

## The *Belemnitella* stratigraphy of the Upper Campanian–basal Maastrichtian of the Middle Vistula section, central Poland

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This taxonomy and stratigraphy of the Upper Campanian and Lower Maastrichtian *Belemnitella* lineages, from the Middle Vistula section, based on new collections, is presented. The correlation to the basal Maastrichtian standard GSSP at Tercis, France, is provided based on inoceramid bivalve stratigraphy. The artificial neural networks (ANN), particularly the self-organizing Kohonen algorithm, was applied to taxonomic discrimination. Eight morphotypes within the genus *Belemnitella*, understood here as natural species populations, were recognized. Five of these are assigned to known taxa: *Belemnitella mucronata*, *B. posterior*, *B. minor* (= *B. minor* I and *B. minor* II), *B. langei* and *B. najdini*; and three, *B. sp. a*, *B. sp. 1* and *B. sp. 2*, are left in open nomenclature. Four *Belemnitella* zones are proposed. Due to its palaeogeographic position, between Western and Eastern Europe, the Middle Vistula section is characterized by the co-occurrence of *Belemnitella* species from those two areas. Consequently, it enables better correlation of *Belemnitella*-based schemes; the East European *B. najdini* and *B. posterior* are placed next to West European *B. minor* chronospecies I and II. The Campanian/Maastrichtian boundary, as currently defined, is placed at the top of the *najdini*–*posterior* Zone, which is an equivalent of the *Belemnella*-based boundary, i.e. at the base of the *Belemnella obtusa* / *Belemnella vistulensis* zones. Within the top of the *najdini*–*posterior* Zone occurs a level (an interval of only a few metres), where nearly all of the Upper Campanian *Belemnitella* disappear. This level coincides with taxonomic changes observed within the co-occurring representatives of genus *Belemnella*.

Key words: Campanian, Maastrichtian, Vistula section, belemnites, biostratigraphy, artificial neural networks, Campanian/Maastrichtian boundary.

### INTRODUCTION

In the Late Campanian and Early Maastrichtian, belemnites played an important role in marine ecosystems of Europe. Particularly well represented and fast evolving were members of the genus *Belemnitella*, widely distributed and with high stratigraphic potential. Unfortunately, although a number of biostratigraphic zonations based on this genus were proposed, no uniform *Belemnitella* subdivision for the whole of Europe exists. Christensen (1999) reviewed Upper Campanian *Belemnitella* zonation for northwestern Europe and concluded that neither the standard zonation of Jeletzky (1951b) nor Naidin's (1979) zonation, established on the record in Eastern Europe, can be applied there. Consequently, he proposed a new zonation, based on large or very large *Belemnitella* from Norfolk, England (Christensen, 1995), but again admitted that his new subdivision is only of local significance (Christensen 1999, 2000b). Taking into account the importance of the group in the Campanian and Maastrichtian stratigraphy, the need of

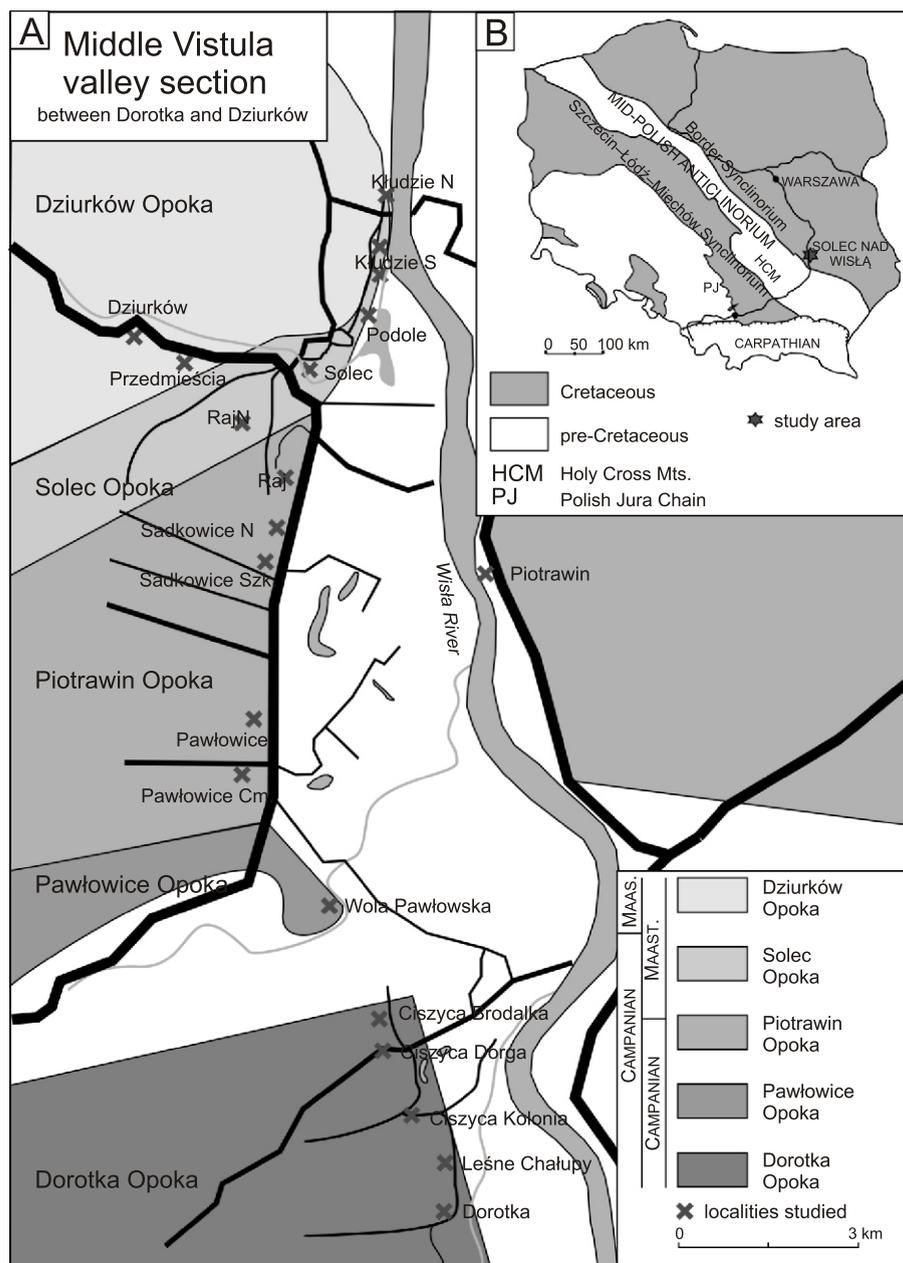
establishing a reliable *Belemnitella*-based subdivision applicable throughout Europe is clear.

In this context, the belemnite record of the Middle Vistula section in Poland is particularly promising. The palaeogeographic position of this area, between Western and Eastern Europe, and its rich and diverse macro- and microfaunal record, offer a unique opportunity to combine the east- and west-European *Belemnitella* records. These records are constrained in a well-established stratigraphic framework based on various biostratigraphies as well as chemo- and magnetostratigraphy (see Walaszczyk, 2012, as well as Peryt and Dubicka, 2015; Plasota et al., 2015; Remin et al., 2015). The genus *Belemnitella* from the Vistula section has not been studied since Kongiel's (1962) belemnite monograph.

The present study provides the taxonomic and stratigraphic interpretations of the latest Campanian and earliest Maastrichtian belemnites of the genus *Belemnitella* from the Middle Vistula section. The correlations of the belemnite succession, as worked out herein, with other groups, as well as with belemnite zonations in other areas, are discussed. Representative and/or topotype material of selected *Belemnitella* species is presented.

The study has been carried out according to Remin's (2012) methodology, based on artificial neural networks (ANN) (Fausett, 1994; Haykin, 1994; Patterson, 1996), in particular the self-organizing Kohonen networks (Kohonen, 1982), and the integrated biometric procedure, independent of the generic mem-

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**Fig. 1A** – geological sketch-map of the Upper Campanian through the Lower Maastrichtian in the Middle Vistula section, central Poland (after [Walaszczyk, 2004](#)); **B** – location of the Vistula (Wisła) River in Poland and the Upper Cretaceous deposits in extra-Carpathian Poland (after [Pożaryski, 1974](#))

bership of the material. The powerful algorithm used by Kohonen networks is commonly used to solve different kinds of classification problems and was successfully applied to species-level taxonomic recognition in belemnites ([Remin, 2007, 2008, 2012](#); [Remin in Niebuhr et al., 2011](#)), and e.g., to Paleozoic corals ([Wrzolek and Remin, 2008](#)). The study is the first attempt at correlating European *Belemnitella* populations from different regions, using the new methodological approach and the new integrated biometric procedure.

#### GEOLOGICAL SETTING, BELEMNITE SUCCESSION AND ORIGIN OF THE STUDIED BELEMNITES

The Upper Campanian–basal Maastrichtian part of the Middle Vistula section is best exposed in a series of natural and artificial exposures in the left bank of the Vistula River, between the villages of Dorotka and Dziurków ([Fig. 1](#)). The Cretaceous forms a homocline, dipping gently to the NE ([Fig. 1](#)). The studied interval is composed of white to grey siliceous marls (opoka), referred to the five informal lithostratigraphic units

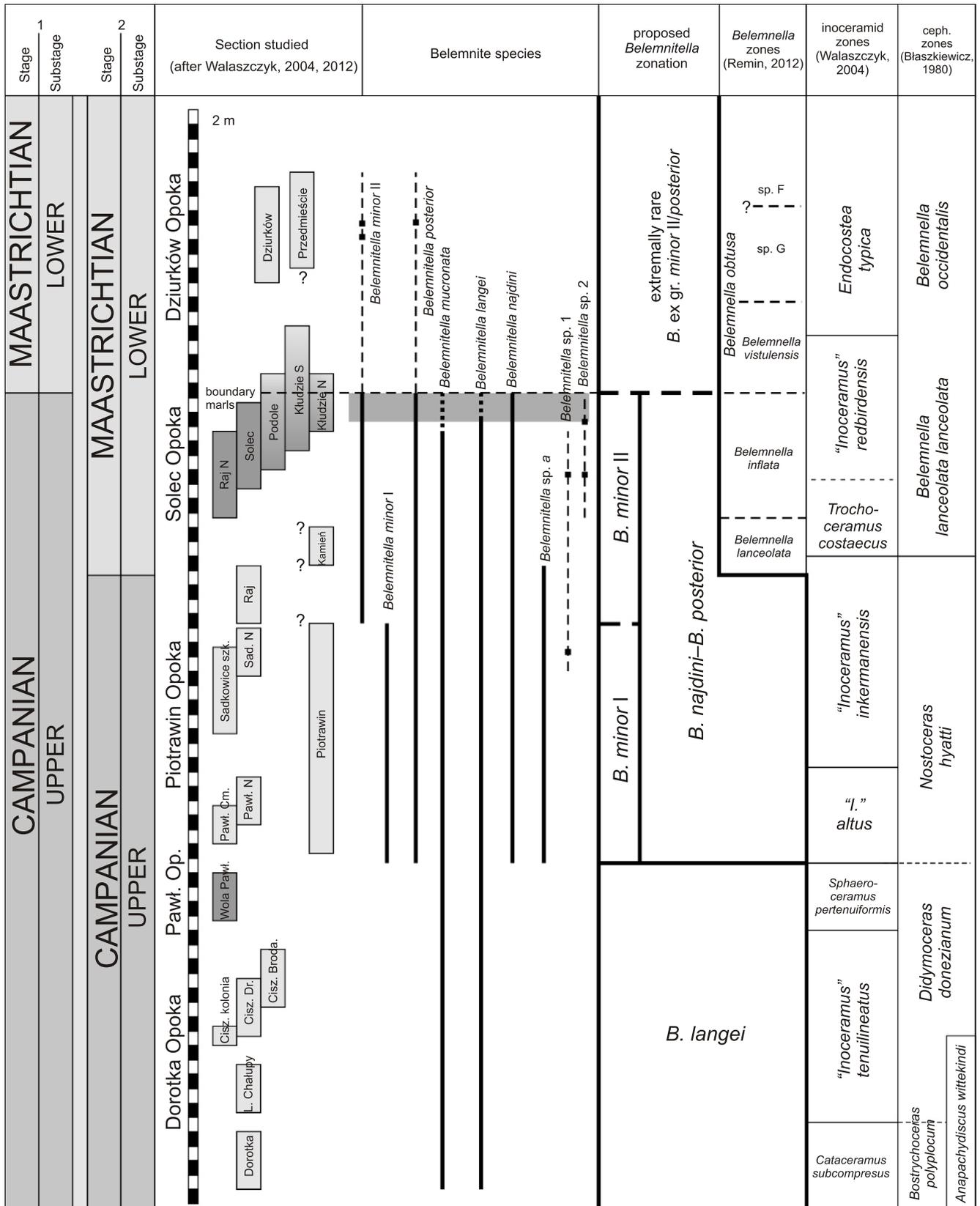


Fig. 2. Stratigraphic ranges of belemnite species and proposed belemnite zonation for the Middle Vistula section, central Poland

Inoceramid zones after Walaszczyk (2004); cephalopod zones after Błaszkiwicz (1980); base of the Maastrichtian according to (1) the stratotype in Tercis, France; (2) the conventional subdivision for the Boreal Realm, based on belemnites; belt below the “boundary marls” show few metres interval where most of the *Belemnitella* forms disappear

(Walaszczyk, 2004): Dorotka, Pawłowice, Potrawin, Solec and Dziurków opokas (Figs. 1 and 2).

The lower part of the studied succession, between the vilages of Dorotka and Wola Pawłowska (see Figs. 1 and 2), is represented by the Dorotka and Pawłowice opokas units, and has so far yielded only few complete specimens of *Belemnitella*, represented by *B. mucronata* and *B. langei*. In inoceramid terms, this part of the succession belongs to the *Cataceramus subcompresus*, “*Inoceramus*” *tenuilineatus* and *Sphaeroceramus pertenuiformis* zones of Walaszczyk (2004, 2012).

The higher part of the succession is available in a series of outcrops between Pawłowice Cemetery and Raj, represented by the Piotrawin Opoka. Within this unit the belemnites become more common, culminating in the Sadkowice, Raj and Raj N sections, around the traditionally defined Campanian/Maastrichtian boundary (Boreal definition). In inoceramid terms this interval represents the “*Inoceramus*” *altus* and “*Inoceramus*” *inkermanensis* zones of Walaszczyk (2004; Fig. 2).

Starting from the top of the Raj section, *Belemnitella* is accompanied by *Belemnella* (Remin, 2012), which tends to dominate, with simultaneous frequency decrease in *Belemnitella*. This is the uppermost part of the “*Inoceramus*” *inkermanensis* Zone and the lower part of the *Trochoceramus costaecus* inoceramid Zone and the lower part of the *Belemnella lanceolata* Zone (Fig. 2).

The succession of Raj N represented by the Solec Opoka, is relatively rich in belemnites, dominated by *Belemnella*. It represents the “*Inoceramus*” *redbirdensis* Zone and the *Belemnella inflata* Zone.

Still higher, the sections of Podole, Kłudzie S and Kłudzie N contain the “boundary marls”, a marly bed, which lies between the Solec and Dziurków opokas. *Belemnitella*s in the interval close to the “boundary marls” are very rare; *B. ex gr. minor* II/posterior (cf. Fig. 2) is the only form which crosses the “boundary marls”. In inoceramid terms, this interval belongs to the “*Inoceramus*” *redbirdensis* Zone; in *Belemnella* terms it is an equivalent of the *Belemnella inflata* and lower part of the *Belemnella obtusa* zones.

The two youngest sections, Przedmieścia and Dziurków, represented by the Dziurków Opoka, yielded only single specimens of *B. ex gr. minor* II/posterior. This part of the succession belongs to the *Endocostea typica* inoceramid Zone (Walaszczyk, 2004, 2012). In *Belemnella* terms it represents the *Belemnella obtusa* Zone of Remin (2012).

The whole studied succession yielded >140 complete *Belemnitella* guards and several dozen more or less incomplete specimens. Also available for study are the large collections of Pożaryski, Błaszkiwicz and Kongiel, housed in the Museum of the Earth of the Polish Academy of Science, Warsaw, and in the Museum of the Polish Geological Institute in Warsaw.

## BIOSTRATIGRAPHY

Traditionally in Europe, the Campanian was subdivided into Lower and Upper substages, with the boundary between them placed at the extinction level of the belemnite genus *Gonioteuthis* (i.e. Jeletzky, 1958). Belemnites were also used to define the base of the Maastrichtian stage and of the Lower/Upper Maastrichtian boundary, with the FADs of *Belemnella lanceolata* (Schlotheim, 1813) and *Belemnitella junior* (Nowak, 1913) respectively (e.g., Arkhangelsky, 1912; Jeletzky, 1951a, b).

During the 1995 Brussels Symposium, it was agreed that the Campanian stage should be subdivided into three

substages of possibly equal duration (Hancock and Gale, 1996). Also discussed was the new definition of the base of the Maastrichtian Stage (Odin, 1996). The latter was finally defined as an arithmetic mean of twelve bio-events and placed at the 115.2 m level of the Tercis section (Odin, 2001), the GSSP for the base of the Maastrichtian stage, and ratified then by the International Commission on Stratigraphy in 2001 (Odin, 2001; Odin and Lamaurelle, 2001).

### TRADITIONAL BELEMNITELLA-BASED ZONATION

After the belemnite extinction at the end of the Early Campanian, only a single belemnite genus *Belemnitella* (d’Orbigny, 1840), represented by a single species, *Belemnitella mucronata* (Schlotheim, 1813), persisted in the later Campanian (see Christensen, 1997a, b). In the Middle and Late Campanian (e.g., Christensen, 1997a, b), *Belemnitella* speciated and expanded geographically. The newly evolved species provided the basis for the biostratigraphic subdivisions of the Middle and Upper Campanian, which differ geographically (Fig. 3).

The Upper Campanian, in the Boreal definition, of north-western Europe was subdivided into three belemnite zones (Jeletzky, 1951), in ascending order the *Belemnitella mucronata*, *B. minor* and *B. langei* zones (Fig. 3). According to Christensen (1995, 1996, 1999), the zones of *B. minor* and *B. langei* of Jeletzky (1951b) should be abandoned.

The belemnite zonation for the Upper Campanian of Eastern and Central Europe was proposed by Najdin (1964a, b, 1975, 1979; see Fig. 3), who distinguished the *B. mucronata* Zone (lower) and *B. langei* Zone (upper). The latter zone he subdivided into (in ascending order): *B. langei minor*, *B. langei langei*, and *B. langei najdini* zones (cf. Fig. 3). Christensen (1995, 1996, 1999, 2000b) criticized this zonation, arguing that *B. minor* should neither be considered a subspecies of *B. langei*, as proposed by Najdin (1979), nor be placed into the *B. langei* group as suggested by Kongiel (1962).

Peake and Hancock (1961, 1970) and Wood (1988) proposed slightly different *Belemnitella* zonations, based on the record in the Upper Campanian of Norfolk, eastern England. Christensen (1995) reinvestigated the Norfolk belemnite material, and proposed a zonation based mainly on newly erected species: *B. mucronata*, *B. woodi*, *B. minor* I, *B. minor* II and *B. minor* III (= *B. minor* II; cf. Fig. 3). Christensen (1999) suggested that his new zonation might be regarded a standard *Belemnitella* zonation in Europe. However, in 2000, he rejected his previous opinion and concluded that the *Belemnitella* zonation of Norfolk was no longer applicable throughout Europe (although it can be applied in the Maastricht area of the Netherlands; see Keutgen, 2011).

After the sudden appearance of *Belemnella lanceolata* and of the so-called “primitive” *Belemnella*, i.e., *B. licharewi* Jeletzky, 1941, representatives of *Belemnella* became dominant across Europe; in many areas this genus almost completely replaced the genus *Belemnitella*. Consequently, the belemnite stratigraphic subdivision of the Lower Maastrichtian is based primarily on *Belemnella* (see discussion in Remin, 2012).

### NEW BELEMNITELLA-BASED ZONATION OF THE MIDDLE VISTULA SECTION

The biometric procedure, with the use of the artificial neural networks (ANN), particularly the self-organizing Kohonen algorithm, applied herein, follows Remin (2012; see this paper for presentation of the method), who also discussed and compared

Stage	1		2		Proposed zones for the Vistula	NW Europe	Russian Platform	Conventional zones
	Substage		Substage					
MAASTRICHTIAN	LOWER		MAASTRICHTIAN	LOWER	not exposed	<div style="border: 1px solid black; padding: 2px;">la</div> <i>B. fastigata</i> <i>B. cimbrica</i> <i>B. sumensis</i>	<i>Belemnella sumensis</i>	<i>Belemnella occidentalis</i>
					extremely rare <i>B. ex gr. minor III/posterior</i>	<i>B. obtusa</i> <i>B. sp. F</i> <i>B. sp. G</i> <i>B. vistulensis</i>	<i>obtusa</i> <i>pseudo-</i> <i>btusa</i>	<i>Belemnella lanceolata</i>
CAMPANIAN	UPPER		CAMPANIAN	UPPER	<i>B. minor II</i>	<i>inflata</i> <i>lanceolata</i>	<i>Belemnella licharewi</i>	
					<i>B. najdini– B. posterior</i>	<i>B. minor II</i>	<i>B. I. najdini</i>	<i>B. najdini</i>
					<i>B. minor I</i>	<i>B. lanceolata</i>	<i>B. I. langei</i>	<i>B. minor</i>
					<i>B. langei</i>	<i>B. I. minor</i>		
					<i>B. mucronata</i>	<i>B. woodi</i> <i>B. mucronata</i>	<i>B. mucronata</i>	<i>B. mucronata</i>

Fig. 3. The correlation of proposed belemnite zones

I – Middle Vistula section (central Poland) – this article; la – *Belemnella* zones of the Middle Vistula section (Remin, 2012); II – NW Europe, *Belemnella* zones after Schulz (1979), *Belemnitella* zones (after e.g., Christensen, 1995, 1999, 2000b); III – Russian Platform (e.g., Naidin, 1975, 1979); IV – conventional belemnite zones (Jeletzky, 1951a, b, 1958; Birkelund, 1957); base of the Maastrichtian according to (1) the stratotype in Tercis, France; (2) the conventional subdivision for the Boreal Realm, based on belemnites

his new method with the former methods of Kongiel (1962), Christensen (1975) and Schulz (1979). The terms and measurements used for belemnites description follow Christensen (1995) and Remin (2008, 2012) and are summarized in Figure 4.

RECOGNITION OF *BELEMNITELLA* SPECIES  
BY THE KOHONEN NEURAL NETWORKS  
AND STATISTICAL VERIFICATION  
OF THE MORPHOGROUPS

The material studied was subdivided into three stratigraphic samples, each consisting of a sufficient number of guards: (1) Sadkowiec Szkoła–Sadkowiec N; (2) Raj and (3) Raj N–Dziurków (Raj N, Podole, Kłudzie, Przedmieścia and Dziurków). Belemnites from each stratigraphic sample were ana-

lysed independently using a two-layered Kohonen neural network with 29 inputs (29 characters of the guard; Fig. 5). The structures of applied SOM (self-organizing maps) are shown in Figure 5. For testing purpose, two independent simulations were executed on the belemnite guards from the Pawłowice Cemetery, Pawłowice Posesja, and Piotrawin sections, equivalent sections of the stratigraphic samples (1) and (2). Every single guard, from the test sections, was subjected to simulation using a Kohonen networks trained on the material from stratigraphic samples (1) and (2), and classified to one of the morphogroups recognized in them. In a similar way the material from the sections of Dorotka, Leśne Chałupy, Ciszycza, Ciszycza Brodalka and Wola Pawłowska was analysed. Belemnite guards from those locations were subjected to Kohonen networks trained on the material from stratigraphic samples (1 and 2).

>140 newly collected complete guards of *Belemnitella* were subdivided by the Kohonen networks into morphogroups re-

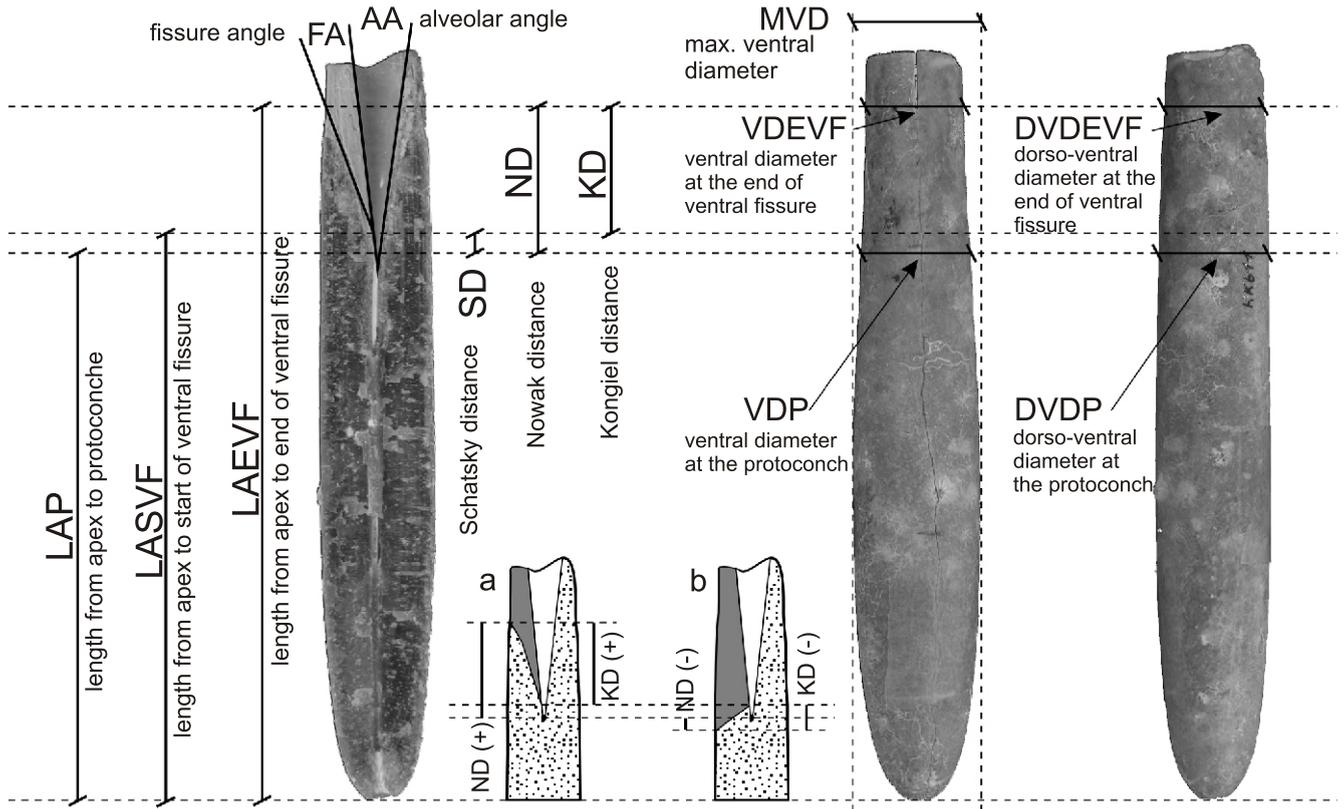


Fig. 4. Terminology and measurements of external and internal features of belemnite guard (Remin, 2008)

Two not illustrated features are: LABVF – length from apex to most posterior part of ventral fissure; RDBSVF (= LASVF – LABVF), for details see Remin (2008, 2012); **a**, **b** – the internal structure of the guard and different position of the bottom of the ventral fissure: **a** – ND (+) and KD (+) are positive (+) when the outer end of the bottom of the ventral fissure is swept forward from the protoconch and from the inner end of the bottom of the ventral fissure respectively; **b** – ND (-) and KD (-) are negative (-), when the outer end of the bottom of the ventral fissure is swept back from the protoconch and from the inner end of the bottom of the ventral fissure respectively

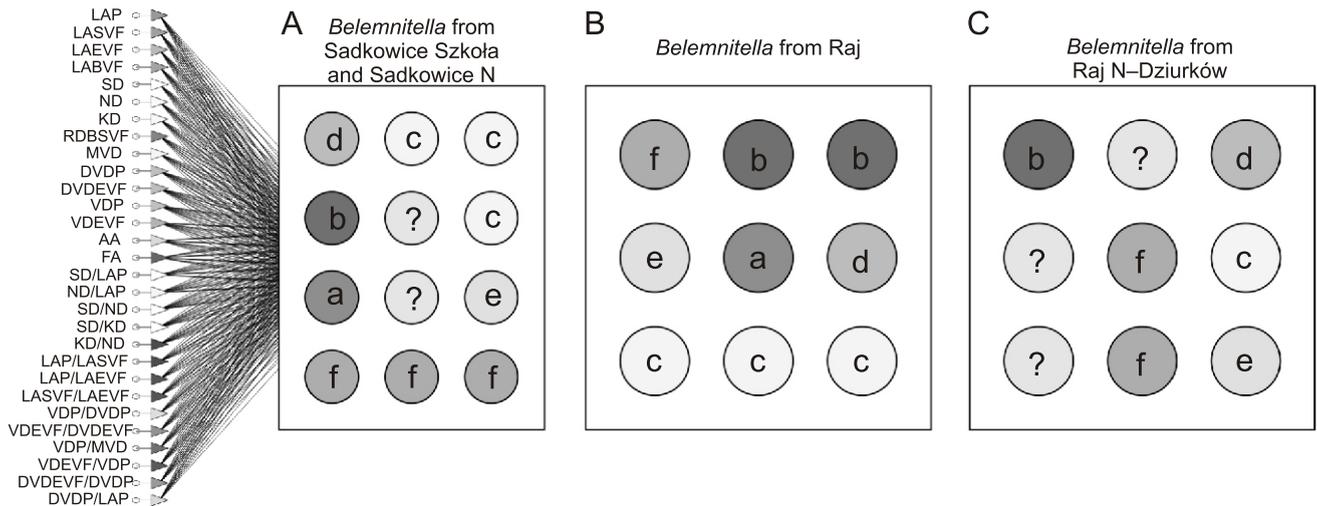


Fig. 5. Structure of the applied self organized maps

**A** – 12 (3 4) neurons in the output layer with 53 guards analysed from the interval Sadowice Szkoła–Sadowice N (1) of the Vistula section; **B** – 9 (3 3) neurons in the output layer with 43 guards analysed from Raj (2); **C** – 9 (3 3) neurons in the output layer with 22 guards analysed from Raj N–Dziurków (3)

garded here as natural populations and verified statistically, following Remin's (2012) procedure, first applied to the genus *Belemnella*. Six morphogroups were revealed in exploration of the SOM within the stratigraphic samples (1) and (2), labeled a through f, and five morphogroups (b, c, d, e, f) were revealed within stratigraphic sample (3; see Figs. 6–8). The position of particular morphogroups on the SOM indicates the level of their similarity, e.g. in the hyperspace of stratigraphic sample (1) (Fig. 5A), morphogroup c is most similar to group d, and least similar to group f. Such relationships are confirmed by comparison of mean values of particular characters (Fig. 6).

All morphogroups are characterized by small confidence intervals, implying their high morphological stability. Slightly larger confidence intervals in morphogroups from stratigraphic sample (3; see Fig. 8), resulted from smaller number of analysed specimens.

Figures 6–9 show that means of particular features in morphogroups a–f differ markedly (Fig. 5). In most cases, statistically significant differences concern three or more characters between recognized morphogroups, allowing their easy separation.

Statistical characteristics of all morphogroups combined from all three stratigraphic samples (1–3) are shown in Figure 9. Morphogroups f, e, b are characterized by large and thick guards, whereas morphogroups a, c, d are represented by small and slender guards. The morphogroup d seems to be most distinct and it is characterized by very large fissure angles and a very small Kongiel distance (Fig. 9).

From among six well-defined morphogroups five are assigned to known species: b = *B. posterior*, c = *B. langei*, d = *B. najdini*, e = *B. mucronata*, f = *B. minor* (referred here to *B. minor* I and *B. minor* II). Morphogroup a (= *Belemnitella* sp. a) in addition to *Belemnitella* sp. 1 and *Belemnitella* sp. 2 are left in open nomenclature (see Systematic Palaeontology).

## GROUPING RESULTS

**Dorotka, Leśne Chałupy, Ciszycza, Ciszycza Brodalka, Wola Pawłowska sections:** specimens from these locations are classified into morphogroups e and c (= *B. mucronata* and *B. langei* respectively).

**Piotrawin, Pawłowice Cemetery, Pawłowice North, Sadkowiec Szkoła, Sadkowiec North, Raj sections:** specimens from these locations are classified into morphogroups a, b, c, d, e and f (= *Belemnitella* sp. a, *B. posterior*, *B. langei*, *B. najdini*, *B. mucronata* and *B. minor* I respectively). In addition, a single specimen of *Belemnitella* sp. 1 appeared for the first time in the Sadkowiec North section.

**Raj North, Solec, Podole, Kłudzie South, Kłudzie North sections:** the specimens are referred to morphogroups a, b, c, d, e and f (= *Belemnitella* sp. a, *B. posterior*, *B. langei*, *B. najdini*, *B. mucronata* and *B. minor* I, *B. minor* II, respectively). Single specimens from Raj N and Podole represent *Belemnitella* sp. 1 and *Belemnitella* sp. 2.

**Przedmieście, Dziurków:** specimens are classified into morphogroups b and f (= *B. posterior* and *B. minor* II).

## NEW BELEMNITELLA ZONATION

Based on the taxonomic study presented above, four *Belemnitella* zones (concurrent and interval range zones) are defined in the Upper Campanian of the Middle Vistula section (Figs. 2 and 3). The interval ranges from the *Belemnitella langei*

Zone to the top of *Belemnitella minor* II interval range Zone or *B. najdini*–*B. posterior* concurrent Zone; all are located in the Tercis-defined Upper Campanian.

The proposed zonations are based on both taxa commonly recognizable in Western Europe and taxa more characteristic of Eastern Europe. The scheme based on taxa characteristic of Western Europe includes three zones: *B. langei*, *B. minor* I, and *B. minor* II (Figs. 2 and 3). The zonation based on the Eastern European taxa is composed of the zones of *B. langei* and *B. najdini*–*B. posterior*. *Belemnitella najdini* and *B. posterior* are rare in Western Europe but are well represented in Central and East European successions.

The *Belemnitella* zonation, proposed herein, is correlated against the inoceramid and *Belemnella* zonations, as recently worked out (Walaszczyk, 2004; Remin, 2012, respectively; Figs. 2 and 3). Accordingly, the Campanian/Maastrichtian boundary, as defined in Tercis, corresponds to the top of the *B. minor* II or alternatively to the top of the *B. najdini*–*B. posterior* concurrent Zone (Figs. 2 and 3). Nearly all *Belemnitella* species disappear within an interval of only a few metres around this level (Fig. 2). Higher up, the only survivors belongs to *B. ex gr. minor* II/posterior and are represented by single specimens. This is also the base of the *Belemnella obtusa* and *Belemnella vistulensis* Zones (Remin, 2012), the base of which defines the base of the Maastrichtian in terms of the *Belemnella* clade (cf. Figs. 2 and 3).

Brief characteristics of the *Belemnitella* zones are given below.

**The *Belemnitella langei* interval range Zone;** the base of the zone is defined by the FAD of the index taxon, and its top by the simultaneous FADs of *B. minor* I, *B. posterior* and *B. najdini*. Only two *Belemnitella* species, *B. langei* and *B. mucronata*, occur in this zone. The zone corresponds to the interval embracing the *Cataceramus subcompressus* Zone up to the *Sphaeroceramus pertenuiformis* Zone.

In the Vistula section the lower boundary of the zone is not exposed (Fig. 2). Its upper boundary is placed between the Wola Pawłowska section and the base of the Pawłowice Cemetery and Piotrawin sections, which are separated by an observational gap of a few metres (Fig. 2).

**The *Belemnitella minor* I interval range Zone;** the base of the zone is defined by the FAD of the index taxon or by the FADs of *B. najdini* and *B. posterior*. Its upper boundary is defined by the FAD of *B. minor* II. Five *Belemnitella* species were recognized in this zone (Fig. 2). It corresponds to the “*Inoceramus*” *altus* and lower and middle parts of the “*Inoceramus*” *inkermanensis* zones.

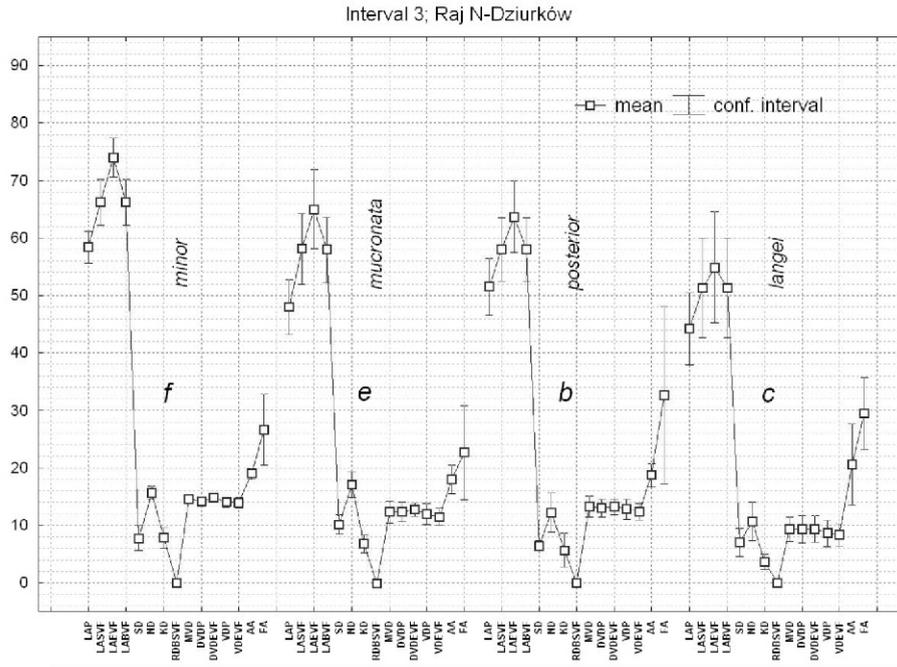
In the Vistula section the lower boundary of the zone is not exposed. It lies somewhere below the base of the Pawłowice Cemetery and Piotrawin sections and the Wola Pawłowska section (Fig. 2). Its top is located between the Sadkowiec N and Raj sections, which are separated by a minute observational gap (Fig. 2).

**The *Belemnitella minor* II interval range Zone;** the base of this zone is defined by the FAD of the index taxon and its top by LADs of *B. najdini* and *B. langei*. Five *Belemnitella* species were recognized in this zone (Fig. 2). It corresponds to the upper part of the “*Inoceramus*” *inkermanensis*, up to the middle part of the “*Inoceramus*” *redbirdensis* zones. In terms of the *Belemnella* zonation, it covers the whole interval of the *Belemnella lanceolata* and *Belemnella inflata* zones (Fig. 2).

In the Vistula section the lower boundary is located in the Raj section. Its top is exposed at the “boundary marls” in the sections of Podole, Kłudzie S and Kłudzie N (Fig. 2).

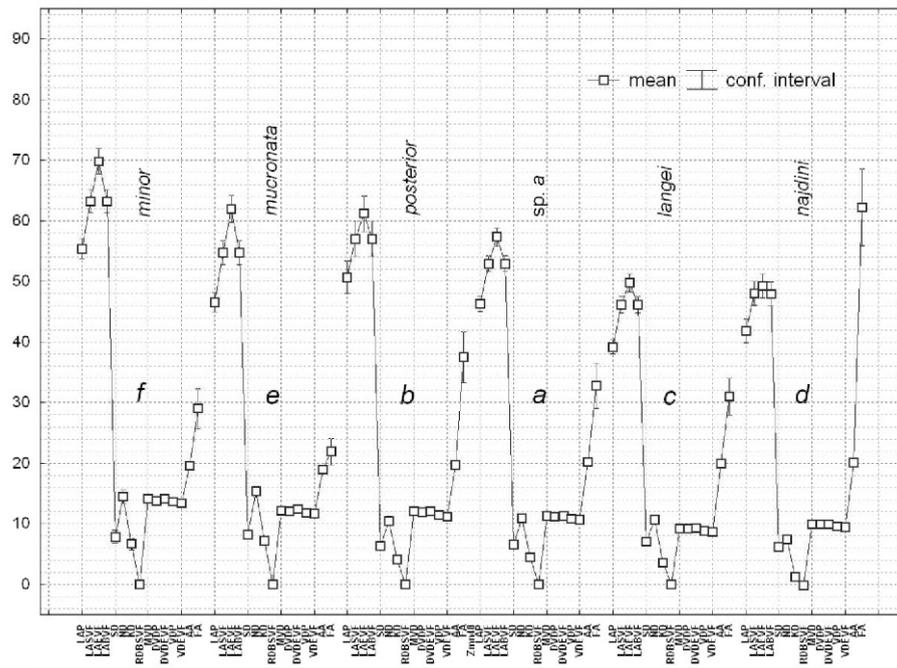
**The *Belemnitella najdini*–*Belemnitella posterior* concurrent range Zone;** the base of the zone is defined by the





**Fig. 8. Means and 95% confidence intervals of features**

Groups *b*, *c*, *e*, *f* from interval (3) Raj N–Dziurków



**Fig. 9. Means and 95% confidence intervals of features in groups *a+a*, *b+b+b*, *c+c+c*, *d+d*, *e+e+e*, *f+f+f* from two (1+2) or three (1+2+3) succeeding intervals respectively**

FAD of the index taxa or simultaneous entry of *B. minor* I. Its upper boundary is defined by the LADs of *B. najdini* and *B. langei*, which seem to disappear simultaneously. Six *Belemnitella* species were recognized in this zone (Fig. 2). The zone corresponds to the interval embracing “*Inoceramus*” *altus* to the middle part of the “*Inoceramus*” *redbirdensis* zones. In terms of the *Belemnella* zonation, the upper part of this zone corresponds to the *Belemnella lanceolata* and *Belemnella inflata* zones (Fig. 2).

In the Vistula section the lower boundary of the zone is not exposed. It lies somewhere below the base of the Pawłowice Cemetery and Piotrawin sections and the Wola Pawłowska section (Fig. 2). Its top is located at the “boundary marls” exposed in the Podole, Kludzie S and Kludzie N sections (Fig. 2).

## DISCUSSION AND CONCLUSIONS

Four *Belemnitella* zones were established within the Upper Campanian and none in the Lower Maastrichtian. In the *Belemnitella*-based zonation, the Campanian/Maastrichtian boundary in the Middle Vistula section is placed at the top of the *B. najdini*–*B. posterior* and *B. minor* II zones. This boundary is represented by a distinctive lithological unit – the “boundary marls”. It corresponds closely to the base of the *Belemnella obtusa* / *Belemnella vistulensis* zones (Figs. 2 and 3), the *Belemnella*-boundary markers (see Remin, 2012). This boundary also corresponds to the Campanian/Maastrichtian boundary in Krons Moor, northern Germany (Niebuhr et al., 2011).

The *Belemnitella* zonation as worked out herein differs from zonations recognized in other European areas (Fig. 3). The main difference concerns the use of *B. posterior* and of *B. najdini* and the stratigraphic position of *B. langei*, which precedes *B. minor* I in the Middle Vistula section.

Surprisingly, the level around the “boundary marls” in the Vistula section, corresponding closely to the Campanian/Maastrichtian boundary, represents a critical point in the evolutionary history of both *Belemnitella* and *Belemnella*. At this level, within an interval of only a few metres, nearly all Late Campanian *Belemnitella* taxa disappear. The only survivors are rare *B. ex gr. minor* II/*posterior*. This extinction event within the *Belemnitella* lineage corresponds to an evolutionary turnover within the genus *Belemnella* (cf. Remin, 2012).

The succession of taxa within the genus *Belemnitella* may be summarized as follows.

*Belemnitella mucronata* (Schlotheim, 1813) seems to be a well-defined species (Christensen et al., 1975). It is characteristic of the uppermost Lower and lowermost Upper Campanian. This species has been also noted higher in the Upper Campanian (Kongiel, 1962; Christensen, 1975, 1997a, b).

Less clear is the understanding of *Belemnitella minor* Jeletzky, 1951, the index species of the uppermost Campanian (see discussion in Christensen et al., 1975; Christensen, 1995). In the present paper, the author follows the interpretation of Christensen (1995, 1999), with two chronospecies, *B. minor* I and *B. minor* II, distinguished in the lineage. *B. minor* from the Vistula section is slightly smaller and is characterized by a smaller Schatzky distance than the populations of *B. minor sensu* Christensen (1995) from Norfolk. The Vistula material also differs from east European populations of the species

*Belemnitella langei* Jeletzky, 1948, is interpreted here in the sense of its holotype and paratypes. Statistically valid topotype material of this species is inaccessible. Various concepts of this species were discussed by Christensen (1995), who showed

marked differences between *B. langei sensu* Jeletzky (1948), *B. langei sensu* Schulz (1978), and *B. langei sensu* Birkelund (1957). Schulz (1978) suggested that *B. langei* is an East European species, with restricted occurrences in Western Europe. Christensen (1995) did not confirm this statement, although he was able to recognize *B. langei* only on the basis of a few specimens in Norfolk (Christensen, 1995). Summarizing, there are five, largely incompatible, definitions of *B. langei*: (1) the type material from Ukraine; (2) *langei sensu* Birkelund from Denmark (= *B. schulzi*) with large range of variation; (3) *langei sensu* Schulz from Germany; *langei sensu* Christensen from Norfolk, England; and *langei* as understood herein, based on 38 specimens, from the Vistula section, Poland. Up to now, Christensen’s concept of *B. langei* from Norfolk is commonly accepted. In this respect the material from the Vistula section differs only by smaller mean values of the fissure angle.

So far, *Belemnitella najdini* Kongiel, 1962 was understood only in the sense of its original diagnosis based on its holotype and paratype. The topotype population of *B. najdini* described herein (19 specimens) is statistically representative. The species has been commonly used as a marker of the uppermost Upper Campanian in Eastern Europe (e.g., Najdin, 1964a, b, 1979). Herein it is used in the zonation for the Vistula section.

*B. posterior* Kongiel, 1962 is understood here in the sense of its holotype and paratypes. The studied population of this species is well compatible with populations referred to as *B. posterior* by Kongiel (1962) and Christensen (1998b, unpubl. report). The topotype population studied herein is statistically representative.

As mentioned above, understanding of particular species differs for various reasons. Another complicating factor is rather poor understanding of the biological significance of such taxonomically critical characters as the Schatzky distance (SD) or the fissure angle (FA).

To omit subjectivity in selecting taxonomically critical characters, the author implemented the same taxonomic procedure for both Upper Campanian and Maastrichtian belemnite genera – *Belemnitella* and *Belemnella*. This allows the comparison of selected features in both genera and the tracking of their evolutionary changes within the whole interval studied.

## SYSTEMATIC PALAEOLOGY

### CONVENTION

The terms and measurements used to describe belemnite guards follow Christensen (1995) and Remin (2008, 2012; see Fig. 4). The following abbreviations are used: LAP – length from the apex to the protoconch; LASVF – length from the apex to the start of the bottom of the ventral fissure; SD (Schatzky distance) – distance between the mid-point of the protoconch and the start of the ventral fissure at the alveolar wall; ND (Nowak distance) – distance between the midpoint of the protoconch and the end of the bottom of the ventral fissure on the outer surface of the rostrum; KD (Kongiel distance) – distance between the start of the bottom of the ventral fissure at the alveolar wall and its end on the outer surface of the rostrum; MVD – maximal ventral diameter; DVDP – dorsoventral diameter at the protoconch; DVDEVF – dorsoventral diameter at the end of the ventral fissure; VDP – ventral diameter at the protoconch; VDEVF – ventral diameter at the end of the ventral fissure; AA – alveolar angle; FA – fissure angle; and BI (Birkelund Index) =

LAP/DVDP. Besides AA and FA (angles in degrees), all other measurements are in millimetres.

#### REPOSITORIES

The material is housed in the collections of the S.J. Thugutt Geological Museum, Faculty of Geology, at the University of Warsaw; specimens prefixed by ZI/65/abbreviations of the outcrop, e.g. ZI/65/Raj/001. The locations are shown in Figure 1; abbreviations for individual outcrops are as follows: Ciszycza Brodalka – Cisz/Broda; Ciszycza droga – Cisz/dr; Dorotka – Dor; Dziurków – Dziu; Kłudzie N – KłudzN; Kłudzie S – KłudzS; Pawłowice Cemetery – Pawl/Cm; Pawłowice Posesja – Pawl/pos; Piotrawin – Piotr; Podole – Podole; Przedmieścia – Przedm; Raj – Raj; Raj N – RajN; Sadkowice N – SadN; Sadkowice Szkoła – Sad/szk; Wola Pawłowska – Wola/Pawl. Specimens prefixed with Mcd– are stored in the Museum of the Earth in Warsaw of the Polish Academy of Sciences.

#### GENERAL REMARKS

The west European *Belemnitella* and biostratigraphic schemes based on the genus are relatively well-known (Birkelund, 1957; Christensen, 1975–2002; Keutgen, 2011), however, their direct relationships to east European forms and biostratigraphic schemes (Jeletzky, 1941; Naidin, 1952, 1975, 1979; Nikitin, 1958; Naidin and Beniamowski, 2006; Olferev et al., 2007; Benyamovskiy et al., 2012) are far from satisfactory. From the Upper Campanian through Lower Maastrichtian more than twenty taxa (species, subspecies and variants) have been described within the genus (e.g., Jeletzky, 1941–1964; Vassilenko and Rassmyslowa, 1950; Naidin, 1952–1979; Christensen, 1975–2002; Birkelund, 1957; Nikitin, 1958; Kongiel, 1962; Schulz, 1982). The taxonomic status of many of these taxa remains uncertain (discussion in Christensen, 1988, 1993, 1996, 1997a, b).

Six morphotypes, plus two other forms, revealed by the Kohonen neural network analysis, are interpreted herein as distinct species. Five of them can be referred to established forms, while the remaining three are left in open nomenclature. Their final taxonomic interpretation requires further investigations, particularly comparison with East European material and “giant” forms of *B. mucronata* of Wood (1988) from England. The species recognized herein are subdivided into two main groups, the *Belemnitella mucronata* group that includes forms generally large and stout, and the *Belemnitella langei* group which is characterized by small and slender forms. The *Belemnitella mucronata* group comprises *B. mucronata*, *B. minor* (= *B. minor* I and *B. minor* II), and *B. posterior*. The *Belemnitella langei* group comprises *B. sp. a*, *B. langei* and *B. najdini*. Although different in external and internal morphology, both groups are characterized by a similar evolutionary pattern within the Late Campanian and Early Maastrichtian. The forms change from generally longer and stouter to shorter and more slender.

Kongiel (1962) introduced four classes of “relative thickness” (= DVDEVF herein; see Fig. 4): I – 4.0–7.0 mm; II – 7.5–10.5 mm; III – 11.0–14.0 mm; IV – 14.5–17.5 mm, however, this classification has not been used by other authors.

Christensen (1995) proposed a classification of relative length of species of *Belemnitella* based on the Birkelund Index (BI = LAP/DVDP): (1) BI < 4 guard stout, (2) BI 4–5 guard slender, (3) BI > 5 guard very slender. It is worthy of note that “relative length” *sensu* Christensen (1995) is not equal to “relative length” *sensu* Kongiel (1962) or other East European researchers. For Christensen, it is the elongation (slenderness),

whereas, e.g. for Kongiel, it is the length from apex to the start of the ventral fissure on the outer surface of the guard (= LAEVF herein; see Fig. 4). Christensen (1995) introduced a classification of size-ranges of species of *Belemnitella* based on length from apex to protoconch (LAP): (1) guard small LAP <55 mm; (2) guard large LAP 55–65 mm; (3) guard very large LAP >65 mm. However, such length-ranges cause marked disproportion between small, large and very large guards. According to it, most belemnites are characterized by small, eventually medium-size guards.

For these reasons, it was essential to propose a more balanced classification of size-ranges based on length from the apex to the protoconch (LAP) or length from the apex to the end of ventral fissure (LAEVF). The latter length seems to be better for two reasons: (1) when LAEVF is measurable, it allows all other features to be measured; (2) this length is easy to measure even during the fieldwork and does not require splitting of the guard. The biometric characteristics presented herein are based on complete specimens from the Vistula section. The

Table 1

Ranges of size categories of selected external and internal features

	Size			
	small	medium	large	very large
	length			
LAEVF	<55 mm	55–65 mm	65–75 mm	>75 mm
LAP	<45 mm	45–55 mm	55–65 mm	>65 mm
	diameters			
MVD	<10 mm	10–12 mm	12–14 mm	>14 mm
DVDP	<10 mm	10–12 mm	12–14 mm	>14 mm
VDP	<10 mm	10–12 mm	12–14 mm	>14 mm
	internal features			
SD	<7 mm	7–9 mm	9–11 mm	>11 mm
ND	<9 mm	9–12 mm	12–15 mm	>15 mm
KD	<3 mm	3–5 mm	5–7 mm	>7 mm
AA	<19°	19–21°	21–22°	>22°
FA	<25°	25–40°	40–60°	>60°

The descriptive terms are shown in Figure 4

adopted size-ranges of selected parameters characterizing particular *Belemnitella* species are summarized in Table 1.

Family Belemnitellidae Pavlow, 1914  
Genus *Belemnitella* d’Orbigny, 1840  
(ICZN 1985, Opinion 1328; name no. 2269)

**Type species.** – *Belemnites mucronatus* Schlottheim, 1813: 111, by subsequent designation of Hermannsen (1846: 105); ICZN Opinion 1328 (1985), name no. 2979 (cf. discussion by Christensen et al., 1973, 1975, 1982; Christensen, 1975, 1995).

**Diagnosis.** – Small, medium to large belemnitellids (max. LAP up to 80 mm) with a deep, cone-shaped alveolus. The guard is usually flattened ventrally. Alveolus connected with the surface of the guard through long ventral fissure. The bottom of the ventral fissure is variable. Alveolar angle (AA) varies between 17 and 24° and is rather constant within the genus.

The ornamentation consists of variably developed dorso-lateral longitudinal depressions and dorso-lateral straight double furrows, in addition to single lateral furrows. Vascular imprints relatively well developed, especially in larger specimens. Sometimes longitudinal striae are present on the ventral side of the guard. The vascular imprints branch off the dorso-lateral double furrows posteriorly under an angle  $<30^\circ$ . Schatzky distance (SD) relatively long, usually  $>4$  mm, commonly between 6–10 mm; sometimes larger, up to 16 mm. The relationship of LAP and DVDP is isometric (Fig. 10).

**O c c u r r e n c e.** – The genus *Belemnitella* is known from the Lower Santonian up to the uppermost Maastrichtian. The representatives of *Belemnitella* are widely distributed in the North European Province, North American Province and are also known from the northern peripheries of the Tethyan Realm.

#### *Belemnitella mucronata* group

**R e m a r k s.** – This group includes species of different size, stout or slender with small to medium fissure angles. The bottom of the ventral fissure is rather straight and the Schatzky distance is small, medium and only in some cases large.

Kongiel (1962) included in the group *B. mucronata* and *B. posterior*. Christensen's concept of the *B. mucronata* group is different. Besides these two species he included also *B. minor* I and *B. minor* II, both *sensu* Christensen, *B. woodi* Christensen, 1995, *B. schulzi* Christensen, 2000, and *B. carlsbergensis* Christensen, 1998.

Christensen (1995) described *B. pauli*, a transitional form between the *B. mucronata* group and the *B. langei* group.

The following species are included in the group in the present paper: *B. mucronata*, *B. minor* I and *B. minor* II, both *sensu* Christensen, *B. woodi*, *B. pauli* and *B. misburgensis*, 2000 and *B. posterior*. *Belemnitella minor*, as understood herein, differs from the nominate species of Christensen, in being smaller and having smaller Schatzky distances. *B. woodi*, *B. pauli* and *B. misburgensis*, are understood according to Christensen (1995).

#### *Belemnitella mucronata* (Schlotheim, 1813) (Fig. 11A–N)

1813. *Belemnites mucronatus* Schlotheim: 111 (after Christensen, 1995).

pars 1975. *Belemnitella mucronata* (Schlotheim); Christensen: 52–56.

pars 1975a. *Belemnitella mucronata* (Schlotheim); Christensen et al.: 27–57.

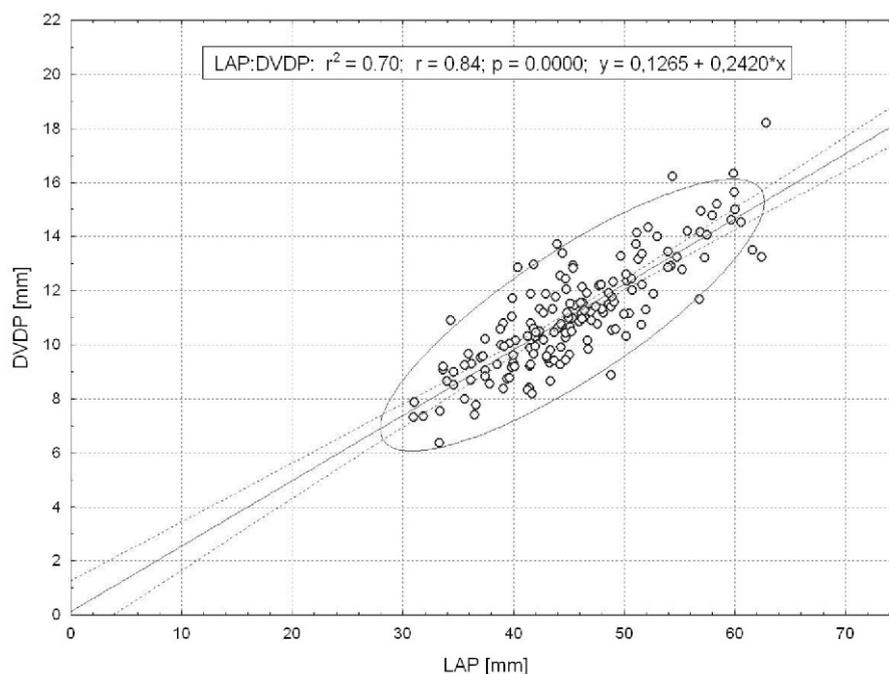
pars 1995. *Belemnitella mucronata* (Schlotheim); Christensen: 46–49.

pars 1999. *Belemnitella mucronata* (Schlotheim); Christensen: 110–112.

pars 2000b. *Belemnitella mucronata* (Schlotheim); Christensen: 156.

**N e o t y p e.** – Specimen no. kca 5/2, from the middle part of the *basiplana-spiniger* Zone (lower Upper Campanian) of the Germania IV pit near Hannover, Germany, designated by ICZN 1985 (Opinion 1328); described and figured by Christensen et al. (1975: pl. 1 fig. 1).

**M a t e r i a l.** – 24 specimens from the Vistula section: Dor/001, Dor/004, Cisz/dr/002, Cisz/broda/008, Cisz/broda/014, Pawl/pos/006, Sad/szk/035, SadN/004, SadN/014, SadN/016, Piot/001, Piot/018, Raj/031, Raj/045,



**Fig. 10.** Scatter diagram, regression and 95% ( $\alpha = 0.05$ ) confidence interval of the regression line; relationship of LAP and DVDP for all analysed specimens of the genus *Belemnitella* from the Vistula section



Fig. 11. *Belemnitella mucronata* (Schlotheim, 1813)

**A** – Sad/szk/035, Sadkowiec Szkoła section; **B–D** – B – SadN/004, C – SadN/014, D – SadN/016, Sadkowiec N section; **E, F** – E – Piot/001, F – Piot/018, Piotrawin section; **G–J** – G – Raj/031, H – Raj/046, I – Raj/064, J – Raj/070, Raj section; **K–N** – K – RajN/031, L – RajN/034, M – RajN/041, N – RajN/045, Raj N section; 1 – ventral view; 2 – dorso-ventral view and the inner structure of the guard

Raj/046, Raj/055, Raj/064, Raj/070, RajN/031, RajN/034, RajN/041, RajN/047, Podole/006.

**Description.** – Guard medium to large, stout to moderately slender (mean LAEVF = 62 mm; max LAEVF up to 69.5 mm); LAP medium (mean LAP = 46.6 mm; max. LAP up to 51.6 mm); guard generally subcylindrical in ventral view and subconical to conical in lateral view, markedly flattened ventrally over its entire length; DVDP slightly larger than VDP. Mean value of Birkelund Index BI = 3.9 with an observed range 3.20–4.79. Apical end moderately obtuse to acute, usually with well defined mucro.

SD medium to large (mean = 8.2 mm); ND and KD very large with mean values of 15.4 and 7.2 mm, respectively, significantly larger than in other forms of *Belemnitella* from the studied interval; FA small (mean = 22°), smallest among the studied representatives of the genus *Belemnitella* (Fig. 9); AA small to medium (mean = 19°). Shape of bottom of ventral fissure usually straight.

Well-developed dorso-lateral longitudinal depressions continue posteriorly in dorso-lateral double-furrows. Vascular markings well defined especially in large specimens, mainly on ventral and lateral side; longitudinal striae present sometimes. The complete biometry of *Belemnitella mucronata* (morphogroup e) is summarized in Table 2.

**Remarks.** – The specimens with complete biometry of morphogroup e were compared with the topotype population of *B. mucronata* from the Germania IV Quarry, the type locality for the neotype of *B. mucronata* (cf. Christensen et al., 1975). The analysis revealed that morphogroup e is characterized by only slightly larger values of LAP and slightly smaller values of DVDP, albeit these differences are very small. This is expressed by different BI values. The study population is slender (mean BI = 3.9) in comparison to the topotype population which is characterized by smaller BI values (mean BI = 3.4), although this could be related to simple environmental variability than to real species diversity. All other features do not show any significant differences (cf. Christensen et al., 1975). Consequently, I interpret morphogroup e as representing *B. mucronata*.

Form *B. minor*, *B. mucronata* differs by markedly smaller length-features, diameters and FA (Fig. 9).

*B. mucronata* differs from *B. posterior* by slightly smaller length-features and significantly larger ND and KD (Fig. 9). It is also characterized by a markedly smaller FA (mean = 21.6°) than *B. posterior* (mean = 37.5°).

From *Belemnitella* sp. a and *B. langei*, *B. mucronata* differs by significantly larger length-features, all diameters as well as SD, ND and KD (Fig. 9). Additionally *B. mucronata* has a significantly smaller FA (mean = 21.6°) than observed in *Belemnitella* sp. a (mean = 32.8°) and *B. langei* (mean = 31°).

The comparison of *B. najdini* and *B. mucronata* show that length-features, all diameters as well as SD, ND and KD are significantly different and are larger in *B. mucronata* (Fig. 9). In contrast, *B. najdini* is characterized by a very large FA (mean = 62.2°).

**Occurrence.** – In the Vistula section, *B. mucronata* is known from the Upper Campanian (according to the Tercis definition) and was recorded from: Doroitka, Ciszycza Brodalka, Pawłowice Cemetery, Pawłowice Posesja, Sadkowice Szkoła, Sadkowice N, Raj, Raj N and Podole. It is known from the North European Province and the northern part of the Tethyan Realm.

*Belemnitella minor* Jeletzky, 1951

(= *B. minor* I Jeletzky, 1951 and *B. minor* II Christensen, 1995)  
(Fig. 12A–L)

1853. *Belemnitella mucronata* (Schlotheim); Sharpe: 6, pl. 1, fig. 2 (non figs. 1, 3; after Christensen, 1995).

1951a. *Belemnitella mucronata* mut. *minor* Jeletzky: 203.

1951b. *Belemnitella mucronata* mut. *minor* Jeletzky; Jeletzky: 87, pl. 1, fig. 3.

pars1975. *Belemnitella minor* Jeletzky; Christensen: 56–58.

pars1995. *Belemnitella minor* I Jeletzky; Christensen: 55–64.

pars1995. *Belemnitella minor* II Christensen: 64–69.

Table 2

Biometry and descriptive statistics of the *Belemnitella mucronata* (= morphogroup e)

Variables [mm] * in [°]	n	Mean	Confidential interval: -95%	Confidential interval: +95%	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
LAP	19	46.60	44.97	48.23	46.22	39.83	51.63	11.44	3.383	0.776
LASVF	19	54.79	52.80	56.77	54.27	46.90	62.80	16.89	4.109	0.943
LAEVF	19	61.97	59.78	64.16	61.30	52.95	69.53	20.60	4.539	1.041
LABVF	19	54.75	52.80	56.69	54.27	46.90	62.09	16.28	4.035	0.926
SD	19	8.18	7.49	8.87	8.00	5.92	11.71	2.07	1.438	0.330
ND	19	15.36	14.43	16.30	15.22	12.44	20.05	3.76	1.940	0.445
KD	19	7.18	6.55	7.81	7.03	5.47	10.79	1.71	1.308	0.300
RDBSVF	19	-0.04	-0.12	0.04	0.00	-0.71	0.00	0.03	0.163	0.037
MVD	19	12.17	11.68	12.66	12.08	10.45	13.80	1.05	1.026	0.235
DVDP	19	12.06	11.58	12.53	12.06	10.45	13.74	0.98	0.988	0.227
DVDEVF	19	12.45	12.01	12.89	12.41	10.67	14.17	0.83	0.914	0.210
VDP	19	11.82	11.34	12.30	11.76	10.09	13.52	1.00	0.998	0.229
VDEVF	19	11.61	11.14	12.08	11.41	10.13	13.69	0.97	0.984	0.226
AA*	19	18.99	18.45	19.52	19.31	16.42	20.90	1.25	1.117	0.256
FA*	19	21.96	19.78	24.13	21.29	13.90	29.12	20.33	4.509	1.034

n – number of observations; the descriptive terms are shown in Figure 4

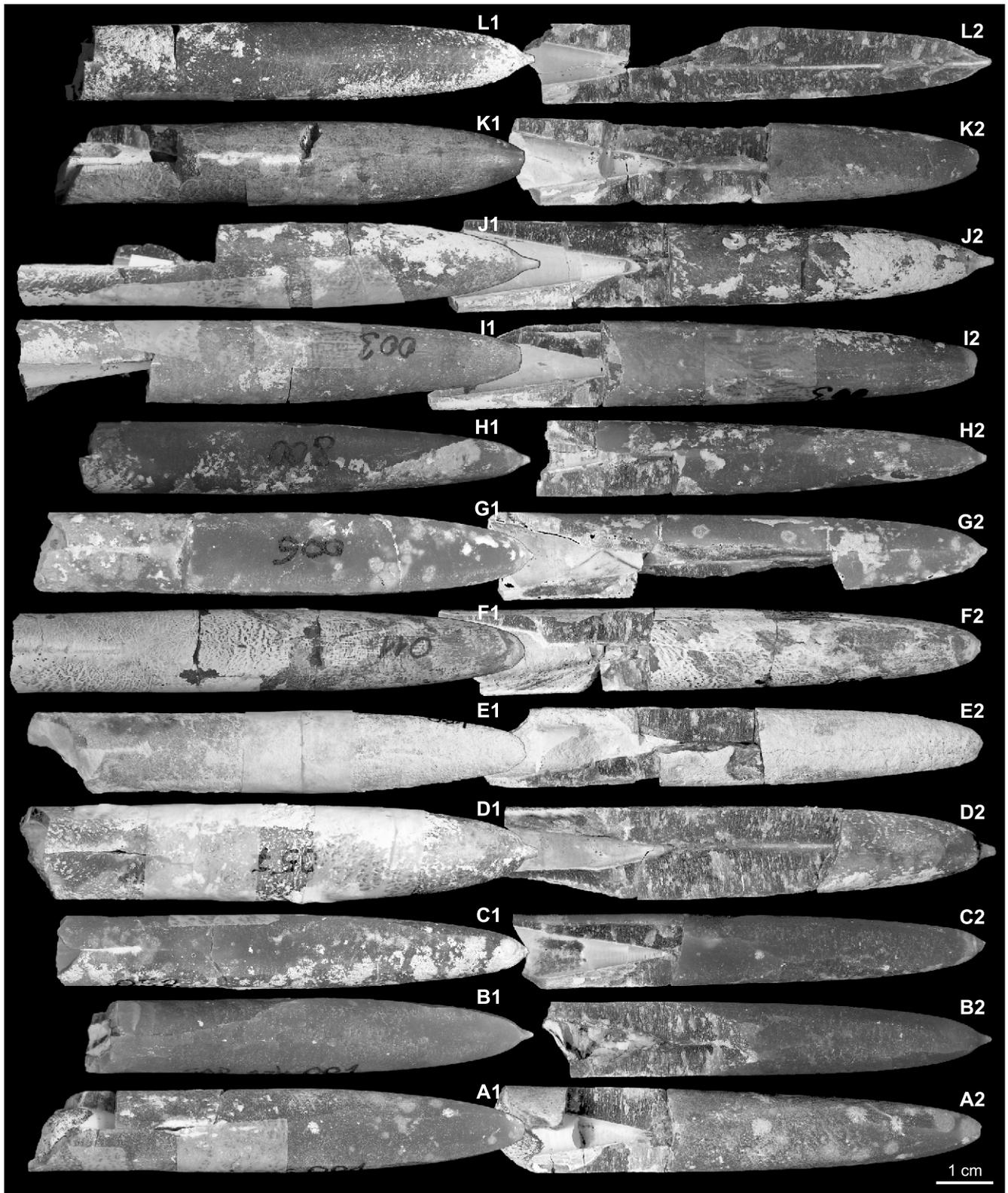


Fig. 12. *Belemnitella minor*

*Belemnitella minor* I Jeletzky, 1951: **A** – Pawł/pos/001, Pawłowice Posesja section; **B–E**: **B** – Sad/szk/001, **C** – Sad/szk/053, **D** – Sad/szk/057, **E** – Sad/szk/064, Sadkowice Szkoła section; **F** – SadN/011, Sadkowice N section; *Belemnitella minor* II Christensen, 1995: **G** – Piot/006, Piotrawin section; **H** – Raj/006, Raj section; **I–L**: **I** – RajN/003, **J** – RajN/005, **K** – RajN/038, **L** – RajN/062, Raj N section; other explanations as in [Figure 11](#)

pars1999. *Belemnitella minor* I Jeletzky; Christensen: 113–114.  
pars1999. *Belemnitella minor* II Christensen: 114–118.

**General remarks.** – The concept of *B. minor* based on its original diagnosis, used by the East European researchers (e.g., Jeletzky, 1951a, b; Naidin, 1952; Kongiel, 1962) is not identical with the concept of Christensen (1995) based on the holotype and followed recently in West Europe (Christensen, 1995, 1999; Keutgen and Jagt, 1999; Keutgen et al., 2010; Jagt, 2012). According to the original diagnosis of Jeletzky (1951a), *B. minor* differs from *B. mucronata* by its smaller guard and diameter and markedly larger fissure angle.

Christensen (1995) distinguished three chronospecies within the lineage of *B. minor*: *B. minor* I, *B. minor* II and *B. minor* III. The latter was included in the synonymy of *B. minor* II (Christensen, 1999). *B. minor* from the Middle Vistula section shows a similar developmental trend through its stratigraphic range when compared to subspecies of *B. minor* recognized in Norfolk and the Mons region in Belgium. Consequently, two stratigraphic forms are distinguished: *B. minor* I Jeletzky, 1951 and *B. minor* II Christensen, 1995. *B. minor* from the Middle Vistula section is slightly smaller and has a generally smaller SD. The taxonomic description is limited to the nominate species (= *B. minor*) where differences between the two subspecies are stressed.

**Type.** – The holotype (BGS GSM 7747), by original designation, is the original of Sharp (1853: pl. 1; fig. 2) from the Upper Campanian, near Norwich, Norfolk; it was refigured by Jeletzky (1951a: pl. 1, fig. 3) and Christensen (1995: pl. 1, figs. 4–7; pl. 4, fig. 5).

**Material.** – 20 specimens from MVVS: Pawl/pos/001, Sad/szk/001, Sad/szk/023, Sad/szk/053, Sad/szk/057, Sad/szk/062, Sad/szk/064, SadN/002, SadN/011, Piot/006, Raj/006, Raj/057, Raj/058, Raj/066, RajN/003, RajN/005, RajN/038, RajN/062, KłodzN/006, Dziu/019.

**Description.** – Guard large to very large, stout to moderately slender (mean LAEVF = 69.9 mm; max LAEVF up to 78.0 mm); LAP medium to very large (mean LAP = 55.4 mm; max. LAP up to 61.6 mm); the guard generally subcylindrical in ventral view and subconical to high conical in lateral view and

markedly flattened ventrally over its entire length; DVDP slightly larger than VDP. Mean value of Birkelund Index = 4.0 with an observed range 3.35–4.56. Apical end more or less obtuse, sometimes moderately acute, usually with well-defined mucro.

SD medium to large (mean = 7.8 mm); ND and KD large to very large with mean values of 14.5 mm and 6.6 mm respectively. SD, ND, KD are in most cases larger than in other forms of *Belemnitella* from the study interval. FA medium (mean = 29°); AA medium (mean = 19.6°). Shape of bottom of ventral fissure usually straight and only sometimes slightly curved or undulating.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows usually well-developed. Vascular markings well-defined, mainly on ventral and lateral side; some specimens with pseudogranulation on ventral side; longitudinal striae present on posterior dorsal side. The complete biometric characteristics of *Belemnitella minor* (morphogroup f) are summarized in Table 3.

**Remarks.** – Jeletzky (1950) recognized three types of variation within a species. One of it is a mutation, applied to chronological subspecies. *B. minor* was established by Jeletzky (1951a) as *B. mucronata* mut. *minor*. This taxon, *sensu* Jeletzky differs from *B. mucronata* mut. *senior* Nowak, 1913 (= *B. mucronata mucronata*; compare Birkelund, 1957; Christensen, 1986, 1995) in its smaller guard and diameters, larger fissure angle, irregular bottom of ventral fissure and being less conical in lateral view. Thus, according to Jeletzky (1950), *B. minor* is more slender and a stratigraphically younger subspecies (mutant) of *B. mucronata mucronata*. A specimen figured as *B. mucronata* by Sharpe (1853: pl. 1 fig. 2) was designated by Jeletzky (1951a) as the holotype of *B. mucronata* mut. *minor*.

For 25 years, since Jeletzky (1951) designated his new subspecies (mutant), this taxon has been used as an index fossil of the lower part of the Upper Campanian. However, when establishing his new subspecies, Jeletzky (1951) did not split the holotype to verify its internal characters. Nevertheless, he reported them in the original diagnosis of *B. minor*. This inaccuracy has been the reason why *B. minor* has been interpreted dif-

Table 3

Biometry and descriptive statistics of the *Belemnitella minor* (= morphogroup f)

Variables [mm] * in [°]	<i>n</i>	Mean	Confidential interval: –95%	Confidential interval: +95%	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
LAP	20	55.38	53.71	57.05	54.97	49.07	61.57	12.69	3.562	0.797
LASVF	20	63.22	61.30	65.14	63.48	54.60	71.13	16.79	4.098	0.916
LAEVF	20	69.86	67.71	72.01	70.15	58.65	77.98	21.15	4.599	1.028
LABVF	20	63.22	61.30	65.14	63.48	54.60	71.13	16.79	4.098	0.916
SD	20	7.84	6.79	8.89	7.83	4.06	12.60	5.02	2.240	0.501
ND	20	14.48	13.35	15.61	14.99	9.57	18.66	5.82	2.413	0.540
KD	20	6.64	5.73	7.54	6.75	3.07	9.77	3.74	1.935	0.433
RDBSVF	20	0.00	–	–	0.00	0.00	0.00	0.00	0.000	0.000
MVD	20	14.09	13.52	14.67	14.05	11.73	17.17	1.51	1.229	0.275
DVDP	20	13.82	13.30	14.33	14.04	11.59	16.23	1.23	1.109	0.248
DVDEVF	20	14.14	13.55	14.73	14.23	11.47	16.93	1.57	1.254	0.280
VDP	20	13.66	13.09	14.22	13.78	11.70	16.90	1.48	1.216	0.272
VDEVF	20	13.40	12.81	14.00	13.28	11.22	16.61	1.59	1.262	0.282
AA*	20	19.59	19.13	20.04	19.60	17.48	21.03	0.93	0.966	0.216
FA*	20	28.98	25.72	32.25	27.74	15.88	44.22	48.75	6.982	1.561

Explanations as in Table 2

ferently by a number of authors. Birkelund (1957) as well as Kongiel (1962) placed *B. minor* into the synonymy of *B. langei*. Naidin (1964a, b) recognized *B. minor* together with *B. najdini* as subspecies of *B. langei*. Finally, in 1975 C.J. Wood split the holotype of *B. minor* (cf. Christensen, 1975; Christensen et al., 1975). It turned out that the internal characters did not agree with the original diagnosis and, as a consequence, the legitimacy of *B. minor* was questioned.

Based on the biometric data, it was reported (Christensen, 1975; Christensen et al., 1975) that the holotype of *B. minor* in most of its characters falls within the variability range of the topotype population of *B. mucronata*, although the *stratum typicum* of *B. minor* was placed stratigraphically much higher (Christensen et al., 1975). Later it was found, however (Christensen, 1995), that *B. minor*, based on the concept of its holotype (non original diagnosis) corresponded to *B. mucronata sensu Jeletzky (1964)* and to very large specimens of *B. mucronata sensu Wood (1988)*.

Christensen (1975), based on the concept of the holotype, recognized a homogeneous population of *B. minor* from Balsvik and Bjarnum from the basal Maastrichtian (*Belemnella lanceolata* Zone). However, later it turned out that, based on the same material from the basal Maastrichtian, Christensen (1998a) recognized this population as representing a new species: *Belemnitella carlsbergensis* Christensen, 1998. This shows how the understanding of this species changed through time. Additionally, it shows that the analyses of topotype populations of *B. minor* (performed by Christensen in 1995) were necessary to correctly understand other so far described populations of *Belemnitella minor* (e.g., those from Balsvik and Bjarnum). Such variable interpretations of *B. minor* might raise doubts concerning the homogeneity of other populations of *minor*. All these data shows that the consensus of what should be understood under the name of *B. minor* is still open to discussion.

Nevertheless, the specimens with complete biometry of morphogroup *f* best correspond biometrically to populations

commonly described as *B. minor sensu Christensen (e.g., 1995, 1999)*. Additionally, within the stratigraphic range of the herein recognized population of morphogroup *f* two succeeding stratigraphic forms are distinguished, representing *B. minor* I and *B. minor* II (cf. Christensen, 1995, 1999). The comparison of the means of particular features of older (= *B. minor* I) and younger (= *B. minor* II) representatives of *B. minor* shows that, through the stratigraphic range of this form, guards tend to be longer with increasing values of the Schatzky distance, Nowak distance and Kongiel distance (cf. Fig. 13).

It is worthy of note, that the specimens of *B. minor* from the succeeding intervals of the Middle Vistula section (Fig. 13) are smaller and have a smaller Schatzky distance than typical populations of *B. minor*, e.g. from Norfolk (Christensen, 1995, 1999). However, the development pattern through time is very similar and the stratigraphic forms recognized herein generally follow the diagnosis of the chronospecies of *B. minor* recognized by Christensen (1995, 1999). According to the original diagnosis, differences between the two succeeding forms recognized in Norfolk are rather small. *B. minor* I is characterized by large guards with Birkelund Index about 4 (from 3.2 to 4.9 for individuals); mean value of Schatzky distance in samples range from 8 to 9.5 mm; mean for AA and FA is 18.5–19° and 28°, respectively. *B. minor* II is closely similar and is characterized by a stouter guard (Birkelund Index is about 3.5) and larger Schatzky distance (~11.5–12 mm). In general, *B. minor* II differs from *B. minor* I by being a little bit stouter and having a larger Schatzky distance (cf. Christensen, 1995 and emended diagnosis of Christensen, 1999).

In the present study material from the Vistula section, the succeeding forms are characterized by the following mean values of selected characters (cf. also Fig. 13):

***B. minor* I:** LAP = 53.8 mm; LAEVF = 67.1 mm; DVDP = 13.64; SD = 6.94 mm (from 4 to 9 mm); AA = 20°; FA = 29.1°; the Birkelund Index varies from 3.35 to 4.30 giving mean value c. 4.0.

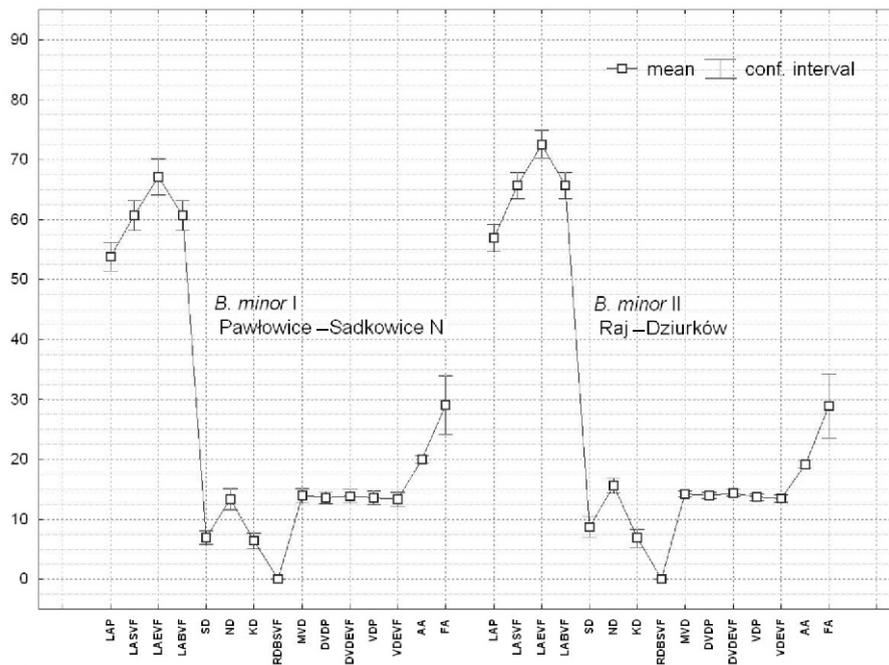


Fig. 13. Means and 95% confidence intervals of features in populations of *B. minor* from two succeeding intervals (Pawłowice–Sadkowiec N and Raj–Dziurków)

These are equivalents of *B. minor* I and *B. minor* II, respectively

**B. minor II:** LAP = 57.0 mm; LAEVF = 72.6 mm; DVDP = 14.00; SD = 8.74 mm (from 5.9 to 12.6 mm); AA = 19.1°; FA = 28.9°; the Birkelund Index varies from 3.6 to 4.56 giving mean value c. 4.1.

Keutgen et al. (2010) summarized that populations of *B. minor I* in Norfolk, Mons and the Maastricht area are characterized by a mean BI ranging from 3.7 to 4.2 and a mean SD ranging from 8.0 to 10.5 mm, while the corresponding mean values of populations of *B. minor II* in these regions vary from 3.5 to 3.8 and 10.4 to 12.3 mm, respectively. The corresponding values (BI and SD) for the *B. minor I* from the Vistula valley are c. 4.0 and 6.9. In the case of *B. minor II*, BI is 4.1 and SD is 8.74.

Summarizing, the population of *minor I* and *minor II* from the Vistula valley is characterized by slightly smaller guards, with similar BI for the population of *minor I* and slightly larger BI for that of *minor II*. The SD of *minor I* from the Vistula section is generally similar to that of North European populations of *minor I* whereas *minor II* is characterized by a slightly smaller mean SD albeit reaching up to 12.6 mm in particular individuals. Whether these differences result from different development pattern of the populations or represent simple ecologic dependency is a question open to discussion. In my opinion such differences in the mean values are to be expected, reflecting regional particularities which I treat as taxonomical unimportant.

*B. minor* differs from *B. posterior*, in its significantly larger length-features, all diameters as well as ND, KD (Fig. 9). *B. posterior* is characterized by a markedly larger FA (mean = 40°) than *B. minor* (mean = 27°).

From *Belemnitella* sp. a, *B. langei* and *B. najdini* it differs in significantly larger length-features, all diameters as well as ND, KD (Fig. 9). Additionally *B. najdini* is characterized by a significantly larger FA (mean = 61°) than *B. minor* (mean = 27°).

**Occurrence.** – In the Vistula section, *B. minor* is known from the Upper Campanian and Lower Maastrichtian (Tercis definition) and was recorded from: Pawłowice Posesja, Piotrawin, Sadkowiec Szkoła, Sadkowiec N, Raj, Raj N, Kludzie N and Dziurków. Additionally, this taxon is known from broad areas of the North European Province: Belgium, the Netherlands and England.

*Belemnitella posterior* Kongiel, 1962  
(Fig. 14A–N)

pars 1962. *Belemnitella posterior* Kongiel: 95, pl. 19, figs. 1–9. pars 1998b. *Belemnitella posterior* Kongiel: 1–7 (Christensen, unpubl. report).

**Type.** – The holotype (Mcd 214), by original designation is the original of Kongiel (1962: 95, pl. 19, figs. 7–9), from Kołczyn in the Middle Vistula valley section; Upper Campanian, local level *r* of Pożaryski (1938). It is refigured here (Fig. 14E1, E2) in addition to paratype (Fig. 14F1, F2) and are housed in the Mu-

seum of the Earth in Warsaw of the Polish Academy of Sciences.

The specimens most similar to the means of population of *B. posterior* (cf. with descriptive statistics, Table. 4) are Sad/szk/029 i Sad/szk/031, both from Sadkowiec Szkoła.

**Material.** – 18 specimens from the Middle Vistula section: Pawl/pos/007, Sad/szk/012, Sad/szk/021, Sad/szk/031, Sad/szk/065, SadN/010, SadN/012, Raj/001, Raj/005, Raj/008, Raj/012, Raj/047, Raj/059, Pdole/022, Pdole/026, Dziu/005; Mcd 214 – holotype from the Kołczyn nad Wisłą and Mcd 212 – paratype from the Solec nad Wisłą.

**Description.** – Guard medium to large, sometimes very large, generally slender (mean LAEVF = 61.2 mm; max LAEVF up to 74 mm); LAP medium to large (mean LAP = 50.7 mm; max LAP up to 62.4 mm); the guard is subcylindrical to slightly lanceolate in ventral view and subconical to subcylindrical in lateral view and is markedly flattened ventrally; DVDP slightly larger than VDP. Mean value of Birkelund Index BI = 4.2 with an observed range 3.53–4.86. Apical end more or less acute, sometimes moderately obtuse, then with well-defined mucro.

SD small to medium (mean = 6.4 mm); ND and KD medium with mean values 10.5 mm and 4.1 mm respectively. FA medium to large (mean = 37.5°); AA generally medium (mean = 19.8°). Shape of the bottom of the ventral fissure is usually straight, sometimes slightly curved.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows present, in some specimens relatively well-expressed. Vascular markings generally well-defined, mainly on ventral and lateral side. The complete biometry of *Belemnitella posterior* (morphogroup *b*) is summarized in Table 4.

**Discussion and remarks.** – The specimens with complete biometry of morphogroup *b* were compared with the small population from the Vistula section originally distinguished by Kongiel (1962) as *Belemnitella posterior*. Kongiel's species has been designated on the basis of 8 specimens from the uppermost Campanian and lowermost Maastrichtian (Boreal definition) of the Middle Vistula section, from the local levels *r*, *s*, *t* and *u* of Pożaryski (1938) and was included in the *B. mucronata* group (Kongiel, 1962). The mean values of particular features of this small topotype population of *B. posterior* analyzed by Kongiel are more or less equal to those of the present study's morphogroup *b*, which by the way, can also be treated as a topotype population for this species. Additionally, during Kohonen network simulations, the holotype and paratype of *B. posterior* (Fig. 14E, F) has been also included in morphogroup *b* recognized herein.

There is also a high similarity of morphogroup *b* with what has been considered a population of *B. posterior* from the Piotrawin Quarry by Christensen (1998b). Christensen (1998b) in his unpublished report stated that *B. posterior* is a well defined albeit rare species. Within the study material from the Piotrawin pit in the Middle Vistula section, Christensen distinguished a population of *B. posterior* (26 specimens) with the following mean values of features: LAP = 47.1 mm; SD = 7.0 mm; MVD = 12.0 mm; DVDP = 12.0 mm; VDP = 11.8 mm; AA = 19.8°; FA = 28.7°; BI = 3.9. These values are only insignificantly different from the here presented population of morphogroup *b* (= *B. posterior*). Consequently, I interpret morphogroup *b* as representing *B. posterior* and the studied population may be regarded as statistically representative for this species.

*B. posterior* seems to be an East European species. Records in West European sections are either misinterpretations and have recently been referred to *B. minor II* (Robaszynski and Christensen, 1989;

<i>Belemnitella posterior</i> – holotype (Mcd 214) and paratype (Mcd 212)							
Specimen	LAP	LASVF	LAEVF	LABVF	SD	ND	KD
Mcd 214	55.71	62.57	66.32	62.57	6.86	10.61	3.75
Mcd 212	63.62	69.98	72.07	69.98	6.36	8.45	2.09
RDBSVF	MVD	DVDP	DVDEVF	VDP	VDEVF	AA	FA
0.00	14.63	13.82	14.16	14.02	13.76	21.61	42.58
0.00	15.05	14.76	15.03	14.76	14.57	21.39	60.28

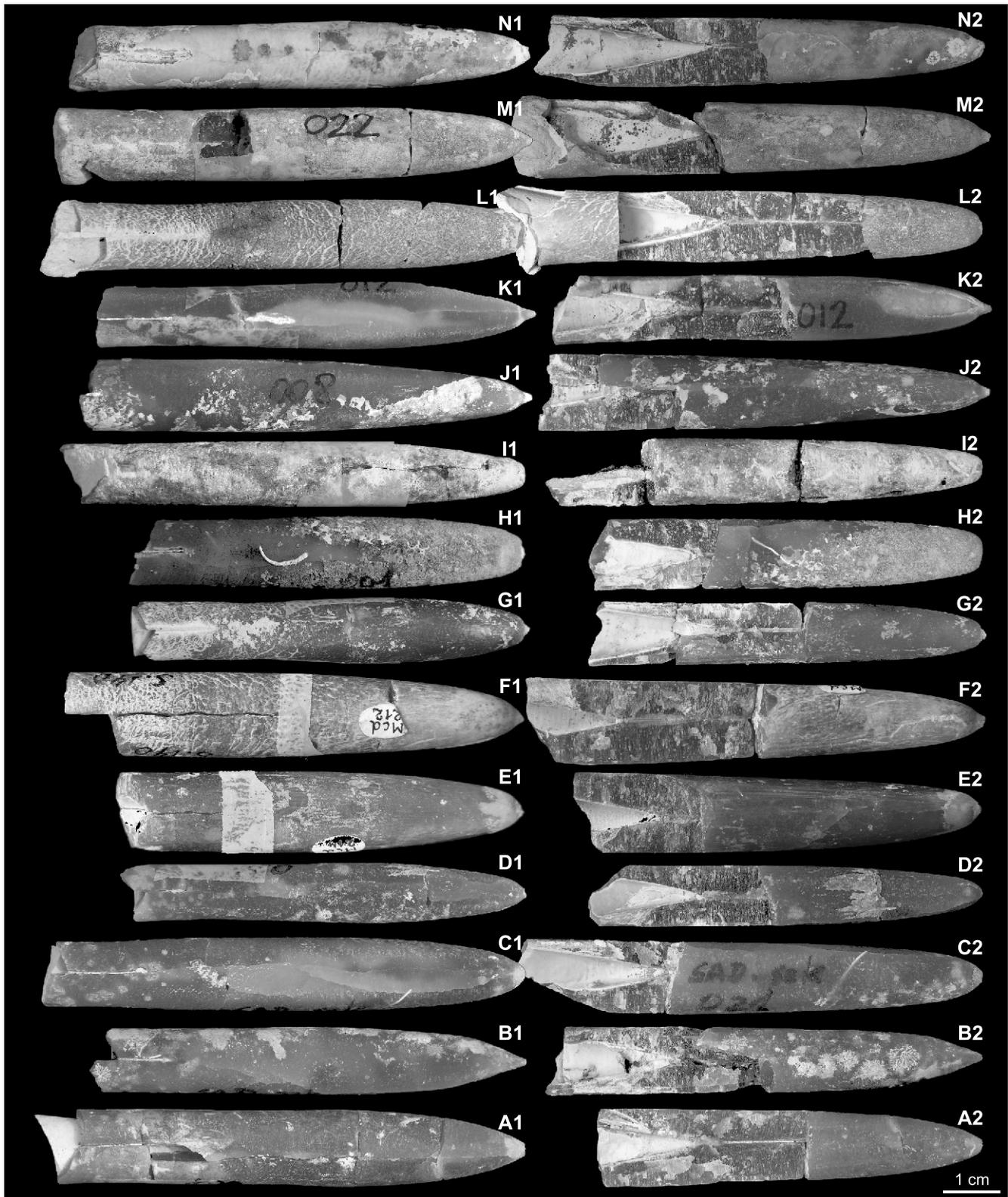


Fig. 14. *Belemnitella posterior* Kongiel, 1962

A – Pawł/pos/007, Pawłowice Posesja section; B–D – B – Sad/szk/012, C – Sad/szk/021, D – Sad/szk/031, Sadkowiec Szkoła section; E – Mcd 214, holotype, Kołczyn nad Wisłą (original of Kongiel, 1962); F – Mcd 212, paratype, Solec nad Wisłą (original of Kongiel, 1962); G – SadN/012, Sadkowiec N section; H–L – H – Raj/001, I – Raj/005, J – Raj/008, K – Raj/012, L – Raj/059, Raj section; M, N – M – Podole/022, N – Podole/026, Podole section; other explanations as in Figure 11

Table 4

Biometry and descriptive statistics of the *Belemnitella posterior* (= morphogroup *b*)

Variables [mm] * in [°]	<i>n</i>	Mean	Confidential interval: –95%	Confidential interval: +95%	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
LAP	16	50.68	48.00	53.37	50.20	43.31	62.40	25.47	5.047	1.262
LASVF	16	57.04	54.20	59.87	56.09	49.32	68.23	28.33	5.323	1.331
LAEVF	16	61.17	58.23	64.10	60.32	52.03	74.06	30.31	5.505	1.376
LABVF	16	57.04	54.20	59.87	56.09	49.32	68.23	28.33	5.323	1.331
SD	16	6.35	5.78	6.92	6.18	4.34	9.48	1.13	1.065	0.266
ND	16	10.48	9.74	11.22	10.43	8.47	13.41	1.95	1.396	0.349
KD	16	4.13	3.45	4.81	4.35	1.89	6.76	1.63	1.277	0.319
RDBSVF	16	0.00	–	–	0.00	0.00	0.00	0.00	0.000	0.000
MVD	16	12.06	11.40	12.73	11.95	9.71	14.49	1.56	1.249	0.312
DVDP	16	11.95	11.31	12.59	11.91	9.79	14.19	1.45	1.203	0.301
DVDEVF	16	12.06	11.40	12.72	11.99	9.93	14.25	1.55	1.243	0.311
VDP	16	11.46	10.73	12.19	11.44	9.21	13.95	1.89	1.376	0.344
VDEVF	16	11.20	10.52	11.89	11.23	9.08	13.31	1.64	1.280	0.320
AA*	15	19.76	19.14	20.38	20.07	16.93	21.13	1.25	1.118	0.289
FA*	16	37.48	33.25	41.72	35.70	25.30	56.41	63.25	7.953	1.988

Explanations as in Table 2

Christensen, 1995) or are questionable at best (Schulz, 1978). Although *B. posterior* and *B. minor* II are relatively similar, the first is easily separated by its significantly larger fissure angle and smaller Schatzky distance.

*B. posterior* is slightly longer and has a slightly larger FA than *Belemnitella* sp. *a* (cf. Fig. 9). These differences are, however, small and it cannot be ruled out that these two forms represent in fact the same species. However, for the time being I treat these two forms separately.

*B. posterior* differs from *B. langei* by significantly larger length-features, slightly larger diameters and a markedly larger FA (Fig. 9). Additionally, *B. langei* possesses an acute apical end in contrast to the obtuse apical part in *B. posterior*.

From *B. najdini* the species *B. posterior* differs in significantly larger length-features, all diameters as well as ND and KD (Fig. 9). *B. najdini* is characterized by very large FA (mean = 62.2°) which is significantly larger than in *B. posterior* (mean = 37.5°).

**O c c u r r e n c e.** – In the Vistula section, *B. posterior* is known from the Upper Campanian and Lower Maastrichtian (Tercis definition) and was recorded from: Pawłowice Posesja, Sadkowice Szkoła, Sadkowice N, Raj, Podole and Dziurków (single find).

#### *Belemnitella langei* group

**R e m a r k s.** – Kongiel (1962) included three species in the *B. langei* group: *B. langei* Jeletzky, 1948, *B. minor* Jeletzky, 1951 and *B. najdini* Kongiel, 1962. The conception of the *B. langei* group of Christensen differs from that of Kongiel (1962), because he placed *B. minor* into the *B. mucronata* group. Christensen also included *B. pulchra* Schulz, 1982, a latest Campanian to early Maastrichtian species (Tercis definition) in the *B. langei* group. All these forms are characterized by small guards, which are generally slender to very slender, with rather small Schatzky distances and large to very large fissure angles.

In the present study the conception of Christensen is generally adopted with the following species included unequivocally in the *B. langei* group: *B. langei*, and *B. najdini*; *Belemnitella* sp. *a* is also included in this group, although with respect to its biometric characteristic it is transitional between *B. langei* and *B. posterior* (Fig. 9), thus between the *mucronata* and *langei* groups. For the time being, due to its uncertain taxonomic status, *B. pulchra* is also placed into this group. However, the latter species, with only minute differences from *B. najdini*, could be, in fact, its synonym.

#### *Belemnitella langei* Jeletzky, 1948 (Fig. 15A–P)

1948. *Belemnitella langei* Jeletzky: 599, text-figs. 3, 4.  
1951b. *Belemnitella langei* Jeletzky; Jeletzky: 93, pl. 2, figs. 3, 5.  
pars 1962. *Belemnitella langei* Jeletzky; Kongiel: 78–79.

**T y p e.** – The holotype, by original designation, is the original of Jeletzky (1948: 599, text-figs. 3, 4) from the uppermost Campanian (Boreal definition) of the Sejm River area, a tributary of Desna River, Ukraine. It came from 1–2 m below the Campanian/Maastrichtian boundary (based on the FAD of *Belemnella lanceolata*) represented by a regional hiatus. It was refigured by Jeletzky (1951b: 93, pl. 2, figs. 3, 5) and Christensen (1986: pl. 7, fig. 5).

**M a t e r i a l.** – 38 specimens from the Middle Vistula valley section: Pawl/pos/005, Pawl/pos/008, Sad/szk/004, Sad/szk/005, Sad/szk/009, Sad/szk/010, Sad/szk/011, Sad/szk/013, Sad/szk/014, Sad/szk/033, Sad/szk/034, Sad/szk/051, SadN/005, SadN/006, SadN/008, SadN/015, SadN/021, Piot/010, Piot/011, Piot/016, Piot/019, Raj/002, Raj/004, Raj/007, Raj/010, Raj/011, Raj/018, Raj/022, Raj/030, Raj/040, Raj/060, Raj/061, Raj/062, Raj/065, Raj/076, RajN/012, RajN/018, RajN/026.

**D e s c r i p t i o n.** – Guard small, only sometimes medium-sized, generally slender to very slender (mean LAEVF =

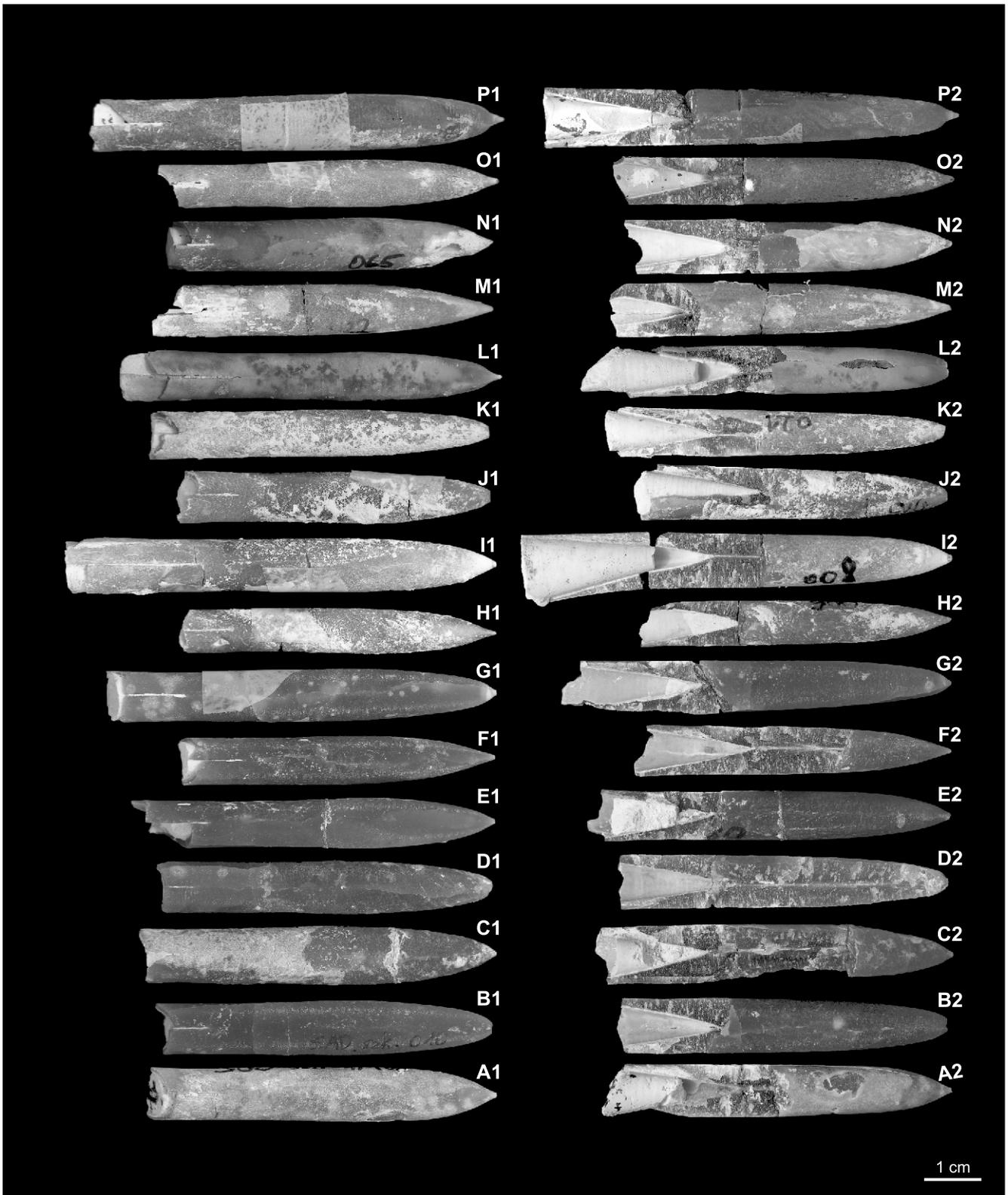


Fig. 15. *Belemnitella langei* Jeletzky, 1948

A – Pawl/pos/005, Pawłowice Posesja section; B–G – B – Sad/szk/010, C – Sad/szk/011, D – Sad/szk/014, E – Sad/szk/033, F – Sad/szk/034, G – Sad/szk/051, Sadkowice Szkoła section; H–K – H – SadN/006, I – SadN/008, J – SadN/015, K – SadN/021, Sadkowice N section; L–N – L – Raj/010, M – Raj/022, N – Raj/065, Raj section; O, P – O – RajN/018, P – RajN/026, Raj N section; other explanations as in Figure 11

49.8 mm; max LAEVF up to 58.7 mm); LAP small (mean LAP = 39.2 mm; max. LAP up to 46.7 mm); the guard is generally subcylindrical, sometimes slightly lanceolate in ventral view and subcylindrical to conical in lateral view, tapering late. It is only slightly flattened ventrally; DVDP slightly larger than VDP. The mean value of Birkelund Index BI = 4.3 with an observed range of 3.66–5.22. Apical end acute to very acute, only rarely slightly obtuse with a rather poorly defined mucro.

SD small, sometimes medium-sized (mean = 7.0 mm). ND medium to large (mean = 10.7 mm); Kongiel distance generally small to medium (mean = 3.7 mm). FA medium to large (mean = 31.0°); AA usually medium to very large (mean = 20.0°; max up to 23.8°). Shape of the bottom of the ventral fissure is usually straight, sometimes slightly curved posteriorly before reaching the outer surface of the guard.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows are present, but poorly developed. Vascular markings present only around the ventral fissure, in other cases weak; in some specimens longitudinal striae may be present. The complete biometry of *Belemnitella langei* (morphogroup c) is summarized in Table 5.

**Discussion and remarks.** – *Belemnitella langei* was designated by Jeletzky (1948), who subsequently (Jeletzky, 1951b) emended the diagnosis of his species. However, he did not study the internal characters of the holotype. The latter were finally reported by Christensen et al. (1975) and turned out to be in agreement with the emended diagnosis of Jeletzky (1951b). According to it, *B. langei* possessed a small and slender guard which is cylindrical or club-shaped in ventral view and conical or cylindrical in lateral view. The Schatzky distance varies from 5 to 7 mm. FA usually oscillates in the range 40–50°, but may be <40° and up to 90°. AA is usually 23–25° and the bottom of the ventral fissure is variable. It is worth mentioning, however, that accurate measurements of FA and AA could not be executed because of weathered alveolar part of the holotype and paratype.

Najdin (1952) understood this form more broadly and included in the *B. langei* group three forms: *B. langei*, *B. minor* (understood in the sense of its original diagnosis, not that of the

holotype) and belemnites subsequently established by Kongiel (1962) as *B. najdini*.

*B. langei* distinguished by Birkelund (1957) was included by Christensen (1995) in the synonymy of *B. minor* III (= *B. minor* II) albeit with a query and subsequently was excluded from it (Christensen, 1999). *B. langei sensu* Birkelund was later given specific rank by Christensen (2000a) and referred to as *B. schulzi*.

Christensen (1986) distinguished *B. aff. langei* as a possible ancestor of *B. langei*, however, the stratigraphic control of his *B. aff. langei* is poor, and it differs markedly from the holotype and specimens of *B. langei sensu* Najdin from the Russian Platform. Moreover, in *B. langei*, the bottom of ventral fissure is usually complexly bent and the fissure angle is large, whereas in *B. aff. langei* the bottom is straight and the FA is very small (mean = 17°), which places this form rather closer to the *B. mucronata* group than to the *B. langei* group.

Schulz (1978) considered *B. langei* as a typical East European species and suggested that most of its records from Western Europe were misconceptions and should be assigned to *B. cf. najdini*. The conception of Christensen (1995) was different in that he included part of the specimens of *B. cf. najdini* recognized by Keutgen and Tuuk (1991) in the synonymy of *B. najdini*. However, the number of specimens analysed by these authors was small (a couple of specimens) and individual features varied markedly (Christensen, 1995). A larger sample from the same stratigraphic level was later studied by Keutgen and Jagt (1999), who showed the presence of two species, what they interpreted to be *B. najdini* and *B. minor* II.

The concept of *B. langei*, despite long-term studies, still remains uncertain and debatable because a topotype population has never been thoroughly described. The intraspecific variability is unknown due to the lack of statistically representative populations from the type locality. Thus, *B. langei* could be understood only in the sense of its holotype and paratype, which seem to fall to a large extent into the variability of what Christensen (1995) considered as *B. langei* from Norfolk, and at least in part fall into population of *B. langei sensu* Birkelund (= *B. schulzi*). Both those populations require further study to de-

Table 5

Biometry and descriptive statistic of the *Belemnitella langei* (= morphogroup c)

Variables [mm] * in [°]	<i>n</i>	Mean	Confidential interval: –95%	Confidential interval: +95%	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
LAP	38	39.17	37.96	40.37	39.24	33.23	46.72	13.47	3.670	0.595
LASVF	38	46.17	44.82	47.53	46.69	38.82	54.88	17.04	4.128	0.670
LAEVF	38	49.82	48.35	51.30	49.90	41.70	58.74	20.24	4.499	0.730
LABVF	38	46.17	44.82	47.53	46.69	38.82	54.88	17.04	4.128	0.670
SD	38	7.01	6.66	7.35	7.04	4.45	8.41	1.10	1.049	0.170
ND	38	10.66	10.14	11.17	10.54	7.95	14.06	2.45	1.565	0.254
KD	38	3.65	3.27	4.03	3.85	0.96	5.90	1.33	1.154	0.187
RDBSVF	38	0.00	–	–	0.00	0.00	0.00	0.00	0.000	0.000
MVD	38	9.20	8.87	9.53	9.17	6.31	11.35	1.00	0.999	0.162
DVDP	38	9.19	8.89	9.49	9.30	6.37	10.81	0.85	0.920	0.149
DVDEVF	38	9.34	9.04	9.64	9.49	6.52	10.71	0.81	0.901	0.146
VDP	38	8.78	8.47	9.08	8.86	5.81	10.68	0.88	0.939	0.152
VDEVF	38	8.71	8.43	8.99	8.84	6.01	10.41	0.72	0.847	0.137
AA*	38	20.04	19.58	20.49	19.74	18.18	23.82	1.91	1.381	0.224
FA*	38	31.03	27.99	34.07	28.41	16.70	56.01	85.65	9.255	1.501

Explanations as in Table 2

cide whether or not they can be synonymized with the herein distinguished *B. langei*. Another complicating problem is the understanding of *B. langei sensu* Schulz from Kronsnoor.

The present study specimens with complete biometry of morphogroup *c* resembles in most of its characters the original concept of *B. langei* Jeletzky, 1948, with reservation concerning especially the fissure angle, which is smaller in the Vistula population (mean FA = 31°) than in the Norfolk populations where it oscillate between 50 and 60°.

In any case, I interpret morphogroup *c* as representing *B. langei* since the differences in FA could be no more than palaeogeographical or palaeoecological variability. As mentioned above, a satisfying consensus concerning the taxonomic status of *B. langei* is very difficult to reach at the moment.

*B. langei* is relatively similar to *B. najdini*, from which it can be separated by its slightly smaller LAP and diameters and significantly larger ND and KD (Fig. 9). *B. najdini* is characterized by a significantly larger FA (mean = 62.2°) than that of *B. langei* (mean = 31°).

**O c c u r r e n c e.** – In the Middle Vistula section, *B. langei* is known from the Upper Campanian (Tercis definition) and was recorded from: Pawłowice Posesja, Sadkowiec Szkoła, Sadkowiec N, Piotrawin, Raj and Raj N and most probably from Podole.

*Belemnitella najdini* Kongiel, 1962  
(Fig. 16A–R)

1962. *Belemnitella najdini* Kongiel: 79–80, pl. 17, figs. 7–9.

1974. *Belemnitella langei najdini*, Naidin: 223.

pars 1991. *Belemnitella cf. najdini*; Keutgen and Tuuk: 13.

pars 1982. *Belemnitella pulchra*; Schulz: 284.

pars 1995. *Belemnitella najdini*; Christensen: 79–80.

?2006. *Belemnitella langei najdini*; Naidin and Beniamovskiy: 437.

?2012. *Belemnitella langei najdini*; Benyamovskiy et al.: 353.

**T y p e.** – The holotype (Mcd 205), by original designation, is the original of Kongiel (1962: 79, pl. 17, figs. 7–9) from the Piotrawin Quarry, Upper Campanian (Tercis definition), local level *t* of Pożaryski (1938). It is refigured here (Fig. 16P1, P2) in addition to paratype (Fig. 16R1, R2) and is housed in the Museum of the Earth in Warsaw of the Polish Academy of Sciences.

<i>Belemnitella najdini</i> – holotype (Mcd 205) and paratype (Mcd 206)							
Specimen	LAP	LASVF	LAEVF	LABVF	SD	ND	KD
Mcd 205	43.66	50.49	50.04	49.77	6.83	6.38	–0.45
Mcd 206	51.19	56.68	55.14	55.14	5.49	3.96	–1.54
RDBSVF	MVD	DVDP	DVDEVF	VDP	VDEVF	AA	FA
–0.72	10.29	9.94	10.26	10.15	10.04	20.36	88.56
–1.54	10.37	9.96	9.72	9.62	9.72	19.85	107.19

**M a t e r i a l.** – 29 specimens from the Middle Vistula valley section: Pawl/pos/010, Sad/szk/008, Sad/szk/018, Sad/szk/041, Sad/szk/048, Sad/szk/069, SadN/018, Piot/002, Piot/004, Piot/005, Piot/008, Piot/009, Piot/013, Piot/014, Piot/015, Piot/020, Piot/022, Raj/003, Raj/019, Raj/021, Raj/026, Raj/037, Raj/039, Raj/054, Raj/073, RajN/024, Podole/017; Mcd 205 – holotype from the Piotrawin Quarry; Mcd 206 – paratype from the Solec nad Wisłą.

**D e s c r i p t i o n.** – Guard small, generally slender to very slender (mean LAEVF = 49.3 mm; max LAEVF up to 56.5 mm); LAP small (mean LAP = 41.8 mm; max. LAP up to 48.8 mm); the guard is subcylindrical or slightly lanceolate in ventral view and subcylindrical to subconical in lateral view and is only slightly flattened ventrally; DVDP slightly larger than VDP. Mean value of Birkelund Index = 4.4 with an observed range of 4.01–5.48. Apical end acute or slightly obtuse with a variably defined mucro.

SD small, sometimes medium (mean = 6.2 mm); ND and KD small or very small with mean values of 7.4 mm and 1.2 mm, respectively, smallest values amongst all of the *Belemnitella* species studied herein (KD also with negative values, min KD = –1.4 mm). FA very large (mean = 62.2°; max up to 100°); AA usually medium to very large (mean = 20.2°); shape of the bottom of the ventral fissure commonly irregular, straight, curved or undulating, very often swept back posteriorly.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows present but weakly defined. Vascular markings present only around the ventral fissure, generally weakly developed or not present. The complete biometry of *Belemnitella najdini* (= morphogroup *d*) is summarized in Table 6.

**D i s c u s s i o n a n d r e m a r k s.** – *Belemnitella najdini* was designated by Kongiel (1962) and it seems to be closely allied to *B. langei*, being generally stratigraphically younger and it is typically included in the *B. langei* group. Due to the lack of statistically representative populations of *B. najdini*, this form has been understood so far only in the sense of its holotype and the relatively small topotype population studied by Kongiel (1962) and Christensen (1998b; unpubl. report) from the Middle Vistula section. Since the Vistula section is the type locality of *B. najdini*, the here established larger population (29 specimens) of *B. najdini* is treated as representative and topotypic for this species. Consequently, it is to this population that comparisons of other should be made.

*B. najdini* is generally considered a rare species and is known mainly on the basis of single specimens. This resulted in relatively wide ranges of variability of particular characters.

Naidin (1974) reported *B. langei najdini* from the uppermost Campanian [Boreal definition] of the Russian Platform.

Schulz (1982) designated a new species – *B. pulchra* of latest Campanian and Early Maastrichtian age (Tercis definition). Part of the Lower Maastrichtian specimens of *B. najdini* distinguished by Kongiel (1962) were assigned by Schulz (1982) to

his new species *B. pulchra*, who stressed its distinctly lanceolate shape in ventral view. However, the differences between these two species are so minute that they could in fact represent a single Kongiel's species.

Christensen (1995) recognized a small population of *B. najdini* from the English Chalk (Norfolk) and included in its synonymy some of the specimens of *B. cf. najdini* recognized by Keutgen and Tuuk (1991). Although, the population analysed by Christensen is very small ( $n = 6$ ) it shows high similarity to morphogroup *d* (= *B. najdini*) recognized herein, except for the larger FA in the Norfolk material (mean FA = 98°).

Keutgen and Jagt (1999) recognized quite large population of *B. najdini* ( $n = 59$ ) characterized by a markedly larger FA (mean FA = 91° with observed range 51–141°), than observed in the Vistula population of *B. najdini*.

Christensen (1998b) in an unpublished report concerning the belemnites from the Piotrawin pit of the Middle Vistula section recognized and analysed a small population of *B. najdini* (9 specimens). It differs in no significant respect from the popula-



Table 6

Biometry and descriptive statistic of the *Belemnitella najdini* (= morphogroup *d*)

Variables [mm] * in [°]	N	Mean	Confidential interval: –95%	Confidential interval: +95%	Median	Minimum	Maximum	Variance	Standard Deviation	Standard Error
LAP	27	41.84	39.89	43.80	42.04	30.93	48.79	24.5	4.95	0.952
LASVF	27	48.07	46.09	50.04	49.27	36.06	55.26	24.9	4.99	0.960
LAEVF	27	49.26	47.25	51.26	50.80	35.92	56.51	25.7	5.07	0.976
LABVF	27	47.89	45.92	49.87	48.75	35.26	55.26	25.0	5.00	0.962
SD	27	6.22	5.83	6.62	6.21	4.49	8.34	1.0	1.00	0.193
ND	27	7.42	6.86	7.97	7.62	3.96	9.52	1.9	1.40	0.268
KD	27	1.19	0.76	1.62	1.37	–1.36	3.55	1.2	1.08	0.209
RDBSVF	27	–0.17	–0.36	0.01	0.00	–1.81	0.41	0.2	0.47	0.091
MVD	27	9.98	9.39	10.58	10.23	6.90	13.59	2.3	1.50	0.289
DVDP	27	9.93	9.38	10.48	10.26	7.33	12.88	1.9	1.39	0.268
DVDEVF	27	9.97	9.42	10.51	10.30	7.53	12.95	1.9	1.38	0.265
VDP	27	9.49	8.94	10.04	9.59	6.83	12.85	1.9	1.39	0.267
VDEVF	27	9.37	8.84	9.90	9.56	6.78	12.60	1.8	1.34	0.258
AA*	27	20.16	19.84	20.48	20.10	18.60	22.22	0.7	0.81	0.156
FA*	27	62.22	55.85	68.58	60.32	36.97	99.79	258.7	16.09	3.096

Explanations as in Table 2

tion of the group *d* recognized herein, with the following means of selected features: LAP = 44.5 mm; SD = 6.1 mm; MVD = 10.6 mm; DVDP = 9.9 mm; VDP = 9.9 mm; AA = 19.8°; FA = 62.1°; BI = 4.5. All these values are statistically the same as the present study topotype population of *B. najdini* (= morphogroup *d*; cf. Fig. 9). For the above-mentioned reasons, I interpret specimens with the complete biometry of morphogroup *d* as representing *B. najdini*.

**Occurrence.** – In the Vistula section, *B. najdini* is known from the Upper and uppermost Campanian (Tercis def.) and was recorded from: Pawłowice Posesja, Sadkowiec Szkoła, Sadkowiec N, Piotrawin, Raj, Raj N and Podole. It is also known from sparse locations in England, the Netherlands and from the Russian Platform.

*Belemnitella* sp. *a*  
(Fig. 17A–K)

**Material.** – 20 specimens from Middle Vistula valley section: Pawl/cm/001, Sad/szk/002, Sad/szk/003, Sad/szk/028, Sad/szk/029, Sad/szk/030, Sad/szk/032, Sad/szk/036, Sad/szk/038, Sad/szk/042, Sad/szk/050, Sad/szk/058, Sad/szk/060, Sad/szk/063, Piot/003, Piot/017, Raj/020, Raj/025, Raj/052, Raj/067.

Specimen Sad/szk/002 from the Sadkowiec Szkoła section, south of the Solec nad Wisłą is the specimens most similar to the mean values of the population of morphogroup *a* (= *Belemnitella* sp. *a*); its biometric data are summarized below (cf. with descriptive statistics, Table 7).

Biometric data of the Sad/szk/002							
Specimen	LAP	LASVF	LAEVF	LABVF	SD	ND	KD
Sad/szk/002	45.32	51.00	55.04	51.00	5.68	9.72	4.05
RDBSVF	MVD	DVDP	DVDEVF	VDP	VDEVF	AA	FA
0.00	11.06	11.02	11.12	10.55	10.64	20.62	34.33

**Description.** – Guard medium-sized, generally slender (mean LAEVF = 57.3 mm; max LAEVF up to 62.5 mm); LAP medium (mean LAP = 46.4 mm; max. LAP up to 50.7 mm); the guard is usually subcylindrical (rarely slightly lanceolate) in ventral view and subconical to subcylindrical in lateral view and is flattened ventrally over its entire length; DVDP larger than VDP. Mean value of the Birkelund Index is 4.1, with an observed range of 3.72–4.65. Apical end acute or obtuse; in the latter case with a rather well-defined mucro.

SD small to medium (mean = 6.6 mm). ND and KD generally medium, sometimes large with mean values of 11.0 mm and 4.4 mm, respectively. FA medium to large (mean = 32.8°). AA medium to large (mean = 20.2°). Shape of the bottom of the ventral fissure is commonly straight.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows rather poorly developed. Vascular markings generally variable, best expressed around the ventral fissure, they then weaken towards the ventral and lateral sides. The complete biometry of *Belemnitella* sp. *a* is summarized in Table 7.

**Discussion and remarks.** – Morphogroup *a* is the only morphogroup that cannot be assigned at a species-level to commonly recognized forms. The biometry of the population of *Belemnitella* sp. *a* is very similar to the original diagnosis of *B. minor* Jeletzky, 1951, understood in the sense of its original diagnosis (but not with respect to the holotype). It is slightly smaller and thinner than *B. mucronata* and has larger alveolar and fissure angles. In addition, it is characterized by smaller values of SD, ND and KD, which also agrees with the original diagnosis (but not with the holotype).

The stratigraphic position of *Belemnitella* sp. *a* is also compatible with the diagnosis of *B. minor* originally defined by Jeletzky (1951b), being younger than *B. mucronata*. It is possible that such species-populations commonly recognizable as *B. langei minor*, especially in Eastern Europe (Birkelund, 1957; Jeletzky, 1948, 1951b, 1958; Naidin, 1952) within the interval with “*Pachydiscus wittekindi*”, “*Bostrychoceras polyplacum*” and “*Belemnitella langei*” was what Jeletzky had in mind when he



Fig. 17. *Belemnitella* sp. a

**A–G** – A – Sad/szk/002, B – Sad/szk/028, C – Sad/szk/030, D – Sad/szk/036, E – Sad/szk/042, F – Sad/szk/058, G – Sad/szk/060, Sadkowiec Szkoła; **H, I** – H – Piot/003, I – Piot/017, Piotrawin; **J, K** – J – Raj/020, K – Raj/052, Raj; other explanations as in [Figure 11](#)

Table 7

Biometry and descriptive statistics of *Belemnitella* sp. a (= morphogroup a)

Variables [mm] * in [°]	<i>n</i>	Mean	Confidential interval: –95%	Confidential interval: +95%	Median	Mini- mum	Maxi- mum	Variance	Standard Deviation	Standard Error
LAP	20	46.36	45.11	47.60	46.24	39.65	50.69	7.08	2.662	0.595
LASVF	20	52.91	51.61	54.21	52.96	46.15	57.14	7.71	2.777	0.621
LAEVF	20	57.32	55.73	58.90	57.27	48.71	62.50	11.46	3.385	0.757
LABVF	20	52.91	51.61	54.21	52.96	46.15	57.14	7.71	2.777	0.621
SD	20	6.56	6.04	7.07	6.15	5.45	8.77	1.20	1.097	0.245
ND	20	10.96	10.40	11.51	11.08	9.06	13.05	1.42	1.191	0.266
KD	20	4.40	3.84	4.97	4.17	1.69	6.23	1.45	1.205	0.269
RDBSVF	20	0.00	–		0.00	0.00	0.00	0.00	0.000	0.000
MVD	20	11.32	11.05	11.58	11.31	10.10	12.42	0.32	0.566	0.127
DVDP	20	11.16	10.91	11.41	11.18	10.06	12.33	0.28	0.529	0.118
DVDEVF	20	11.29	11.02	11.57	11.20	10.37	12.45	0.35	0.587	0.131
VDP	20	10.81	10.57	11.05	10.87	9.56	11.70	0.27	0.520	0.116
VDEVF	20	10.65	10.40	10.91	10.70	9.39	11.63	0.30	0.547	0.122
AA*	19	20.23	19.78	20.69	20.31	18.27	21.79	0.88	0.939	0.215
FA*	20	32.77	29.11	36.44	32.81	21.69	56.15	61.45	7.839	1.753

Explanations as in Table 2

designated his *B. minor*. Although, the stratigraphic range of *B. sp. a* is slightly higher than mentioned above.

Currently, *B. minor* is understood only in the sense of its holotype (not of the original diagnosis) and this definition is widely accepted, however, it is markedly different from the original diagnosis (i.e. Christensen, 1975, 1995; cf. also remarks to *B. minor*).

*Belemnitella* sp. 1  
(Fig. 18A–B)

**M a t e r i a l.** – Two specimens from Vistula section form Raj N and Podole. Biometric data are summarized in the table below.

Biometric data of the Podole/011 and Raj N/004, respectively							
Specimen	LAP	LASVF	LAEVF	LABVF	SD	ND	KD
Podole/011	58.34	63.68	66.65	63.68	5.33	8.31	2.97
RajN/004	62.81	68.72	72.20	68.73	5.91	9.39	3.47
RDBSVF	MVD	DVDP	DVDEVF	VDP	VDEVF	AA	FA
0.00	15.78	15.22	15.10	14.98	14.52	19.10	54.13
0.00	19.49	18.21	18.42	18.12	17.37	17.70	56.53

On the one hand, *Belemnitella* sp. a is similar to *B. posterior*, being slightly smaller and having a smaller FA (Fig. 9). On the other hand, *Belemnitella* sp. a is also similar to *B. langei*, which is smaller and possesses a smaller FA than *Belemnitella* sp. a (Fig. 9). Thus, *Belemnitella* sp. a, in its biometric characteristic, is transitional between *B. langei* and *B. posterior* (cf. Fig. 9). Therefore, for the time being, *Belemnitella* sp. a is left in open nomenclature.

From *B. najdini*, the recognized population of *Belemnitella* sp. a differs in markedly larger length-features, diameters as well as ND and KD which can reach in *B. najdini* even negative values (Fig. 9). *B. najdini* is characterized also by very large FA values (mean = 62.2°), which are significantly larger than in *Belemnitella* sp. a (mean = 32.8°).

**O c c u r r e n c e.** – In the Vistula section *Belemnitella* sp. a is known from the Upper and uppermost Campanian (Tercis definition) and was recorded from: Pawłowice Cemetery, Sadkowiec Szkoła, Sadkowiec N, Piotrawin and Raj.

**Description.** – Both specimens Podole/011 and RajN/004 are large (LAEVF = 66.7 mm and 72.2 mm; LAP = 58.3 mm and 62.8 mm), respectively, and are very thick and stout (MVD = 15.8 mm and 19.5 mm). Both are cylindrical to slightly lanceolate in ventral view and cylindrical in lateral view and are markedly flattened ventrally over the entire length; DVDP only slightly larger than VDP. The Birkelund Index is 3.83 for Podole/011 and 3.45 for RajN/004. In both specimens the apical end is moderately obtuse with a well define mucro.

SD small (= 5.3 mm and 5.9 mm); ND generally small (= 8.3 and 9.4 mm) and KD (= 3.0 and 3.5 mm); fissure angle large, approximately 55° and alveolar angle small (= 19.1 and 17.7°). Shape of the bottom of ventral fissure is straight, slightly swept back posteriorly, before reaching the outer surface of the guard.

Very well-developed dorso-lateral longitudinal depressions continue posteriorly into dorso-lateral double-furrows as far back as to the apical area. Vascular markings very well-defined especially on ventral and lateral side; longitudinal striae clearly visible on both dorsal and ventral side.

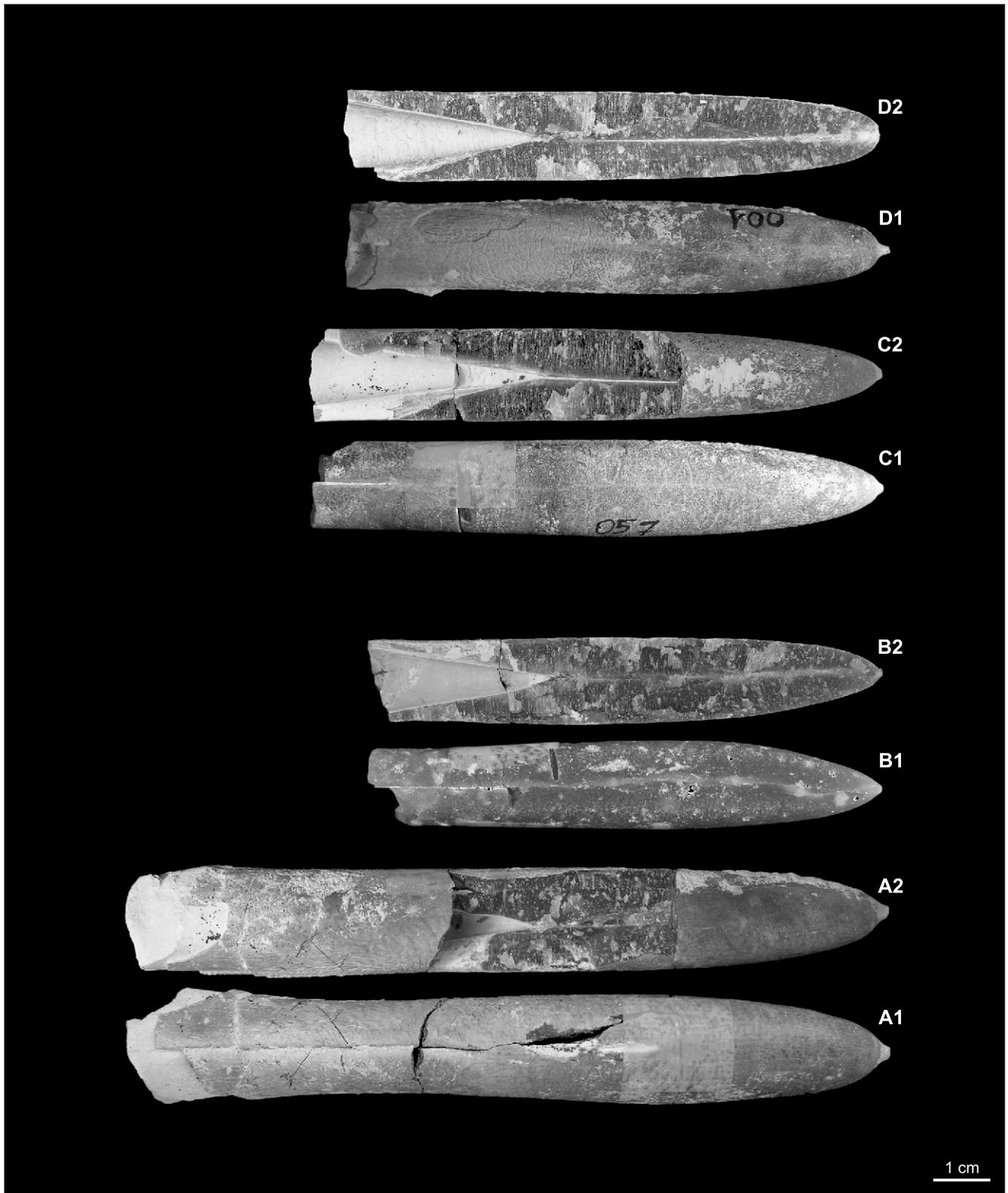


Fig. 18. *Belemnitella* sp. 1 (A, B) and *Belemnitella* sp. 2 (C, D)

A – RajN/004, RajN; B – Podole/011, Podole; C – RajN/057, RajN; D – SadN/001, Sadkowiec N; other explanations as in [Figure 11](#)

**Discussion and remarks.** – In several Kohonen-network simulations these two specimens always grouped together at the same winning neuron. Additionally, these two specimens were always classified on the SOM in the neighborhood of *B. minor* (= morphogroups *f*) and *B. posterior* (= morphogroup *b*). Such a classification on the SOM suggests its connection with the *mucronata* group.

The biometry of these specimens differs markedly in comparison from the rest of the morphogroups recognized herein and to other forms commonly recognizable elsewhere. Most probably, this form represents a new species, but for the time being it cannot completely be excluded that the specimens represent extreme variants of *B. minor* or *B. posterior*. Designation of a new species would thus be premature. Therefore, until statistically representative material becomes available, this form is left in open nomenclature.

**Occurrence.** – In the Vistula section *Belemnitella* sp. 1 is known from the Upper Campanian (Tercis definition) and was recorded from Raj N and Podole.

*Belemnitella* sp. 2  
(Fig. 18C–D)

**Material.** – Two specimens from the Vistula section, from Sackowice N and Raj N. Biometric data are summarized in the table below.

Biometric data of the Sad N/001 and Raj N/057, respectively							
Specimen	LAP	LASVF	LAEVF	LABVF	SD	ND	KD
SadN/001	59.93	69.96	86.38	69.96	10.03	26.45	16.42
RajN/057	59.89	66.05	86.27	66.05	6.16	26.38	20.22
RDBSVF	MVD	DVDP	DVDEVF	VDP	VDEVF	AA	FA
0.00	16.54	15.65	16.21	16.17	15.34	19.23	9.40
0.00	17.19	16.35	16.18	16.68	15.58	15.19	11.47

**Description.** – Both specimens SadN/001 and RajN/057 are very large with LAEVF reaching values not recognized in other forms (LAEVF = 86.4 mm and 86.3 mm, respectively); LAP large, being 59.9 mm in both specimens. All the diameters are very large, which makes the guard very stout. Both are cylindrical in ventral and lateral views and are markedly flattened ventrally over the entire length; DVDP only slightly smaller than VDP. The Birkelund Index is 3.83 for SadN/001 and 3.66 for RajN/057. In both specimens the apical end is moderately obtuse with a well-defined mucro.

SD medium to large (= 10.0 mm and 6.20 mm). Other internal characters reach extreme values: ND (= 26.5 mm and 26.4 mm) and KD (= 16.4 mm and 20.2 mm) are extremely large. FA extremely small (= 9.4 and 11.5°); AA small (= 19.2 and 15.2°). Shape of the bottom of the ventral fissure is straight.

Dorso-lateral longitudinal depressions and dorso-lateral double-furrows well-developed. Vascular markings well-de-

veloped on the ventral and lateral side, especially around the ventral fissure

**Discussion and remarks.** – The studied specimens are morphologically almost identical with respect to their external and internal characters. Extreme values of length from apex to the end of ventral fissure as well as Nowak distance, Kongiel distance and fissure angle, clearly separate these specimens from any other forms recognized herein and known from the available literature.

During the Kohonen-networks simulations, these two specimens always classified together with a high activation of the winning neuron. In addition, both specimens have activated neurons in the neighbourhood of *B. minor* (= morphogroups *f*) on the SOM (Fig. 5), suggesting their relationship with the *mucronata* group.

The biometry of these specimens does not allow assigning them to any of the morphogroups recognized herein, nor to forms known from literature. Most probably they represent a new species. Similarly, as in case of *Belemnitella* sp. 1, due to the small number of studied specimens (2), this form is left in open nomenclature, until a statistically representative collection becomes available.

**Occurrence.** – In the Vistula section *Belemnitella* sp. 2 is known from Sackowice N and Raj N, from the Upper Campanian (Tercis definition).

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