

# *Belemnitella schulzi* sp. nov. from the uppermost Campanian and lowest Maastrichtian chalks of northwest Germany and Denmark

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## ABSTRACT:

CHRISTENSEN, W.K. 2000. *Belemnitella schulzi* sp. nov. from the uppermost Campanian and lowest Maastrichtian chalks of northwest Germany and Denmark. *Acta Geologica Polonica*, **50** (1), 55-66. Warszawa.

*Belemnitella schulzi*, a new belemnitellid species from the uppermost Campanian of northwest Germany and lowermost Maastrichtian of Denmark, is described, utilising biometric methods. Previously, this new species was referred to as *B. langei* in Denmark and *B. cf. najdini* in northwest Germany. *B. schulzi* sp. nov. is compared with Upper Campanian and Maastrichtian species of *Belemnitella* from west and central Europe, and these are briefly reviewed.

**Key words:** *Belemnitella schulzi* sp. nov., uppermost Campanian, lowest Maastrichtian, Germany, Denmark.

## INTRODUCTION

BIRKELUND (1957) described *Belemnitella langei* JELETZKY, 1948, from the chalk exposed in the western part of Hvide Klint on the island of Møn, Denmark (Text-fig. 1). On belemnite evidence, she considered this locality to be late Late Campanian in age. However, SURLYK (1984) placed this locality in his *jasmundi-acutirostris* brachiopod Zone, which essentially is earliest Maastrichtian in age. According to SURLYK (1982) this brachiopod zone equates with the lower part of the *Belemnitella lanceolata* Zone of SCHULZ (1979) (Text-fig. 2)

SCHULZ (1978) suggested that *B. langei* is an east-European species, which probably occurs in northwest Europe only in the lower part of the *B. langei* Zone of the Kronsmoor pit, northwest Germany (Text-figs 1-2). He also suggested that most or all records of *B. langei* from northwest

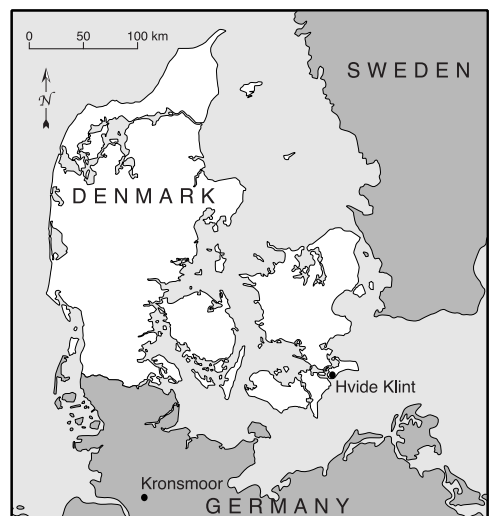


Fig. 1. Map showing the location of the Kronsmoor pit in northwest Germany and Hvide Klint on the island of Møn, Denmark (after SURLYK 1984)

SUB-STAGES	BIOZONES, NW GERMANY	BRACHIOPOD ZONES, NW EUROPE	
LOWER MAA lower	<i>obtusa</i>	<i>spinosa-</i> <i>subtilis</i>	Belemnitella schulzi sp. nov.
	<i>pseudobtusa</i>	<i>acutirostris-</i> <i>spinosa</i>	
	<i>lanceolata</i>		
UPPER CPM upper		<i>grimmensis/ granulosus</i>	
	<i>tenuicostata-</i> <i>longicollis</i>		

Fig. 2. Stratigraphical scheme, showing upper Upper Campanian and lower Lower Maastrichtian biozones of northwest Germany, brachiopod zones of northwest Europe and range of *Belemnitella schulzi* sp. nov.; biozones after SCHULZ (1978, 1979, 1996) and brachiopod zones after SURLYK (1982, 1984); vertical axis not to scale

Europe are misconceptions, and that these forms probably should be assigned to *B. cf. najdini* KONGIEL, 1962. SCHULZ (1996) recorded this species from the upper part of the *B. langei* Zone and the superjacent *grimmensis/granulosus* Zone of Krons Moor, except the topmost 5 m of the latter, which have not yielded belemnites.

CHRISTENSEN (1995) showed that neither *B. langei* of BIRKELUND nor *B. langei* of SCHULZ is conspecific with *B. langei* JELETZKY. It is shown below that *B. langei sensu* BIRKELUND differs in no significant respect from *B. cf. najdini sensu* SCHULZ, whereas the latter differs markedly from *B. najdini*. Therefore, *B. langei sensu* BIRKELUND and *B. cf. najdini sensu* SCHULZ are placed in synonymy with *Belemnitella schulzi* sp. nov.

#### SYSTEMATIC PALAEOLOGY

Terminology, measurements and biometric methods used below were discussed by CHRISTENSEN (1975, 1986, 1991, 1995). Measured characters and

their abbreviations are as follows: length from apex to protoconch (LAP), dorso-ventral diameter at protoconch (DVDP), lateral diameter at protoconch (LDP), maximum lateral diameter (MLD), Schatzky distance (SD), fissure angle (FA), and alveolar angle (AA). The Birkelund Index (BI) of CHRISTENSEN (1995) is the length from the apex to the protoconch divided by the dorso-ventral diameter at the protoconch. Measurements are in mm and degrees.

Species variation is analysed by univariate and bivariate biometric methods and is summarised by descriptive statistics.

In the univariate analysis the following statistics were calculated: arithmetical mean value ( $\bar{X}$ ), standard deviation ( $s$ ) and coefficient of variation (CV). In addition, the observed range (OR) and number of specimens ( $N$ ) are reported.

The regression line is written  $y = a + bx$ . The following statistics were calculated: the slope ( $b$ ), the standard deviation of the slope ( $s_b$ ), the intercept on the y-axis ( $a$ ), the standard deviation of the intercept ( $s_a$ ), the standard deviation of the regression line ( $s_{yz}$ ) and the correlation coefficient ( $r$ ).  $N$  is the number of specimens.

Family Belemnitellidae PAVLOV, 1914  
[ICZN 1985, Opinion 1328, name no. 572]

Genus *Belemnitella* D'ORBIGNY, 1840  
[ICZN 1985, Opinion 1328, name no. 2269]

TYPE SPECIES: *Belemnites mucronatus* SCHLOTHEIM, 1813, p. 111, by subsequent designation by HERRMANNSEN (1846, p. 105); ICZN (1985), name no. 2279.

DIAGNOSIS: See CHRISTENSEN (1997a).

REMARKS: The classification of size ranges of species of *Belemnitella* based on the length from the apex to the protoconch (LAP) and the slenderness of the guard based on the mean value of the Birkelund Index by CHRISTENSEN (1995) are used herein. **Size:** 1) guard small, LAP less than 55 mm; 2) guard large, LAP 55-65 mm; 3) guard very large, LAP larger than 65 mm. **Slenderness:** 1) guard stout, mean BI less than 4; 2) guard slender, mean BI 4-5; 3) guard very slender, mean BI larger than 5.

DISTRIBUTION: *Belemnitella* appeared probably at the base of the Santonian and persisted to the end of the Maastrichtian. It occurred in the North

European and North American Provinces of the North Temperate Realm, in addition to the northern European margin of the Tethyan Realm (CHRISTENSEN 1997a, b).

*Belemnitella schulzi* sp. nov.

(Pl. 1, Figs 1-30)

1957. *Belemnitella langei* JELETZKY; BIRKELUND, p. 31, Pl. 2, Fig. 6; Pl. 3, Fig. 1; Text-fig. 2.  
 1978. *Belemnitella* cf. *najdini* KONGIEL; SCHULZ, pp. 78, 81.  
 1995. *Belemnitella langei sensu* BIRKELUND; CHRISTENSEN, p. 70, Pl. 8, Figs 10-13.  
 1995. *Belemnitella* cf. *najdini sensu* SCHULZ; CHRISTENSEN, p. 72.  
 1997a. *Belemnitella langei sensu* BIRKELUND; CHRISTENSEN, p. 74.  
 1997b. *Belemnitella* cf. *najdini sensu* SCHULZ; CHRISTENSEN, p. 74.  
 1998a. *Belemnitella langei sensu* BIRKELUND; CHRISTENSEN, p. 15.  
 1998a. *Belemnitella* cf. *najdini sensu* SCHULZ; CHRISTENSEN, p. 15.  
 1998b. *Belemnitella langei sensu* BIRKELUND; CHRISTENSEN, p. 18.  
 1998b. *Belemnitella* cf. *najdini sensu* SCHULZ; CHRISTENSEN, p. 18.

DERIVATION OF THE NAME: The species is named in honour of the late Dr. M.-G. SCHULZ, Kiel, Germany.

HOLOTYPE: MMH 7846, western part of Hvide Klint, island of Møn, Denmark (figured by BIRKELUND 1957, Pl. 2, Fig. 6 as *Belemnitella langei* JELETZKY); *jasmundi-acutirostris* brachiopod Zone, lowermost Maastrichtian (SURLYK, 1984). It was refigured by CHRISTENSEN (1995, Pl. 8, Figs 10-13 as *B. langei sensu* BIRKELUND) and is here figured on Pl. 1, Figs 1-4).

DIMENSIONS OF THE HOLOTYPE: Length from apex to protoconch, 53.2 mm; dorso-ventral diameter at protoconch, 13.5 mm; lateral diameter at protoconch, 13.3 mm; maximum lateral diameter, 13.5 mm; Schatzky distance, *c.* 8 mm; fissure angle, 33.0°; alveolar angle, 21.0°; Birkelund Index, 3.9.

MATERIAL: 14 specimens from the western part of the Hvide Klint, island of Møn, Denmark; lowermost Maastrichtian, *jasmundi-acutirostris* brachiopod Zone; 21 specimens from the uppermost

Campanian *grimmensis/granulosus* Zone, Kronsmoor, northwest Germany, ex M.-G. SCHULZ Collection.

DIAGNOSIS: Guard large and slender; Schatzky distance medium-sized; fissure angle large; alveolar angle large; vascular markings conspicuous around ventral fissure and weakly developed or not present elsewhere.

DESCRIPTION: Guard large (maximum length from apex to protoconch a little less than 65 mm) and slender, subcylindrical in ventral view and subcylindrical or high conical in lateral view; guard slightly or not flattened ventrally; dorso-ventral diameter at protoconch equal to lateral diameter at protoconch; relationship between length from apex to protoconch and dorso-ventral diameter at protoconch isometric; mean value of Birkelund Index *c.* 4, with an observed range from *c.* 3.5 to 5; apical end commonly acute, with a well defined mucro.

Schatzky distance medium-sized, mean value *c.* 8 mm, with an observed range from 4.5 mm to 11 mm; fissure angle large, mean value *c.* 55°, with a large observed range from 13° to 89°; alveolar angle large, mean value 20°, with an observed range from 18.0° to 22.5°; shape of bottom of ventral fissure variable, straight, concavely curved or s-shaped.

Dorso-lateral depression and double furrows fully developed; vascular imprints usually conspicuous around the ventral fissure and weakly developed or not present elsewhere.

BIOMETRY: Two samples were analysed. 1) 14 specimens from the western part of Hvide Klint on the island Møn, Denmark, lowermost Maastrichtian *jasmundi-acutirostris* Zone. This sample consists of the four nearly-complete specimens analysed biometrically by CHRISTENSEN (1995), in addition to ten alveolar fragments. These were assigned to *B. langei* by BIRKELUND (1957). 2) Seven specimens from the uppermost Upper Campanian *grimmensis/granulosus* Zone of Kronsmoor, northwest Germany (CHRISTENSEN 1995, Table on p. 72). These were obtained from Dr. M.-G. SCHULZ, Kiel, and referred to as *B. cf. najdini*. The two samples were analysed only by univariate biometric methods due to the small number of specimens.

In addition, Dr. N. KEUTGEN (unpublished) has analysed 24 specimens from the *grimmensis/granulosus* Zone of Kronsmoor by univariate and bivariate methods, and he has kindly placed the results at my disposal.

Character	<i>N</i>	$\bar{X}$	<i>s</i>	CV	OR
LAP	4	47.7	4.2	8.7	43.1-53.2
DVDP	4	12.4	1.0	8.0	11.1-13.3
LDP	4	12.4	0.9	7.4	11.2-13.3
MLD	4	12.5	1.0	7.8	11.2-13.5
SD	10	7.9	1.4	17.4	6.1-10.2
FA	11	53.4	23.6	44.1	13.0-88.5
AA	14	19.9	1.2	5.9	18.5-22.5
BI	4	3.9	0.3	8.1	3.5-4.2

Table 1. Univariate analysis of *Belemnitella schulzi* sp. nov. from the lowermost Maastrichtian of the western part of Hvide Klint, island of Møn, Denmark

Character	<i>N</i>	$\bar{X}$	<i>s</i>	CV	OR
LAP	7	51.6	4.5	8.7	44.4-57.7
DVDP	7	12.6	1.0	8.1	11.2-13.7
LDP	7	12.6	1.1	8.4	11.5-13.8
MLD	7	12.7	1.1	8.5	11.5-14.1
SD	7	8.0	1.7	20.6	5.3-10.3
FA	7	56.1	22.9	40.9	37.0-90.0
AA	7	18.8	0.8	4.0	18.0-20.0
BI	7	4.1	0.3	7.7	3.5-4.6

Table 2. Univariate analysis of *Belemnitella schulzi* sp. nov. from the uppermost Campanian *grimmensis/granulosus* Zone of Kronsnoor, northern Germany; after CHRISTENSEN (1995)

Character	<i>N</i>	$\bar{X}$	<i>s</i>	CV	OR
LAP	24	49.1	7.1	14.4	27.0-63.5
DVDP	24	12.0	1.8	15.0	6.0-14.2
SD	22	8.1	1.6	19.8	4.5-11.0
FA	22	55.8	17.5	31.4	20.0-85.0
AA	20	19.9	1.1	5.5	18.0-22.0
BI	24	4.1	0.4	9.8	3.7-5.2

Table 3. Univariate analysis of *Belemnitella schulzi* sp. nov. from the uppermost Campanian *grimmensis/granulosus* Zone of Kronsnoor, northern Germany; after N. KEUTGEN, unpublished

UNIVARIATE ANALYSIS: The results of the three analyses are shown in Tables 1-3.

BIVARIATE ANALYSIS: The results of this analysis are as follows: DVDP = 1.354 + 0.216 LAP; *N* = 24; *r* = 0.837; *s<sub>a</sub>* = 1.492; *s<sub>b</sub>* = 0.030; *s<sub>yx</sub>* = 1.007. The

correlation coefficient is very highly significant (*P* < 0.001, with 22 degrees of freedom). The *t*-test on the *y*-intercept showed that the intercept does not differ significantly from zero, implying an isometric relationship of the variates (*t<sub>a</sub>* = 0.905; 0.40 > *P* > 0.30, with 22 degrees of freedom).

DISCUSSION: The results of the univariate analysis of *B. schulzi* sp. nov. from Kronsnoor by CHRISTENSEN (1995) and KEUTGEN (unpublished), respectively, are very closely similar with one exception (Tables 2-3). CHRISTENSEN reported that the mean value of the alveolar angle is *c.* 19°, whereas it is *c.* 20° in KEUTGEN's sample. The latter mean value may be a better estimate of the sample parameter, because it is calculated on the basis of a larger number of specimens.

With respect to the size, slenderness and internal characters (*cf.* Table 1-3), as well as surface markings, shape in ventral and lateral views, shape of the bottom of the ventral fissure and form of the apical end, the lowermost Maastrichtian *B. langei sensu* BIRKELUND differs in no significant respect from the uppermost Upper Campanian *B. cf. najdini sensu* SCHULZ. In contrast, *B. langei sensu* BIRKELUND differs from *B. langei* JELETZKY, and *B. cf. najdini* differs from *B. najdini* (see below). Because of this, the new species *B. schulzi* is erected to accommodate the two concepts *B. langei sensu* BIRKELUND and *B. cf. najdini sensu* SCHULZ. This new species is attributed to the *B. mucronata* group of CHRISTENSEN (1995) due to its large guard and medium-sized Schatzky distance. However, the mean value of the fissure angle in *B. schulzi* sp. nov. is larger than in most species of the group (see Table 4), and the bottom of the ventral fissure may be irregular as in species of the *B. langei* group.

CHRISTENSEN (1995) placed *B. langei* of BIRKELUND in synonymy with *B. minor* JELETZKY, 1951, subspecies II CHRISTENSEN, 1995 with a query, because the variation of *B. langei* of BIRKELUND was inadequately known at that time. It is now known that *B. langei* of BIRKELUND differs markedly from *B. minor* II (see below). Moreover, CHRISTENSEN (1995) noted that *B. cf. najdini* was closely similar to *B. minor* JELETZKY, 1951 subspecies III CHRISTENSEN, 1995 (= *B. minor* II; see CHRISTENSEN 1997b, 1998a, 1999) with respect to size and slenderness, but that it differed in its larger fissure angle and smaller SCHATZKY distance. The affinity to *B. minor* is discussed in detail below.

DISTRIBUTION: *Belemnitella schulzi* sp. nov. has

been recorded only from the western part of Hvide Klint, island of Møn, Denmark and the Kronsmoor pit, northwest Germany (Text-fig. 1). In Denmark it is distributed in the lowermost Lower Maastrichtian *jasmundi-acutirostris* brachiopod Zone, which equates with the lower half of the *Belemnitella lanceolata* Zone of SCHULZ (1979). It occurs at Kronsmoor in the uppermost Campanian, that is in the upper part of the *langei* Zone and the overlying *grimmensis/granulosus* Zone, except the topmost 5 m (SCHULZ 1978) (Text-fig. 2). The upper part of the *langei* Zone and the overlying *grimmensis/granulosus* Zone was correlated with the Paramoudra Chalk of Norfolk, which was placed in the *Belemnitella minor* II Zone by CHRISTENSEN (1995, Text-figs 1-2) (Text-fig. 3).

COMPARISON WITH UPPER CAMPANIAN AND MAASTRICHTIAN SPECIES OF *BELEMNITELLA*

More than two dozen species, subspecies and varieties of *Belemnitella* from the Upper Campanian and Lower Maastrichtian of the North European belemnite Province of CHRISTENSEN (1975, 1997b) have been established, notably by eastern European workers. Many of these are poorly understood, because they were commonly erected on the basis of relatively little material and the variation of critical characters was rarely studied by appropriate methods (CHRISTENSEN 1986, 1990, 1993).

The affinity of *B. schulzi* sp. nov. to species of the *B. mucronata* group and *B. langei* group of

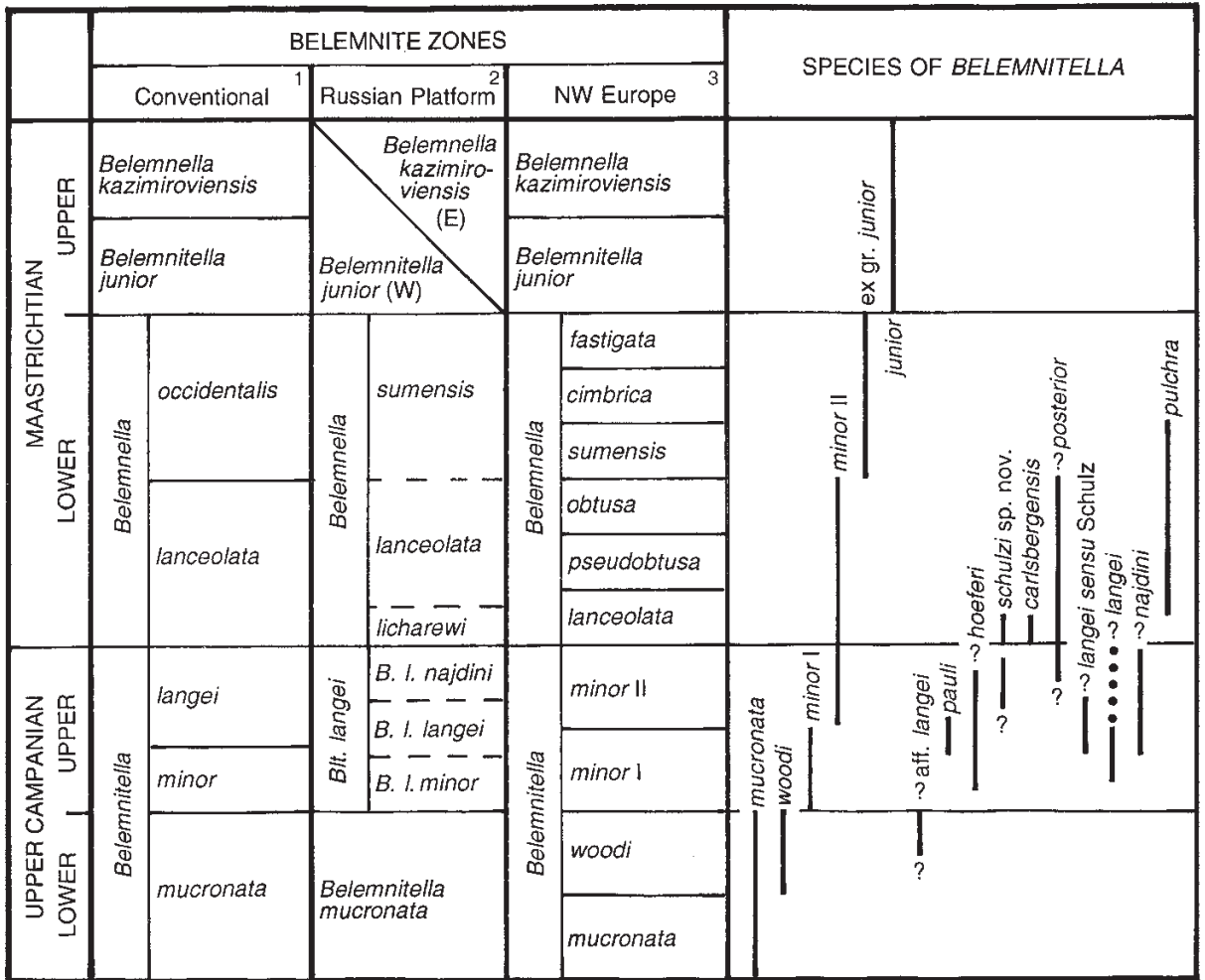


Fig. 3. Stratigraphical scheme, showing Upper Campanian and Maastrichtian belemnite zones and ranges of *Belemnitella* species; Blt – *Belemnitella*; Column 1 – after JELETZKY (1951b, 1958) and BIRKELUND (1957); column 2 – after NAIDIN (1979); column 3 – after CHRISTENSEN (1995, 1999) for the Upper Campanian, and after SCHULZ (1979) for the Lower Maastrichtian; vertical axis not to scale

Species	Source	Max. LAP in mm	$\bar{X}_{BI}$	$\bar{X}_{SD}$ in mm	$\bar{X}_{FA}$ in degrees	$\bar{X}_{AA}$ in degrees
<i>Belemnitella mucronata</i> group						
<i>B. schulzi</i> sp. nov.	1)	<65	c. 4	8	55	20
<i>B. mucronata</i>	2)	c. 65	3.3-3.6	7-9	15-25	20-21
<i>B. woodi</i>	2)	<65	3.3-3.8	c.10	25-30	c. 19
<i>B. minor</i> I	2)	70	c. 4	9	30	c. 19
<i>B. minor</i> II	2)	70	3.6	12	28	c. 19
<i>B. pauli</i>	2)	60	c. 4	c. 7	c. 70	c. 20
<i>B. ex gr. junior</i>	3)	65	c. 4	c. 7	c. 26	18.5
<i>B. junior</i>	3)	75	4.6	c. 8	c. 30	19
<i>B. aff. langei</i>	4)	c. 55	4.4-4.6	c. 7	c. 17	c. 20
<i>B. hoeferi</i>	5)	60	4.4	c. 9	17	20.5
<i>B. carlsbergensis</i>	6)	c. 70	4.3	7-9	30-34	20
<i>Belemnitella langei</i> group						
<i>B. langei</i>	2)	55	4.3	5-6	50-64	c. 19
<i>B. najdini</i>	2)	c. 50	4.7	c. 6	c. 100	21
<i>B. najdini</i>	7)	c. 50	4.4	6.5	c. 90	20
<i>B. pulchra</i>	3)	60	c. 6	c. 6	57	20
Other						
<i>B. langei</i> sensu SCHULZ	2)	<65	c. 5	c. 6	40	17

Table 4. Key measurements of uppermost Campanian – Maastrichtian species of *Belemnitella*; the mean value of the Birkelund Index (BI), Schatzky distance (SD), fissure angle (FA), and alveolar angle (AA) are based on representative samples or weighted grand means of several samples; LAP = length from apex to protoconch; 1 – this paper, 2 – after CHRISTENSEN (1995, 1999), 3 – after KEUTGEN & VAN DER TUUK (1990), 4 – after CHRISTENSEN (1986, 1993), 5 – after CHRISTENSEN (1998a), 6 – after CHRISTENSEN (1998b), 7 – after KEUTGEN & JAGT (1999)

CHRISTENSEN (1995), as well as *B. langei sensu* SCHULZ is discussed below (Tables 4-5, Text-fig. 3). This discussion is restricted to species occurring in western and central Europe, most of which I myself have been able to study, and where a sound stratigraphical framework and relatively accurate correlations are available. These species are briefly reviewed.

#### *Belemnitella mucronata* group

Twelve species and subspecies are placed in this group (Tables 4-5, Text-fig. 3).

1) *B. mucronata* (SCHLOTHEIM, 1813). This species is based on the neotype, from the lower Upper Campanian *Pachydiscus stobaei/Galeola papillosa basiplanata* Zone of Misburg, northern Germany, proposed by CHRISTENSEN & al. (1975) (Opinion 1328 of

the International Commission on Zoological Nomenclature 1985). It is widespread in the North European Province and has also been recorded from the northern margin of the Tethyan Realm in Europe. It occurs in the uppermost Lower and lower Upper Campanian. It has been recorded previously also from the upper Upper Campanian and Lower Maastrichtian, but CHRISTENSEN (1998b) argued that these records were based on misconceptions.

*B. schulzi* sp. nov. differs from *B. mucronata* in its more slender guard, larger fissure angle and feebly developed vascular markings.

2) *B. woodi* CHRISTENSEN, 1995. This species was first described from the upper part of the lower Upper Campanian of Norfolk, England by CHRISTENSEN (1995). It has been recorded subsequently from the Zeven Wegen Member of the

Gulpen Formation, northeast Belgium (KEUTGEN 1995, KEUTGEN & JAGT 1999), the uppermost part of the Craie de Nouvelles of the Mons Basin, Belgium (CHRISTENSEN 1999) and the Upper Campanian of the Höver-Misburg-Ahlten area near Hannover (NIEBUHR & *al.* 1997). It is worthy of note, however, that CHRISTENSEN (*unpublished*) did not recognise *B. woodi* from the last-mentioned area.

*B. schulzi* sp. nov. differs from *B. woodi* in its more slender guard, smaller Schatzky distance, larger fissure angle and larger alveolar angle.

3) *B. minor* JELETZKY, 1951. JELETZKY (1951a) designated the original of SHARPE (1853, Pl. 1, Fig. 2), from the Upper Chalk near Norwich, England as holotype for this taxon. CHRISTENSEN & *al.* (1975) showed subsequently that some of the inner characters of the holotype did not agree with those given in the diagnosis. They remarked that the only significant distinction between *B. minor* and *B. mucronata* was that the holotype of *B. minor* was more slender than the majority of specimens of the type series of *B. mucronata*. CHRISTENSEN (1993) noted that *B. minor* could be understood only in the sense of its holotype, because statistically evaluated samples from the type area were not available. He questioned the legitimacy of *B. minor* since it fell within the variation of *B. mucronata*. The legitimacy was also questioned by SCHULZ (1978), and OLSZEWSKA (1990) placed *B. minor* in synonymy with *B. mucronata*.

CHRISTENSEN (1995), on the basis of biometric analysis of several samples from the type area in Norfolk, showed that *B. minor* was a well defined species, which he split into three chronological subspecies: *B. minor* I, the nominotypical subspecies, from the lower part of the upper Upper Campanian, *B. minor* II CHRISTENSEN, 1995, from the upper part of the upper Upper Campanian, and *B. minor* III CHRISTENSEN, 1995, from the lower Lower Maastrichtian. The last was subsequently placed in synonymy with *B. minor* II (CHRISTENSEN 1997b, 1998a, 1999).

According to the original diagnosis, *B. minor* was considered to be a small, slender and younger subspecies of *B. mucronata*, hence the name (JELETZKY 1951a, b). However, the name is unsuitable, because *B. minor* is larger than *B. mucronata* (Table 4). Moreover, *B. minor* I is more slender than *B. mucronata*, whereas *B. minor* II and *B. mucronata* do not differ with respect to this character (CHRISTENSEN 1995, 1999) (Table 4).

*B. minor* was used previously as a zonal index fossil for the lower part of the upper Upper

Campanian (JELETZKY 1951b, 1958) (Text-fig. 3). However, CHRISTENSEN (1995) argued that this conventional zone should not be maintained, since the concepts based on its diagnosis and holotype differed markedly.

*B. minor* I and *B. minor* II have been recorded recently from the Maastricht-Aachen-Liège district (KEUTGEN 1995, 1996; KEUTGEN & JAGT 1999) and Mons Basin (CHRISTENSEN 1999).

*B. schulzi* sp. nov. differs from *B. minor* I in its smaller guard, larger fissure angle, larger alveolar angle and weakly developed vascular markings, and from *B. minor* II in its smaller and more slender guard, smaller Schatzky distance, larger alveolar angle, larger fissure angle, and weakly developed vascular markings.

4) *B. ex gr. junior* NOWAK, 1913. KEUTGEN & VAN DER TUUK (1990) described this taxon from the upper Lower Maastrichtian *Belemnella sumensis*, *B. cimbrica* and *B. fastigata* Zones of the Maastricht-Aachen-Liège district. Later, KEUTGEN (1996) referred this form to *B. junior* and argued that *B. junior* should not be used as a zonal index fossil for the lower Upper Maastrichtian, as had been done for almost half a century (see review by CHRISTENSEN 1996) (Text-fig. 3), because it appeared earlier in the Maastricht-Aachen-Liège district than elsewhere. It is, however, open to discussion if the upper Lower Maastrichtian *B. ex gr. junior* is conspecific with *B. junior*. KEUTGEN (1996, p. 62) compared statistically specimens of *Belemnella* from the upper Lower Maastrichtian with a small sample of *B. junior*, consisting of only 16 specimens, from the Upper Maastrichtian. According to this comparison the two samples of *Belemnella* did not differ in any of their critical characters, that is size and shape of the guard, as well as internal characters. CHRISTENSEN (1999) noted, however, that this conclusion was open to discussion, because the sample of *B. junior* was rather small. He suspected that it might be possible to detect significant differences between upper Lower Maastrichtian and Upper Maastrichtian forms of *Belemnella* when larger samples were compared or to detect evolutionary trends when closely spaced samples were analysed.

*B. schulzi* sp. nov. differs from *B. ex gr. junior* in its larger fissure angle, larger alveolar angle and weakly developed vascular markings.

5) *B. junior* Nowak, 1913. This Upper Maastrichtian species is widely distributed in the North European Province and has been recorded also from the north-

ern margin of the Tethyan Realm (CHRISTENSEN 1997b). *B. schulzi* sp. nov. differs from *B. junior* in its smaller and stouter guard, larger fissure angle, larger alveolar angle and weakly developed vascular markings.

6) *B. posterior* KONGIEL, 1962. This species was established on the basis of seven nearly-complete and three fragmentary specimens from the uppermost Upper Campanian and lower Lower Maastrichtian of the Middle Vistula Valley section of Poland and placed in the *B. mucronata* group by KONGIEL (1962). According to KONGIEL *B. posterior* was a rare species which occurred in the late Late Campanian and died out in the Early Maastrichtian. It differed from *B. mucronata* mainly in its larger fissure angle and smaller Schatzky distance. According to OLSZEWSKA (1990) the specimens placed in *B. posterior* by KONGIEL belong to *B. mucronata*, *B. langei* and *B. najdini*. CHRISTENSEN (1995, p. 73) suggested that *B. posterior* is best treated as a *nomen dubium*.

*B. posterior* was recorded later from the Lower Maastrichtian of Belgium and northwest Germany (SCHULZ 1982, SCHULZ & SCHMID 1983b), and FLETCHER & WOOD (1978) recorded *B. cf. posterior* from the Lower Maastrichtian of Northern Ireland. As mentioned above *B. posterior* is closely similar to *B. mucronata*, but differs in some of its internal characters. However, no published evidence was presented that the internal characters of the specimens from Northern Ireland, Belgium and northwest Germany were studied. Thus, these records are open to discussion.

KONGIEL (1962) provided a univariate biometric analysis of *B. posterior* and remarked that the estimated length of the guard was 125 mm, the Schatzky distance varied from 3.0 to 15.0 mm and was usually 5.0 to 7.0 mm, the fissure angle varied from 41° to 90° and was commonly 41° to 60°, and the alveolar angle varied from 19° to 23° and was usually 21° to 23°. However, it is worthy of note that the sample of *B. posterior* analysed by KONGIEL consisted of only 10 specimens, which were lumped from a very thick stratigraphical interval, that is the uppermost Upper

Campanian and the lower Lower Maastrichtian. The results of the biometric analysis of KONGIEL are thus open to discussion. Therefore, *B. posterior* can be interpreted only with respect to its types. I studied the holotype and the larger of the two paratypes in 1997 and made linear measurements of these (Table 5). As interpreted on the basis of these two specimens, *B. posterior* is a large and slender species with a small Schatzky distance, a large fissure angle and a large alveolar angle. For the time being, it is regarded as a legitimate species, which differed from *B. mucronata* in its more slender guard and larger fissure angle, and from *B. minor* II in its more slender guard, smaller Schatzky distance and larger alveolar angle. For the sake of completeness, it should be mentioned that CHRISTENSEN (1998a) discussed the two types and noted that it was uncertain if these were extreme variants of *B. minor* II or represented a separate species.

*B. schulzi* sp. nov. differs from *B. posterior* in its larger Schatzky distance, smaller alveolar angle and feebly developed vascular markings.

7) *B. aff. langei* CHRISTENSEN, 1986. This species has a very limited area of distribution and has been recorded only from the middle Upper Campanian of the Vomb Trough (CHRISTENSEN 1986) and Båstad Basin (CHRISTENSEN 1993) in southern Sweden. *B. schulzi* sp. nov. differs from *B. aff. langei* in its larger and stouter guard and larger fissure angle.

8) *B. pauli* CHRISTENSEN, 1995. This species has been recorded only from the upper Upper Campanian of Norfolk (CHRISTENSEN 1995). *B. schulzi* sp. nov. differs from *B. pauli* in its smaller fissure angle and weakly developed vascular markings.

9) *B. carlsbergensis* CHRISTENSEN, 1998. This species has been recorded only from the lowermost Lower Maastrichtian of the Kristianstad Basin in Scania, southern Sweden (CHRISTENSEN 1998b). It was assigned previously to *B. minor* by CHRISTENSEN (1975), but CHRISTENSEN (1993) noted that this record was based on a misconception. However, it was uncertain at that time to which

No.	LAP	LVDP	LDP	SD	FA	AA	BI	KONGIEL (1962)	Age
Mcd 214	56.3	13.8	14.0	6	41	21	4.1	Pl. 19, Figs 7-9	uppermost Upper Campanian
Mcd 212	63*	14.7	14.6	7	65	23	4.3	Pl. 19, Figs 1-3	lower Lower Maastrichtian

Table 5. Critical measurements of the holotype and one of the paratypes of *Belemnitella posterior*; fissure and alveolar angles after KONGIEL (1962). Mcd 214, holotype; Mcd 212, paratype; \* = estimated



species this form should be assigned. OLSZEWSKA (1990) erroneously placed it in synonymy with *B. mucronata* (see discussion by CHRISTENSEN 1993). CHRISTENSEN (1998b) placed the Swedish form in his new species *B. carlsbergensis*.

The observed range of the fissure angle of *B. carlsbergensis* and *B. schulzi* sp. nov. is very large and closely similar, 13° to 90° in *B. schulzi* sp. nov. and 13° to 82° in *B. carlsbergensis*. However, the mean values differ. The mean value varies from *c.* 30° to 35° in *B. carlsbergensis* and is *c.* 55° in *B. schulzi* sp. nov. Moreover, *B. schulzi* sp. nov. differs from *B. carlsbergensis* in its smaller guard, feebly developed vascular markings and well defined mucro.

10) *B. hoeferi* (SCHLOENBACH, 1867). This upper Upper Campanian species occurs only in the northern part of the Tethyan Realm in Europe, that is in the northern Ultrahelvetic series and the Gosau Group of the Northern Calcareous Alps in Austria, and possibly at Chartreuse in the Sub-Alpine Chain, Savoie, southeastern France (CHRISTENSEN 1988a). *B. schulzi* sp. nov. differs from *B. hoeferi* in its larger and stouter guard and larger fissure angle.

#### *Belemnitella langei* group

CHRISTENSEN (1995) placed three species in this group, *B. langei* JELETZKY, 1948, *B. najdini* KONGIEL, 1962, and *B. pulchra* SCHULZ, 1982.

1) *B. langei*. This upper Upper Campanian species is poorly known, because it is understood only in the sense of the holotype and paratype, and statistically evaluated samples from the type locality in Ukraine are not available. The Birkelund Index is 4.6 in both the holotype and paratype, the Schatzky distance is *c.* 6.5 mm in the paratype, the fissure angle is *c.* 60° in the holotype and *c.* 55° in the paratype, and the alveolar angle is 19° to 20° in the holotype and 20° to 21° in the paratype. The measurements of the fissure and alveolar angles were obtained from M.-G. SCHULZ, who noted that the alveolar angles cannot be measured accurately, because the alveolus of the types is weathered. Both specimens are slightly lanceolate in ventral view and the vascular markings are conspicuous only around the ventral fissure. Since the variation is not known, the concept of this species is open to question and differs from one author to another as shown by CHRISTENSEN (1995). CHRISTENSEN (1995)

analysed biometrically two small samples of *B. langei* from the middle and upper part of the *B. minor* I Zone of Norfolk (Table 4).

*B. schulzi* sp. nov. differs from *B. langei* from Norfolk in its larger and stouter guard, larger Schatzky distance, larger alveolar angle and weakly developed vascular markings.

*B. langei* was used previously as a zonal index fossil for the uppermost Upper Campanian (JELETZKY 1951b, 1958; BIRKELUND 1957) (Text-fig. 3), but CHRISTENSEN (1995) suggested that this conventional zone should not be maintained, because the concept of this species differed from one author to another. Moreover, it has been shown recently that *B. langei* does not occur in the Maastricht-Aachen-Liège district (KEUTGEN 1996), the Höver-Misburg-Ahlten area (NIEBUHR & *al.* 1997) and the Mons Basin (CHRISTENSEN 1999).

2) *B. najdini*. This species was described from the upper Upper Campanian and Lower Maastrichtian of the Middle Vistula Valley section, Poland (KONGIEL 1962). The stratum typicum is reported to be Upper Campanian and most of the material, including the holotype, came from this level. The Lower Maastrichtian paratype (KONGIEL 1962, Pl. 17, Figs 10-12) was placed in *B. pulchra* by SCHULZ (1982). *B. najdini* was recorded from the upper Upper Campanian Paramoudra<sub>1</sub> Chalk and possibly the uppermost Upper Campanian Paramoudra<sub>2</sub> Chalk of Norfolk (CHRISTENSEN 1995). The specimens from the Paramoudra<sub>2</sub> Chalk were referred to as *B. ex gr. langei* – *najdini* by CHRISTENSEN (1995), but KEUTGEN & JAGT (1999) placed these in *B. najdini* with a query. It also occurs in the upper Upper Campanian of northeast Belgium and southeast Netherlands (KEUTGEN & JAGT 1999). It is suggested, therefore, that *B. najdini* is late Late Campanian in age.

CHRISTENSEN (1995) analysed biometrically six specimens of *B. najdini* from Norfolk (Table 4). KEUTGEN & JAGT (1999) analysed a large sample of this species, consisting of 75 specimens, from the upper Upper Campanian of the Maastricht-Liège district in southeast Netherlands and northeast Belgium (Table 4). They showed that the relationship of the length from the apex to the protoconch and the dorso-ventral diameter at the protoconch was allometric; adult specimens were more slender than juvenile specimens. Since the sample from the Maastricht-Liège district consisted mainly of juvenile and adolescent specimens, the mean value of the Birkelund Index is smaller in this sample ( $\bar{X}_{BI} = 4.4$ )

than in the sample from Norfolk ( $\bar{X}_{BI} = 4.7$ ) (Table 4).

*B. schulzi* sp. nov. differs from *B. najdini* in its larger and stouter guard, larger Schatzky distance, smaller fissure angle and weakly developed vascular markings.

3) *B. pulchra*. This species was established on the basis of only six adult specimens from the Lower Maastrichtian *Belemnella lanceolata* – *B. sumensis* Zones of the Krons Moor pit, northwest Germany (SCHULZ 1982). The holotype came from the *sumensis* Zone. The length from the apex to the protoconch of these varies from c. 47 to 53 mm, with a mean value of c. 50 mm (SCHULZ 1982). It was later recorded from the Lower Maastrichtian *sumensis* Zone of the Maastricht-Aachen-Liège district (KEUTGEN & VAN DER TUUK 1990, KEUTGEN in JAGT & al. 1995, KEUTGEN 1997) and from the *Belemnella obtusa/Belemnitella minor* II Zone of the Mons Basin (Christensen 1999). Moreover, a single, fully-grown specimens was reported from the *sumensis* Zone of Bavaria in southern Germany (SCHULZ & SCHMID 1983a).

Most of the specimens from the Maastricht-Aachen-Liège district are small, that is with a length from the apex to the protoconch less than 55 mm, but in one specimen the length from the apex to the protoconch is 59.5 mm (KEUTGEN & VAN DER TUUK 1990) and not 50.5 mm as erroneously reported by CHRISTENSEN (1995, Table 12) (Table 4). *B. pulchra* occurs from the upper half of the *Belemnella lanceolata* Zone to the top of the *Belemnella sumensis* Zone (SCHULZ 1982, KEUTGEN & VAN DER TUUK 1990) (Text-fig. 3).

*B. schulzi* sp. nov. differs from *B. pulchra* in its larger and more stout guard, larger Schatzky distance and feebly developed vascular markings.

#### *Belemnitella langei sensu* SCHULZ, 1978

SCHULZ (1978) recorded this poorly known species from the lower part of the *langei* Zone of Krons Moor, northern Germany (Text-fig. 2). He did not describe this taxon, but four specimens, ex M.-G. SCHULZ Collection, were analysed biometrically by CHRISTENSEN (1995), who also figured three of these (CHRISTENSEN 1995, Pl. 8, Figs 14-17; Pl. 9, Figs 15-21) (Table 4).

*B. schulzi* sp. nov. differs from *B. langei sensu* SCHULZ in its stouter guard, larger Schatzky distance, larger fissure, larger alveolar angle and weakly developed vascular markings.

#### THE UPPER CAMPANIAN *BELEMNITELLA* ZONATION

The conventional Upper Campanian *Belemnitella* zonation of northwest Europe includes three interval zones, in ascending order, the lower Upper Campanian *B. mucronata* Zone and the upper Upper Campanian *B. minor* Zone below and the *B. langei* Zone above (Text-fig. 3). This zonation was introduced by JELETZKY (1951b) and has been used subsequently by numerous workers. A slightly different zonation is used on the Russian Platform, the *B. mucronata* Zone below and the *B. langei* Zone above (NAIDIN 1979). The latter zone is subdivided into three subzones, in ascending order, the *B. langei minor*, *B. langei langei*, and *B. langei najdini* Subzones (Text-fig. 3). However, *B. minor* should not be considered as a subspecies of *B. langei*, because it differs markedly from this species (see discussion above).

JELETZKY's zonation was critically assessed by CHRISTENSEN (1995, 1996, 1999), who argued that the *B. minor* and *B. langei* Zones of JELETZKY should not be maintained (see also discussion of the eponymous species above).

CHRISTENSEN (1995) subdivided the Upper Campanian chalks of Norfolk, England, into four informal *Belemnitella* zones on the basis of large to very large species. These are, in ascending order: the lower Upper Campanian *B. mucronata* Zone below and the *B. woodi* Zone above, and the upper Upper Campanian *B. minor* I Zone below and *B. minor* II Zone above (Text-fig. 3). This zonation has been shown subsequently to be applicable elsewhere in northwest Europe, namely the Mons Basin in southern Belgium (CHRISTENSEN 1999), the Maastricht-Aachen-Liège district (KEUTGEN 1995, 1996; KEUTGEN & JAGT 1999), and the Misburg-Höver-Ahlten area near Hannover (CHRISTENSEN 1995, NIEBUHR & al. 1997). CHRISTENSEN (1999) suggested, therefore, that these zones may be regarded as formal zones, since they have been recognised in widely spaced areas in northwest Europe. As mentioned above, CHRISTENSEN (unpublished) did not recognise *B. woodi* from the last-mentioned area, and *B. mucronata* is distributed there in the entire lower Upper Campanian, except the uppermost part. It is replaced by a new species in the uppermost part of the lower Upper Campanian, that is the upper part of the *vulgaris/stolleyi* Zone. Moreover, it is worthy of note that *B. minor* II does not occur in the uppermost Upper Campanian of Krons Moor; it is replaced there by *B. schulzi* sp. nov. Thus, the Upper Campanian *Belemnitella* successions of Krons Moor and the

Misburg-Höver-Ahlten area differ in part from those of Norfolk, the Maastricht-Aachen-Liège district, and the Mons Basin.

### Acknowledgements

I thank the late Dr. M.-G. SCHULZ, Kiel, who placed belemnite material from NW Germany at my disposal; Dr. N. KEUTGEN, Stellenbosch, South Africa, who gave me the results of a biometric analysis of a sample of *Belemnitella schulzi* sp. nov. from Kronsmoor; Mr. S.L. JAKOBSEN, Copenhagen, who made the photographs, and Mrs Lisa BELHAGE, Copenhagen, who prepared Text-fig. 1. I also thank the journal referee, Mr. C.J. WOOD, Croydon, England, for constructive criticism of the manuscript.

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Manuscript submitted: 23 September 1999

Revised version accepted: 10th November 1999

## PLATE 1

*Belemnitella schulzi* sp. nov. from the lowermost Maastrichtian of Denmark (Figs 1-14) and the uppermost Campanian (*grimmensis/granulosus* Zone) of Krons Moor, northwest Germany (Figs 15-30; *ex* M.-G. SCHULZ Collection); figured specimens are coated with ammonium chloride, and are natural size

- 1-4** – MMH 7846, holotype; 1 - dorsal view, 2 – lateral view, 3 – ventral view, 4 – view of the split anterior end, showing internal characters; figured as *Belemnitella langei* by BIRKELUND (1957, Pl. 2, Fig. 6)
- 5-8** – MMH 7864; 5 – dorsal view, 6 – lateral view, 7 – ventral view, 8 – view of the split anterior end, showing internal characters; figured as *Belemnitella langei* by BIRKELUND (1957, Text-fig. 2)
- 9-12** – MMH 7847; 9 – dorsal view, 10 – lateral view, 11 – ventral view, 12 – view of the split anterior end, showing internal characters; figured as *Belemnitella langei* by BIRKELUND (1957, Pl. 3, Fig. 1)
- 13** – MGUH 25493; view of the split anterior end, showing internal characters
- 14** – MGUH 25494; view of the split anterior end, showing internal characters
- 15-18** – MGUH 25495; 15 – dorsal view, 16 – lateral view, 17 – ventral view, 18 - view of the split anterior end, showing internal characters
- 19-22** – MGUH 25496; 19 – dorsal view, 20 – lateral view, 21 – ventral view, 22 - view of the split anterior end, showing internal characters
- 23-26** – MGUH 25497; 23 – dorsal view, 24 – lateral view, 25 – ventral view, 26 - view of the split anterior end, showing internal characters
- 27-30** – MGUH 25498; 27 – dorsal view, 28 – lateral view, 29 – ventral view, 30 - view of the split anterior end, showing internal characters

