has been placed above the "craie glauconifère" (cf. Schumacker-Lambry *in* Streel *et al.*, 1977).

In the upper part of the Zeven Wegen Chalk, there is a second change in the dinoflagellate assemblages according to Foucher (*in* Robaszynski *et al.*, 1985). Several species disappear (e.g. *Aldorfia deflandrei, Senonias-phaera protrusa*), while new ones appear (e.g. genera *Areoligera* and *Cladopyxidium)*. This boundary was not recognized by Wilson (1974) and Schumacker-Lambry (*in* Streel *et al.*, 1977) due to inadequate sampling. The latter author recognized *S. protrusa* in her sample H.11 near the top of the Zeven Wegen Chalk.

3.3.3. Maastrichtian

According to Foucher (*in* Robaszynski *et al.*, 1985), the Campanian-Upper Maastrichtian boundary at Halembaye (Froidmont Horizon) is marked by the disappearance of a few taxa such a *Hystrichodinium pulchrum, Odontochitina wetzeli* and *O. operculata*. These species range into the Lower Maastrichtian Beutenaken Chalk in the Cadier en Keer Borehole, so that the real boundary is between the Lower and Upper Maastrichtian. However, *H. pulchrum* was mentioned by Schumacker-Lambry (*in* Streel *et al.*, 1977, pl. 5, fig. 6-7) from her sample E.10 (Upper Maastrichtian Lanaye Chalk) in the ENCI Quarry.

A new species appearing at the boundary between Lower and Upper Maastrichtian is *Northidinium perforatum* according to Foucher (*in* Robaszynski *et al.*, 1985). Wilson (1974) placed the first appearance at the base of the Zeven Wegen Chalk ("craie glauconifère"), whereas Schumacker - Lambry (*in* Streel *et al.*, 1977) found the lowermost specimens above the Lixhe Horizon (her sample H.7).

The boundary between the Gulpen and Maastricht Formations in the ENCI Quarry (Lichtenberg Horizon) was taken as the boundary between biozones IV and Va by Wilson (1974). This boundary would be marked by the appearance of two species : *Cyclonephelium perforatum* and *Deflandrea galeata*. Schumacker-Lambry (*in* Streel *et al.*, 1977) and Herngreen *et al.* (1986) placed this boundary slightly higher in the "Mb" or in Hofker's (1966) foram zone H. However, *D. galatea* was found in Halembaye in flint of the Lixhe-Lanaye Chalk by Lejeune-Carpentier (1942). Thus, its first appearance is below the Lichtenberg Horizon. The lowermost specimens of *Cyclonephelium perforatum* found by Wilson (1974) in ENCI Quarry were from the Schiepersberg Chalk (*fide* Herngreen *et al.*, 1986), those found by Schumacker-Lambry (*in* Streel *et al.*, 1977) from the Emael Chalk. Herngreen *et al.* (1986) found *C. perforatum* in the Meerssen Chalk ("Md") in the Bunde Borehole, and only cf. *C. perforatum* at the base of the Maastricht Formation in that borehole. This mean that it is questionable if *C. perforatum* may be used for distinguishing the Maastricht Formation from the underlying Gulpen Formation by means of Dinoflagellates.

4. CONCLUSIONS

The Santonian age of the Hergenrath Clay at Welkenraedt, Valkenburg and in open karst fissures in the 's-Gravenvoeren Borehole seems now well established by the study of miospore and dinoflagellate assemblages (Batten *et al.*, 1987, 1988).

The Lower Campanian Vaals Formation at Halembaye is distinguished from the Upper Campanian Zeven Wegen Chalk by dinoflagellate assemblages. This boundary has not been recognized in the spores and pollen assemblages (lack of data for the Zeven Wegen Chalk), nor in the nannoflora.

The upper portion of the Zeven Wegen Chalk at Halembaye is distinguished by changes in the nannoflora (*Prediscosphaera stoveri* appears) and in the dinoflagellate assemblages (e.g. appearance of genera *Areoligera* and *Cladopyxidium*). This upper portion of the Upper Campanian is also characterized by the belemnite *Belemnitella mucronata "minor"*.

The Campanian-Maastrichtian boundary (boundary between Zeven Wegen Chalk and Beutenaken Chalk), noticed in the nannoflora by the appearance of *Lithraphidites praequadratus* and *Reinhardtites levis*, has no marked change in the dinoflagellate assemblages. Data on miospores are incomplete.

The boundary between the Gulpen and Maastricht Formations within the Upper Maastrichtian sequence seems to coincide with the appearance of the coccolith *Nephrolithus frequens*. Whether the dinoflagellate *Cyclonephelium perforatum* appears at this boundary or only much higher is still an open-ended question. Several pollen species which appear to be relatively frequent and abundant in the Maastricht Formation in the Bunde Borehole have not been observed in the Lixhe-3 and Lanaye Chalks of the ENCI Quarry. These may be used for regional correlation.

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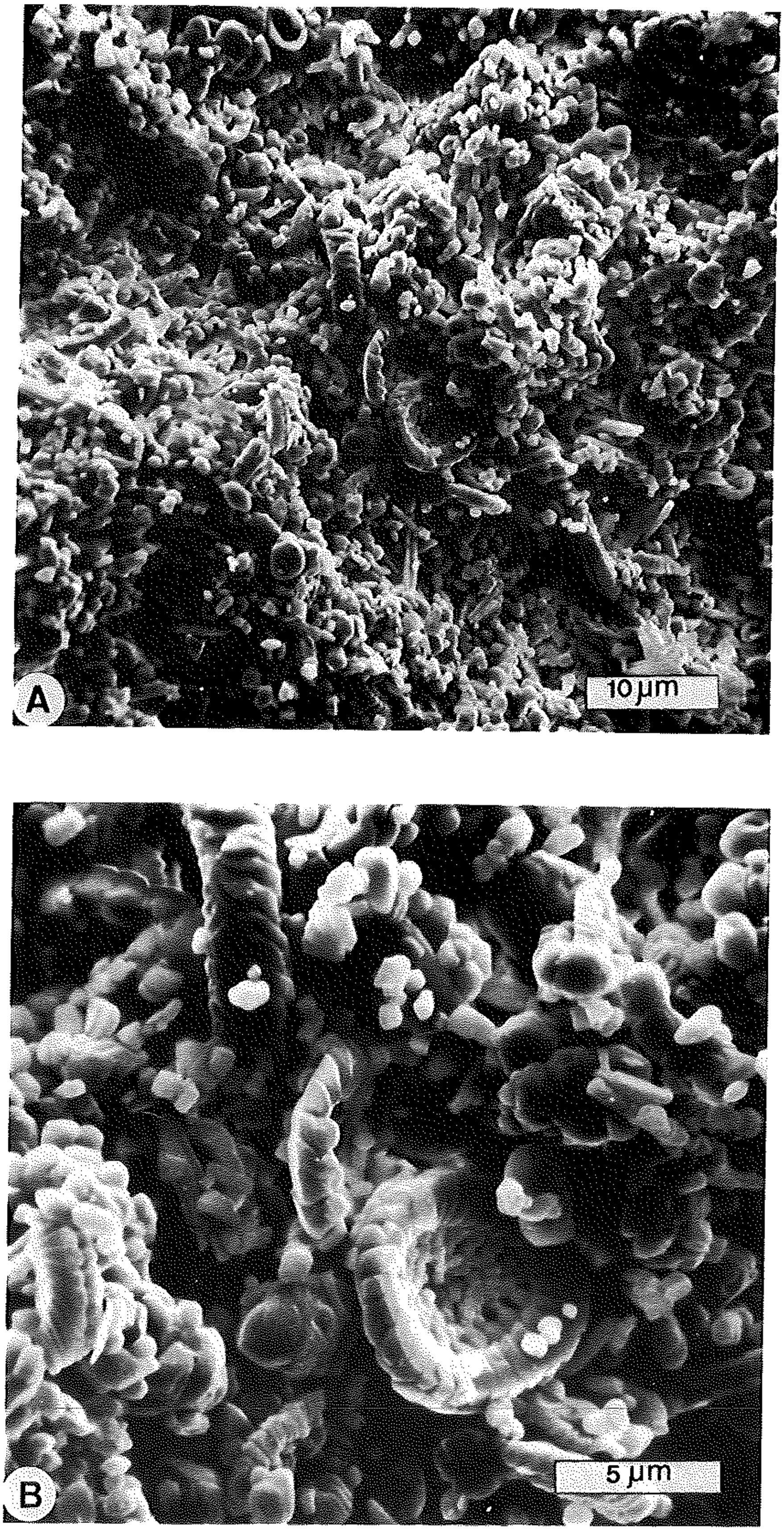

Plate 3 - Fresh, undisturbed surface of a fragment of Zeven Wegen Chalk from Grez-Doiceau in northern Liège (by courtesy of Ing. Ch. Schroeder, Liège University).