281

Netherlands Journal of Geosciences / Geologie en Mijnbouw 82 (3): 275-281 (2003)

Faunal/floral and isotopic responses to Milankovitch precession cycles and environmental changes in the upper Gulpen Formation (Upper Maastrichtian) at the CBR-Lixhe and ENCI-Maastricht bv quarries

P.J. Felder[1], E. Keppens[2], B. Declercq[2], S. Normand[1] & M. Streel[1]

[1] Université de Liège, Paléontologie, Sart Tilman B18, BB4000 Liège 1, Belgium; e-mail: Sjeuf.felder@wanadoo.nl; maurice.streel@ulg.ac.be
[2] VUB, Laboratory of Stable Isotope Geochemistry (CHROBWE), Pleinlaan 2, B-1050 Brussels, Belgium; e-mail: ekeppens@vub.ac.be

Manuscript received: June 2000; accepted: October 2001

Abstract

Two sections, just below the Nivelle Horizon in the upper Gulpen Formation (Upper Maastrichtian), and seven kilometres apart (CBR-Lixhe and ENCI-Maastricht bv quarries) have been analysed (samples every 5 cm) for dinocyst, pollen grains and bioclast contents as well as for carbon and oxygen isotopic composition, to obtain better insight into the influence of weathering on these sediments. The CBR section lies above groundwater level, while that at the ENCI quarry is some metres below. At the former quarry we recognised the influences of weathering (karst) nearby.

At ENCI, palynological, bioclast and stable isotope results of the carbonate phase (mainly consisting of coccoliths) co-vary remarkably, displaying two cycles which may be interpreted tentatively as climatic fluctuations. The $\partial^{18}O$ curve varies roughly between -1.6‰ and -1.1‰ (on PDB scale), corresponding to a temperature change of about 2°C. Less negative values (i.e. cooler seawater) coincide with larger amounts of pollen of Normapolles and Triporates type assumed to represent temperate forest elements of a vegetation also containing tropical elements such as palms. Assuming the 5 cm sample intervals at ENCI to correspond to 1 ka, climatic maxima (and minima) may be 20-25 ka apart, obviously recalling Milankovitch precession cycles.

These are independent of a sharp sedimentological change noted in the upper part of the lowest cycle (samples 42 to 24). Upwards of sample 42, bioclast contents increase and dinocysts, *Spiniferites* in particular, decrease significantly, corresponding to a marked shallowing. This turning point is also recorded in the $\partial^{13}C$ curve at ENCI. Bioclast percentages appear to follow composite trends that are influenced by both climatic and sedimentological conditions.

Keywords: palynomorphs, bioclasts, stable isotopes, Upper Maastrichtian, the Netherlands, Belgium

Introduction

Unpublished studies carried out at the Université de Liège (Normand, 1993; Mustapha, 1994), and focusing on the type area of the Maastrichtian Stage (Fig. 1), revealed differences in the results obtained, which could possibly be ascribed to changes the rocks had undergone subsequent to sedimentation. To study these differences, a trajectory of 3 metres was sampled every 5 cm and analysed at the CBR-Lixhe quarry, and a similar sequence (2.6 m) at the ENCI-Maastricht bv quarry (Fig. 2).

The upper Lixhe Member 3 (Gulpen Formation), of Late Maastrichtian age, was chosen since this part of the sequence was below groundwater level at the ENCI quarry, while being well above it at the other locality (Fig. 2). Rocks exposed at the CBR quarry are in general influenced by karstic phenomena. The chalk structure is more loose, and its colour brighter than at the ENCI quarry. In places, in addition to dissolution pipes, at this quarry even overlying sands were seen penetrating the chalks. Otherwise, within the chosen trajectory, sedimentation was assumed to have been tranquil. The flint beds present allowed a

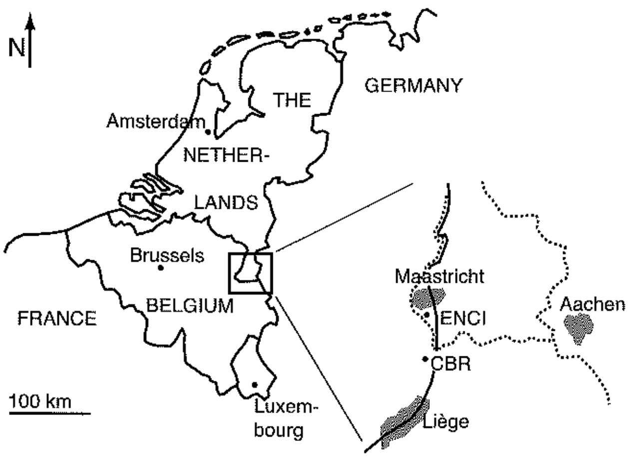

Fig. 1. Map showing location of quarries sampled.

detailed correlation between both quarries (Fig. 3).

Both lithological data and bioclast analyses permit a bed-by-bed correlation of the sections sampled, in marked contrast to results obtained in previous studies. Dinocysts as well as stable isotopes at both quarries varied, so that only on the basis of relative changes in these values could similarities be noted. Pollen grain analyses showed that at the CBR quarry Cenozoic species had infiltrated; in fact, it may be assumed that the majority of pollen grains in this section is allochthonous. Thus, in these poorly weathered sediments some data can only be judged relatively. The influence of the mild weathering on and infiltration of foreign material in these strata, may also have triggered such changes that comparisons can no longer be made. For this reason, we will here present all data obtained, but discuss in more detail only the ENCI quarry.

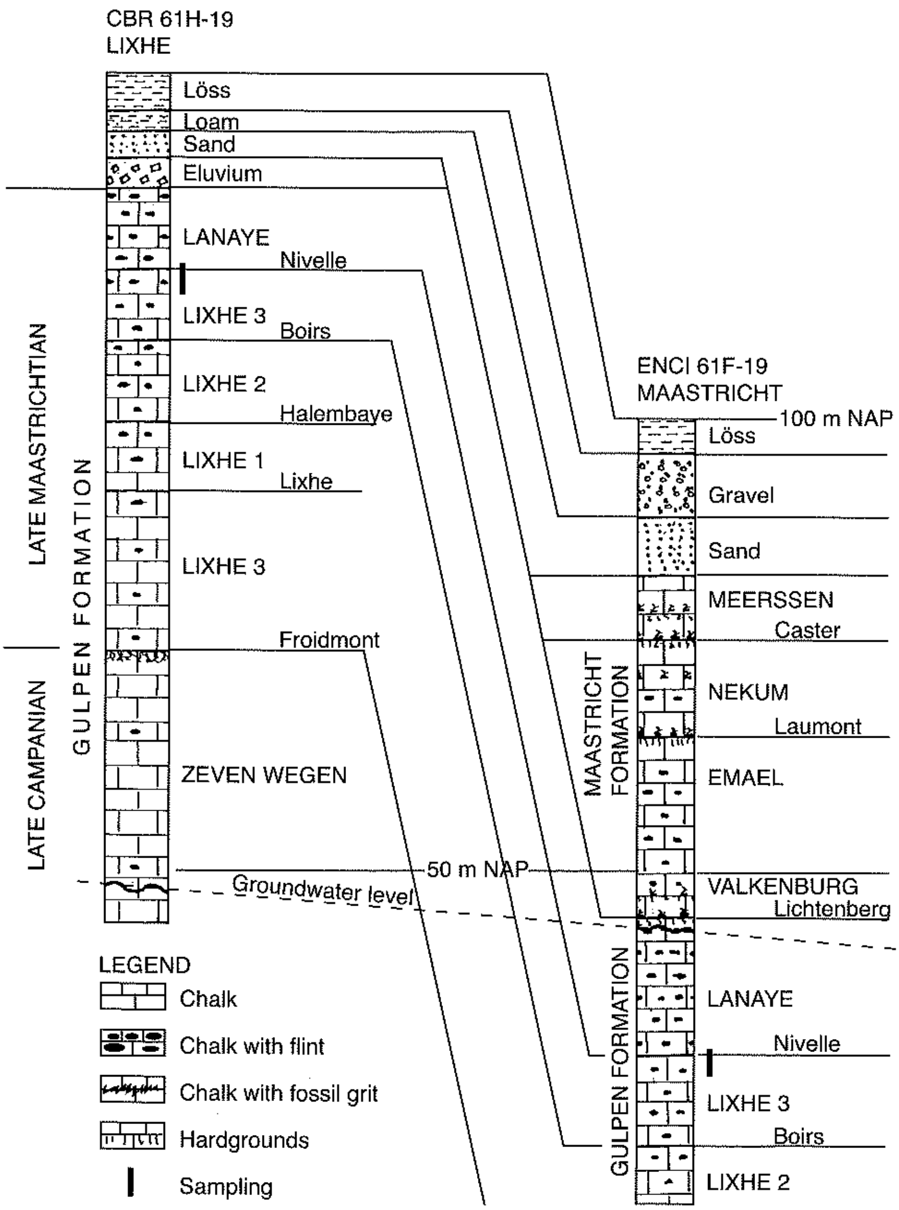

Fig. 2. Chrono- and lithostratigraphy of sections sampled (CBR-Lixhe and ENCI-Maastricht bv quarries).

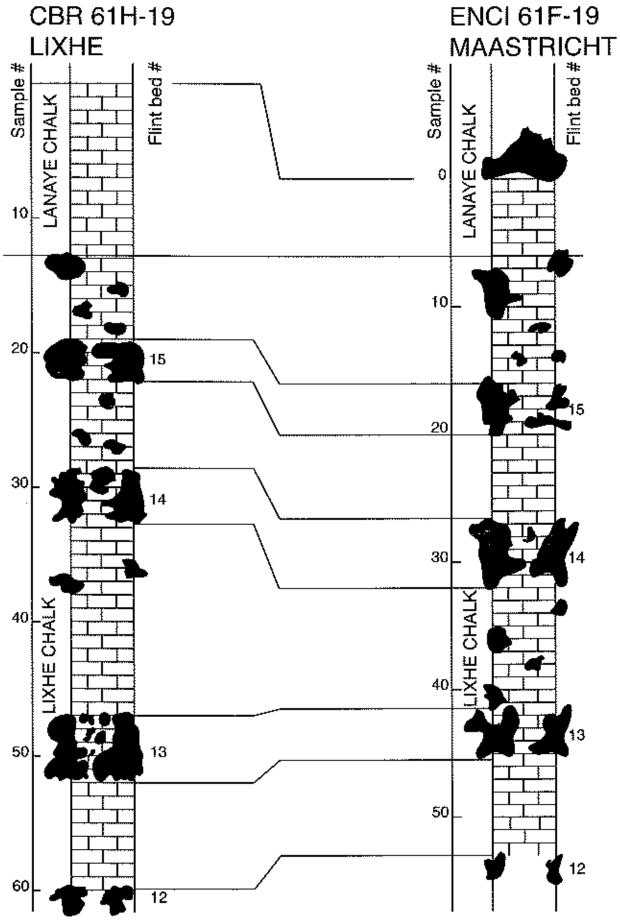

Fig. 3. Lithological correlation between sections sampled.

Methods

Prior to taking samples, the sites were first cleaned thoroughly and the samples to be taken were indicated by means of engraved lines, every 5 cm. After that, a lithological log was measured (Fig. 3). The samples were taken by using a hammer and wood chisel, making sure that at each site some 250 g of chalk were collected. At the ENCI quarry 52 samples (every 5 cm) were taken from a nearly grey chalk with flints. At the CBR quarry, 60 samples were taken from a near white chalk with flints. At both localities, samples were taken in a continuous section without flints. Each sample was crushed by a rolling pin and sieved to isolate the bioclasts (1-2.4 mm) from the mainly coccolithic matrix. A small volume (a few mg) of the matrix was used for isotopic and palynological analyses (20 g).

Results

Lithology

During our lithostratigraphic studies at both localities we noted dissolution phenomena above groundwater level, which mostly were connected to karst. Especially at the CBR quarry the chalk shows a high porosity as a result of karst at the site of sampling. Locally, the overlying Oligocene sands has piped down in lenses. The colour of the chalk at the CBR quarry is very nearly white, while at the ENCI quarry it is evenly grey. Despite these differences a detailed correlation between both sites was possible thanks to the flint levels present (Fig. 3).

Bioclasts

Bioclasts studied (1-2.4 mm) have allowed to sections sampled to be correlated and subdivided into six sequences, here indicated as A to F (Fig. 4). Remarkable is the increase in the number of bioclasts upwards from sequence C in both sections. The bioclasts encountered, in differences in total numbers, show a correlation which differs from a correlation based on lithology. These differences, however, are easily explained as flint beds postdate sedimentation, while differences in bioclast numbers reflect differences in grainsize during deposition. Since correlations based on bioclasts are of a primary nature, we will adopt these correlations between the sequences and in all other sections.

Isotopes

Results of stable isotopes (^{18}O-^{16}O and ^{13}C-^{12}C) analyses are indicated in Fig. 5 in $\partial^{18}O‰$ PDM values; Fig. 8 shows the $\partial^{13}C‰$ PDB values. For reference, in both illustrations the correlation between sequences A-F are adopted. $\partial^{18}O‰$ PDM values in both sections do not show obvious similarities. Remarkable are the higher values for the CBR quarry (Fig. 5). In the ENCI samples, $\partial^{18}O‰$ PDM values are clearly subdivided into two peaks, each of them further subdivided into five smaller peaks. At the CBR quarry this development is not seen. $\partial^{13}C‰$ PDB values show more similarities (Fig. 8) between both localities. Both lines in this graph are more or less parallel. Remarkable, however, is that at the CBR quarry lower values were found than at the ENCI quarry.

Dinocysts

The number of dinocysts (and fragments) encountered differs enormously between both quarries (Fig. 6). At the ENCI quarry, ten times more dinocysts per gram were found than at the other locality. Considerable differences in absolute numbers were also noted vertically within the same quarry. The lower half of

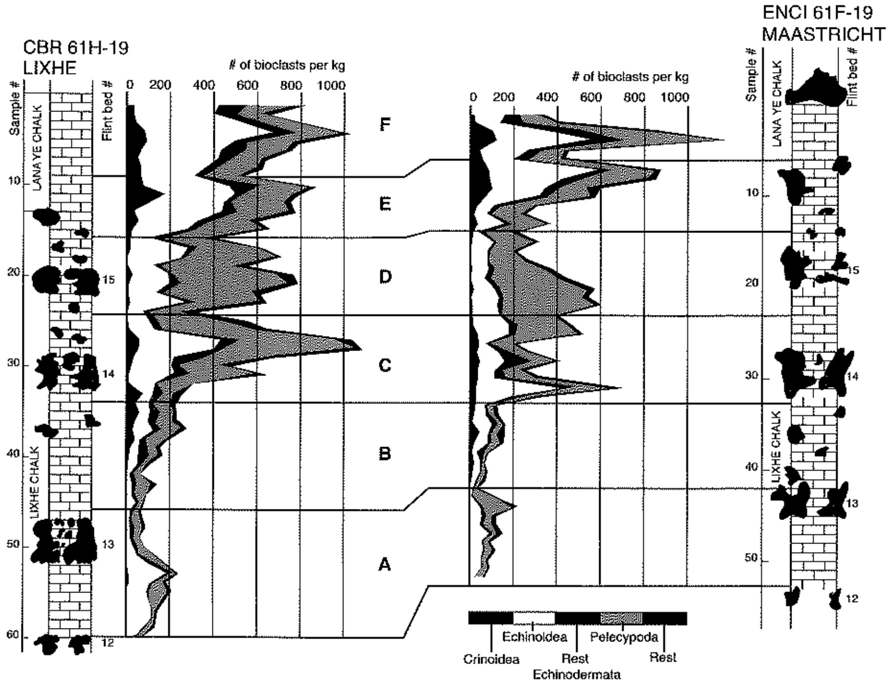

Fig. 4. Absolute numbers and percentages of Crinoidea bioclasts (1-2.4 mm) in samples from CBR-Lixhe and ENCI-Maastricht bv quarries. Crinoidea units CR6b and CR6c are indicated. Here, peaks are numbered, and the higher amounts (above 5 and 10%) are shown in black in order to indicate higher amounts in sequences B and D.

the section sampled, at both quarries, appears to be richer in dinocysts than the upper half. A comparison of the number of dinocysts with the bioclast sequences (A to F) reveals that there is but one possible line of correlation, in the middle of sequence C to be precise.

Pollen and spores

The total number of pollen and spores encountered at both quarries differs considerably. At the CBR quarry, in addition to a small number of pollen and spores known from Maastrichtian and Cenozoic strata alike, there also are a certain number of exclusively Cenozoic species (Fig. 7). These Cenozoic pollen may have infiltrated with penetrating meteoric water which triggered karst. Of note is also that similarities in the number of Cenozoic and 'Maastrichtian and Tertiary' pollen are such that we may conclude that all pollen in the CBR section have infiltrated.

Discussion and conclusions

The lithological similarities (Fig. 3) and correlations

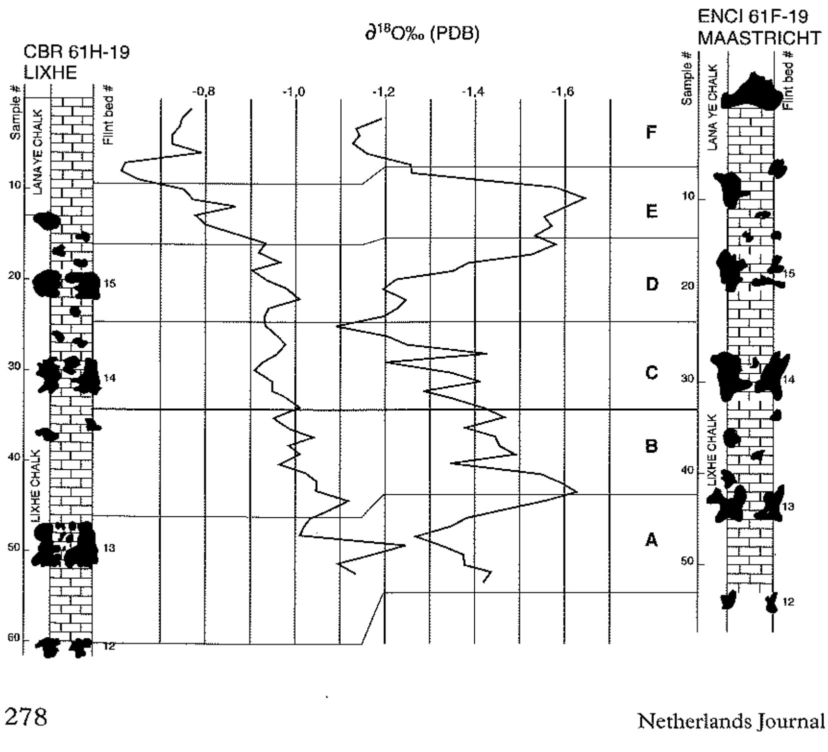

Fig. 5. The $\partial^{18}O$‰ (PDM) values in the sections sampled.

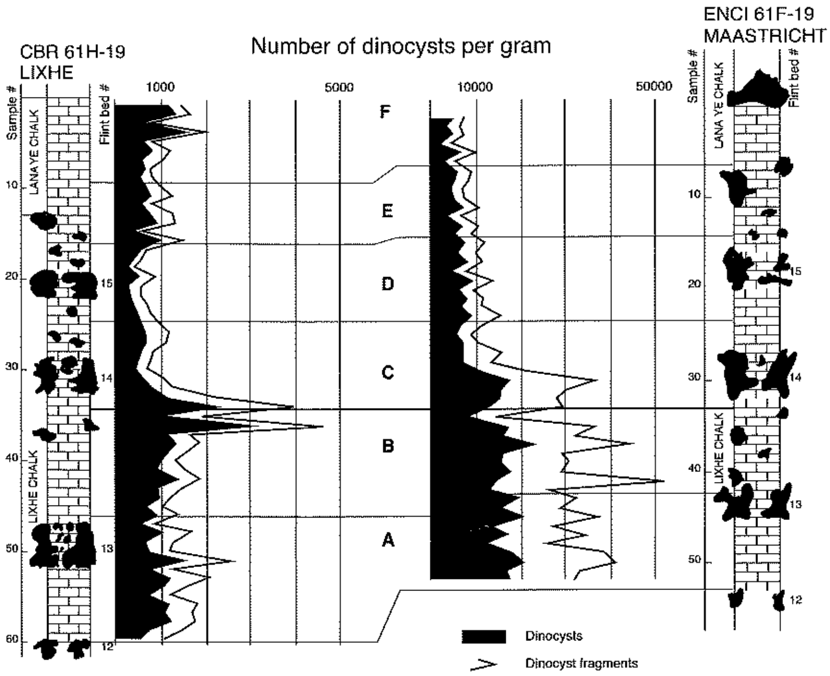

Fig. 6. Dinocysts per gram of sediment in sections sampled.

based on bioclasts (Fig. 4) indicate that at both quarries the same stratigraphic sequence was sampled. Small discrepancies between lithology-based correlations and those based on bioclasts may be ascribed to the fact that the flint beds are of secondary development in these rocks and do not need to conform to primary deposition.

Remarkable are the differences encountered in previous investigations. In isotope analyses discrepancies of 0.5 in $\partial^{18}O‰$ PDM values (Fig. 5) were found. Such differences may be explained if one assumes meteoric water to have triggered changes within the sediment. Indications for the infiltration of meteoric water at the CBR quarry have been found in the form of washed-in sand lenses and Cenozoic pollen. These local sand lenses, stemming from overlying sandy deposits, infiltrated during or subsequent to the Oligocene.

Dinocysts studies (Fig. 6) also show ten-fold differences in absolute numbers between both localities, which may be connected to dissolution by infiltrating meteoric water. With pollen and spores discrepancies

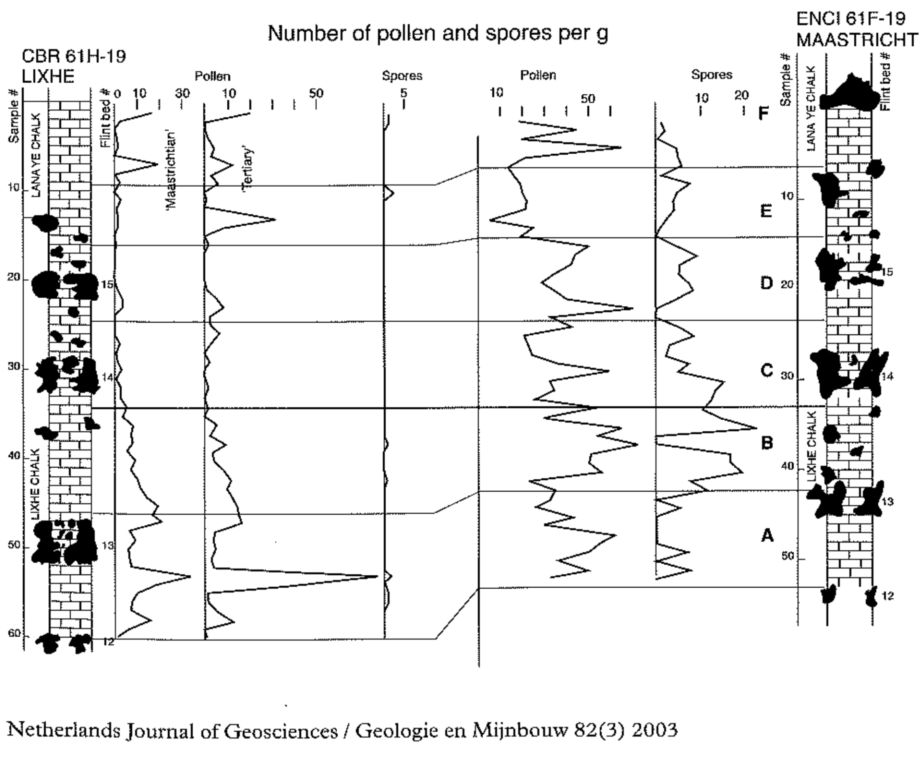

Fig. 7. Pollen and spores per gram of sediment in sections sampled.

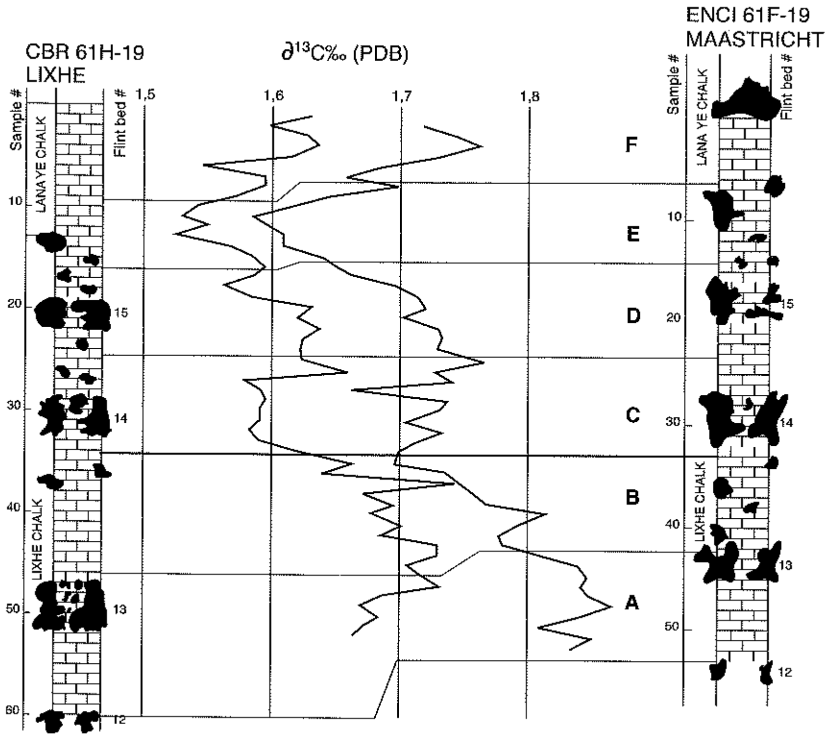

Fig. 8. The $\partial^{13}C‰$ (PDM) values in the sections sampled.

are such that comparisons can no longer be made. The meteoric water has probably dissolved pollen and spores present and replaced them by Cenozoic forms. From these analyses it appears that resultats obtained from studies of sequences both below and above groundwater level cannot be compared directly.

Despite these differences, relative similarities have been found both in $\partial^{13}C‰$ PDM values (Fig. 8) and in numbers of dinocysts (Fig. 6). These similarities are an indication of the fact that values encountered are relatively reliable. We may also assume the values found at the ENCI quarry are more reliable than those at the CBR quarry. For this reason, the discussion below will focus exclusively on results obtained at the former locality.

The results from the ENCI quarry of the values of stable isotopes $\partial^{18}O$ and $\partial^{13}C$ (Figs 5, 6) appears to follow cyclic variations based on several successive samples for each trend. The $\partial^{18}O$ curve forms two cycles with minima (= maximum temperatures) at samples 10 and 42 and maxima (= minimum temperatures) at samples 3 and 24, between -1.1‰ and -1.6‰ (on PDM scale), which can be interpreted as climatic fluctuations. In the Late Cretaceous ice-free ocean the 0.5‰ shift would correspond to a 2°C temperature change. Assuming the 5 cm-interval in this section to correspond to 1 ka (Felder, 1996), the climatic maxima (and minima) are 20-25 ka apart, an order of magnitude that obviously recalls the Milankovitch precession cycle.

Spores and pollen grains (Fig. 7) are rare (20-100 per g of sediment) compared to dinocysts, which are very abundant in the chalks at the ENCI quarry (between 10,000 to 50,000 per g of sediment). However, the variations of even low amounts of a group of pollen grains, i.e. Normapolles and Triporates (Nortripores in Fig. 9) varying from 5 to 50 grains per g of sediment, matches the climatic curve as based on the $\partial^{18}O$ data well. When taking an arbitrary limit at 18 grains per g of sediment, the sequence can be roughly subdivided into a number of phases, in part corresponding to bioclast sequences A to F (Fig. 9), show-

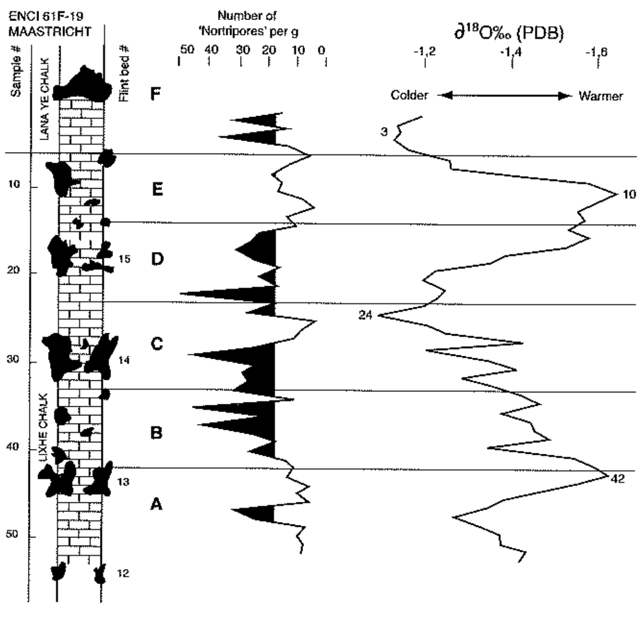

Fig. 9. Number of Normapolles and Triporates (Nortripores) per gram at the ENCI-Maastricht bv section compared to the diagram of the stable isotope $\partial^{18}O‰$ (PDM).

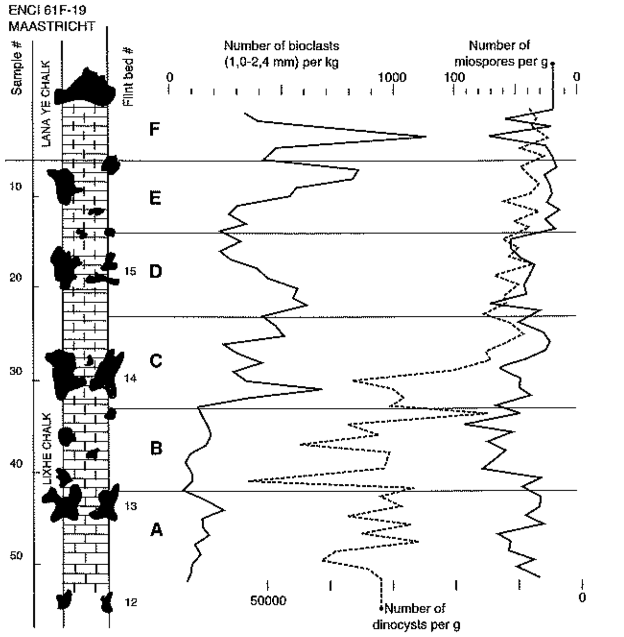

Fig. 10. The number of bioclasts (1-2.4 mm) per kg of sediment compared to the number of dinocysts and miospores per g of sediment at the ENCI-Maastricht bv section.

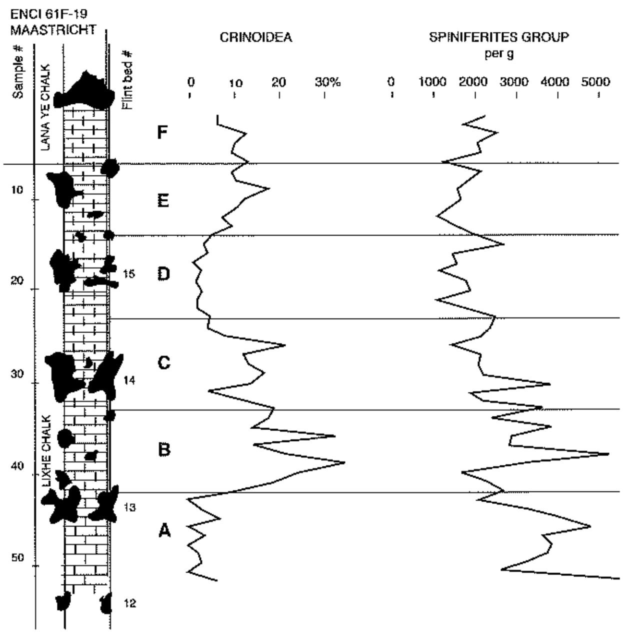

Fig. 11. The percentages of Crinoidea compared to the *Spiniferites* group per gram of sediment at the ENCI-Maastricht bv quarry.

ing a double alternation of majority of samples with samples fewer than 18 grains per g of sediment and a majority of samples with more than 18 grains per gram. The correlation with the climatic curve does not demonstrate a strong covariation but obviously phases A and E correspond to warmer climates. Normapolles and Triporates are assumed to represent temperate elements of a vegetation containing also elements such as palms. Their variations might reflect small changes in the corresponding climate.

Dinocyst distribution along the section at the ENCI quarry (Fig. 10) does not show any relationship with the climatic curve or with the subdivision into phases A to F, based on bioclasts. However, it does show a sharp change in sample 25 with many values around 30,000 and 40,000 below this limit and values of around 10,000 above it. The number of bioclasts (Fig. 10) displays an inverse trend which is antipathetic with the decreasing number of dinocysts. Among the dinocysts, the *Spiniferites* group shows the same tendency, i.e. >2,000 below this limit and <2,000 above it (Fig. 11). *Spiniferites* may be considered to correspond to outer neritic waters. The *Spiniferites* group may tentatively be regarded as the most offshore quantitatively important category (Schiøler et al., 1997). The percentage curve of Crinoidea (Fig. 11) is very similar to the curve of concentrations of *Spiniferites*, except for sequence A. The Crinoidea curve might therefore integrate both the climatic signal observed (Fig. 5) and the sedimentological change observed in Figs 10 and 11.

References

Felder, P.J., 1996. Late Cretaceous (Santonian/Maastrichtian) sedimentation rates in the Maastricht (NL) Liège/Campine (B) and Aachen (D) area. Annales de la Société géologique de Belgique 117 (1994): 311-319.

Mustapha, A., 1994. Les minéraux argileux du Crétacé supérieur de l'est de la Belgique et des régions limitrophes (Pays-Bas et Allemagne): genèse, argilostratigraphie, organisation séquentielle, implications paléographiques et paléoclimatiques. Université de Liège (Liège) (unpubl. thesis).

Normand, S., 1993. Etude palynologique quantitative du Maastrichtien supérieur dans les carrières CBR à Halembaye et ENCI à Maastricht. Université de Liège (Liège): 58 pp. (unpubl. thesis).

Schiøler, P., Brinkhuis, H., Roncaglia, L. & Wilson, G.J., 1997. Dinoflagellate biostratigraphy and sequence stratigraphy of the Type Maastrichtian (Upper Cretaceous), ENCI Quarry, The Netherlands. Marine Micropaleontology 31: 65-95.