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THE HAUTES FAGNES AREA (NE BELGIUM) AS A MONADNOCK DURING THE LATE CRETACEOUS[1]

by

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(16 figures, 1 table and 4 plates)

RESUME.- Morphologiquement, l'aire des Hautes Fagnes (NE de la Belgique) est actuellement un sommet régional qui culmine quelque 100-150 m au dessus du plateau de l'Ardenne, faiblement incliné (1°) vers le NW. Récemment, plusieurs dépôts du Crétacé tardif résiduel ont été échantillonnés afin de reconstruire la transgression graduelle Campanienne-Maastrichtienne sur cette aire qui a fonctionné comme un monadnock pendant cette période. Chaque succession commence par un conglomérat de base dont l'âge est progressivement de plus en plus jeune vers le sommet des Hautes Fagnes, indiquant une immersion, étape par étape, de l'aire envisagée. Les dépôts ont été analysés quant à leurs assemblages de bioclastes, de restes de poissons et de macrofaune «phosphatisée» autant que de groupes de microfossiles comme les foraminifères, les ostracodes et les spicules d'éponges. Ceci permet une brève discussion du paléoenvironnement et de l'âge de ces strates complètement décalcifiées.

ABSTRACT.- Morphologically, the Hautes Fagnes area (NE Belgium) is at present a regional high, rising some 100-150 m above the Ardennes plateau, which is slightly inclined to the NW (1°). Recently, a number of residual Late Cretaceous deposits in this area have been sampled in an attempt to reconstruct the gradual Campanian-Maastrichtian transgression onto the area, which acted as a monadnock during this period. Each succession starts with a basal conglomerate, which becomes progressively younger towards the summit of the Hautes Fagnes, indicating the step by step inundation of the area. The deposits have been analysed for bioclast assemblages, fish remains and phosphatised macrofauna, as well as for various microfossil groups, such as forams, ostracodes and sponge spicules. These allow a brief discussion of the paleoenvironment and age of these completely decalcified strata.

I.- INTRODUCTION

The residual Late Cretaceous deposits in the Hautes Fagnes area (NE Belgium) have been drawing the attention of geologists since the past century. Dumont (1847), Dewalque (1886, 1898), Holzapfel (1907), Renier (1928, 1932) and Bourguignon (1956) among others have reported on the occurrence of Cretaceous flints on the highest parts of the Hautes Fagnes (e.g. La Vecquée south of Spa, Hockai, Mont Rigi, Königliches Torfmoor near Neu-Hattlich, Beleu, Trois Hêtres). Other occurrences at Baronheid and Cronchamps were described by Demoulin only a few years ago.

However, little was known about the exact age of the sediments. Dewalque (1886) listed some macrofossils from flints at Hockai that were held to indicate a Senonian (= Late Campanian) to Maastrichtian age. Bourguignon (1956) discovered some phosphatised fossils at Beleu which were identified as possible Campanian markers.

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This paper is dedicated to the memory of the late Prof. Pol Bourguignon.

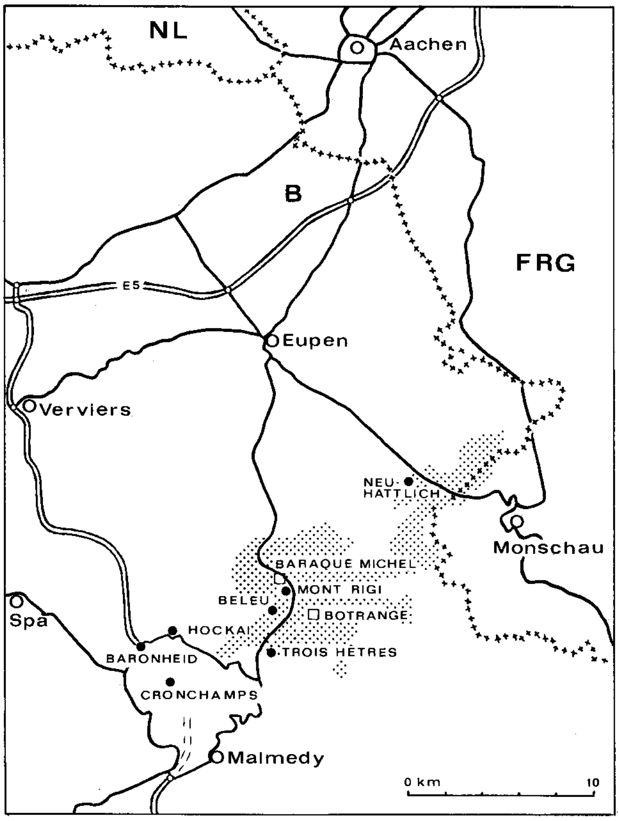

Figure 1.- Location map for the Hautes Fagnes area (NE Belgium).
Black dots : localities with residual Late Cretaceous deposits discussed in this paper.
Punctuated : area 600 m or more above sea level.

On the basis of lithology, the flints and basal conglomerate at Hockai were correlated with the Lixhe-Lanaye chalk and the Wahlwiller Horizon of the Late Maastrichtian succession in the Maastricht-Halembaye area, respectively (Felder & Albers, 1980). Gullentops (1987) assumed an early Campanian (Herve-Vaals) age for the glauconitic sand and loam in e.g. the Mont Rigi section near the summit of the Hautes Fagnes massif.

The presence of the residual Late Cretaceous deposits on the highest parts of the Hautes Fagnes area has previously been interpreted quite differently. According to Hancock & Kauffman (1979), the Hautes Fagnes had been a stable massif from the end of the Paleozoic onwards. Consequently, they assumed a Maastrichtian sea level rise of no less than 650 m compared to the actual sea level. Robaszynski (1981) and Gullentops (1987) however, have argued that the Hautes Fagnes had not been uplifted until post-Cretaceous times, whereas Macar (1954) and Demoulin (1986) have suggested that this uplift occurred only after the Oligocene transgression, since extensive Oligocene sand deposits occur on the northern flank of this massif.

However, the main problem in all these discussions was the lack of reliable stratigraphic data. Only recently, rich and diverse assemblages of silicified microfossils (forams, ostracodes, sponge spicules) and bioclasts (bivalves, brachiopods, echinoids, cirripedes, sponge fragments, fish remains, etc.) have been discovered in an apparently normal stratigraphic succession in the residual deposits at Hockai (Bless & Felder, 1989) and, subsequently, at six other localities as well (this paper). Moreover, a rich and equally diverse assemblage of phosphatised macrofossils and fish remains has lately been found at Beleu (this paper). In addition, a large collection of macrofossils in eluvial flints found by Mr. A. Petit (Stembert) at several localities on top of the Hautes Fagnes massif has yielded new information (Dhondt & Jagt, 1990). These finds allow an accurate dating of the residual deposits at seven different localities (fig. 1), and hence a reconstruction of the structural-depositional history of the area.

The field work consisted of digging trenches in the slope of an abandoned railway cutting at Hockai and a shallow (1.35 m) hole at Cronchamps. At the other localities the help of a bulldozer was required to make temporary excavations with a depth between about 2.5 and 5 m. Despite this, the base of the Late Cretaceous was not reached in a 4.9 m deep shaft at Neu-Hattlich (section on figure 11 partially completed with data from a nearby - 200 m - hand-drilled well). Rapidly infiltrating and occasionally quickly rising ground water posed a problem in several of these excavations, causing their almost immediate collapse. A sludge pump (generously provided by Mr. K. Kerres, Raeren) proved to be very useful in solving the problem temporarily. All sections were sampled from bottom to top (except for the Quaternary overburden), each sample covering an interval of 30 to 50 cm, or less in case lithological changes were observed. Subsequently, the samples were washed and sieved. The sieve fraction 0.125-1.0 mm was examined for microfossils, fraction 1.0-2.4 mm for bioclasts, and fraction over 2.4 mm for macrofossils and lithology of rock fragments.

3.- LITHOLOGY

The residual Late Cretaceous deposits in the Hautes Fagnes area are completely decalcified. The matrix of residual loam consists of varying amounts of sand, silt, clay and silicified chalk grains. A poorly sorted basal conglomerate with usually poorly rounded pebbles of quartz, quartzite or phyllite (up to 18 cm in diameter) occurs in nearly all sections, with the exception of

Cronchamps and Neu-Hattlich, where the base of the Late Cretaceous was not reached. The local (Cambro-Ordovician) basement rock is the source of these pebbles.

Normally, the basal conglomerate is capped by a more fine-grained gravel or coarse-grained sand, sometimes associated with flint nodules and/or large silicified chalk remnants. Flint and silicified chalk of varying shape (nodular, plate-like, «cavernous», «paramoudra»), size (a few mm up to 50 cm), colour (whitish, grey, brownish or black) and transparency (glassy-translucent to granular-opaque) are common to abundant in the higher parts of the sections. The silicified chalk remnants indicate that the original deposit (presumably with the exception of the basal conglomeratic/glauconitic layers) was a relatively pure chalk, with a similar admixture of insoluble residue as observed, for example, in the Maastricht/Aachen/Liège area to the north (5 to 15 % IR).

Dark green or brownish glauconite grains are common to abundant in the basal portion of the sections, notably immediately above (but sometimes mixed with) the basal conglomerate. Phosphate grains, nodules, thin plate-like lenses and phosphatised fossils are common to abundant in the lower, glauconitic portion of the Beleu section. No flint, silicified chalk or silicified fossils were found in that part of the section, this in contrast to the upper part of the Beleu section and all other sections.

The lithologic succession of basal conglomerate, gravel/coarse sand with glauconite (and phosphate in the Beleu section), silicified chalk/flint has no stratigraphic significance as will be indicated below. It rather reflects similar changes in the depositional environment, due to increasing distance to the shoreline, coinciding with decreasing water energy and increasing water depth.

4.- FOSSIL ASSEMBLAGES

Five different categories of fossil assemblages were studied:

- Microfossils : silicified forams, ostracodes and sponge spicules.
- Bioclasts : 1.0-2.4 mm large, silicified or (only in the Beleu section) phosphatised fragments of bryozoans, sponges, bivalves, brachiopods, echinoderms, cirripedes, faecal pellets (only recognised in lower part of Beleu section) and fish teeth and bones.
- Fish teeth and bones (only recognised in lower part of the Beleu section) in fraction over 2.4 mm.
- phosphatised macrofossils: sponges, corals, cephalopods, bivalves, gastropods, brachiopods, echinoderms (all only recognised in lower part of the Beleu section).
- External and internal moulds in eluvial flint (mainly bivalves, brachiopods, echinoids and bryozoans).

Their significance in interpreting the stratigraphy and/or paleoecology of the residual Late Cretaceous deposits is briefly discussed below.

4.1.- MICROFOSSILS - FORAMS

Silicified forams were observed in 58 of the 67 samples studied for the present report. Frequently, very rich and diverse assemblages occur. The identification of species follows the systematics proposed by Hofker (1957a, 1957b, 1966), Kaever (1961), Koch (1977) and Schijfsma (1946).

Three species groups are distinguished within the genus *Bolivinoides*: *B.* gr. *decoratus* with 3 or 4 pustules on the last chamber (includes *B. decoratus, B. granulatus* and *B. peterssoni*), *B.* gr. *australis* with 5 or 6 pustules on the last chamber, and *B.* gr. *giganteus* with 7 or 8 pustules on the last chamber. Experience has shown that in the successive *Bolivinoides* assemblages specimens with 3, 4, 5 and 6 pustules respectively on the last chamber predominate. This roughly matches the results of earlier studies on sections elsewhere (Hofker, 1961; Meessen *et al.*, 1978; Robaszynski *et al.*, 1985; Robaszynski & Christensen, 1989) and in the Hautes Fagnes (Bless & Felder, 1989). *B.* gr. *decoratus* with predominantly 3 pustules on the last chamber is frequently associated with *Neoflabellina leptodisca, Globorotalites michelinianus* and *Stensioeina pommerana.* This assemblage characterizes the lower part of Hofker's (1966) foram zone A (early Late Campanian, *conica/senior* to *basiplana/spiniger* Zones).

B. gr. *decoratus* with predominantly 4 pustules on the last chamber usually occurs together with *N. leptodisca, G. hiltermanni, S. pommerana* and occasionally with *G. michelinianus* and/or *Eponides beisseli.* This assemblage characterizes the upper part of Hofker's (1966) foram zone A (late Late Campanian, *polyplocum/minor* to *grimmensis/granulosus?* Zones).

The middle part of Hofker's foram zone A (*roemeri* Zone), in which there is a near-equal number of specimens of *B.* gr. *decoratus* with 3 or with 4 pustules on the last chamber, seems to be absent in the Hautes Fagnes sections. This gap coincides with the change in lithology at 1.6 m in the Hockai section (fig. 7).

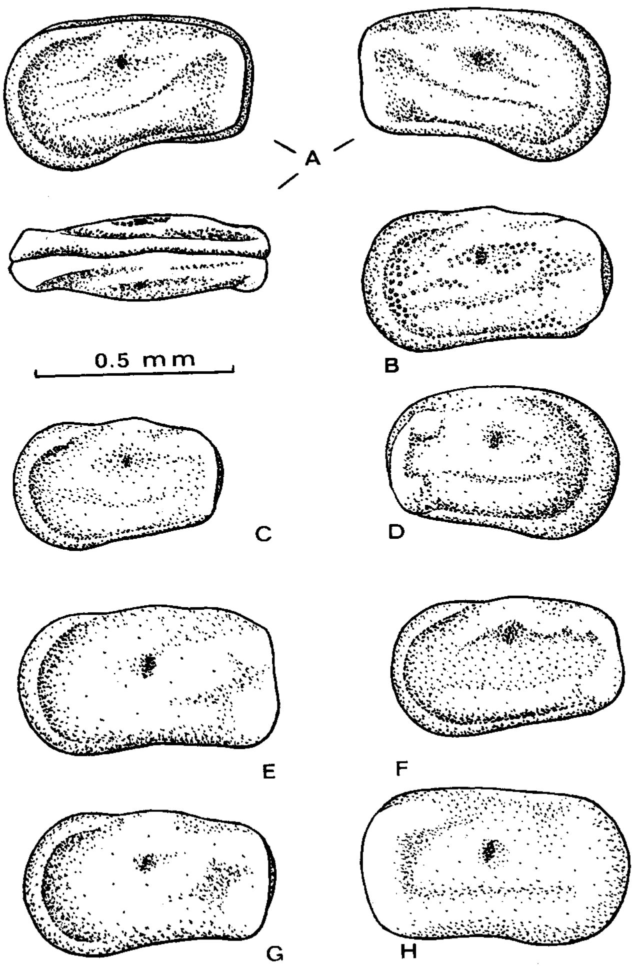

Figure 2.- Representatives of ostracode genus *Cytherelloidea* from Late Campanian strata in Hautes Fagnes area.

A: *C. auricularis* (Bosquet), Trois Hêtres, 0.50-0.85 m; B: *C.* cf. *tricostata* Joergensen, Baronheid-2, 0.0-0.50 m; C-D: *C. obliquirugata* (Jones & Hinde), Baronheid-3, 0.30-0.80 m and Trois Hêtres, 1.35-1.85 m; E, G-H: *C. levigata* Herrig, Hockai, resp., 2.6-3.6 m, 1.5-1.6 m and 1.0-1.5 m;
F: *C.* cf. *circumvallata* Bonnema, Hockai, 1.5-1.6 m.

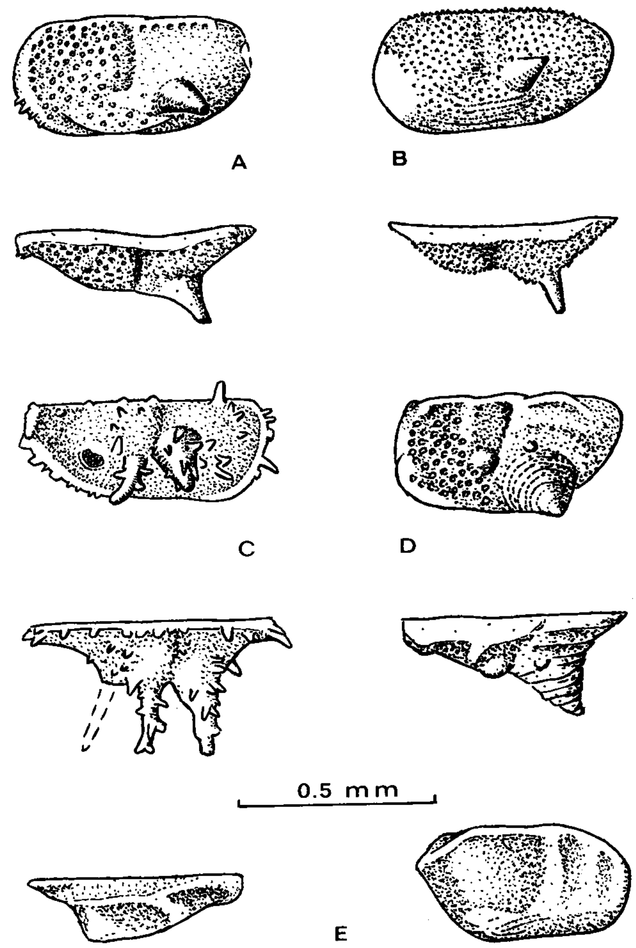

Figure 3.- Representatives of ostracode genus *Bythoceratina* from glauconite-bearing deposits in Hautes Fagnes area.

A: *B.* cf. *umbonatoides* (Kaye), early Late Maastrichtian, Neu-Hattlich; B: *B. bonnemai* Deroo, late Late Campanian, Hockai, 2.6-3.6 m; C: *B. tricuspidata* (Jones & Hinde), early Late Campanian, Baronheid-3, 0.30-0.80 m; D: *B. slavantensis* (Veen), early Late Campanian, Hockai, 1.0-1.5 m; E: *B. compressa* (Veen), early Late Campanian, Baronheid-3, 0.30-0.80.

Comparable Late Campanian foram assemblages have been reported from the early Late Campanian Craie d'Obourg and Craie de Nouvelles and from the late Late Campanian Craie de Spiennes of the Mons area in SW Belgium (Robaszynski & Christensen, 1989).

B. gr. *australis* with prevailingly 5 pustules on the last chamber occurs along with *N. reticulata, E. beisseli* and *S. pommerana.* This assemblage characterizes Hofker's (1966) foram zone C (earliest Late Maastrichtian, *tegulatus/junior* Zone). *B.* gr. *australis* with predominantly 6 pustules on the last chamber commonly occurs together with *N. reticulata* and *E. beisseli,* whereas *S. pommerana* is absent. This assemblage is tentatively correlated with Hofker's (1966) foram zone E (early Late Maastrichtian, *tegulatus/ junior* to *argentea/junior?* Zones).

Low numbers of *B.* gr. *giganteus* are frequently associated with *B.* gr. *australis.* However, they never become dominant. Therefore, it is assumed that the middle Late Maastrichtian (Hofker's 1966 foram zones F-J) is not represented in the studied sections.

Early Campanian forams were recognized in the glauconitic gravel at Cronchamps (*Spirophthalmidium cretaceum* associated with *S. pommerana*) and in the basal conglomerate at Hockai (*Ataxophragmium crassum*). Early Maastrichtian foram assemblages were not recognized. This suggests a sedimentary gap between the Late Campanian and Late Maastrichtian, comparable to that in e.g. the Halembaye section at Haccourt (cf. Jagt, 1988).

Remarkable is the frequent occurrence of *Cymbalopora radiata* in assemblages with *B.* gr.

decoratus and *N. leptodisca*. Schijfsma (1946) already reported this species from the Upper Hervian (= Late Campanian) in the SE Netherlands. Hofker (1957a), however, assumed this species to be restricted to the Late Maastrichtian foram zones J to M.

4.2.- MICROFOSSILS - OSTRACODES

Rich and diverse ostracode assemblages are frequently associated with the forams (compare also Bless & Felder, 1989). However, they have only limited stratigraphic significance. Remarkable, however, is the frequency and diversity of the genus *Cytherelloidea* (fig. 2) in samples with Late Campanian foram assemblages. The same phenomenon is observed in the Late Campanian Zeven Wegen Chalk in the Maastricht-Aachen-Liège area (Bless, 1988). Presumably, the frequency and high diversity of this thermophilic genus (Sohn, 1962; Clarke, 1982; Kemper, 1987) reflects a warm-up of the sea water during the Late Campanian (Bless, 1989). According to Kozur (1972), this genus would be most abundant in shallow neritic facies with a depth of less than 35 m.

Another genus with a peculiar distribution pattern in the Hautes Fagnes area is *Bythoceratina*. Several species were found (fig. 3), but only in sponge-bearing and glauconitic samples of the Late Campanian (Baronheid, Hockai) and Late Maastrichtian (Neu-Hattlich). This suggests a preference for nearshore environments, irrespective of their age.

4.3.- SPONGES

Siliceous or phosphatised (only in the lower part of the Beleu section) sponge fragments and isolated spicules, representing a wide variety of lithistid and hyalid taxa, abound in the lower portions of the various sections, notably in the glauconitic sediments and immediately overlying strata, irrespective of their age. Presumably, the predominantly lithistid sponges preferred shallow (high-energy) nearshore environments. In this respect, it should be noted that sponges also abound in the presumably shallow nearshore limestones and chalk of the Late Maastrichtian Kunrade lithofacies in the SE Netherlands (Felder & Bless, 1989).

4.4.- BIOCLASTS

Silicified or phosphatised (only in the lower part of the Beleu section) bioclasts were studied in the 1.0-2.4-m sieve fraction only. With few exceptions these are restricted to the lower conglomeratic or glauconitic portion of the various sections. Fragments of bivalves, bryozoans and sponges predominate in the silicified bioclast assemblage. Faecal pellets and fish teeth and bones abound in the phosphatic lower portion of the Beleu section.

In the upper (flint-bearing) part of the various sections, silicified bioclasts are generally rare or even absent. However, the frequent presence of occasionally large numbers of internal and external moulds of molluscs, echinoderms and bryozoans emphasizes that this peculiar distribution may have been influenced by differential fossilisation processes (silicification, phosphatisation, decalcification).

4.5.- A PHOSPHATISED MACROFAUNULE FROM THE BELEU SECTION

The first record of phosphatised macrofossils from the Beleu section was published by Bourguignon (1956), who mentioned the presence of, among other taxa, *Baculites vertebralis* and «*Galerites*» *sulcatoradiatus* in the glauconitic sand between the basal conglomerate and the flint-bearing loam at the top.

For the present study, a phosphatised macrofaunule of more than 200 specimens was collected from the 0.35-0.80 m interval (Table 1, Plates 1-2). It comprises phosphatised internal moulds of nuculid, pectinid and other bivalves, rhynchonellid and terebratulid brachiopods, baculitid ammonites, a nautiloid, trochid and other gastropods, and remains of belemnites, sponges, bryozoans, echinoids and solitary corals. Some of these groups are briefly discussed below.

4.5.1.- Solitary corals

These belong without doubt to the genus *Parasmilia* (Pl. 2 : A), and possibly to the species *P. excavata* (von Hagenow), which is known to occur in the Vijlen and Lixhe-1 Members of the Gulpen Formation (late Early to early Late Maastrichtian) in the Maastricht-Aachen-Liège area.

4.5.2.- Belemnites

The material includes a number of well-preserved moulds of alveoli and some fragmentary guards, all of which are honeycombed by *Entobia*, a clionid sponge boring. These specimens must unfortunately remain indeterminate, but are referable either to *Belemnitella* or *Belemnella*.

4.5.3.- Baculitid ammonites

Internal moulds of phragmocones and body chambers were found, which are all referred to *Baculites vertebralis* Lamarck (syn.: *B. faujasi* Lamarck). The better preserved specimens (Pl. 1 : A-Q) show the form to be medium sized, slowly

Table 1.- Phosphatised macrofaunule from Beleu

Fossil group	Number of specimens
belemnites	
- fragments of guard	18
- moulds of alveoli	24
sponges and bryozoans	88
bivalves	
- nuculid	2
- pectinid	1
- indeterminate	6
brachiopods	
- *Cretirhynchia* gr. *limbata*	1
- *Cretirhynchia* cf. *retracta*	2
- *Cretirhynchia* sp.	1
- *Carneithyris* gr. *carnea/subcardinalis*	10
baculitid ammonites (*Baculites vertebralis*)	15
gastropods	
- trochid	3
- ? aporrhaid	1
- indeterminate	3
nautiloids (*Eutrephoceras* sp.)	1
solitary corals (*Parasmilia* cf. *excavata*)	2
echinoids	
- *Echinocorys* sp.	1
- *'Galerites sulcatoradiatus'* of Bourguignon	1
indeterminate remains	numerous

With the exception of Bourguignon's (1956) *'Galerites sulcatoradiatus'* the macrofaunule tabulated above was obtained by processing half a cubic metre of sediment.

tapering, compressed, with whorl breadth to height ratios of 0.55 to 0.70. Whorl section (Pl. 1 :C, G, M-Q) is oval, with dorsum more broadly rounded than venter. In some specimens, sides are markedly flattened, in others less so. Greatest breadth is at or near mid-flank. Most specimens are smooth, some bear ornament, consisting of weak and strong striae that are most obvious on the venter, which they cross in a broad convexity. They are less obvious on the outer and inner flanks and very faint on the dorsum. In one specimen on the inner flank there is an incipient groove, giving the dorsolateral area an angular appearance. The sutures show deeply incised, narrow, bifid elements and are typical of the genus.

Neither in suture details, whorl profile nor in style of ribbing are there any appreciable differences with material referred to *B. vertebralis* in the literature. Where well documented (see e.g. Kennedy, 1986, 1987; Kennedy *et al.,* 1986; Birkelund, 1979) *B. vertebralis* is an exclusively Late Maastrichtian species. It presumably includes *Baculites* sp. 1 from the base of the (Late Maastrichtian) Valkenburg Member at Cadier en Keer in the SE Netherlands (Kennedy, 1987, Pl. 28, figs 1, 4-6).

4.5.4.- Brachiopods

They belong to groups that are well known from Campanian to Maastrichtian strata throughout western and central Europe. The representatives of the Rhynchonellidae (Cyclothyridinae) comprise at least two (possibly three) species of the genus *Cretirhynchia,* viz. *C.* gr. *limbata* (von Schlottheim), *C.* cf. *retracta* (Roemer) and *C.* sp. *C. limbata* is confined mainly to the Maastrichtian, but there are also records from the Late Campanian (Popiel-Barczyk, 1989; Surlyk, 1982; Johansen & Surlyk, in press). The single specimen of *C.* gr. *limbata* is undoubtedly conspecific with forms occurring in the upper Vijlen and Lixhe, possibly also in the Lanaye (all Late Maastrichtian) in the Maastrichtian type area. These forms correspond to Pettitt's (1950, pl. 2, figs 12a, b; text-fig. 7) large form of *C. limbata* and are of Late Maastrichtian age (Jagt, 1988).

Two specimens in the present collection (Pl. 2 : B-D) are compared with *C. retracta* (possible synonym : *C. triminghamensis* Pettitt), which is widely distributed in the Maastrichtian, but also appears in the Late Campanian of northern Ireland (Wood, 1967).

The Terebratulidae (Carneithyridinae) is represented by a few specimens referable to *Carneithyris* gr. *carnea/subcardinalis* (Pl. 2 : E-F), a group known from the Late Campanian and Maastrichtian (Asgaard, 1975; Steinich, 1965; Surlyk, 1984; Popiel-Barczyk, 1989; Owen, 1987) and widely distributed in the Maastrichtian. Representatives of this group are common especially in the Late Maastrichtian Lanaye Member, and somewhat rarer in the Vijlen Member in the area west of the River Maas (Haccourt, Belgium; ENCI Maastricht, SE Netherlands).

4.6.- FISH REMAINS FROM THE BELEU SECTION

Fish remains (teeth and bones) abound in the glauconitic basal conglomerate and overlying sand (interval -0.30 to 1.30 m) in the Beleu section. Most of the teeth are strongly abraded. However, some of the elasmobranch teeth present characteristics which allow a comparison with well-preserved teeth from the Maastricht-Aachen-Liège area (compare Albers & Weiler, 1964; Van de Geyn, 1937; Herman, 1977; Leriche, 1929). The preliminary list includes the following species.

Centrophoroides appendiculatus (Agassiz) (Pl. 3: B): one abraded tooth fragment. The cusp shows part of the mesial cutting edge without the irregular serration, the distal cutting edge and a part of the apron on the labial face. Only the infundibulum on the lingual face of the root is recognizable (Campanian-Maastrichtian).

Squatina sp., possibly *S. hassei* Leriche (Pl. 3 : D): one abraded cusp with on the lower part of the labial face a remnant of the apron (*S. hassei* is confined to the Maastrichtian).

Heterodontus rugosus (Agassiz) (Pl. 3 : F): one practically complete cusp of an adult specimen, belonging to a tooth in the last anterior row of the upper or lower jaw (Campanian-Maastrichtian).

Palaeohypotodus sp., presumably *P. bronni* (Agassiz) (Pl. 3 : H): two abraded cusps of lateral teeth (only one figured here) with a flat labial and convex lingual face, and with a very broad base (*P. bronni* ranges from the Maastrichtian into the Paleocene).

Pseudocorax affinis (Agassiz) (Pl. 4: B): four abraded cusps showing characteristic triangular outline, of which only the here figured specimen possesses the typical serrated cutting edge (Maastrichtian).

Squalicorax sp., probably *S. pristodontus* (Agassiz) (Pl. 4 : D): one abraded fragment of a cusp showing the serrated cutting edge, possibly representing the top of the medial cutting edge (*S. pristodontus* ranges from the Campanian into the Maastrichtian).

Synechodus lerichei Herman (Pl. 4: F): one abraded fragment of a cusp of a posterior tooth showing the typical vertical folds (cutting edges) (Campanian-Maastrichtian).

Other fish remains comprise *Enchodus* sp., *Pycnodus?* sp., vertebrae and other fragments of bony fishes. This preliminary list matches that of the Late Maastrichtian faunas in the Maastricht-Aachen-Liège area. Further study on the fish remains is being carried out by one of us (J.P.H.R.).

4.7.- EXTERNAL AND INTERNAL MOULDS IN ELUVIAL FLINT

Numerous external and internal moulds of bryozoans, serpulids, belemnites, pectinid, limid, ostreid, placunopsid, bakevellid, spondylid, plicatulid and inoceramid (?) bivalves, craniid brachiopods and holasterid and cidarid echinoids have been recognized in eluvial flints, which were found scattered all over the Hautes Fagnes area above 600 m altitude by A. Petit (Stembert). This assemblage (comprising some 100 specimens) would suggest a correlation with the middle upper Gulpen Formation (early Late Maastrichtian) in the Maastricht-Aachen-Liège area. The assemblage studied does not comprise any taxa that appear to be restricted to the middle and/or Late Maastrichtian (Dhondt & Jagt, 1990).

5.- REMARKS ON THE SECTIONS

5.1.- CRONCHAMPS (fig. 5)

Two holes were dug in meadows 300 and 400 m east of the Chapelle Notre Dame des Neiges at Cronchamps, respectively. In the first one (not figured) only flint-bearing sandy loam (at least 30 cm thick) with abundant sponge spicules was recognized. In the second section (fig. 5), the base of the Late Cretaceous could not be reached because of abundant gravel in the 1.35 m deep hole. The lower gravel-bearing interval (0.0-0.85 m) with some glauconite-rich streaks yielded an Early Campanian foram assemblage (asociated with ostracodes and abundant sponge spicules and sponge remains, as well as some bivalve fragments). The flint-bearing top of the section (0.85-1.15 m) yielded abundant sponge spicules only. By inference, this part of the section was tentatively dated as Late Campanian.

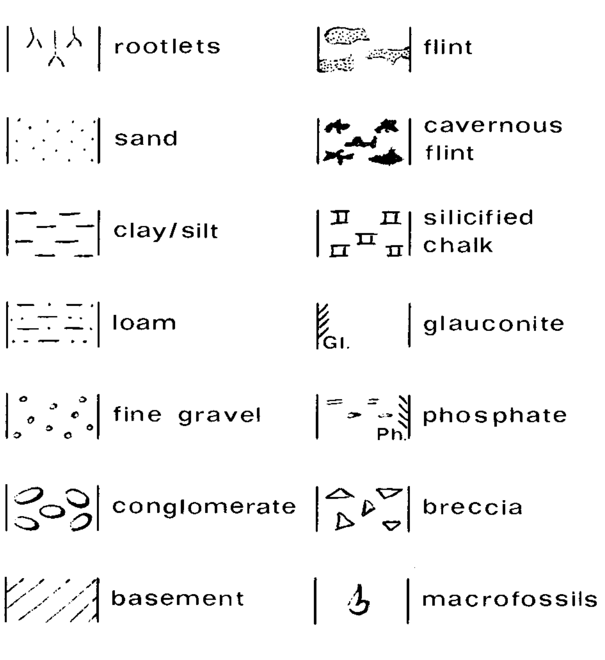

Figure 4.- Legend to figures 5-12.

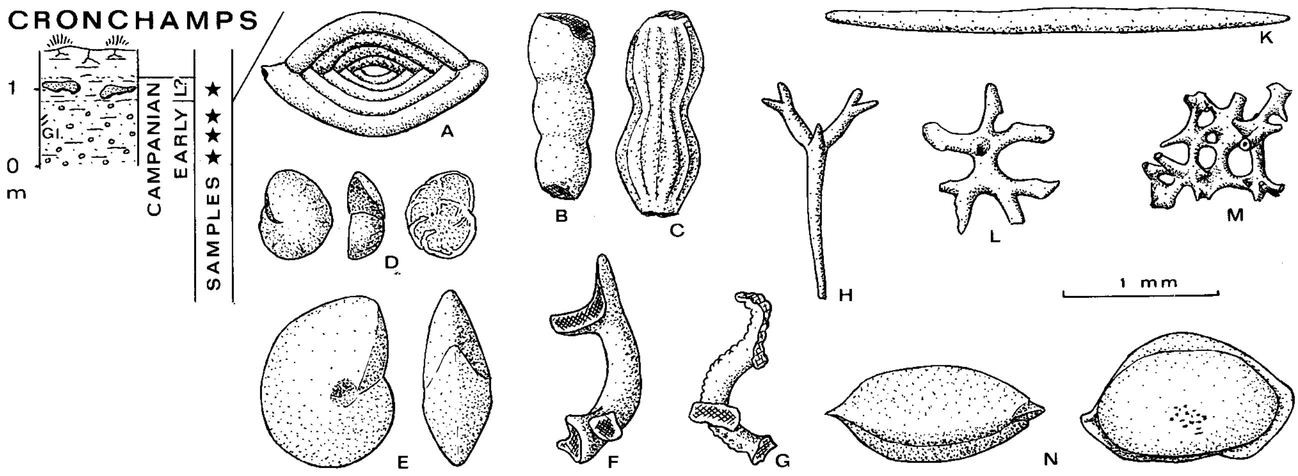

Figure 5.- Lithologic log of the Cronchamps section, its stratigraphic interpretation and selected microfossil contents.
A- *Spirophthalmidium cretaceum* (Reuss); B- *Nodosaria monile* Hagenow; C-*Nodosaria vertebralis* Reuss; D-*Stensioeina pommerana* Brotzen; E-*Lenticulina* sp.; F-M - Sponges spicules; N- Internal mould of *Bairdia* sp.

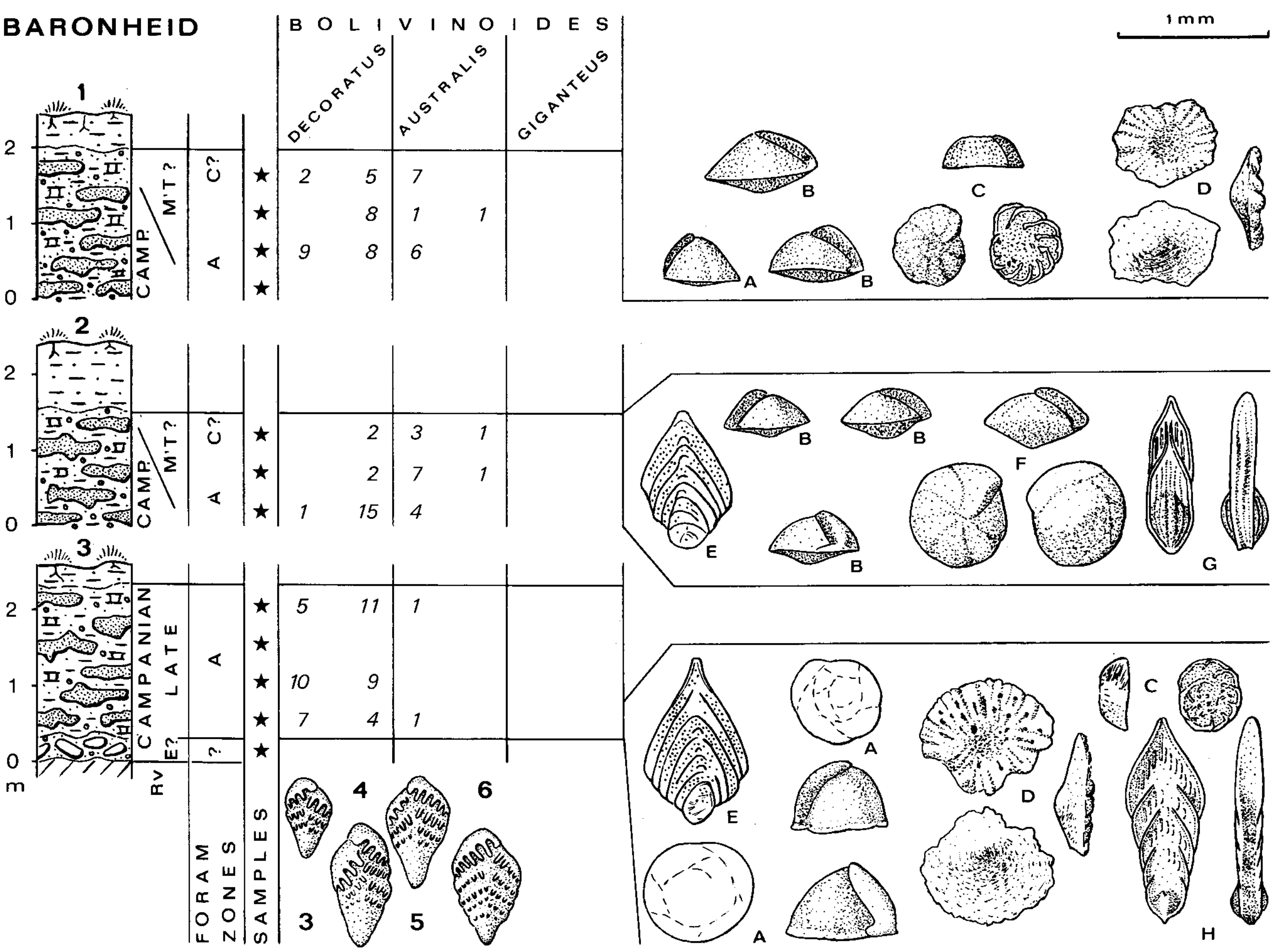

Figure 6.- Lithologic log of the Baronheid sections 1, 2 and 4, their stratigraphic interpretation and selected foram contents.
A- *Globorotalites michelinianus* (d'Orbigny); B- *Globorotalites hiltermanni* Kaever; C- *Stensioeina pommerana* Brotzen; D- *Cymbalopora radiata* (Hagenow); E- *Neoflabellina leptodisca* (Wedekind); F- *Eponides beisseli* Schijfsma; G-H- *Frondicularia* spp.

5.2.- BARONHEID (fig. 6)

Four holes (arranged from north to south at 50 m distance from each other) were made along the SW slip road to the Verviers-Malmédy motorway at Baronheid with the help of a bulldozer. Hole 4 (not figured) revealed strongly weathered Cambro-Ordovician phyllites only. The contact between the Late Cretaceous deposits and the weathered basement was observed in hole 3. Although the only 10 cm-thick basal conglomerate did not yield any fossils, it was tentatively dated as Early Campanian (comparison with Cronchamps and Hockai). The overlying, slightly glauconitic loam with gravel and abundant, very large (up to 50 cm) flint nodules yielded rich and diverse early Late to late Late Campanian foram and ostracode assemblages, associated with abundant sponge spicules and some bivalve fragments. Holes 1 and 2 yielded late Late Campanian foram assemblages, which near the top of the successions may have been mixed with Late Maastrichtian elements. The anomalous associations of *B.* gr. *decoratus and B.* gr. *australis* cannot be explained otherwise.

5.3.- HOCKAI (fig. 7)

For a more detailed description of this section, the reader is referred to Bless & Felder (1989). The lower portion of the basal conglomerate (with up to 18 cm large pebbles of phyllite and quartzite) has yielded an Early Campanian foram assemblage along with a large number (more than 800 fragments/kg) of silicified bivalve fragments. The foram assemblages from the glauconitic interval (1.0-1.6 m) are characteristic of the early Late Campanian, and those from the interval with small (less than 20 cm), black cavernous flints (1.6-3.6 m) of the late Late Campanian. The lithologic change at 3.6 m (onset of large, more granular flints) is marked by the appearance of Late Maastrichtian foram assemblages. The top of the succession (above 8.6 m) is tentatively referred to the Late Maastrichtian foram zone E (predominance of *B.* gr. *australis* with 6 pustules on the last chamber). The rather pronounced boundaries between the various lithofacies containing fossil assemblages of different ages suggest that there are sedimentary gaps between them.

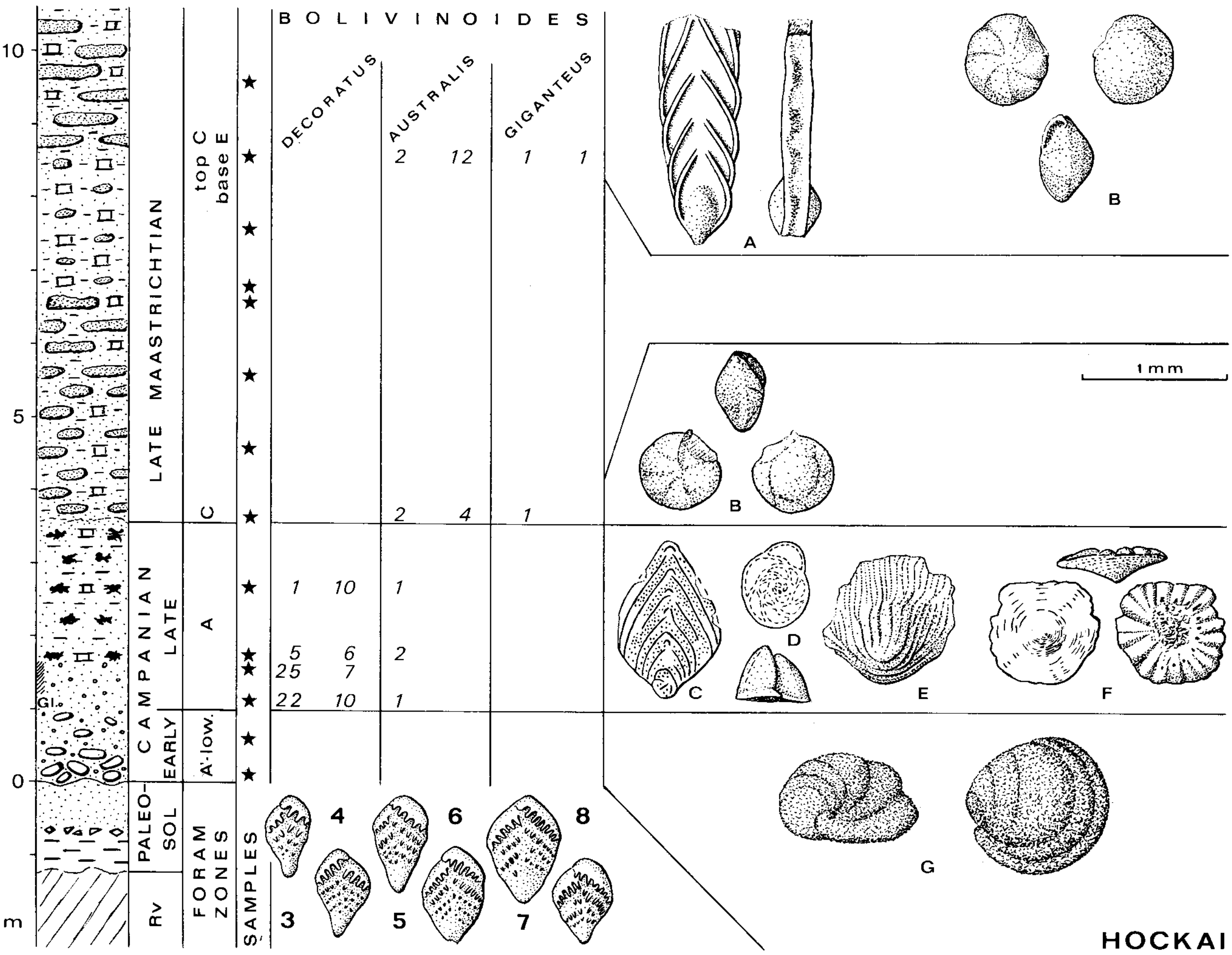

Figure 7.- Lithologic log of the Hockai section, its stratigraphic interpretation and selected foram contents.

A: *Frondicularia ogivalis* Marie; B: *Eponides beisseli* Schijfsma; C: *Neoflabellina leptodisca* (Wedekind); D: *Globorotalites michelinianus* (d'Orbigny); E: *Flabellina radiata* (d'Orbigny); F: *Cymbalopora radiata* (Hagenow); G: *Ataxophragmium crassum* (d'Orbigny).

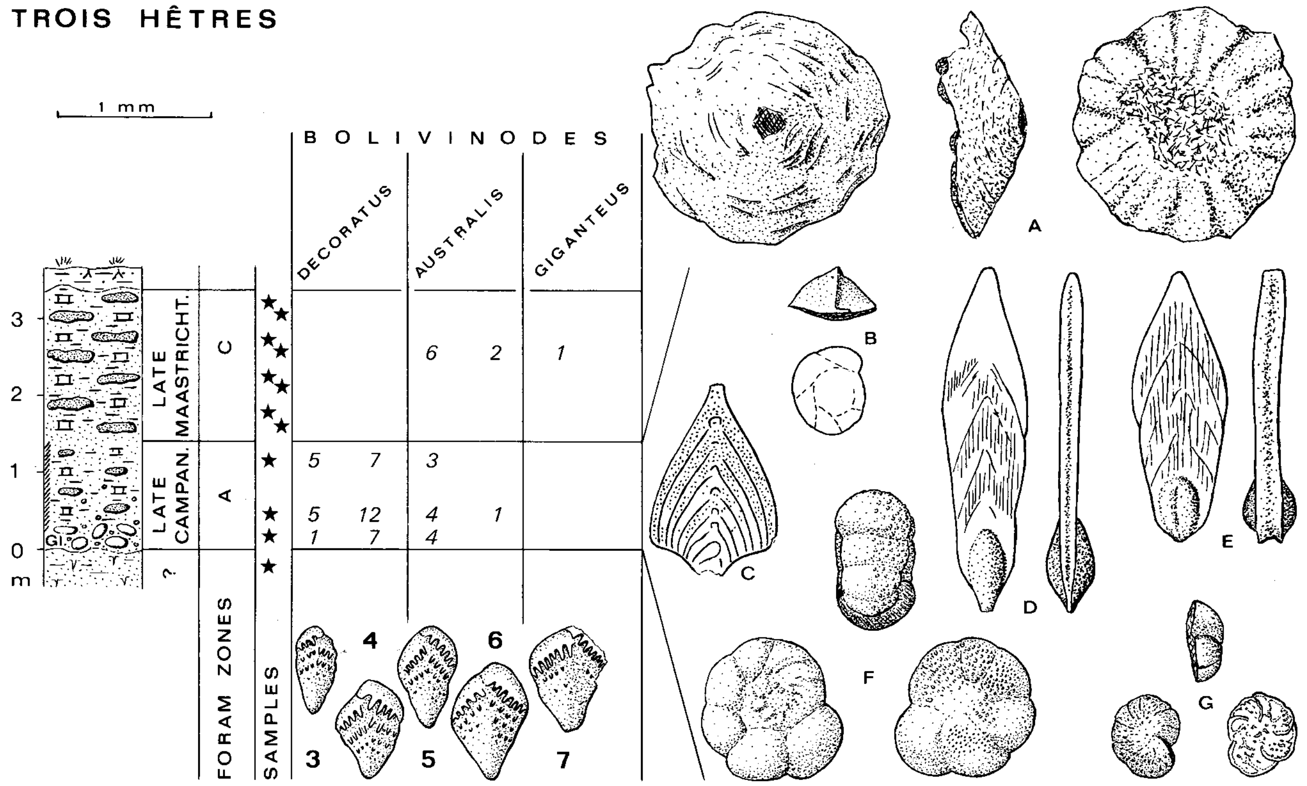

Figure 8.- Lithologic log of the Trois Hêtres section, its stratigraphic interpretation and selected foram contents.

A: *Cymbalopora radiata* (Hagenow); B: *Globorotalites michelinianus* (d'Orbigny); C: *Neoflabellina leptodisca* (Wedekind); D-E: *Frondicularia* spp.; F: *Gavelinella* cf. *lorneiana* (d'Orbigny); G: *Stensioeina pommerana* Brotzen.

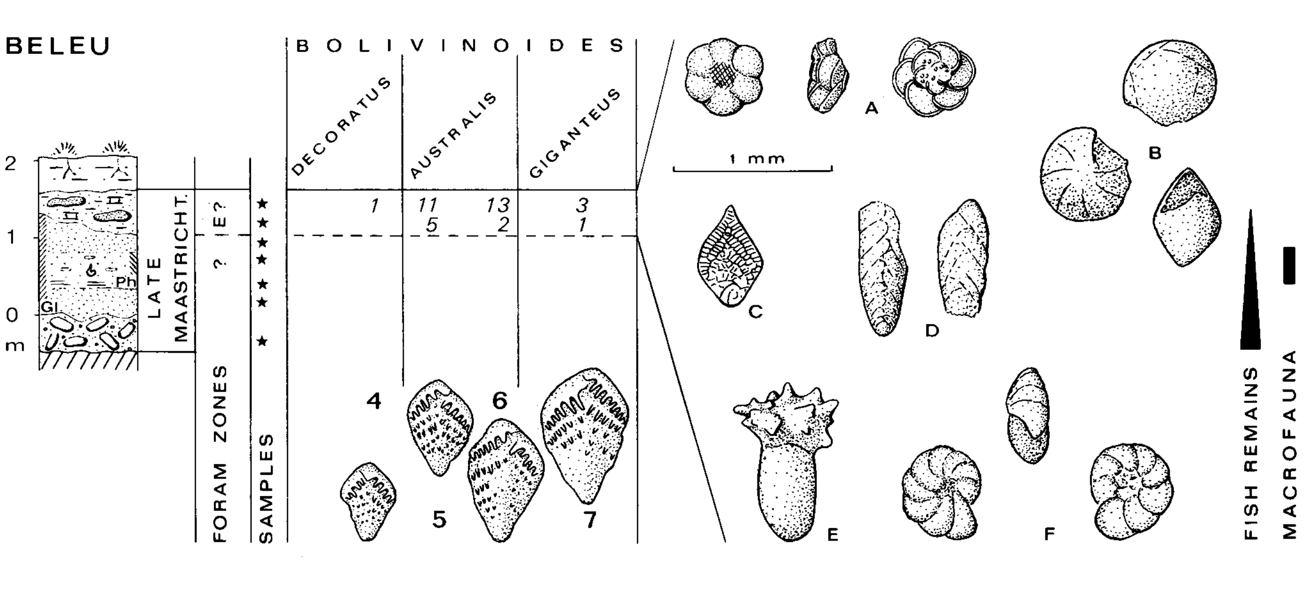

Figure 9.- Lithologic log of the Beleu section, its stratigraphic interpretation and selected foram contents. Bars to the right indicate distribution of phosphatised macrofaunule and fish teeth described herein.

A: *Gobotruncana* sp.; B: *Eponides beisseli* Schijfsma; C: *Neoflabellina reticulata* (Reuss); D: *Bolivina incrassata* Reuss; E: *Globulina* sp. with fistulose chamber; F: *Gavelinopsis* sp.

5.4.- TROIS HETRES (fig. 8)

A hole made with the help of a bulldozer showed a sandy, bioturbated deposit of unknown age overlain by a glauconitic basal conglomerate of Late Cretaceous age. Provisionally, this sandy deposit is considered to be the top of the paleosol which formed on the Cambro-Ordovician basement rock. The basal conglomerate as well as the overlying glauconitic loam with some gravel and small flints (0.0-1.35 m interval) yielded late Late Campanian foram assemblages. Early and early Late Campanian fossils were not recognized in this section. The interval between 1.35 and 3.35 m with large flints contains several poorly preserved, monotonous foram assemblages (notably with *Gyroidinoides* spp.; compare also the many poor assemblages in the Hockai section). However, one sample at 2.85 m yielded a small Late Maastrichtian assemblage (with *B.* gr. *australis* with predominantly 5 pustules on last chamber). Therefore, the entire 1.35-3.35 m interval is dated as Late Maastrichtian.

5.5.- BELEU (fig. 9)

The locality name is also spelt Baileu or Beaulou. The section is located some 60 m west of the «Vivier Marquet». The more than 30 year old section described by Bourguignon (1956) was restudied (fig. 9). Two additional holes (not figured) were made with the help of a bulldozer at 15 and 25 m distance, respectively. The second hole revealed strongly weathered Cambro-Ordovician phyllites only, whereas the third hole showed an almost identical lithologic succession as the one described by Bourguignon (1956), including phosphate-enriched layers, but most surprisingly, yielded only very few fossils. Thus, on the one hand, the weathered surface of the Cambro-Ordovician basement has a very irregular relief; and on the other hand, the preservation potential of organisms varies considerably even within extremely short distances.

The glauconitic basal conglomerate (with up to 18 cm large, poorly rounded pebbles of phyllite, quartz and quartzite) and overlying glauconitic sand with gravel in the figured section yielded an extremely rich assemblage of faecal pellets and fish teeth and bones, indicative of a Late Maastrichtian age. The phosphatised macrofaunule from the 0.35-0.8 m interval suggests an early Late Maastrichtian age. No forams or ostracodes were discovered in this part of the section. Since the foram assemblages from the flint-bearing loam in the upper part of the succession suggest a correlation with foram zone E, the glauconitic interval is attributed to foram zone C. In this section there is no sign of fossils that are confined to the Early and/or Late Campanian.

Bourguignon (1956) mentioned the irregular echinoid «*Galerites*» *sulcatoradiatus* from this section and on this evidence referred it to the Campanian. In this respect, it should be stressed that Schulz (1985) has pointed out that forms commonly identified as *G. sulcatoradiatus* (Goldfuss) in fact comprise two different species : a Late Campanian one, which he referred to «*Echinogalerus*» *hemisphaericus* (Desor), and a Maas-

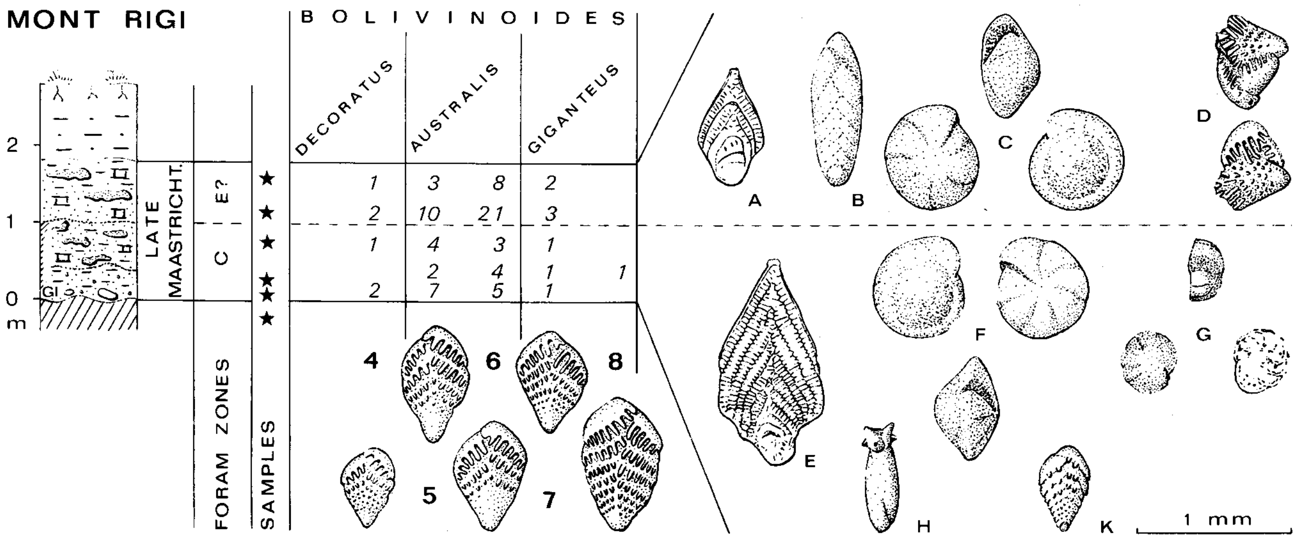

Figure 10.- Lithologic log of the Mont Rigi section, its stratigraphic interpretation and selected foram contents.

A,E: *Neoflabellina reticulata* (Reuss); B: *Bolivina incrassata* Reuss; C,F: *Eponides beisseli* Schijfsma; D: *Bolivinoides* gr. *australis* Edgell, with last chambers grown almost perpendicularly onto earlier ones; G: *Stensioeina pommerana* Brotzen; H: *Globulina?* sp. with fistulose chamber; K: *Bolivinoides paleocenicus* (Brotzen).

trichtian one assigned to «*G.*» *sulcatoradiatus*. It is here considered inopportune to base an age assignment on an imperfectly preserved specimen. On the other hand, the balance of evidence (brachiopods and baculitid cephalopods in particular; cf. chapter 4.5.) suggests that the original age assignment was incorrect.

5.6.- MONT RIGI (fig. 10)

Immediately southwest of the laboratory of the Mont Rigi field station, a hole was made with the help of a bulldozer. The basal conglomerate on top of the weathered phyllites and quartzites of the Cambro-Ordovician basement, as well as the overlying glauconitic interval of loam with some gravel and small flints, respectively, yielded early Late Maastrichtian foram assemblages belonging to foram zone C. The upper portion of the succession (1.0-1.8 m) yielded foram assemblages which are tentatively referred to foram zone E. No Early or Late Campanian microfossils were noted in this section.

5.7.- NEU-HATTLICH (fig. 11)

At the western border of the nature reserve of the «Tourbière royale» or Brackvenn, an almost 5 m deep hole was made with the help of a bulldozer. Moreover, at some 200 m and 250 m distance, two hand-drilled holes, each about 50 cm in depth, were made. The 5 m deep hole did not reach the base of the Late Cretaceous. The 4.3 m thick succession only yielded Late Maatrichtian foram assemblages tentatively placed in foram zone E. The shallow hand-drilled hole at about 200 m to the west yielded a glauconitic, flint-bearing loam with a rich and diverse assemblage of forams, ostracodes, sponge spicules and some bryozoan fragments, pointing to the Late Maastrichtian foram zone C. Because of the many flints, the base of the Cretaceous could not be penetrated. The second borehole revealed weathered Cambro-Ordovician basement only. The occurrence of Late Cretaceous flints at this locality had already been observed by Holzapfel (1907).

6.- CORRELATION OF SECTIONS

Figure 12 presents a synoptical comparison of the bio-/lithostratigraphy and depositional environment of the Late Cretaceous strata in the various sections, arranged from the SW to the NE, as well as some of the most relevant paleontological information collected from them (with the exception of the fish remains and phosphatised fossils at Beleu). Despite the important lateral changes in the lithofacies, five ecozones (I to V in left-hand column on figure 12) are readily distinguished, each of them characterized by a specific foram assemblage. Presumably, the

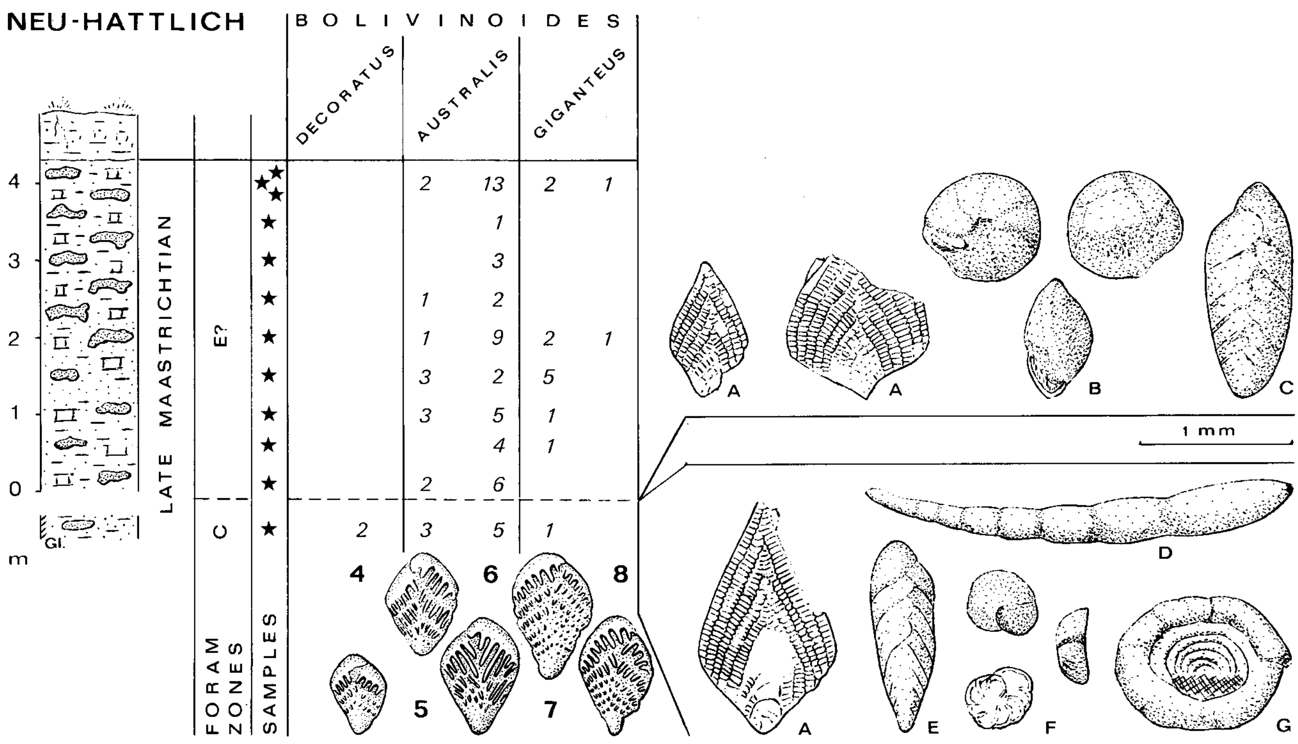

Figure 11.- Lithologic logs of the Neu-Hattlich section, its stratigraphic interpretation and selected foram contents.

A: *Neoflabellina reticulata* (Reuss); B: *Eponides beisseli* Schijfsma; C: *Bolivina incrassata gigantea* Wicher; D: *Nodosaria filiformis* Reuss; E: *Bolivina incrassata* Reuss; F: *Stensioeina pommerana* Brotzen; G: «*Ammodiscus*» sp.

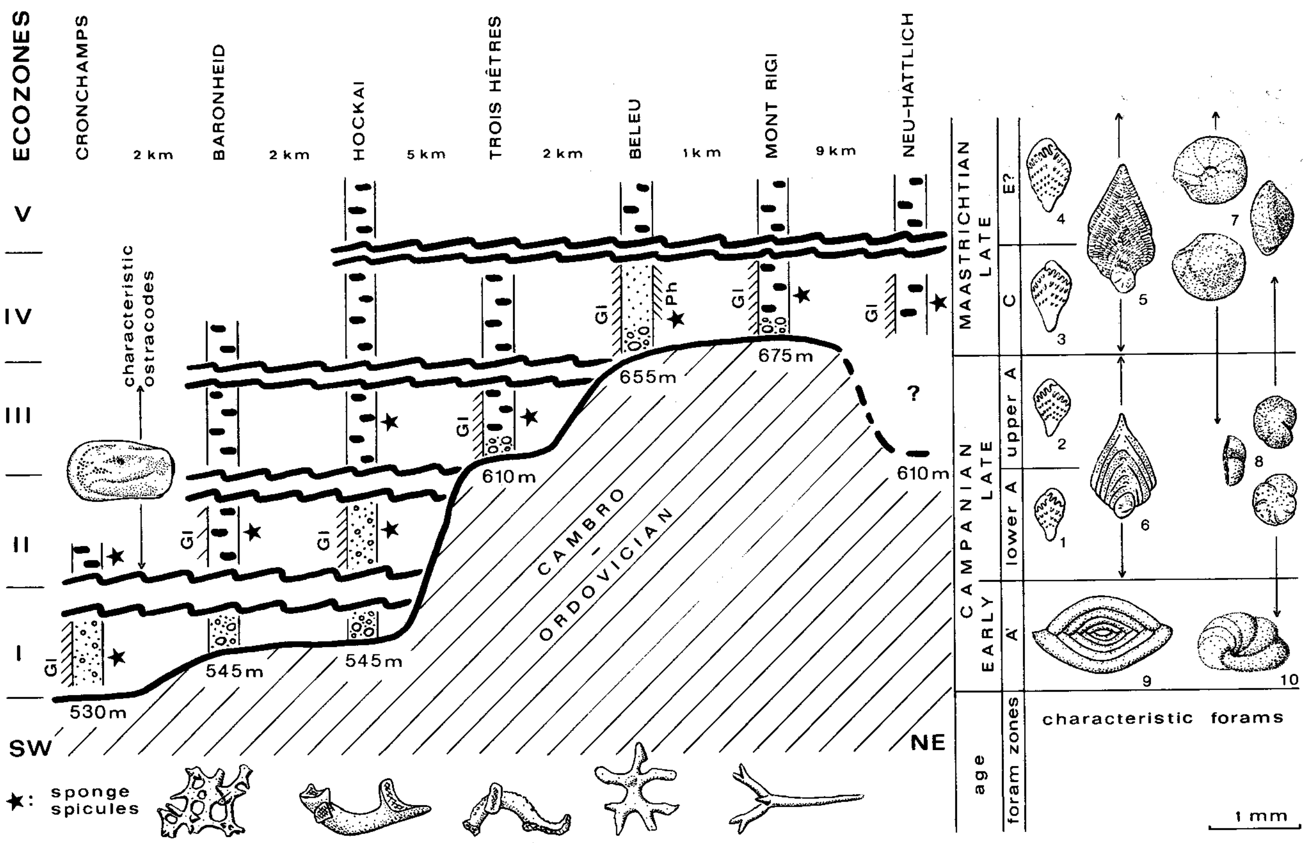

Figure 12.- Synthesis of Late Cretaceous deposits in the Hautes Fagnes area arranged from the SW to the NE (no vertical scale), their stratigraphic interpretation and some characteristic stratigraphic (forams, ostracodes) and paleoecological (sponges) elements. Note close correlation between transgressive trend of successively onlapping Cretaceous deposits and present-day height above sea level (indicated underneath each section) suggesting that actual morphology (at least from the SW to the NE) already existed during the Late Cretaceous.

Characteristic ostracodes : Late Campanian in the Hautes Fagnes is characterized by frequency and diversity of genus *Cytherelloidea*; the same is true for southern Limburg and Campine area. Presumably, this genus indicates a warming phase of the sea water (cf. Bless, 1989).

Characteristic forams : 1: *Bolivinoides* gr. *decoratus* (Jones) with predominantly three pustules on last chamber; 2: *B.* gr. *decoratus* with predominantly four pustules on last chamber; 4: *B.* gr. *australis* with predominantly six pustules on last chamber; 5: *Neoflabellina reticulata* (Reuss); 6: *N. leptodisca* (Wedekind); 7: *Eponides beisseli* Schijfsma; 8: *Stensioeina pommerana* Brotzen; 9: *Spirophthalmidium cretaceum* (Reuss); 10: *Ataxophragmium crassum* (d'Orbigny).

boundaries between these ecozones comprise more or less important sedimentary gaps, reflecting the influence of repeated tectonic activity and/or eustatic sea level fluctuations.

Early Campanian and early Late Campanian strata only occur in the SW (Cronchamps, Baronheid, Hockai) at 530 to 545 m altitude. Late Late Campanian strata were not only recognized at Baronheid and Hockai (at Cronchamps these were presumably removed by erosion), but also at Trois Hêtres, where they start with a basal conglomerate at 610 m altitude. Finally, Late Maastrichtian strata occur almost everywhere (these were presumably eroded in the southwestern section of Cronchamps and partially also at Baronheid), but only at Beleu (655 m altitude) and Mont Rigi (675 m altitude) do they start with a basal conglomerate directly on top of the Cambro-Ordovician basement. Thus, between Cronchamps in the SW and Mont Rigi in the NE, the present-day steplike relief between 530 m and 675 m altitude was inundated step by step by the Late Cretaceous (Campanian-Maastrichtian) sea in such a way that it can be assumed that this part of the actual relief of the Hautes Fagnes, at least from the SW to the NE, already existed some 80 million years ago.

At Neu-Hattlich, in the northeasternmost part of the area, the base of the Late Cretaceous was not reached. However, it seems likely that the sequence there also starts with a basal conglomerate on top of the Cambro-Ordovician basement. If we accept that the present-day relief of the Hautes Fagnes in a SW-NE direction roughly reflects the Late Cretaceous relief some 80 MA ago, then we can assume that the basal conglomerate at Neu-Hattlich (if present) was formed in late Late Campanian time. It should be noted that the altitude of the Neu-Hattlich section matches that of the Trois Hêtres section (610 m), where the lower portion of the succession is of

Late Campanian age. However, even the slightest change in the original inclination of the area would have changed the moment of inundation of that part of the Hautes Fagnes.

All the deposits yielded fossil assemblages characteristic of the Boreal Realm. The relative frequency and diversity of the ostracode genus *Cytherelloidea* in the Late Campanian strata (irrespective of their lithofacies) at Baronheid, Hockai and Trois Hêtres suggest a transitory warm-up of the sea water during that period, similar to the one observed in the Maastricht-Aachen-Liège area (Bless, 1988, 1989).

It should be noted, that the sections of Hockai, Beleu, Mont Rigi and Neu-Hattlich all end somewhere in the early Late Maastrichtian foram zone E. There are no indications whatsoever for the presence of younger strata. The fossil contents of eluvial flints found scattered over the Hautes Fagnes area above 600 m altitude does not comprise any elements which point to a younger deposit either (Dhondt & Jagt, 1990). This remarkable phenomenon will be discussed below.

7.- A LATE CRETACEOUS MONADNOCK

The available data permit the distinction between three main tectonic units during the Late Cretaceous, each of them characterized by its own complex structural-sedimentary history (figs. 13, 14). These are, from north to south, the present-day Rur Valley Graben, which was uplifted because of tectonic inversion during the Late Cretaceous, the block-faulted pre-Late Cretaceous peneplain of the Maastricht-Aachen-Liège area (referred to as the Maastricht peneplain below), and the Hautes Fagnes area.

Before the Late Cretaceous, the Rur Valley Graben was downwarped and filled with Triassic to Early Cretaceous deposits, whereas the Maastricht peneplain and Hautes Fagnes area remained largely outside this sedimentary environment. But at least from the Santonian onwards, the Maastricht peneplain was repeatedly flooded by the sea until the Early Tertiary as testified by the deposits on top of it. However, differential movements of the intensely block-faulted basement produced important differences in the local sedimentary successions (fig. 14; compare also Bless, 1988).

The Hautes Fagnes area apparently was a regional morphologic high to the southeast of the Maastricht peneplain, rising some 100-150 m above it. This explains why the Santonian clays (Hergenrath Clay) and sands (Aachen Sand) only occur around the northwestern base of this high, below, say 350 m altitude (e.g. to the east of Eupen). Further downwarp of the Maastricht peneplain and Hautes Fagnes, or eustatic sea level rise, resulted in the step by step inundation of the Hautes Fagnes high, which acted as a monadnock during the Santonian and Campanian. Only at the onset of the early Late Maastrichtian, was the Hautes Fagnes monadnock completely flooded.

On the other hand, the Rur Valley block was uplifted because of tectonic inversion from at least the Early Campanian onwards, when it started to act as a source for siliciclastics in the immediate neighbourhood area (Bless *et al.*, 1987, 1988). It was only since the beginning of the middle Late Maastrichtian (end of foram zone E/start of foram zone F; Bless *et al.*, 1987), that the Rur Valley block was incorporated in the sedimentary area again.

Most remarkable is the fact that deposition on the Rur Valley block apparently started again at a time when there is no more evidence of sedimentation on the Hautes Fagnes. There, the sedimentary successions end somewhere in the early Late Maastrichtian foram zone E, whereas the fossil assemblages in eluvial flint scattered on top of the Hautes Fagnes above 600 m altitude do not appear to be younger that the early Late Maastrichtian.

This coincidence supports the idea that the Rur Valley block on the one hand and the Hautes Fagnes monadnock on the other acted as the opposite scales of a balance with the complexly faulted Maastricht peneplain somehow in a near-pivot or equilibrium position, inclining then to the south (Campanian to early Late Maastrichtian) and then to the north (middle Late Maastrichtian to Early Tertiary).

8.- PALEOMORPHOLOGY OF THE HAUTES FAGNES

The newly obtained stratigraphical data on the Hautes Fagnes clearly indicate the step by step encroachment onto this area of the Late Cretaceous deposits. This undoubtedly is an indication of the existence of a regional high or monadnock during the Santonian to Maastrichtian.

As far as can be deduced today, the successive steps of the Late Cretaceous transgression were each time stopped along transverse NW-SE running lineaments (fig. 15), which were identified by Demoulin (1988), who proved the post-Oligocene activity of these faults.

The westernmost of these fault lines (A), the Hockai fault zone of Demoulin (1988), comprises the Verviers and Sècheval faults on the northern

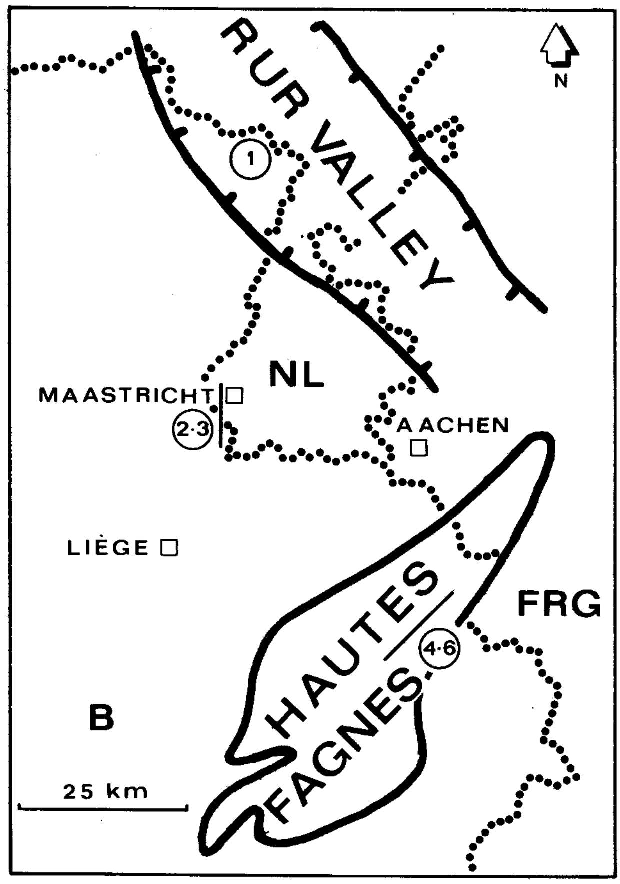

Figure 13.- Principal structural elements during Late Cretaceous (numbers refer to sections shown in figure 14). Sedimentation in the Rur Valley area did not start until the Late Maastrichtian. Deposition in the Maastricht-Aachen-Liège area is marked by differential warping of the block-faulted basement from the Santonian into the Paleocene. The highest part of the Hautes Fagnes area was slowly drowned during the Campanian and Maastrichtian, but uplifted during the latest Maastrichtian.

slope of the Hautes Fagnes and the NW-SE oriented segment of the Hoëgne valley downstream (north) of Hockai before being prolonged in a southeasterly direction towards Malmédy. This fault zone separates the area of Cronchamps, Baronheid and Hockai to the SW (Early to early Late Campanian transgression) from that of Trois Hêtres to the NE (late Late Campanian transgression). It at present corresponds to a c. 40 m high slope east of Hockai.

The second fault zone (B), the Baelen fault zone of Demoulin (1988), runs parallel to the southwestern edge of the summit of the Hautes Fagnes area, which is outlined here by the 640 m contour line. It passes between the Trois Hêtres area to the SW (late Late Campanian transgression) and the Hautes Fagnes summit to the NE (early Late Maastrichtian transgression at Beleu and Mont Rigi). In the present landscape, this fault zone is marked by a c. 40 m high slope.

The new observations on the Late Cretaceous transgression on the Hautes Fagnes presented above allow one to suppose that these faults were already active at the end of the Mesozoic, determining at that time the morphology of the Hautes Fagnes (at least from the SW to the NE), whose flanks progressively decreased in height towards the surrounding pre-Late Cretaceous peneplain. The fault slopes were then responsible for the successive halts of the Late Cretaceous transgression around the Hautes Fagnes monadnock, which remained partially above sea level for a long time.

The rather abrupt lateral facies changes in the Late Cretaceous deposits in this area fit very well with the rapid changes in paleotopography of the at that time already masked faults in the basement rock. It should be borne in mind, however, that the concomitant changes in water depth were only relative and cannot have been very important as will be outlined below.

Most likely, the basal conglomerates represent beach deposits formed in the intertidal zone (0 m water depth). Prior to their formation, the sea level will have been lower than the altitude at which they were deposited. This means that the maximum water depth of, for instance, flint-bearing chalk formed synchronously with these basal conglomerates in more offshore sections must have been less than the present-day difference in altitude between the successive residual deposits, the more so since their thickness has been reduced considerably because of the complete decalcification (chalk originally constituting to 90-95 % of the deposit) of the sediments.

Thus, the water depth for the early Late Campanian flint-bearing chalk in the Baronheid section cannot have exceeded 65 m (not taking into account the thickness of the deposit itself), being the difference between the altitude of the basal conglomerates at Trois Hêtres (610 m) and Baronheid (545 m). Similarly, one can calculate a maximum water depth of only 45 m for the late Late Campanian flint-bearing chalk in the Trois Hêtres section from the difference in altitude of the basal conglomerate at Beleu (655 m) and at Trois Hêtres (610 m).

In principle, these already surprisingly small figures must be further reduced by the original thickness of the deposits and by an unknown factor for at least recent rejuvenation of the fault slopes which is suggested by their freshness.

The existence of a Late Cretaceous residual high or monadnock does not at all contradict Gullentops' (1987) ideas that the Hautes Fagnes area was not uplifted until post-Cretaceous time. Naturally, the Hautes Fagnes constituted a

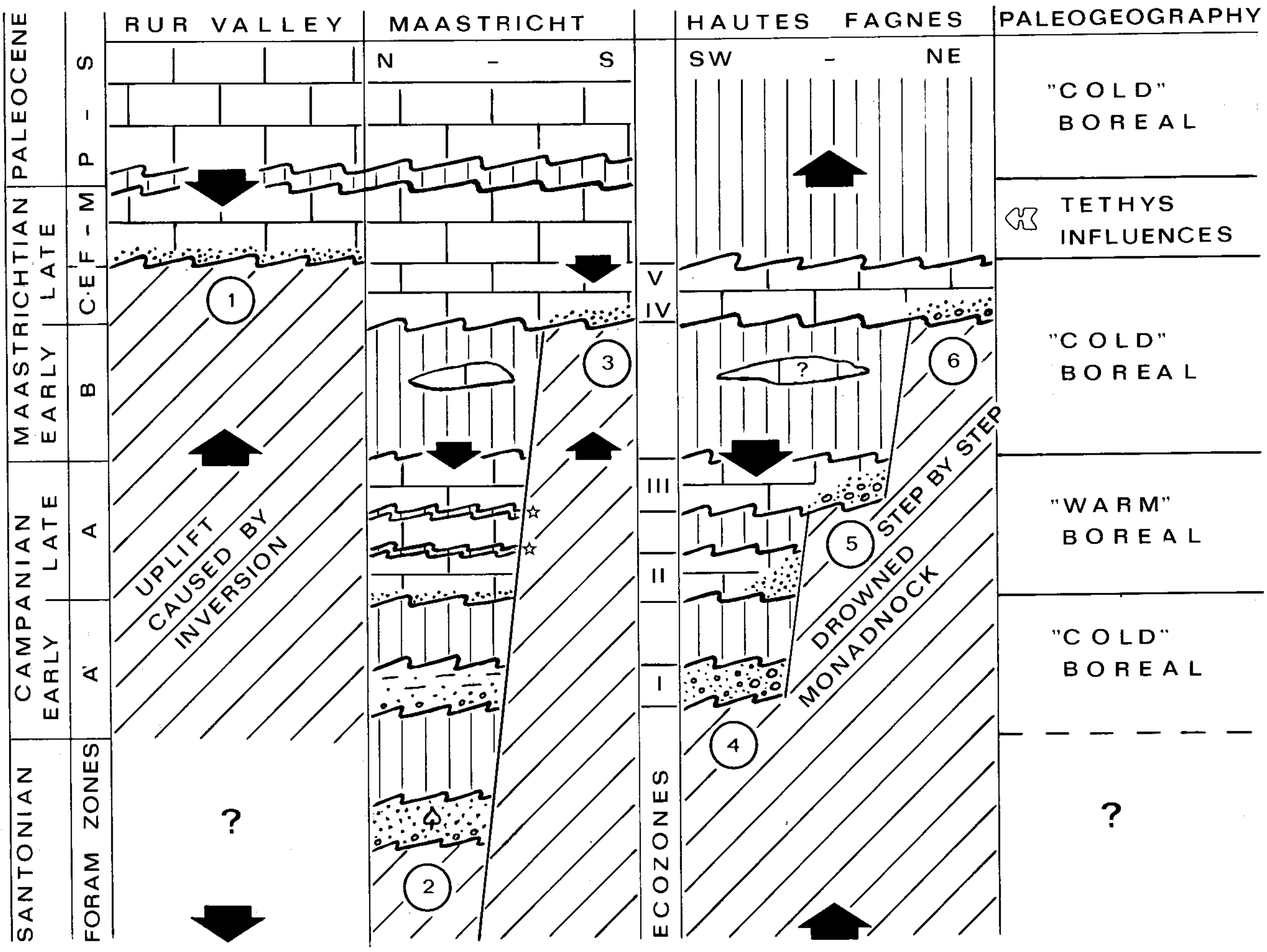

Figure 14.- Depositional history of some selected sections in the Rur Valley Graben, Maastricht and Hautes Fagnes areas. Vertical hatching : sedimentary gaps. Diagonal hatching : pre-Late Cretaceous basement.
Asterisks : presumed hardgrounds indicating minor sedimentary gaps.
1: Molenbeersel borehole; 2: Kastanjelaan borehole/ENCI Quarry; 3: Petit-Lanaye/'s-Gravenvoeren borehole; 4: Cronchamps/Baronheid/Hockai sections; 5: Trois Hêtres section; 6: Beleu/Mont Rigi sections.

monadnock during the Late Cretaceous, which rose above the rest of the pre-Late Cretaceous peneplain (fig. 16). At the same time, it formed an indissoluble (albeit highest) part of the etchplain that included the entire Maastricht peneplain. The Late Cretaceous transgression on this etchplain (fig. 16), which was apparently interrupted several times, cannot be explained by mere eustatic sea level rise. This is best illustrated by the fact that Early Maastrichtian deposits are either very thin (and incomplete) or absent on this etchplain (including the Hautes Fagnes), whereas they are up to 90 m thick in the Antwerp Campine to the NW (Felder *et al.,* 1985; Bless & Felder, 1989). On the other hand, the early Late Maastrichtian foram zone E is practically absent in the Campine area, whereas this interval is represented by up to 35 m thick deposits on the Maastricht peneplain. These examples demonstrate that Late Cretaceous eustatic sea level fluctuations were repeatedly overprinted by regional, differential tectonic movements.

The Hautes Fagnes area formed a monadnock also during the Oligocene transgression on this etchplain, and it was drowned again step by step. Demoulin (1987) argued that the extensive Oligocene sand deposits preserved on the northern slope of the Hautes Fagnes at 500 m altitude correspond to an Oligocene shoreline and thus mark a stage of the transgression that did not invade the higher portions (above 500 m) of the area until later. Frequently, these Oligocene sands rest directly on the Cambro-Ordovician basement (Demoulin, 1987). This indicates that the erosion of the Late Cretaceous deposits on the Hautes Fagnes had been largely completed in pre-Oligocene times. The presence of Oligocene sand on top of the residual Late Cretaceous deposits at e.g. Hockai, Cronchamps and Baraque Michel (Demoulin, 1987) suggests that the decalcification of these sediments also took place during the pre-Oligocene.

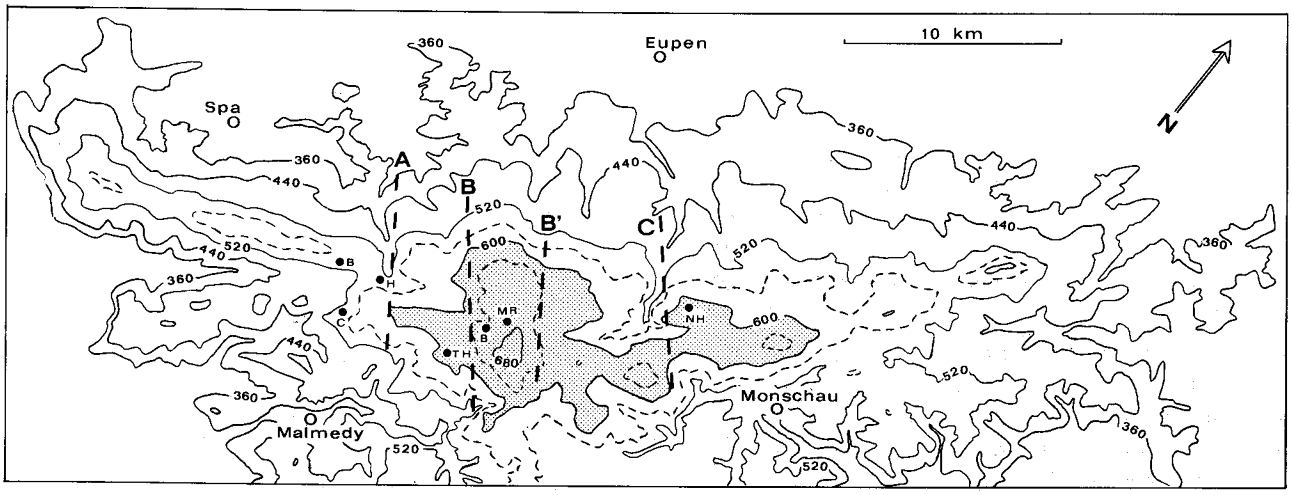

Figure 15.- Contour lines of Hautes Fagnes area and location of Late Cretaceous deposits discussed in this paper. Fat interrupted lines A (Hockai fault zone), B (Baelen fault zone), B' and C indicate position of fault zones identified by Demoulin (1988).

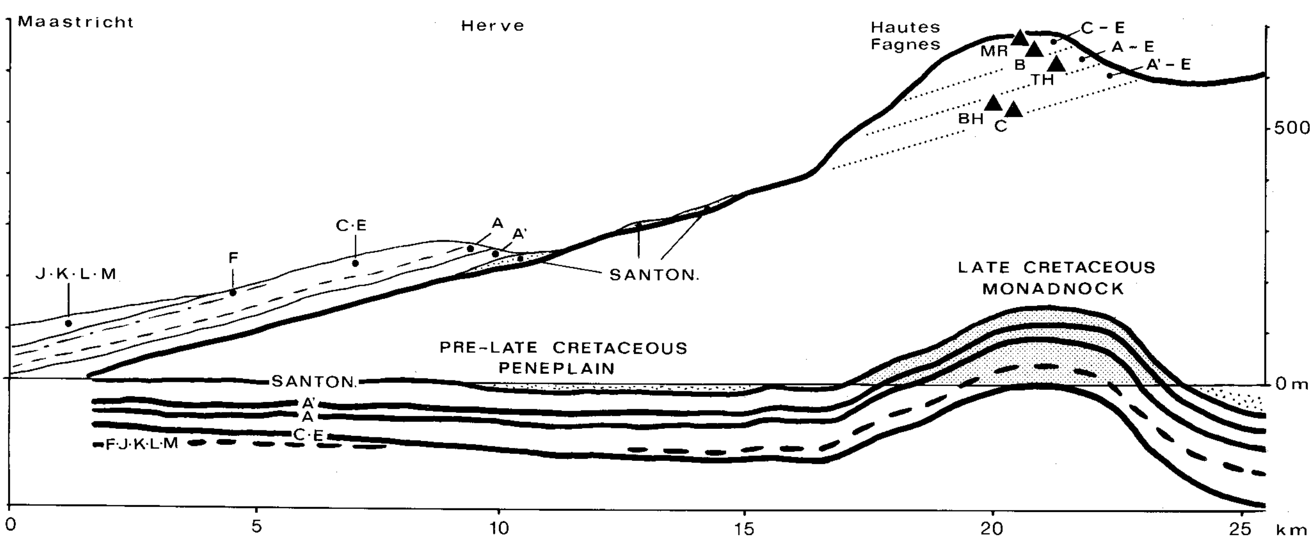

Figure 16.- Relative position of present-day profile of pre-Late Cretaceous basement (fat line, after Gullentops, 1987) between the Maastricht area and Hautes Fagnes during various periods in Late Cretaceous. Age of Campanian-Maastrichtian deposits is shown in terms of foram zones (A'. A, C-E, F, J-K-L-M). Relative position of Late Cretaceous deposits in Hautes Fagnes area is projected onto profile (solid triangles). C: Cronchamps; BH: Baronheid/Hockai; TH: Trois Hêtres; B: Beleu; MR: Mont Rigi.

Consequently, the onset of the final uplift of the etchplain (comprising the Maastricht peneplain and the Hautes Fagnes monadnock) must be dated as Late Oligocene or post-Oligocene. This matches the start of the renewed subsidence of the Rur Valley Graben (Rossa, 1987). However, it is evident that differential upheaval and individualisation of the Hautes Fagnes were maintained up to recent times as is suggested by the freshness of the fault slopes (Demoulin, 1988).

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PLATE 1

Baculites vertebralis Lamarck.

All specimens from the temporary excavation at Beleu, Hautes Fagnes. Collections of the Liège University, Station scientifique Mont Rigi, Hautes Fagnes. Specimens are provisionally numbered as follows :

A-C: specimen 1 (A and B are X3; C is X2.5); D-G: specimen 6 (D-F are X3; G is X3.7); H-M: specimen 7 (H-L are X2.6; M is X5); N: specimen 2 (X4.8); O: specimen 5 (X2.3); P: specimen 4 (X2.7); Q: specimen 3 (X2).

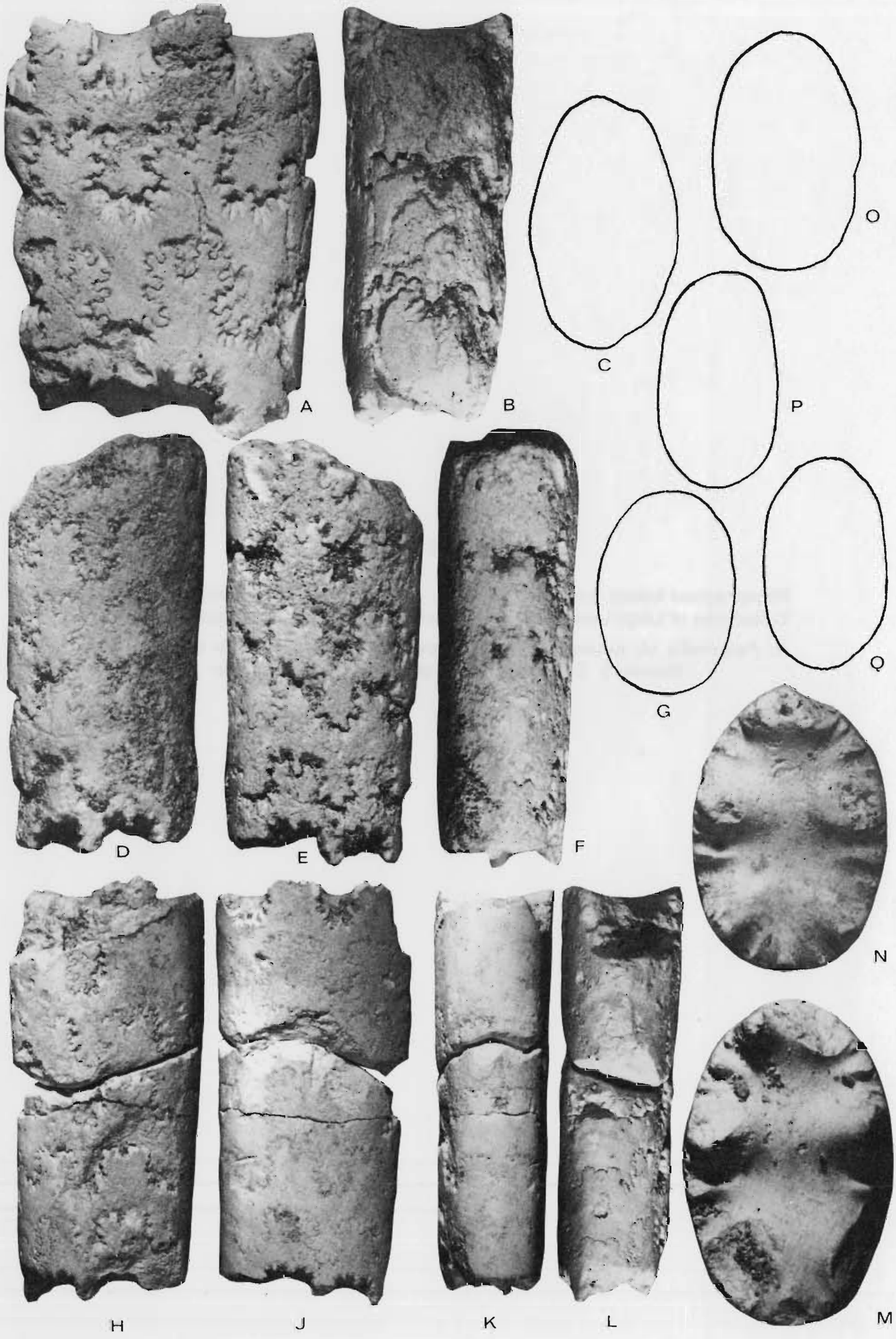
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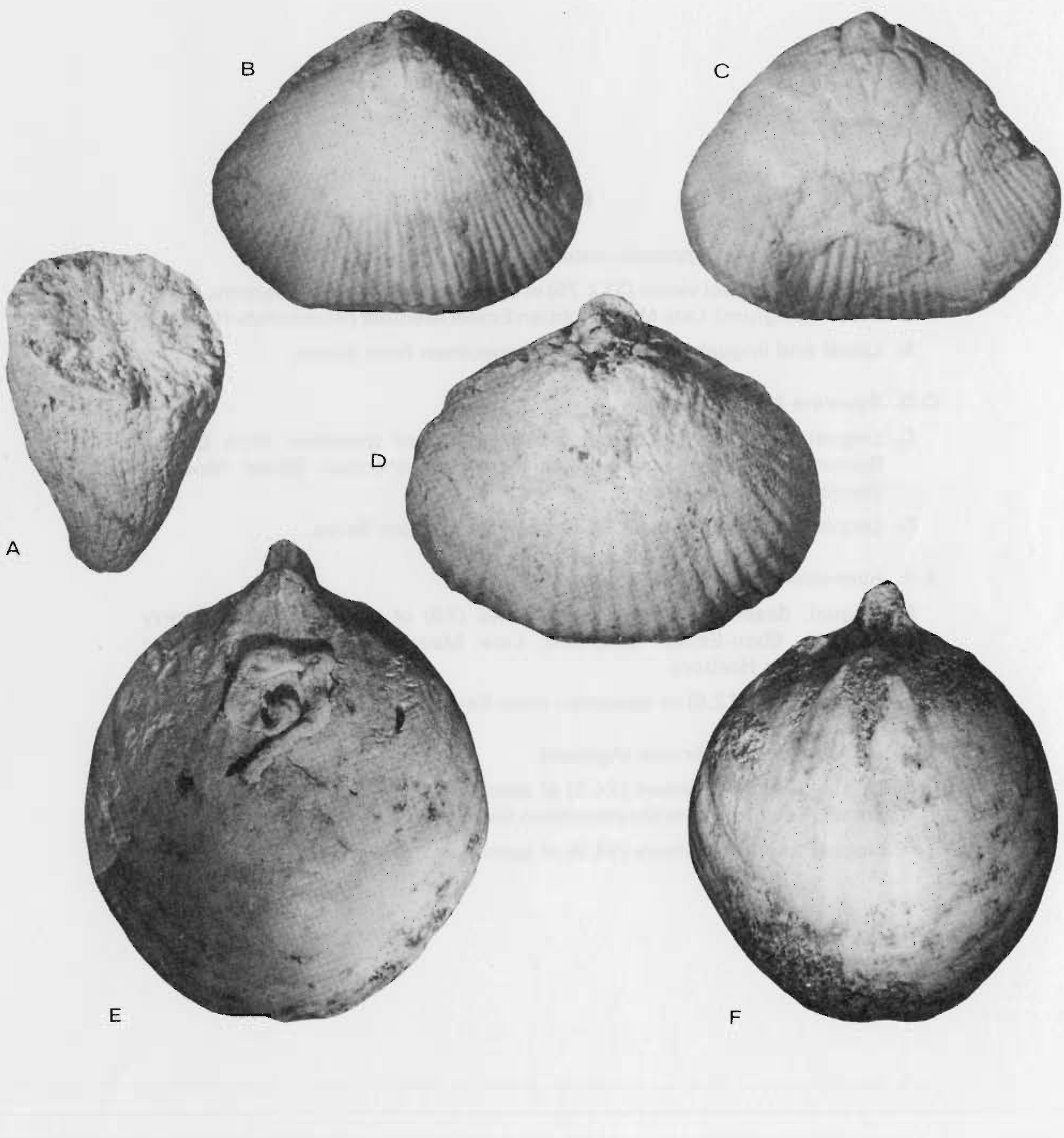
PLATE 2

Phosphatised fossils from the temporary excavation at Beleu, Hautes Fagnes. Collections of Liège University, Station scientifique Mont Rigi, Hautes Fagnes.

A: *Parasmilia* cf. *excavata* (von Hagenow); B-D: *Cretirhynchia* cf. *retracta* (Roemer); E-F: *Carneithyris* gr. *carnea/subcardinalis.*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F

PLATE 3

A-B. *Centrophoroides appendiculatus* (Agassiz)

A. Labial and lingual views (X12.75) of specimen from Quarry Romont, Eben-Emael (Belgium); Late Maastrichtian Emael Member (Romontbos Horizon).

B. Labial and lingual views (X12.2) of specimen from Beleu.

C-D. *Squatina hassei* Leriche

C. Lingual, labial and occursal views (X 3.9) of specimen from Quarry Romont, Eben-Emael (Belgium); Late Maastrichtian Emael Member (Romontbos Horizon).

D. Lingual and distal views (X7.3) of specimen from Beleu.

E-F. *Heterodontus rugosus* (Agassiz)

E. Lingual, basal and labio-mesial views (X8) of specimen from Quarry Romont, Eben-Emael (Belgium); Late Maastrichtian Emael Member (Romontbos Horizon).

F. Labial view (X12.6) of specimen from Beleu.

G-H. *Palaeohypotodus bronni* (Agassiz)

G. Lingual and labial views (X4.1) of specimen from Quarry Romont, Eben-Emael (Belgium); Late Maastrichtian Emael Member (Romontbos Horizon).

H. Lingual and labial views (X4.3) of specimen from Beleu.

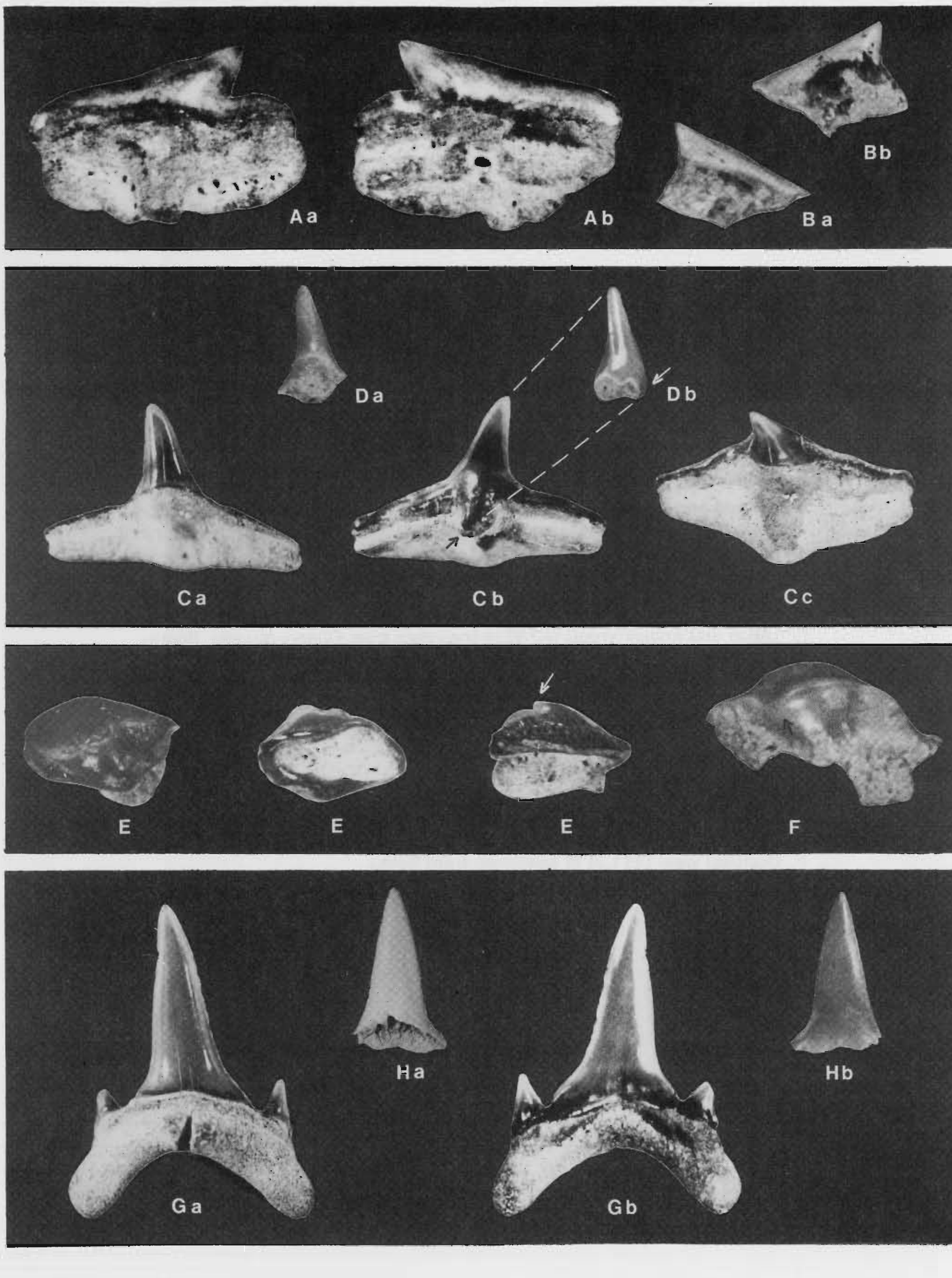
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PLATE 4

A-B. *Pseudocorax affinis* (Agassiz)

A. Lingual and labial views (X4.3) of specimen from Quarry Romont, Eben-Emael (Belgium); Late Maastrichtian Emael Member (Romontbos Horizon).

B. Lingual view (X4.1) of specimen from Beleu.

C-D. *Squalicorax pristodontus* (Agassiz)

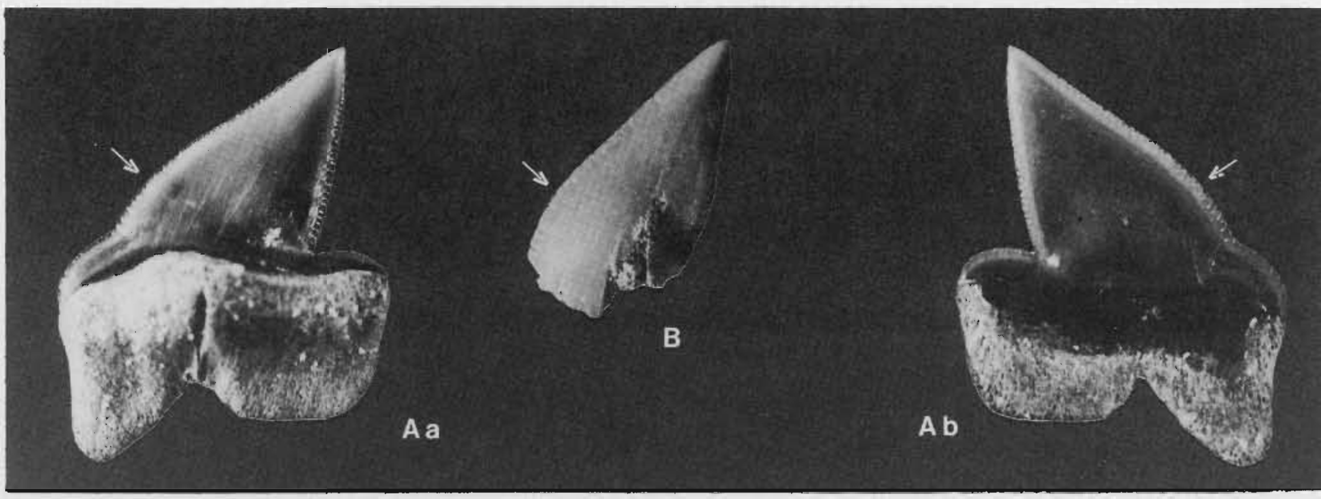
C. Labial and lingual views (X2.6) of specimen from Quarry Nekami, Rooth-Margraten (The Netherlands), Late Maastrichtian Nekum Member (Laumont Horizon).

D. Lingual view (X9.95) of specimen from Beleu.

E-F. *Synechodus lerichei* Herman

E. Lingual and occlusal views (X8.2) of specimen from Quarry Wingerd, Voerendaal (The Netherlands); Late Campanian Benzenrade sandy chalk (2.1 m below top).

F. Occlusal view (X11.3) of specimen from Beleu.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