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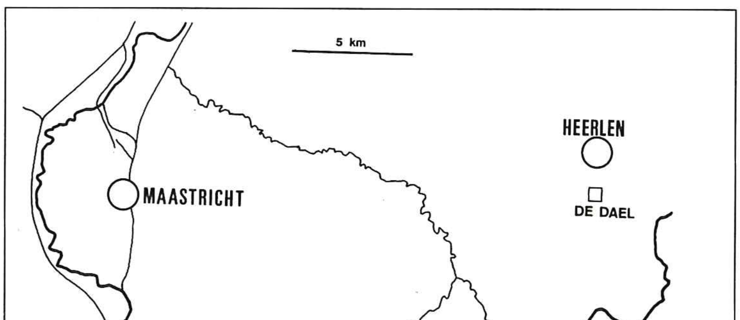

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LATE CAMPANIAN BELEMNITE FAUNAS FROM LIÈGE-LIMBURG (NE BELGIUM, SE NETHERLANDS)*

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[* Contribution no. 3 of the 'Vijlen Groep']

ABSTRACT

Late Campanian belemnite faunas from the Zeven Wegen and Beutenaken members of the Gulpen Formation in Liège-Limburg (NE Belgium, SE Netherlands) include five (sub)species of the genus *Belemnitella* d'Orbigny, 1840, viz. *B. mucronata* (von Schlottheim, 1813), *B. woodi* Christensen, 1995, *B. minor* I Jeletzky, 1951, *B. minor* II Christensen, 1995 and *B. najdini* Kongiel, 1962, which are described herein. CHRISTENSEN's (1995, 1996) concept of *B. minor* is followed, with respect to the holotype. On the basis of these belemnite data more detailed zonal subdivisions of the Zeven Wegen and Beutenaken members are proposed. These allow correlations to be made with Late Campanian strata in Norfolk (SE England) and at Lägerdorf-Kronsmoor (NW Germany). Key taxa amongst echinoids, crinoids, asteroids and ammonites from the Zeven Wegen and Beutenaken members corroborate zonations and correlations based on belemnites.

KEY WORDS

Cretaceous, Campanian, belemnites, paleontology, taxonomy, stratigraphic correlations, Belgium (Limburg, Liège), The Netherlands (Limburg)

RÉSUMÉ

Bélemnites du campanien supérieur de Limbourg et Liège (Belgique et Pays-Bas).
Les du Campanien supérieur des Membres de Zeven Wegen et Beutenaken de la Formation de Gulpen dans le Nord-Est de la Belgique (provinces de Limbourg, Liège) et le Sud-Est des Pays Bas (province de Limbourg) contiennent cinq (sub)speciès du genre *Belemnitella* d'Orbigny, 1840, viz. *B. mucronata* (von Schlottheim, 1813), *B. woodi* Christensen, 1995, *B. minor* I Jeletzky, 1951, *B. minor* II Christensen, 1995 and *B. najdini* Kongiel, 1962. Une révision taxonomique de ces (sub)speciès est proposée. La description paléontologique de *B. minor* suit le concept de CHRISTENSEN (1995, 1996) pour le holotype. L'étude des faunes à bélemnites permet une subdivision plus fine des Membres de Zeven Wegen et Beutenaken, et une corrélation avec les dépôts du Campanien supérieur de Norfolk (SE Angleterre) et de Lägerdorf-Kronsmoor (NW Allemagne). Les zonations et les corrélations des Membres de Zeven Wegen et Beutenaken, basées sur les bélemnites, sont confirmées par les autres fossiles-guides parmi les échinoides, crinoides, astérides et ammonites.

MOTS-CLÉS

Crétacé, Campanien, bélemnites, paléontologie, taxonomie, corrélations stratigraphiques, Belgique (Limbourg, Liège), Pays-Bas (Limburg)

INTRODUCTION

In southern Limburg (The Netherlands) and Limburg-Liège (NE Belgium) (Fig. 1) belemnite species have been shown to be of fundamental importance in correlating Campanian and Maastrichtian strata of different lithofacies (SCHMID, 1967; ROBASZYNSKI *et al.*, 1985; JAGT *et al.*, 1987; KEUTGEN & VAN DER TUUK, 1991; P.J. FELDER & BLESS, 1994; KEUTGEN, 1996). The following Late Campanian species have been recorded previously from this area:

- *Belemnitella mucronata* from the Zeven Wegen Member and the so-called 'Benzenrade Sandy Chalk' (= Benzenrade Member of W.M. FELDER & BOSCH, in press) (see SCHMID, 1959; VAN DER TUUK & BOR, 1980; JAGT, 1984; ROBASZYNSKI *et al.*, 1985; JAGT *et al.*, 1987; JAGT, 1988);
- *Belemnitella 'minor'* from the upper part of the Zeven Wegen Member (ROBASZYNSKI *et al.*, 1985; JAGT, 1988);
- *Belemnitella langei* JELETZKY, 1948 from the upper part of the Zeven Wegen Member (VAN DER TUUK & BOR, 1980);
- *Belemnitella* cf. *najdini* KONGIEL, 1962 from the Beutenaken Member (KEUTGEN & VAN DER TUUK, 1991).

CHRISTENSEN (1995) has recently described in detail late Campanian species of the genus *Belemnitella* from Norfolk. The aim of the present paper is to describe faunas of *Belemnitella* that occur in the late Campanian of Liège-Limburg, on the basis of CHRISTENSEN's species concept. An informal belemnite zonation for the Zeven Wegen and Beutenaken members (*sensu* W.M. FELDER, 1975a, b) and a correlation with sections in Norfolk and NW Germany (Fig. 2) are proposed. Stratigraphic marker species amongst echinoderms (asteroids, crinoids and echinoids) and ammonites are also briefly discussed, since they corroborate zonal subdivisions and correlations based on belemnites.

The authors are both members of the so-called 'Vijlen Groep', a group of professional and amateur palaeontologists and geologists, who agreed to co-operate in order to work out the (bio)stratigraphy of the Zeven Wegen, Beutenaken and Vijlen members of the Gulpen Formation (late Campanian to late Maastrichtian) in detail. So far, seven contributions have already appeared or are currently in press. Details are as follows (see also list of references): no. 1 - Jagt *et al.* (1995); no. 2 - Keutgen (1997); no. 3 - the present paper; no. 4 - Blau *et al.* (1997); no. 5 - P.J. Felder, in press; no. 6 - Jagt, in press b; no. 7 - Jagt *et al.*, in press.

LOCALITIES

The lithology of the Zeven Wegen and Beutenaken members, which together represent the lower portion of the Gulpen Formation (Fig. 3) is briefly discussed here. BLESS *et al.* (1987) distinguished two different lithofacies:

- coarse-grained calcisiltites to fine-grained calcarenites with a few small flints or flint nodules and locally a glauconitic layer at their base, and,
- sandy to silty, glauconitic marls, locally with chalk intercalations, which had previously been referred either to the upper Vaals Formation, the upper Hervian, or to the pre-Valkenburg strata (P.J. FELDER *et al.*, 1985).

1 - southern Limburg (The Netherlands)

A - Pesaken-Crapoel

HOFKER (1966, p. 15, figs 16, 17) was the first to describe the section at Pesaken-Crapoel, which exposes 11 m of Zeven Wegen Member chalk, the lowermost metre of which consists of a glauconitic, sandy chalk ('craie glauconifère), and on top of which rest 10 m of a white, marly calcisiltite, poor in glauconite. Seven belemnite guards, here all assigned to *B. mucronata*, from the 'craie glauconifère' have been studied. No specimens from the upper 10 metres were available.

B - Slenaken

In 1986 and 1987, one of us (NK) collected belemnites in a field northeast of Slenaken, from boulders of the so-called 'Beutenaken Chalk': a yellowish grey, glauconitic calcisiltite with very few, grey flints. Specimens collected are here assigned to *B. minor* II and *B. najdini*.

C - Bovenste Bos quarry

The section exposed at this disused quarry near Epen was described in detail by KEUTGEN & VAN DER TUUK (1991, p. 7, fig. 4) and P.J. FELDER & BLESS (1994, p. 75, fig. 8), but it is now largely covered by scree. Exposed were, in ascending order, the uppermost portion of the Zeven Wegen Member, the Beutenaken Member and the basal portion of the Vijlen Member (Gulpen Formation). One of us (NK) studied the upper two metres of the Beutenaken Member, which here reaches a total thickness of 6.5 m: the 1-2 m interval below the Bovenste Bos Horizon, which defines the boundary between the Beutenaken and Vijlen members, consists of a yellowish grey, coarse-grained, glauconitic calcisiltite, while the 0-1 m interval below this horizon is indurated and represents a chalkstone (*sensu* BROMLEY & GALE, 1982). Belemnites collected from the 2.0-0.7 m interval below the Bovenste Bos Horizon are referred to *B. minor* II and *B. najdini*.

2 - northeast Belgium

A - Ciments Portland Liégeois (CPL) SA quarry, Haccourt

In this largely disused quarry portions of the Vaals and Gulpen formations are exposed, the latter being subdivided into four members (in ascending order: Zeven Wegen, Vijlen, Lixhe 1-3 and Lanaye members) (see ROBASZYNSKI *et al.*, 1985, p. 5, fig. 2). The Beutenaken Member is missing here, which may be explained by synsedimentary tectonics in the area during the late(st) Campanian. For the present paper only the Zeven Wegen Member, 29 m thick and consisting of a white, coarse-grained calcisiltite with a few small to medium-sized black flint nodules, was studied. The lowermost 0.3-0.5 m of this unit is developed as a glauconitic layer (the so-called 'craie glauconifère'). At the top of the member, immediately below the Froidmont Horizon, occurs a well-developed, *c.* 1 m thick chalkstone.

The 0-5 m interval above the base of the member (= Loën Horizon; W.M. FELDER, 1975a) is characterised by *B. mucronata*. No belemnites were available from the 5-10 m interval. The 10-17 m interval yielded early forms of *B. woodi*, while from the 17-28 m interval late forms of the same species were collected. No belemnites from the uppermost metre of the Zeven Wegen Member were available.

B - Teuven

In a road cutting northeast of Teuven (Belgische Geologische Dienst GeoDoc nummer 108E 169), along the road to Heijenrath, the top of the Zeven Wegen and the base of the Beutenaken members was temporarily exposed by removing the thin cover (Keutgen, 1996, pp. 35, 36). In this way, *c.* 1.5 m of Gulpen Formation strata were accessible. The lower 0.5 m of the sediments exposed consists of a light-grey, indurated marly limestone to marly chalk, which W.M. Felder (pers. comm.) assigns to the Zeven Wegen Member. The top of this member is marked by the Slenaken Horizon, which defines the boundary between this and the overlying Beutenaken Member. The sediments assigned to this member consist of a soft, glauconitic, clayey to marly chalk with few, scattered quartz pebbles. These strata have yielded *B. minor* I and *B. najdini*.

TERMINOLOGY AND METHODS

Terminology and methods follow CHRISTENSEN (1995, text-fig. 10), with the shape of guards being measured along the lines proposed by SCHULZ (1982, fig. 1). Abbreviations are as follows:

Bs - lateral diameter halfway between apex and protoconch (in mm)
Bp - lateral diameter at protoconch (in mm)
Bc - lateral diameter at rostrum cavum, ¼ Ls from protoconch (in mm)
Ds - dorsoventral diameter halfway between apex and protoconch (in mm)
Dp - dorsoventral diameter at protoconch (in mm) (corresponds to DVDP of CHRISTENSEN, 1995)
Dc - dorsoventral diameter at rostrum cavum, ¼ Ls from protoconch (in mm)
Ls - length from apex to protoconch (in mm) (corresponds to LAP of CHRISTENSEN, 1995)
BI - Birkelund Index (BI = Ls/Dp) (corresponds to elongation of SCHULZ, 1982 and KEUTGEN & VAN DER TUUK, 1991)
AV - ventral aspect (AV = (Bs-Bc) x 100/Bp in %)
AL - lateral aspect (AL = (Ds-Dc) x 100/Dp in %)
AVs- ventral aspect of rostrum solidum (AVs = (Bs-Bp) x 100/Bp in %)
ALs- lateral aspect of rostrum solidum (ALs = (Ds-Dp) x 100/Dp in %)
SW - Schatzky Distance, the distance in mm between the anterior part of the protoconch and posterior end of the ventral fissure measured along axis of guard (corresponds to SD of CHRISTENSEN, 1995)
AA - alveolar angle, which is dorsoventral angle in degrees between the walls of the alveolus measured in the medium plane between 10 and 20 mm from the protoconch
FA - fissure angle, which is angle in degrees between the walls of the alveolus and the straight line connecting the intersection points of the bottom of the ventral fissure on the wall of the alveolus and the outer margin of the guard.

The range of variation of the various species was analysed using univariate and bivariate statistical methods. The statistical methods and tests used in the present paper are those discussed by CHRISTENSEN (1975, 1995). In the univariate analyses the estimates of the following statistics were calculated: arithmetic mean value, standard deviation (SD), observed range (OR) and number of specimens (N). For samples containing more than 50 specimens regression analyses (regression lines: y = a + bx) were carried out in order to study the relative growth. The estimates of the following statistical parameters were calculated: the slope (b) and the standard deviation of the slope (SD_b), the intercept on the y-axis (a) and the standard deviation of the regression line (SD_{yx}) and the correlation coefficient (r). T-tests on the y-intercepts were performed in order to determine whether the intercept differed significantly from zero. The regression lines of two samples were compared in the way described by HALD (1952).

The following categories are used to characterise the size and relative length of species of *Belemnitella* (compare CHRISTENSEN, 1995):

size - length from apex to protoconch < 55 mm: guard small
- length between 55 and 65 mm: guard large
- length > 65 mm: guard very large

relative length - mean value of BI < 4: guard stout
- mean value of BI 4 to 5: guard slender
- mean value of BI > 5: guard very slender

With the exception of two specimens in the JAGT Collection at the Natuurhistorisch Museum Maastricht (NHMM), all belemnites are in the KEUTGEN Collection (NHMM Keutgen/registration number).

SYSTEMATIC PALAEONTOLOGY

Class Cephalopoda Cuvier, 1794
Subclass Coleoidea Bather, 1888
Order Belemnitida von Zittel, 1895
Suborder Belemnopseina Jeletzky, 1965
Family Belemnitellidae Pavlow, 1914
Genus *Belemnitella* d'Orbigny, 1840
Type species - *Belemnites mucronatus* von Schlottheim, 1813
Diagnosis - see CHRISTENSEN (1975)

Belemnitella mucronata (von Schlottheim, 1813)

1813 *Belemnites mucronatus* VON SCHLOTTHEIM, p. 111.
1980 *Belemnitella mucronata* (Link, 1807)
-- VAN DER TUUK & BOR, p. 123 (*partim*), ? fig. 3.
1984 *Belemnitella mucronata mucronata* (von Schlottheim, 1813)
-- JAGT, pp. 152, 154, fig. 4.
1985 *Belemnitella mucronata* (Link, 1807)
-- ROBASZYNSKI *et al.*, p. 17 (*partim*), pl. 1, ? fig. 2, *non* fig. 3.
1987 *Belemnitella mucronata* (von Schlottheim, 1813)
-- JAGT *et al.*, p. 94, fig. 1a-k.
1995 *Belemnitella mucronata* (Schlotheim, 1813)
-- CHRISTENSEN, p. 46, pl. 2, figs 1-16 (with additional synonymy).

Material -- Six almost complete specimens and one fragment (NHMM Keutgen, nos 21, 22, 24-28) from the lowermost metre of the Zeven Wegen Member ('craie glauconifère') at Pesaken-Crapoel, three almost complete specimens and one fragment (NHMM Keutgen, nos 3, 18-20)

from the lowermost 0.5 m of the Zeven Wegen Member ('craie glauconifère') at the CPL SA quarry, and ten near-complete specimens and six fragments (NHMM Keutgen, nos 1, 2, 4-17) from the Zeven Wegen Member, 0.5-5 m above the Zeven Wegen Horizon at the same quarry.
Description -- Guard small and stout, slightly lanceolate or subcylindrical in ventral view and subcylindrical or conical in lateral view, flattened over its entire length and with a well-developed mucro. Adult specimens show distinct vascular markings and dorsolateral depressions that continue posteriorly in dorsolateral double furrows. Longitudinal striae, less distinct than the vascular markings, are usually present. The shape of the bottom of the ventral fissure is generally straight or almost straight. All available specimens of this species from the Zeven Wegen Member were lumped and analysed statistically (Table 1).

	N	mean	SD	OR		
Ls (mm)	19	39.4	10.0	17.5	to	49.0
Dp (mm)	27	11.6	3.1	4.1	to	16.2
SW (mm)	17	9.1	1.7	6.5	to	12.0
FA (°)	16	18.1	9.8	9.0	to	40.0
AA (°)	18	19.4	1.2	17	to	22
BI	16	3.5	0.4	2.8	to	4.1
AV (%)	16	-2.6	5.7	-9.4	to	8.3
AL (%)	16	-14.8	3.8	-22.0	to	-7.5
AVs (%)	16	-5.2	4.0	-10.8	to	1.7
ALs (%)	16	-12.0	2.5	-16.0	to	-7.5

Table 1. Univariate analysis of *B. mucronata.*

With regard to the Schatzky Distance and alveolar angle, specimens from the 'craie glauconifère' may be distinguished from those from the 0.5-5.0 interval above the base of the CPL SA quarry (Tables 2, 3).

	N	mean	SD	OR		
SW (mm)	7	8.2	1.7	6.5	to	11.5
FA (°)	5	24.2	9.9	9	to	33
AA (°)	6	20.2	1.3	18	to	22

Table 2. Univariate analysis of *B. mucronata* from the 'craie glauconifère'.

	N	mean	SD	OR		
SW (mm)	10	9.7	1.4	7.5	to	12.0
FA (°)	11	15.3	8.8	9	to	40
AA (°)	12	19.1	1.1	17	to	21

Table 3. Univariate analysis of *B. mucronata* from the CPL SA quarry, 0.5-5.0 m above Loën Horizon.

Discussion -- Our sample of *B. mucronata* from the Zeven Wegen Member was compared with the neotype population of this species from Misburg, NW Germany (CHRISTENSEN *et al.*, 1975; CHRISTENSEN, 1995). The variances and mean values of the fissure angle, alveolar angle, and Birkelund Index do not differ significantly at the 5 percent level. A comparison of the length from apex to protoconch showed that the variances are slightly different. Because the difference is not highly significant, it was decided to continue and test the mean values. The t-test of the means gave a value of 1.53, which is not significant (0.20>P>0.10). A comparison of the Schatzky Distance of the two samples displayed that the variances are equal, but the mean values are significantly different (0.01>P>0.002). The t-test of the means gave a value of 3.01 with 92 degrees of freedom. In conclusion: *B. mucronata* from the Zeven Wegen Member differs from *B. mucronata* from Misburg only in its larger Schatzky Distance.

When compared with the type population of *Belemnitella woodi* Christensen, 1995 from Keswick (Norfolk), *B. mucronata* from the Zeven Wegen Member does not differ in its Schatzky Distance, alveolar angle and Birkelund Index. The variances of the length from apex to protoconch are slightly different, but the means do not differ (0.10>P>0.05). A comparison of the fissure angle of the two samples showed that the variances are equal, but the mean values are significantly different (0.02>P>0.01). *Belemnitella mucronata* from the Zeven Wegen Member thus differs from *B. woodi* from Keswick only in its smaller fissure angle.

According to CHRISTENSEN (1995) the mean values in *B. mucronata* of the Birkelund Index range from 3.2 to 3.7, those of the Schatzky Distance from 6.6 to 9.5 mm, those of the alveolar angle from 19 to 21° and those of the fissure angle from 15 to 23°. In *B. woodi* the known ranges of the mean values are as follows: Birkelund Index 3.3-3.8, Schatzky Distance 8.7-10.6 mm, alveolar angle 18-19°, fissure angle 26-30°. We conclude that *Belemnitella* from the 0-5 m interval above the Loën Horizon is well within the known range of *B. mucronata*, but outside that of *B. woodi*, in view of its small mean fissure angle, which is why they are assigned to the former species.

Although our material of *B. mucronata* from the Zeven Wegen Member is limited, a developmental trend has become evident. The earliest representatives of *B. mucronata* from the 'craie glauconifère' are characterised by smaller Schatzky Distances and larger alveolar angles than those from the CPL SA quarry, from the 0.5-5.0 m interval above the Loën Horizon. The latter specimens may be regarded as transitional between *B. mucronata* and *B. woodi*, as they resemble the latter species in their larger Schatzky Distances and smaller alveolar angles. However, on account of their small fissure angles they are here referred to *B. mucronata*.

Belemnitella mucronata from the so-called 'Benzenrade sandy chalk' (= Benzenrade Member of the Vaals Formation of W.M. FELDER & BOSCH, in press) of de Dael (Ubachsberg), southwest of Heerlen (The Netherlands), is characterised by comparatively small Schatzky Distances between 6.1 and 9.4 mm and alveolar angles of about 20° (JAGT *et al.*, 1987). These specimens closely resemble *B. mucronata* from the 'craie glauconifère' of the Zeven Wegen Member, and thus corroborate the correlation of the de Dael section with the lowermost part of this member, as proposed by JAGT *et al.* (1987) and JAGT (1988).

Distribution -- According to CHRISTENSEN (1995), *B. mucronata* is widely distributed in the North European Province with additional records from the northern part of the Tethyan realm. The species ranges from the latest Early Campanian to the early Late Campanian, where it is used as an index fossil. Records from southern Sweden show it to occur also in the middle Late Campanian and earliest Maastrichtian. In Norfolk, the species is recorded from the Pre-Weybourne$_3$ Chalk, while at the CPL SA quarry (Haccourt) it is known to date from the lowermost 5 metres of the Zeven Wegen Member. In southern Limburg, there are records from Pesaken and de Dael-Ubachsberg.

Belemnitella woodi Christensen, 1995
Pl. 1, figs 1-4

1980 *Belemnitella mucronata* (Link, 1807) -- VAN DER TUUK & BOR, p. 123 (*partim*), ? fig. 3.
1980 *Belemnitella langei* Jeletzky, 1948 -- VAN DER TUUK & BOR, p. 124, fig. 4.
1985 *Belemnitella mucronata* (Link, 1807) -- ROBASZYNSKI *et al.*, p. 17 (*partim*), pl. 1, ? fig. 3, *non* fig. 2.
1985 *Belemnitella mucronata "minor"* sensu Jeletzky, 1949 -- ROBASZYNSKI *et al.*, p. 17, pl. 2, fig. 1, ? 2.
1995 *Belemnitella woodi* CHRISTENSEN, p. 50, pl. 3, figs 1-16; text-figs 12A-G (with additional synonymy).

Material -- Twenty-four almost complete specimens and five fragments (NHMM Keutgen, nos 29-36, 49-69) from the Zeven Wegen Member (10-17 m interval), and fifty-nine almost complete specimens and eighteen fragments (NHMM Keutgen, nos 37-48, 70-133; NHMM JJ 2711, JJ 2968) from the Zeven Wegen Member (17-28 m interval) of the CPL SA quarry (Haccourt).
Description -- Guard large and stout, slightly lanceolate or subcylindrical in ventral view and subcylindrical or conical in lateral view, flattened over its entire length, the apical end being obtuse with a mucro. A few specimens have a pointed apical end. Vascular markings are usually well developed around the ventral fissure and are weakly developed or absent elsewhere. Longitudinal striae, which are strongly developed in few specimens, may occur on the posterior part of the guard. Some specimens are almost smooth. Dorso-lateral depressions are present and continue posteriorly in dorso-lateral double furrows. The shape of the bottom of the ventral fissure is variable: mostly straight or nearly straight, but also convexly or concavely curved, S-shaped or undulating.

CHRISTENSEN (1995) distinguished two stratigraphical forms of *B. woodi*, the early form (Table 4) resembling *B. mucronata* in its Birkelund Index, the late form (Table 5) being more slender.

	N	mean	SD	OR		
Ls (mm)	23	42.7	7.3	30.0	to	58.0
Dp (mm)	28	12.2	2.2	8.0	to	15.9
SW (mm)	22	8.5	1.4	6.5	to	11.5
FA (°)	21	24.8	9.3	12	to	45
AA (°)	20	18.8	1.2	17	to	21
BI	23	3.6	0.4	3.0	to	4.8
AV (%)	22	-3.9	5.3	-13.4	to	11.5
AL (%)	22	-15.9	4.5	-23.2	to	-4.6
AVs (%)	23	-6.3	4.8	-13.7	to	5.8
ALs (%)	23	-12.8	2.8	-16.2	to	-7.5

Table 4. Univariate analysis of the early form of *B. woodi* (10-17 m interval above the Loën Horizon).

	N	mean	SD	OR		
Ls (mm)	64	43.9	7.5	23.0	to	58.5
Dp (mm)	76	11.5	2.0	5.5	to	17.1
SW (mm)	56	7.8	1.5	5.5	to	11.5
FA (°)	55	25.9	10.7	11	to	57
AA (°)	53	18.9		1.2 ·	17	to
21						
BI	61	3.9	0.4	3.1	to	4.8
AV (%)	55	5.4	4.9	-16.7	to	6.4
AL (%)	56	-17.8	3.8	-30.8	to	-10.0
AVs (%)	61	-7.3	3.5	-16.7	to	0.0
ALs (%)	61	-14.4	3.0	-24.0	to	-9.1

Table 5. Univariate analysis of the late form of *B. woodi*, (interval 17-28 m above the Loën Horizon).

The scatter plot of the length from apex to protoconch *vs* dorso-ventral diameter at protoconch of the late form of *B. woodi* is shown in Fig. 4, as is the regression line. The equation of the regression is as follows:

$Dp = 1.529 + 0.225\ Ls;\ N = 64;\ r = 0.839;\ SD_a = 0.825;\ SD_b = 0.018;\ SD_{yx} = 1.109.$

The value of the correlation coefficient is very highly significant. A t-test on the y-intercept gave a value of 1.85 with 62 degrees of freedom, which is not significant (0.10>P>0.05), implying an isometric relationship of the two variates.

Discussion -- The early form of *B. woodi* from the 10-17 m interval above the Loën Horizon was compared statistically with the type population of *B. woodi* from Keswick (CHRISTENSEN, 1995), the neotype population of *B. mucronata* from Misburg (CHRISTENSEN *et al.*, 1975; CHRISTENSEN, 1995) and with *B. mucronata* from the Zeven Wegen Member. The two samples of *B. woodi* were compared with the following result. The variances and mean values of the length from apex to protoconch, fissure angle and alveolar angle do not differ significantly at the 5 precent level. The variances of the Schatzky Distances are slightly different. Because the difference is not highly significant, it was decided to continue and test the mean values. The t-test of the means gave a value of 1.60 with 63 degrees of freedom, which is not significant (0.20>P>0.10). The mean values of the Birkelund Indices are different (0.01>P>0.002). The mean Birkelund Index of the Keswick sample (BI = 3.3) is smaller than that of the Haccourt sample (BI = 3.6).

A comparison of *B. woodi* from the 10-17 m interval with the neotype population of *B. mucronata* showed that the variances and mean values of the length from apex to protoconch and the fissure angle are not different, but the mean Schatzky Distances and the mean alveolar angle differ significantly at the 5 percent level. A comparison of the Birkelund Indices of the two samples displayed that the variances and the mean values are significantly different. It can be concluded that *B. woodi* from the 10-17 m interval above the Loën Horizon differs from *B. mucronata* from Misburg in its larger Schatzky Distance, smaller alveolar angle and larger Birkelund Index.

When compared with *B. mucronata* from the same member, *B. woodi* from the 10-17 m interval does not differ in its length from apex to protoconch, Schatzky Distance, alveolar angle, Birkelund Index or shape (AV, AL). A comparison of the fissure angles of the two samples showed that the variances are equal, but the mean values are significantly different (0.05>P>0.02). *Belemnitella* *woodi* from the 10-17 m interval differs from *B. mucronata* from the same member only in its larger fissure angle, and most closely resembles the type population of *B. woodi*, differing from *B. mucronata* from Misburg in the same characters as does *B. woodi* from Keswick. It is somewhat more slender than *B. woodi* from Keswick and *B. mucronata* from Misburg, but its Birkelund Index is similar to that of *B. mucronata* from the Zeven Wegen Member. For that reason the sample of *B. woodi* from the 10-17 m interval is interpreted to represent an early form of *B. woodi*, which is comparable to *B. woodi* from Eaton Limeworks, Keswick and Weybourne (Norfolk) as described by CHRISTENSEN (1995).

The late form of *B. woodi* occurs in the Zeven Wegen Member at the CPL SA quarry (Haccourt) in the 17-28 m interval above the Loën Horizon. It was compared with the late form of *B. woodi* from Catton Grove (CHRISTENSEN, 1995). It was found that the variances and mean values of the length from apex to protoconch, Schatzky Distance, fissure angle, alveolar angle and Birkelund Index do not differ significantly at the 5 percent level.

When compared with *B. woodi* from the 10-17 m interval of the same quarry, *B. woodi* from the upper part of the Zeven Wegen Member does not differ in its length from apex to protoconch, Schatzky Distance, fissure angle, alveolar angle or shape of the guard (AV, AL). A comparison of the Birkelund Index of the two samples showed that the mean values are significantly different ($0.01>P>0.002$). The late form from the 17-28 m interval differs from the early form of *B. woodi* only in being more slender.

The regression lines of length from apex to protoconch *vs* dorso-ventral diameter at protoconch of the *B. woodi* type population (CHRISTENSEN, 1995) and *B. woodi* from the 17-28 m interval at CPL SA quarry were compared with the following results. The variances and the slopes of the regression lines are not different. The t-test of the position of the two lines gave a value of 7.79 with 104 degrees of freedom, which is very highly significant ($P<0.0001$). It is concluded that *B. woodi* from the 17-28 m interval is generally more slender than *B. woodi* from Keswick.

The late form of *B. woodi* from the upper Zeven Wegen Member was also compared with *B. mucronata* from the lower part of that member. It was found that the length from apex to protoconch and the alveolar angles do not differ significantly, but the Schatzky Distances, fissure angles, and Birkelund Indices differ significantly at the 5 percent level. The comparison of the shape of the guards of the two samples revealed that the variances of AV and AL are equal. The mean values of the ventral aspect (AV) are not different, but the means of the later aspects (AL) are. The t-test of the means gave a value of 2.78 with 70 degrees of freedom, which is highly significant ($0.01>P>0.002$). The late form of *B. woodi* from the Zeven Wegen Member differs from *B. mucronata* from the same member in its smaller Schatzky Distance, larger fissure angle, larger Birkelund Index, and in being more conical in lateral view.

Distribution -- In Norfolk, *B. woodi* occurs in the later part of the early Late Campanian, the early form being known from the Pre-Weybourne$_5$ and Weybourne$_1$ Chalks (Eaton Limeworks, Keswick, Weybourne), the late form occurring in the Weybourne$_2$ and Weybourne$_3$ Chalks except for the Catton Sponge Bed (Eaton Golf Course pit, Catton Grove). At the CPL SA quarry, the early form of *B. woodi* occurs in the 10-17 m interval, and the late form in the 17-28 m interval. The species may also occur in the Late Campanian of the Mons Basin (southern Belgium; see CHRISTENSEN, 1995) and in the Hannover area (Germany; see NIEBUHR *et al.*, 1997).

Belemnitella minor I Jeletzky, 1951

1951a *Belemnitella mucronata* mut. *minor* JELETZKY, p. 203.
1951b *Belemnitella mucronata* mut. *minor* Jeletzky -- JELETZKY, p. 87, pl. 1, fig. 3.

1995 *Belemnitella minor* I Jeletzky, 1951 -- CHRISTENSEN, p. 55, pl. 1, figs 4-7; pl. 4, figs 5-15; pl. 5, figs 9-16; pl. 6, figs 11-17 (with additional synonymy).

Material -- Eight almost complete specimens and three fragments (NHMM Keutgen, nos BM1-BM11) from the Beutenaken Member of a road cutting northeast of Teuven (Limburg, Belgium).
Description -- Guards large and slender, slightly lanceolate or subcylindrical in ventral view, subcylindrical or high conical in lateral view and flattened over entire length. The apical end is acute or obtuse with a mucro. The vascular markings, dorso-lateral depressions, and dorso-lateral double furrows are well developed. A few specimens show pseudogranulation on the ventral side and longitudinal striae on the posterior part of the guard. The shape of the bottom of the ventral fissure resembles that of *B. woodi*.

	N	mean	SD	OR		
Ls (mm)	9	49.3	7.1	36.5	to	60.0
Dp (mm)	11	12.9	2.5	8.1	to	17.8
SW (mm)	10	8.6	2.1	5.5	to	12.0
FA (°)	9	37.4	9.4	26	to	54
AA (°)	10	18.5	0.5	18	to	19
BI	9	4.2	0.4	3.8	to	4.8
AV (%)	8	-4.9	2.1	-7.1	to	-1.6
AL (%)	8	-15.1	2.9	-18.7	to	-10.9
AVs (%)	9	-5.1	2.8	-8.1	to	-0.8
ALs (%)	9	-13.6	2.2	-16.7	to	-10.9

Table 6. Univariate analysis of *B. minor* I.

Discussion -- A comparison of *B. minor* I from Teuven (Table 6) with a sample of *B. minor* I from Caistor (Norfolk) (CHRISTENSEN, 1995) showed that the variances and mean values of the length from apex to protoconch, Schatzky Distance, alveolar angle and Birkelund Index do not differ significantly. The variances of the fissure angle of the two samples are equal, but the mean values are significantly different (0.02>P>0.01). *Belemnitella minor* I from Teuven thus differs from *B. minor* I from Caistor only in its larger fissure angle. The observed range of the fissure angle of *B. minor* I from Teuven is well within the known range of that species in England (CHRISTENSEN, 1995).

In comparison with late forms of *B. woodi* from the 17-28 m interval at the CPL SA quarry, *B. minor* I from Teuven does not differ in its Schatzky Distance. A comparison of the length from apex to protoconch, the fissure angle and the Birkelund Index of the two samples showed that the variances are equal, but the mean values are significantly different (0.05>P). A comparison of the alveolar angles revealed that the variances are significantly different (F = 5.76 with 52 and 9 degrees of freedom). *Belemnitella minor* I is distinguished from *B. woodi* by being larger, more slender and more vascularised. Moreover, *B. minor* I from Teuven differs from the late form of *B. woodi* from the Zeven Wegen Member in its larger fissure angle.

Distribution -- In Norfolk, *B. minor* I occurs in the Catton Sponge Bed, Beeston Chalk and the basal Paramoudra Chalk, i.e. the early part of the late Late Campanian. In NE Belgium, the species is currently known from the basal Beutenaken Member; it may also occur in Poland (CHRISTENSEN, 1995) and the Hannover area (NIEBUHR *et al.*, 1997).

Belemnitella minor II Christensen, 1995
Pl. 1, figs 5-8

1991 *Belemnitella* cf. *najdini* Kongiel, 1962 -- KEUTGEN & VAN DER TUUK, p. 13 (*partim*), *non* pl. 2, fig. 1.
1995 *Belemnitella minor* II CHRISTENSEN, p. 64, pl. 7, figs 3- 10; text-fig. 20A-D (with additional synonymy).

Material -- Two almost complete specimens and three fragments (NHMM Keutgen, nos BM18-BM22, BM26) from the Beutenaken Member, 2.0-0.7 m interval below the Bovenste Bos Horizon at the Bovenste Bos quarry, and fifty-four almost complete guards and sixty-two fragments (NHMM Keutgen, nos BM19-BM25, BM27-BM135) from Beutenaken Member chalk boulders in a field near Slenaken.

Description -- Guards are very large and stout. *Belemnitella minor* II closely resembles *B. minor* I as far as surface markings and internal characters (Schatzky Distance, fissure angle and alveolar angle) are concerned, but differs from that species in being stouter (Table 7).

	N	mean	SD	OR		
Ls (mm)	59	48.2	9.6	25.0	to	67.0
Dp (mm)	113	13.4	2.7	6.0	to	17.9
SW (mm)	63	9.4	3.0	4.5	to	19.0
FA (°)	57	26.8	9.6	8	to	46
AA (°)	56	19.1	1.0	18	to	21
BI	59	3.7	0.4	2.7	to	4.6
AV (%)	51	-7.0	4.7	-17.3	to	2.4
AL (%)	51	-19.6	3.7	-27.5	to	-10.0
AVs (%)	59	-6.2	4.2	-14.7	to	6.0
ALs (%)	59	-15.0	2.8	-21.4	to	-9.2

Table 7. Univariate analysis of *B. minor* II.

The scatter plot of the length from the apex to protoconch *vs* the dorso-ventral diameter at protoconch of *B. minor* II is shown in Fig. 5, as is the regression line. The equation of the regression is as follows:

$Dp = -0.417 + 0.283\ Ls$; $N = 59$; $r = 0.913$; $SD_a = 0.802$; $SD_b = 0.016$; $SD_{yx} = 1.257$.

The value of the correlation coefficient (r) is very highly significant. A t-test on the y-intercept gave a value of 0.52 with 57 degrees of freedom, which is not significant (P>0.50), implying an isometric relationship of the two variates.

Discussion -- According to CHRISTENSEN (1995), *Belemnitella minor* II is a chronological sub-species of *B. minor*. In comparison with the type population of *B. minor* II from the $Paramoudra_1$ Chalk at Whitlingham (Norfolk), the specimens from the Beutenaken Member are very similar with regard to the fissure angle, alveolar angle and Birkelund Index. A comparison of the length from apex to protoconch and the Schatzky Distance of the two samples showed that the variances are equal, but the mean values are significantly different (0.01>P>0.002 for Ls and SW). The mean value of the length from apex to protoconch of the Beutenaken Member sample (Ls = 48.2 mm) is thus significantly smaller than the mean value of that from Whitlingham (Ls = 58.0 mm), but it should be noted that the maximum length in both samples is similar (Ls = 67.0 mm for the Beutenaken specimens and Ls = 70.0 mm for the Whitlingham specimens). Therefore, the significantly different mean Ls value is considered to be less important. It is concluded that *B. minor* II from the Beutenaken Member is distinguished from *B. minor* II from Whitlingham only by its smaller Schatzky Distance.

The Beutenaken Member sample contains more juvenile specimens than the Whitlingham sample. According to CHRISTENSEN (1976) belemnite populations found in nearshore deposits comprise juvenile, adolescent and adult specimens, while populations from offshore populations contain mainly adults. The Beutenaken Member was thus probably deposited in a more nearshore environment than the $Paramoudra_1$ Chalk of Norfolk.

In comparison with *B. minor* I from Teuven, *B. minor* II does not differ in the length from apex to protoconch and Schatzky Distance. A comparison of the fissure angles and of the Birkelund Indices of the two samples showed that the variances are equal, but the mean values are significantly different (t = 3.13 with 64 degrees of freedom, 0.01>P>0.002 for FA and t = 3.49 with 66 degrees of freedom, 0.001>P>>0.0001 for BI). A comparison of the alveolar angles revealed that the variances are significantly different (F = 4.00 with 55 and 9 degrees of freedom). *Belemnitella minor* II differs from *B. minor* I from Teuven in being stouter and having a smaller fissure angle.

Belemnitella minor II is very similar to the Early Maastrichtian *B. minor* III Christensen, 1995. According to CHRISTENSEN (1995), *B. minor* II differs from that subspecies only in being larger. The samples of *B. minor* II and of *B. woodi* from the 17-28 m interval of the Zeven Wegen Member were compared with the following results. The variances and mean values of the fissure angle and alveolar angle do not differ significantly at the 5 percent level. The variances of the length from apex to protoconch are slightly different. Because the difference is not highly significant, it was decided to continue and test the mean value. The t-test of the means gave a value of 2.75 with 121 degrees of freedom, which is significant (0.01>P>0.002). The variances of the Schatzky Distance are significantly different (F = 4.00 with 62 and 55 degrees of freedom). The variances of the Birkelund Index are equal, but the mean values are different (0.01>P>0.002). The comparison of the shape of the guards of the two samples revealed that the variances of AV and AL are equal. The mean values of the ventral aspect (AV) do not differ, but the means of the lateral aspect (AL) do. The t-test of the means gave a value of 2.48 with 105 degrees of freedom, which is significant (0.02>P>0.01). Therefore, *B. minor* II differs from the late form of *B. woodi* from the Zeven Wegen Member in being larger and stouter, in having a larger Schatzky Distance, and in being more conical in lateral view.

Distribution -- In Norfolk, *B. minor* II occurs in the Paramoudra Chalk, i.e. the late part of the late Late Campanian. In The Netherlands, the taxon occurs in the Beutenaken Member near Slenaken and at the Bovenste Bos quarry. It may also occur in the Mons Basin and in the Paris Basin (CHRISTENSEN, 1995).

Belemnitella najdini Kongiel, 1962
Pl. 1, fig. 9, 10

1962 *Belemnitella najdini* KONGIEL, p. 79, pl. 17, figs 7-9 (*non* figs 10-12 = *Belemnitella pulchra* Schulz, 1982).
1991 *Belemnitella* cf. *najdini* Kongiel, 1962 -- KEUTGEN & VAN DER TUUK, p. 13 (*partim*), pl. 2, fig. 1.
1995 *Belemnitella najdini* Kongiel -- CHRISTENSEN, p. 79, pl. 4, figs 1-4; pl. 5, figs 5-8 (with additional synonymy).
?1995 *Belemnitella* ex gr. *langei-najdini* -- CHRISTENSEN, p. 80, pl. 9, figs 11-14.

Material -- A single almost complete specimen and one fragment (NHMM Keutgen, nos BSP77, BSP78) from the Beutenaken Member in a road cutting northeast of Teuven, three almost complete specimens and five fragments (NHMM Keutgen, nos BSP1-BSP8) from the Beutenaken Member, 2.0-0.7 m below the Bovenste Bos Horizon at the Bovenste Bos quarry, and forty-seven almost complete specimens and twenty-one fragments (NHMM Keutgen, nos BSP9-BSP76) from float boulders of the Beutenaken Member collected in a field near Slenaken.

Description -- Guard small and slender with a very large fissure angle. The shape of the bottom of the ventral fissure is irregular, ranging from nearly straight, curved, S-shaped to undulating. The guard is slightly lanceolate or subcylindrical in ventral view, subcylindrical or conical in lateral view and is slightly flattened ventrally. The apical end is obtuse or acute, generally with a mucro. The vascular markings are most prominent around the ventral fissure, generally weakly developed or absent elsewhere. Dorso-lateral depressions and dorso-lateral double furrows are present.

	N	mean	SD	OR		
Ls (mm)	53	37.7	4.8	29.0	to	48.0
Dp (mm)	75	8.8	1.1	6.9	to	11.1
SW (mm)	58	6.5	1.4	4.5	to	10.5
FA (°)	59	90.6	21.1	51	to	141
AA (°)	18	20.3	1.5	18	to	23
BI	53	4.4	0.4	3.6	to	5.1
AV (%)	52	1.1	5.1	-7.7	to	13.0
AL (%)	52	-9.3	4.2	-19.7	to	1.0
AVs (%)	53	1.3	4.0	-6.7	to	14.0
ALs (%)	53	-8.4	3.8	-15.8	to	0.0

Table 8. Univariate analysis of *B. najdini*.

The scatter plot of the length from apex to protoconch *vs* dorso-ventral diameter at protoconch of *B. najdini* is shown in Fig. 6, as is the regression line. The equation of the regression is as follows:

$Dp = 2.120 + 0.170\ Ls$; $N = 53$; $r = 0.785$; $SD_a = 0.715$; $SD_b = 0.019$; $SD_{yx} = 0.653$.

The value of the correlation coefficient (r) is highly significant. A t-test on the y-intercept gave a value of 2.97 with 51 degrees of freedom, which is significant (0.01>P>0.002), implying an allometric relationship of the two variates. Juvenile and adolescent specimens are thus stouter than adult ones. Since the relationship Ls *vs* Dp is allometric and changes with growth in *B. najdini*, it is not meaningful to calculate the mean Birkelund Index (Ls/Dp) of a sample without giving the mean length from apex to protoconch. If the correlation of Ls *vs* Dp were perfect (r = 1), the Birkelund Index of *B. najdini* from the Beutenaken Member would vary in the following way:

Ls (mm)	Birkelund Index
29.0	4.1
35.0	4.3
37.7 (mean value)	4.4
40.0	4.5
45.0	4.6
48.0	4.7

Owing to individual variation, the Birkelund Index actually varies between 3.6 and 5.1.

Discussion -- *Belemnitella najdini* from the Beutenaken Member (Table 8) is very similar to *B. najdini* from the Beeston Chalk of Norfolk (CHRISTENSEN, 1995), but differs from those specimens in being smaller and apparently less slender. However, the relationship of length from apex to protoconch *vs* dorso-ventral diameter at protoconch was found to be allometric in the sample from the Beutenaken Member. Taking into account the allometric growth, the Birkelund Indices of the two samples are identical, because the mean length from apex to protoconch of the specimens from the Beeston Chalk (Ls = 48.2 mm; see CHRISTENSEN, 1995) corresponds to a mean Birkelund Index of 4.7 in the sample from the Beutenaken Member, which is identical with the Birkelund Index of 4.7 calculated by CHRISTENSEN for *B. najdini* from Norfolk. It is therefore concluded that *B. najdini* from the Beutenaken Member closely resembles *B. najdini* from the Beeston Chalk and differs from the latter only in its smaller mean size.

Belemnitella langei Jeletzky, 1948 is another species with a large fissure angle. The holotype of that species is characterised by a length from apex to protoconch of Ls = 54.5 mm (see CHRISTENSEN *et al.*, 1975), which is outside the observed range of Ls in the sample of *B. najdini* from the Beutenaken Member and the Beeston Chalk. *Belemnitella langei* attains a larger size than does *B. najdini*, and the latter differs by its more slender guard in addition to its larger fissure angle.

Belemnitella ex gr. *langei-najdini* recorded by CHRISTENSEN (1995) from the Paramoudra$_2$ Chalk of Norfolk is here referred to *B. najdini* with a query. The specimens described are well within the observed range of *B. najdini* from the Beutenaken Member and are slightly more slender and have larger fissure angles than *B. langei* from the Beeston Chalk (compare CHRISTENSEN, 1995).

Belemnitella najdini is also closely allied to *B. pulchra* Schulz, 1982 and *B. langei* (*sensu* SCHULZ, 1978) as described by CHRISTENSEN (1995). It differs from *B. pulchra* by its stouter, less lanceolate guard and slightly larger alveolar angle, and from *B. langei* (*sensu* SCHULZ) by its smaller, slightly stouter guard, distinctly larger alveolar angle and larger fissure angle.

Distribution -- In Norfolk, *B. najdini* occurs in the late Late Campanian in the upper part of the Beeston Chalk and possibly in the Paramoudra Chalk. In The Netherlands and NE Belgium it occurs in the Beutenaken Member. The taxon was first described from the upper part of the Late Campanian *donezianum* Zone to the Early Maastrichtian '*occidentalis*' Zone of the Middle Vistula valley, Poland (KONGIEL, 1962). However, since SCHULZ (1982) referred the Early Maastrichtian specimen figured by KONGIEL (1962, pl. 17, figs 10-12) to *B. pulchra*, *B. najdini* may in fact be restricted to the Late Campanian. The species is also known from the late Late Campanian of the Russian Platform (CHRISTENSEN, 1995).

THE EVOLUTION OF THE *BELEMNITELLA MUCRONATA-WOODI-MINOR* LINEAGE

CHRISTENSEN (1995) described in detail the development from *B. mucronata* to *B. minor* III from the late Early Campanian to Early Maastrichtian. He analysed the evolution of size and slenderness of the guard, in addition to internal characters (Schatzky Distance, fissure angle, alveolar angle). The reader is referred to CHRISTENSEN's paper for a detailed discussion.

In the present paper the development of the shape of the guard was studied. The method to describe the shape of the guards of the genera *Belemnella* Nowak, 1913 and *Belemnitella* d'Orbigny, 1840 was introduced by SCHULZ (1979, 1982). The ventral aspect is given by the AV value, the lateral aspect by the AL value. The smaller the calculated value, the more conical the guard is. Large values point to a subcylindrical or even lanceolate shape in ventral or lateral view.

The results of the present study are summarised in Figs 7 and 8. The data indicate a clear trend within the *B. mucronata-woodi-minor* lineage towards more conical guards. The first species of this lineage, *B. mucronata*, is characterised by a guard which is subcylindrical in ventral and conical in lateral view. The last Campanian representative, *B. minor* II, is typically conical in ventral view and high conical in lateral view.

CORRELATION OF THE LATE CAMPANIAN OF LIÈGE-LIMBURG WITH NORFOLK AND NW GERMANY

Belemnites of the Zeven Wegen Member were first studied in detail by SCHMID (1959, 1967), who recorded from the base of that member ('craie glauconifère') '*Belemnitella senior* Nowak et var.' and '*Gonioteuthis quadrata* (Blainville)' and correlated these deposits with the latest Early and earliest Late Campanian. From the overlying 'craie blanche' (= Zeven Wegen Member) he recorded '*Belemnitella mucronata* (Schlotheim) sensu lato', including '*Belemnitella mucronata minor* Jeletzky' from the upper part of the member. According to SCHMID (1959, 1967) the 'craie blanche' represented the entire Late Campanian with the exception of its latest part, but might contain a hiatus at the top of the 'craie glauconifère'.

SCHMID's views were accepted by VAN DER TUUK & BOR (1980), who regarded *Belemnitella langei* as a synonym of '*Belemnitella mucronata minor* Jeletzky' (= *Belemnitella woodi* Christensen, 1995 in the present paper). VAN DER TUUK (*in* ROBASZYNSKI *et al.*, 1985) mentioned the *in situ* occurrence of *B. mucronata* from the entire Zeven Wegen Member and the appearance of '*B. mucronata minor*' in the uppermost eight metres of this member. He also correlated the Zeven Wegen Member with the entire Late Campanian with the exception of its latest part.

JAGT (1984, 1988), on the basis of belemnites and echinoids, worked out a fairly detailed subdivision of the Zeven Wegen Member as exposed at the CPL SA quarry (Haccourt). The lowermost 0.3 to 0.5 m of the member ('craie glauconifère') are characterised by the co-occurrence of *B. mucronata* and the echinoids *Echinocorys* gr. *conica/lamberti* and *Cardiotaxis heberti* (Cotteau, 1860). These species were held to be indicative of the *conica/mucronata* Zone of Lägerdorf (NW Germany) and probably also at Haccourt. Guards of *Gonioteuthis q. quadrata* (de Blainville, 1827) and *B. praecursor* Stolley, 1897 found in the 'craie glauconifère' were shown to be reworked from the underlying early Early Campanian Vaals Formation. The presence of the echinoids *Echinogalerus* (?) *hemisphaericus* (Desor, 1842) and *Galeola papillosa basiplana* Ernst, 1971 up to 7-8 metres above the base of the Zeven Wegen Member indicate the NW German *basiplana/spiniger* Zone. The overlying deposits were referred to the *roemeri* Zone (compare SCHULZ *et al.*, 1984; SCHULZ, 1985; SCHÖNFELD *et al.*, 1996). Belemnites referred by JAGT (1984, 1988) to *Belemnitella 'minor'* Jeletzky, 1951 with a query range throughout the uppermost 8 metres of the member. Correlation of these deposits with the NW German *polyplocum* Zone was considered tentative, since the index species *Nostoceras (Bostrychoceras) polyplocum* (Roemer, 1841) had not been found.

JAGT (in press a) provided a lengthy discussion of the (macro)biozonation and interregional correlation of the Zeven Wegen Member, as exposed in the CPL SA and nearby CBR-Lixhe quarries (see Fig. 1). In referring to the benthic foraminifer *Gavelinella monterelensis* (Marie, 1941), which at Lägerdorf first occurs in the middle *conica/senior* (= *conica/mucronata*) Zone, SCHÖNFELD

(1990) assumed deposition of the Zeven Wegen Member to have started during the lower *conica/mucronata* Zone, thus supporting JAGT's (1988) views. A number of stratigraphically important ammonoid taxa have lately been recorded from the Zeven Wegen Member (KENNEDY & JAGT, in press), including the recently revised (KAPLAN *et al.*, 1996; KENNEDY & CHRISTENSEN, 1997) puzosiid *Patagosites stobaei* (Nilsson, 1827), the pachydiscid *Pachydiscus (P.) haldemsis* (Schlüter, 1867), the diplomoceratid *Neancyloceras ? phaleratum* (Griepenkerl, 1889) as well as the scaphitid *Trachyscaphites s. spiniger* (Schlüter, 1872). These are typically early Late Campanian species, in ammonite terms, and are considered index fossils for this interval in northern Europe (*phaleratum* Zone of B ASZKIEWICZ, 1980; *vulgaris/stolleyi* Zone of NIEBUHR *et al.*, 1997; see also KAPLAN *et al.*, 1996; KENNEDY & CHRISTENSEN, 1997). Amongst echinoids there are the taxa already mentioned above, as well as *Micraster* gr. *schroederi/glyphus* and *M. stolleyi* Lambert, 1901, which are both valuable species in NW Germany (ERNST *et al.*, 1997a, b; NIEBUHR *et al.*, 1997). Species of the goniasterid asteroid lineage *Nymphaster studlandensis-alseni-peakei* (GALE, 1987; JAGT, in prep.) are also of note, the range of *N. studlandensis* (Schulz & Weitschat, 1971) comparing well with that recorded from England and Germany and *N. alseni* (Schulz & Weitschat, 1975) having been proposed as an alternative index for the *roemeri* Zone.

Here we follow NIEBUHR *et al.* (1997) and ERNST *et al.* (1997a, b) in rejecting SCHULZ's (1985) application of the name *Galerites roemeri* to 'populations' of the genus *Galerites* from the early/middle portion of the late Campanian. This, of course, has implications for zonal names. We here accept those authors' arguments and adopt their use of a *'vulgaris'/basiplana* Zone and a *'vulgaris'/stolleyi* Zone, to replace the *roemeri* Zone of SCHULZ's (1985) and SCHÖNFELD *et al.*'s (1996) schemes.

Belemnite species from the Beutenaken Member were first described by VAN DER TUUK & BOR (1980) and VAN DER TUUK (*in* ROBASZYNSKI *et al.*, 1985), who recorded *'Belemnella lanceolata inflata* (Arkhangelsky, 1912)' and *'Belemnella "occidentalis" sensu* Birkelund, 1957' from the Beutenaken Member. However, their specimens were not collected from that member, but from burrows piping down from the Vijlen Member into the Beutenaken Member. The burrows are filled with a greensand, which belongs to the Vijlen Member (KEUTGEN & VAN DER TUUK, 1991; P.J. FELDER & BLESS, 1994; KEUTGEN, 1996). The specimens of *Belemnella* are now referred to *B. (Pachybelemnella) obtusa* Schulz, 1979 (see SCHULZ & SCHMID, 1983; KEUTGEN & VAN DER TUUK, 1991; KEUTGEN, 1996). *In situ* belemnites from the Beutenaken Member were referred to *B.* cf. *najdini* Kongiel, 1962 by KEUTGEN & VAN DER TUUK (1991), who correlated the Beutenaken Member with the late Late Campanian *'langei'* Zone, but noted that it could not be ruled out that the uppermost part of this member was of early Early Maastrichtian age, in belemnite terms. It is of note that KEUTGEN (1996) was able to collected a single *B. (P.) inflata* (Arkhangelsky, 1912) together with several *B. minor* III at 3.2 m above the base of a greensand at Pesaken-Crapoel, which according to HOFKER (1966, p. 15, figs 16, 17) and W.M. FELDER *et al.* (1978, p. 131, fig. 7/9) is referred to the Beutenaken Member. This specimen of *Belemnella* proves that, at least in some places, the early Early Maastrichtian *lanceolata* and/or *pseudobtusa* zones *sensu germanico* do occur in Liège-Limburg.

Apart from the above-mentioned belemnite species, the Beutenaken Member has not yet yielded other typically late Late Campanian index taxa such as the ammonites *Trachyscaphites pulcherrimus* (Roemer, 1841) and *Jeletzkytes compressus* (Roemer, 1841) or the echinoid *Cardiaster cordiformis* (Woodward, 1833), which are typical *minor/polyplocum* Zone taxa in the Hannover area (ERNST *et al.*, 1997a, b; NIEBUHR *et al.*, 1997). JAGT (in press b) recorded the isocrinid crinoid *Austinocrinus bicoronatus* (von Hagenow, 1840) from the top of the Beutenaken Member or the very base of the Vijlen Member, noting WOOD's (1988) record of comparable specimens from the Beeston Chalk in Norfolk.

The Zeven Wegen and Beutenaken members in Liège-Limburg are here subdivided into three informal belemnite zones, consisting of five informal subzones, because the bases of some of the zones and subzones cannot be precisely defined, due to possible stratigraphic gaps between the various outcrops. The zonal belemnites are, in ascending order, *Belemnitella mucronata*, *B. woodi* and *B. minor* (Fig. 9).

The *B. mucronata* Zone comprises the lower part of the Zeven Wegen Member ('craie glauconifère') in the Pesaken-Crapoel section and the lowermost 6 metres at the CPL SA quarry. It corresponds to the *mucronata* Zone of Norfolk (*sensu* CHRISTENSEN, 1995) and can be correlated with the Pre-Weybourne$_3$ Chalk. According to CHRISTENSEN (1995, text-figs 1, 2) the Pre-Weybourne$_3$ Chalk may be correlated with the upper *conica/mucronata* and the lower *basiplana/spiniger* zones of NW Germany. The presence of the *conica/mucronata* Zone at the very base of the Zeven Wegen Member at the CPL SA quarry appears to be indicated by the occurrence of the echinoid *Echinocorys* gr. *conica/lamberti*, but in Norfolk this group occurs also in equivalents of the NW German *basiplana/spiniger* Zone. At Haccourt, *G. p. basiplana* is recorded from the 0-8 m interval of the Zeven Wegen Member (JAGT, 1988), while in the Lägerdorf standard section this is confined to the upper *basiplana/spiniger* Zone (SCHULZ *et al.*, 1984). These data favour a correlation of the base of the Zeven Wegen Member with a level close to the base of the NW German *basiplana/spiniger* Zone. This interpretation corresponds well with the recent record of the early Late Campanian ammonites *Pachydiscus (P.) subrobustus* Seunes, 1892 and *Hoplitoplacenticeras (H.) marroti* (Coquand, 1859) in Vaals Formation lithofacies near Cottessen (southern Limburg), which indicate that the base of the Late Campanian (i.e. base of *conica/mucronata* Zone *sensu germanico*) occurs within the Vaals Formation (JAGT *et al.*, 1995). However, at present it cannot be ruled out that the basal Zeven Wegen Member at the CPL SA quarry does indeed represent a condensed section with equivalents of both the *conica/mucronata* and lower *basiplana/spiniger* zones.

The *B. woodi* Zone corresponds to the interval about 6 m above the Loën Horizon to the top of the Zeven Wegen Member at the CPL SA quarry. It is subdivided into two subzones: subzone I with the early and subzone II with the late form of the index species. Subzone I corresponds to the 6-17 m interval above the Loën Horizon. Although no belemnite guards were available from the 5-10 m interval and consequently the exact level of the base of the *B. woodi* Zone is unknown to date, the zonal base is tentatively drawn on the 6 m level for the following reasons:

- *Belemnitella mucronata* from the 0.5-5.0 m interval of the Zeven Wegen Member may be regarded as transitional between *B. mucronata* and *B. woodi*, because it resembles the latter species in having a large Schatzky Distance and small alveolar angle. The earliest *B. woodi* is expected to occur immediately above this interval;
- in the coastal section at Weybourne foreshore (Norfolk), *G. p. basiplana* and *E.* (?) *hemisphaericus* were collected from the level of Flint Z (Pre-Weybourne$_5$ Chalk) together with *B. woodi* (see SCHULZ, 1985; CHRISTENSEN, 1995). At the CPL SA quarry the highest record of both echinoid species is from about 7-8 m above the Loën Horizon (JAGT, 1988). It is concluded that *B. woodi* most probably developed from *B. mucronata* before these echinoids disappeared, in the 5-7 m interval above the base of the member.

As a consequence the base of the *B. woodi* Zone is tentatively drawn about 6 m above the base of the member. In Norfolk, the early form of *B. woodi* is known from the Pre-Weybourne$_5$ Chalk and the Weybourne$_1$ Chalk. These deposits can be correlated with the upper *basiplana/spiniger* Zone and the lower *roemeri* Zone *sensu* SCHULZ *et al.* (1984) and SCHÖNFELD *et al.* (1996), and the *'vulgaris'/basiplana* and *'vulgaris'/stolleyi* zones of NIEBUHR et al. (1997). The top of the *basiplana/spiniger* Zone lies within the interval with early *B. woodi*, about 10-13 m above the base of the Zeven Wegen Member.

Subzone II of the *B. woodi* Zone corresponds to the 17-29 m interval of the Zeven Wegen Member. In Norfolk, the late form of *B. woodi* occurs in the Weybourne$_2$ and Weybourne$_3$ chalks. These deposits are correlated with the upper *roemeri* Zone. At present, it cannot be determined whether equivalents of the uppermost Weybourne$_3$ Chalk (Catton Sponge Bed, *polyplocum* Zone), characterised by the first appearance datum (FAD) of *B. minor* I, are represented, since no belemnite guards from the uppermost metre of the Zeven Wegen Member were available. It is assumed that the *polyplocum* Zone is not represented, since the index ammonite has not been found yet. Nevertheless, it is emphasised that the correlation of the uppermost Zeven Wegen Member at the CPL SA quarry with the uppermost *roemeri* Zone *sensu germanico* is preliminary. Further studies are needed to resolve this question.

The *B. minor* Zone comprises the Late Campanian portion of the Beutenaken Member, and includes the *B. minor* I and *B. minor* II subzones. The first subzone was identified in the lowermost metre of this member in a road cutting northeast of Teuven, where *B. minor* I and *B. najdini* were found to co-occur. In Norfolk, these species co-occur in the upper Beeston Chalk. According to CHRISTENSEN (1995, text-figs 1, 2) these deposits can be correlated with the lower *langei* Zone of the Kronsmoor quarry (NW Germany). The *polyplocum* Zone seems to be missing at Teuven. However, it cannot be excluded that the basal part of the Beutenaken Member in fact represents a condensed sequence, comparable to the basal part of the Zeven Wegen Member, and includes equivalents of both the *polyplocum* and *langei* zones.

The *B. minor* II subzone includes the Beutenaken Member of the Bovenste Bos quarry from the 2.0-0.7 m interval below the Bovenste Bos Horizon and boulders of Beutenaken Chalk facies collected in a field near Slenaken. *Belemnitella minor* II and *B. najdini* co-occur at both localities. In Norfolk, *B. minor* II is confined to the Paramoudra Chalk, which is correlated with the upper *langei* and *grimmensis/granulosus* zones of the NW German zonal scheme (CHRISTENSEN, 1995). At present, the Beutenaken Member is exposed only in very few outcrops, which are poorly accessible at that. For that reason, exact data for the base and top of the *B. minor* II subzone cannot be given at this moment (Fig. 9).

CONCLUSIONS

In the present paper the following informal belemnite zones are recognised in the Zeven Wegen and Beutenaken members:

- *Belemnitella mucronata* Zone: lower Zeven Wegen Member, corresponding to the Pre-Weybourne$_3$ Chalk of Norfolk, and to the lower *basiplana/spiniger* Zone and possibly the upper *conica/mucronata* Zone;
- *Belemnitella woodi* Zone: middle and upper Zeven Wegen Member, correlating with the Pre-Weybourne$_5$ Chalk and Weybourne$_{1-3}$ chalks of Norfolk, and with the upper *basiplana/spiniger* and *roemeri* zones (= *'vulgaris'/basiplana* and *'vulgaris'/stolleyi* zones) of NW Germany;
- *Belemnitella minor* Zone: part of the Beutenaken Member, corresponding to the (? upper) Beeston Chalk and the Paramoudra Chalk of Norfolk. The presence of the NW German *polyplocum* Zone (= *minor/polyplocum* Zone) at the very base of the Beutenaken Member is questionable, but the *langei* and *grimmensis/granulosus* zones are indeed represented.

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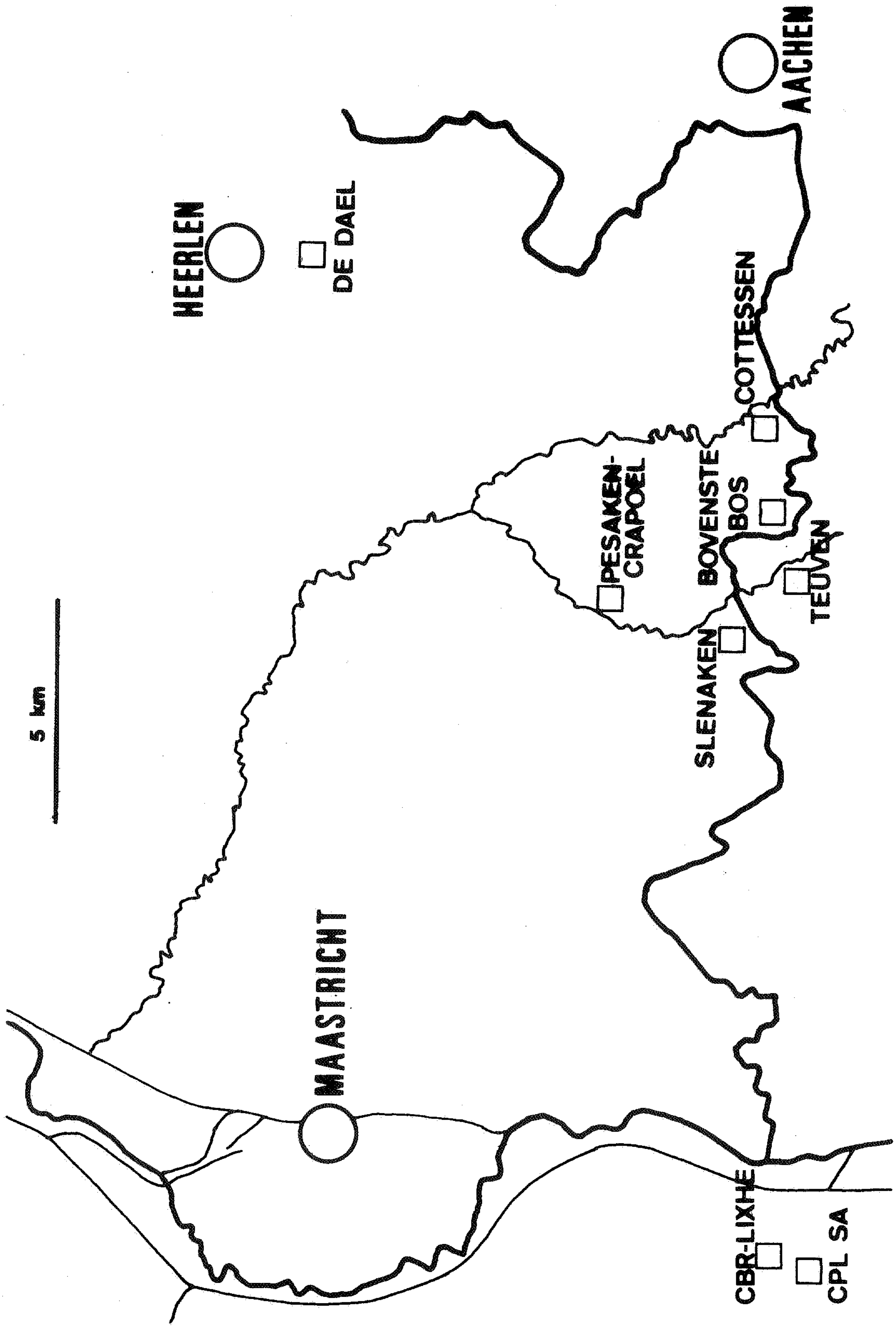

Fig. 1. Map of southern Limburg (The Netherlands) and contiguous areas in NE Belgium and W Germany showing location of sections mentioned in the text.

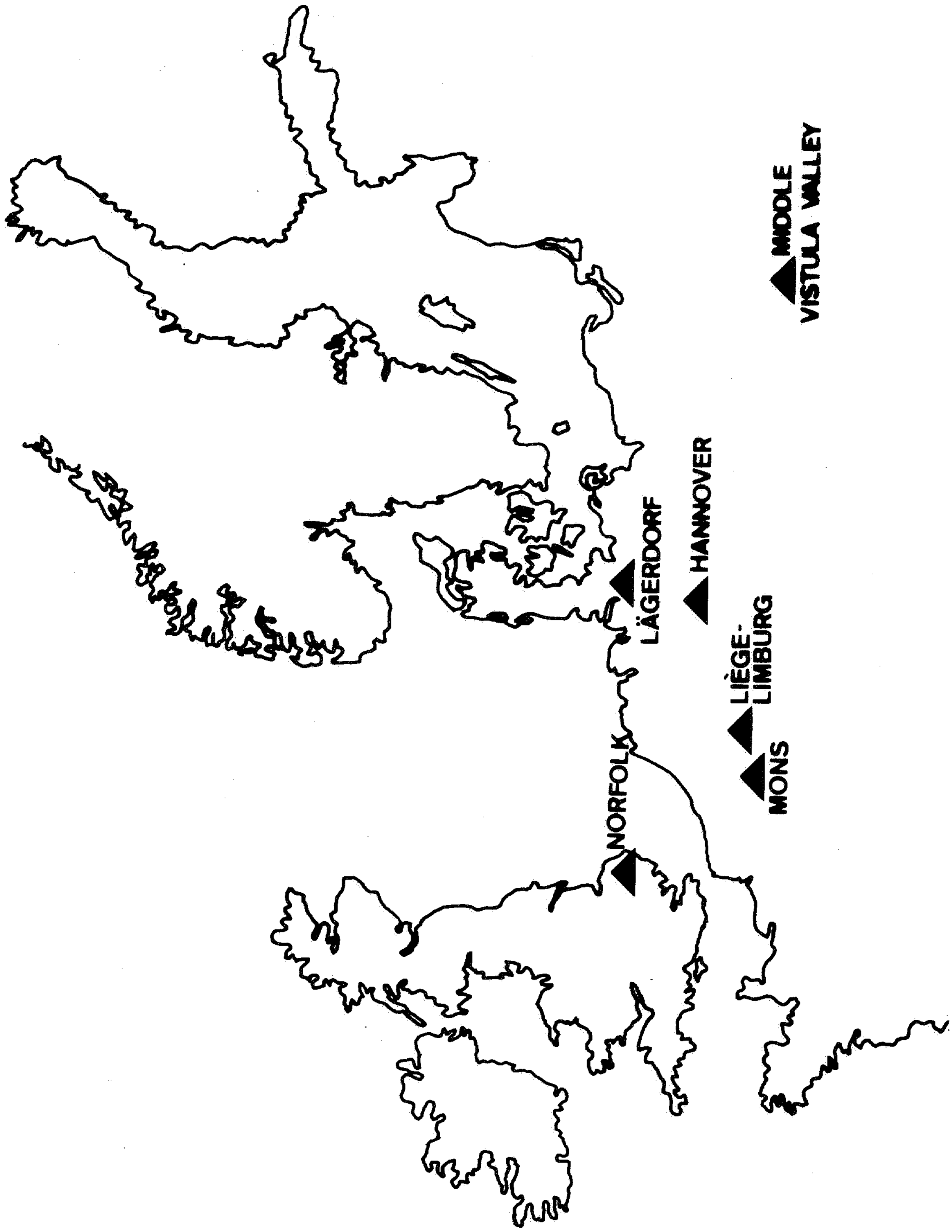

Fig. 2. Map of northern Europe showing locations of sections referred to in the text.

Formation	Member	Stage
MAASTRICHT Formation	MEERSSEN Member	late MAASTRICHTIAN
	NEKUM Member	
	EMAEL Member	
	SCHIEPERSBERG Member	
	GRONSVELD Member	
	VALKENBURG Member	
GULPEN Formation	LANAYE Member	
	LIXHE 1-3 Members	early MAASTRICHTIAN
	VIJLEN Member	
	BEUTENAKEN Member	
	ZEVEN WEGEN Member	late CAMPANIAN
VAALS Formation	BENZENRADE Member	
	TERSTRAETEN Member	early CAMPANIAN
	BEUSDAL Member	
	VAALSBROEK Member	
	GEMMENICH Member	
	COTTESSEN Member	
	RAREN Member	

Fig. 3. Chrono- and lithostratigraphy of Late Cretaceous strata in the (extended) type area of the Maastrichtian Stage (Liège-Limburg) (modified from W.M. FELDER & BOSCH, in press).

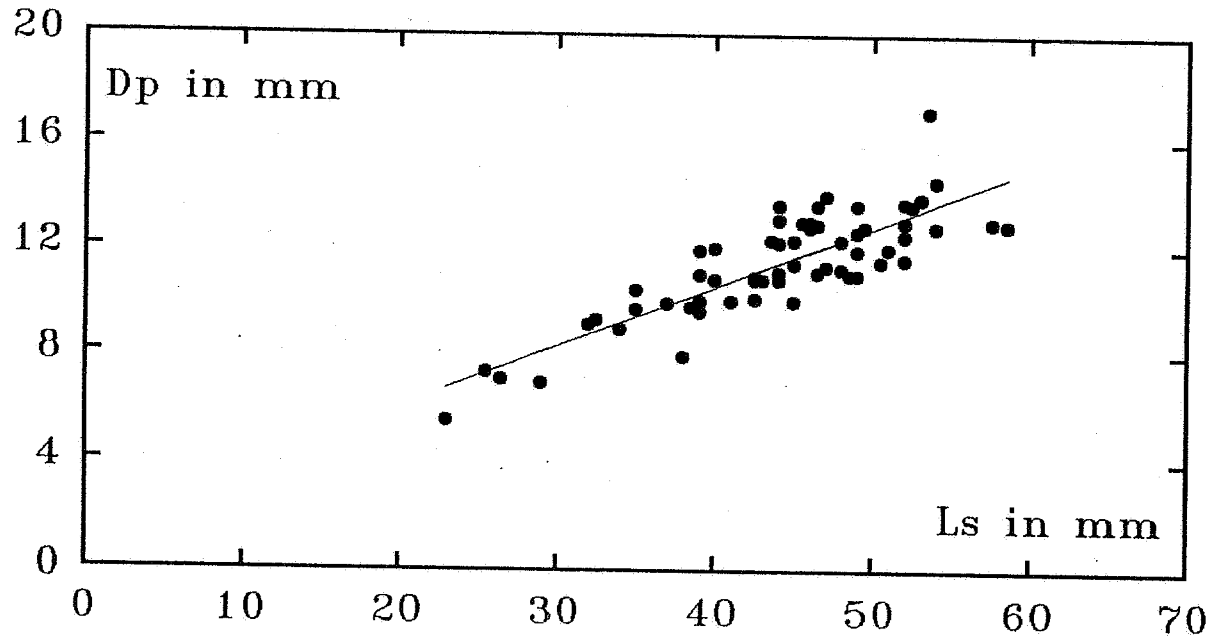

Fig. 4. Scatter plot and regression line of the late form of *Belemnitella woodi* Christensen, 1995, CPL SA quarry (Haccourt), Gulpen Formation (Zeven Wegen Member).

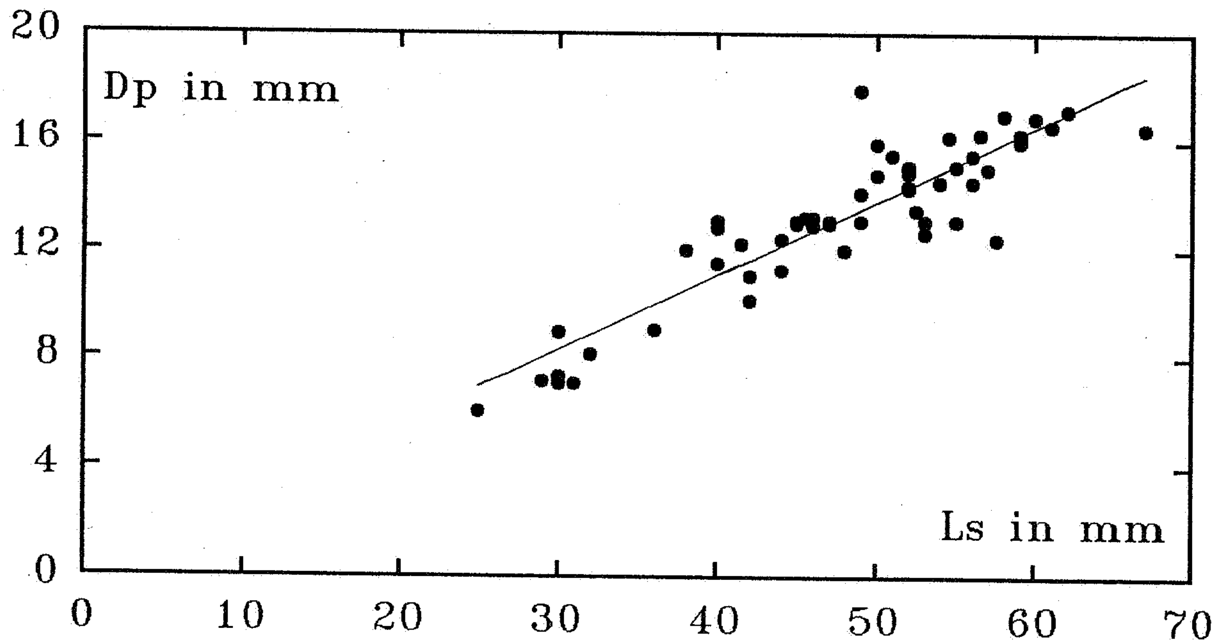

Fig. 5. Scatter plot and regression line of *Belemnitella minor* II Christensen, 1995 from the Beutenaken Member (Gulpen Formation).

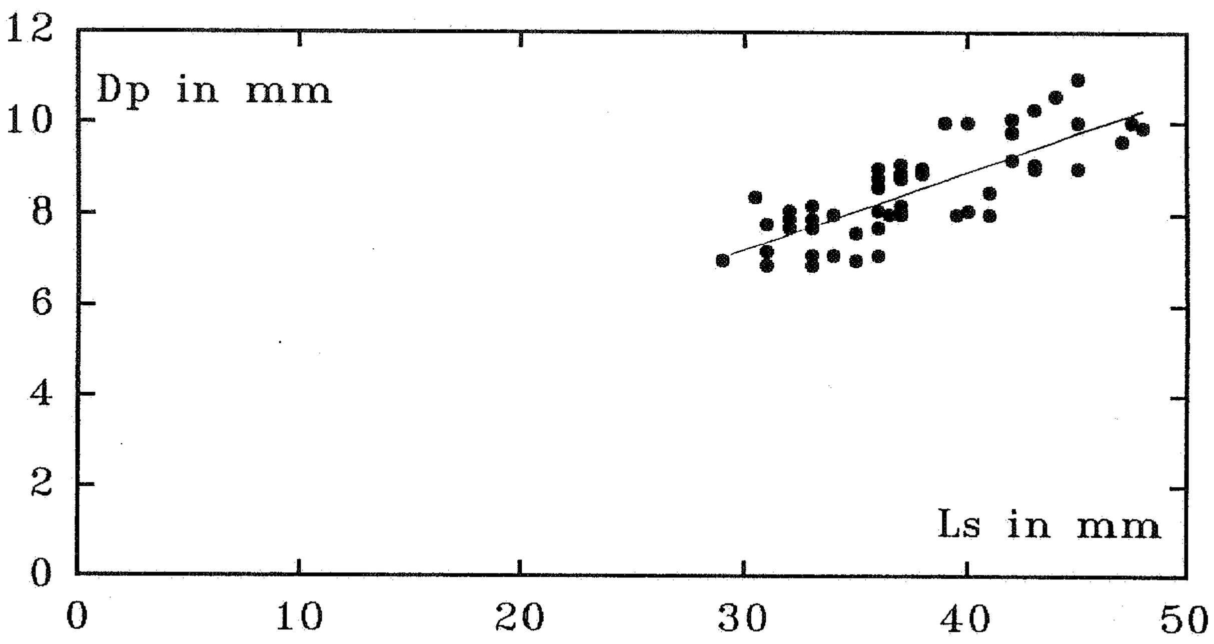

Fig. 6. Scatter plot and regression line of *Belemnitella najdini* Kongiel, 1962 from the Beutenaken Member (Gulpen Formation).

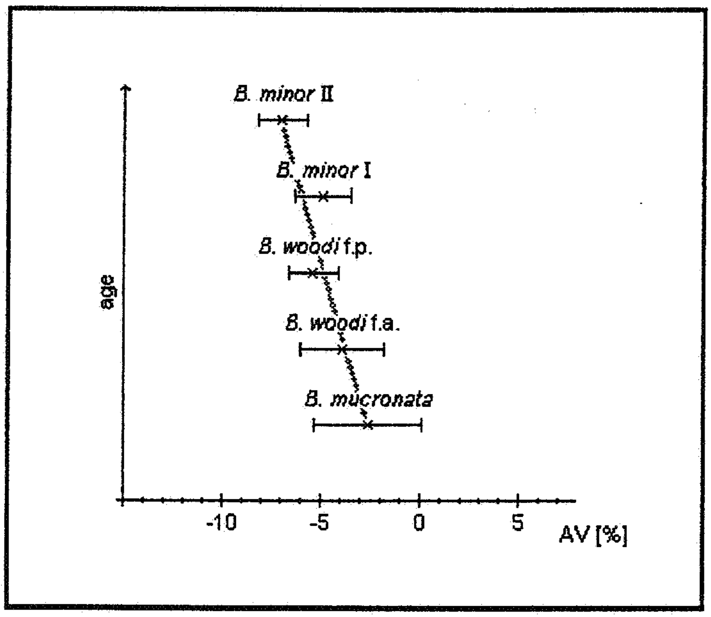

Fig. 7. Evolution of the ventral aspect (AV: mean value and 95% confidence interval) in the *Belemnitella mucronata-woodi-minor* lineage.

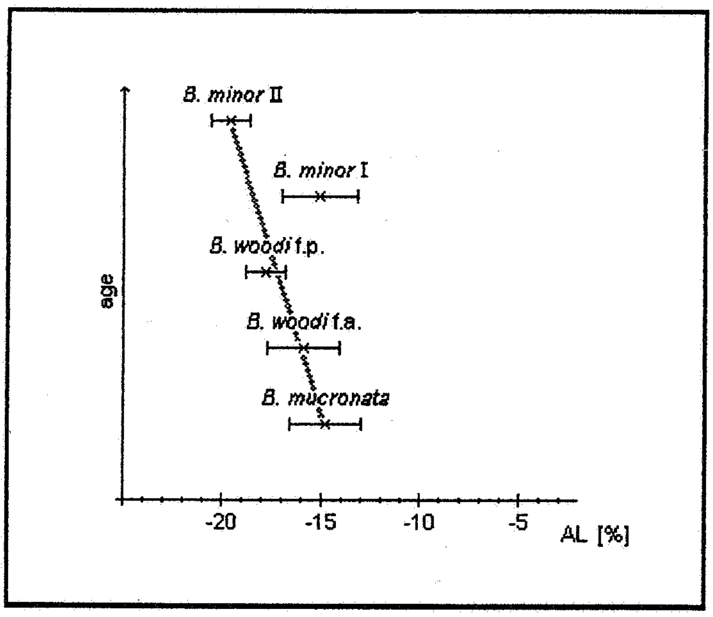

Fig. 8. Evolution of the lateral aspect (AL: mean value and 95% confidence interval) in the *Belemnitella mucronata-woodi-minor* lineage.

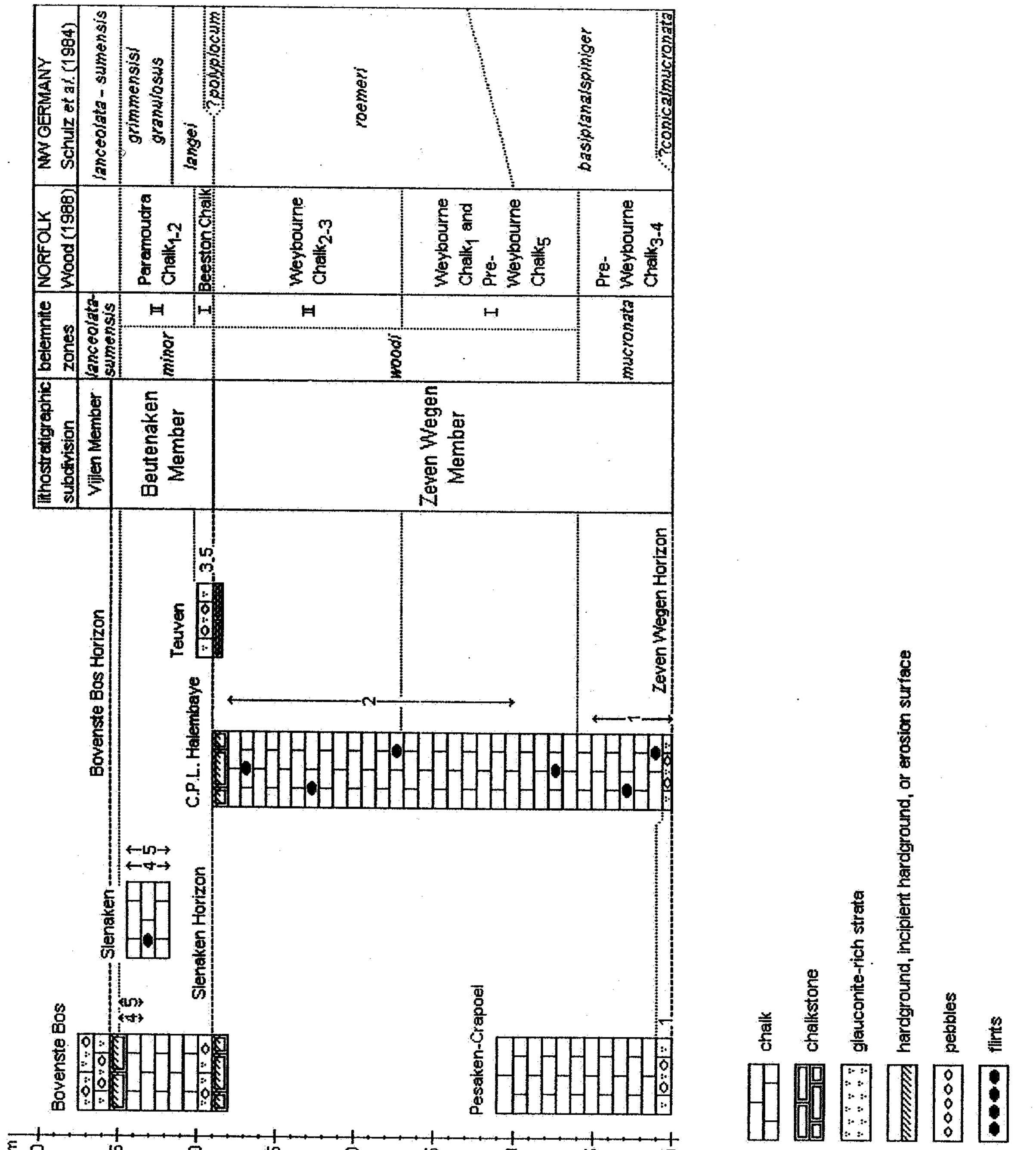

Fig. 9. Subdivision and correlation of Late Campanian deposits in Liège-Limburg with the zonations of the Norfolk chalk (England) and Lägerdorf-Kronsmoor (NW Germany); 1 - *Belemnitella mucronata*, 2 - *B. woodi*, 3 - *B. minor* I, 4 - *B. minor* II, 5 - *B. najdini*.

PLATE 1

Figs 1-4. *Belemnitella woodi* Christensen, 1995; 1, 2 - NHMM JJ 2968 (total length 80 mm); 3, 4 - NHMM JJ 2711 (total length 76 mm), Gulpen Formation, upper Zeven Wegen Member, CPL SA quarry (Haccourt, Liège).

Figs 5-8. *Belemnitella minor* II Christensen, 1995; 5, 6 - NHMM Keutgen/BM 26 (total length 84 mm); 7, 8 - NHMM Keutgen/BM 22 (total length 68 mm), Gulpen Formation, Beutenaken Member, Bovenste Bos quarry (southern Limburg, The Netherlands).

Figs 9, 10. *Belemnitella najdini* Kongiel, 1962; NHMM Keutgen/BSP 6 (total length 65 mm), Gulpen Formation, Beutenaken Member, Bovenste Bos quarry (southern Limburg, The Netherlands).


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