Occurrence and significance of Cenomanian belemnites in the lower Danubian Cretaceous Group (Bavaria, southern Germany)

MARKUS WILMSEN 1, BIRGIT NIEBUHR 1 AND PATRICK CHELLOUCHE 2

1Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie, Sektion Paläozoologie, Königsbrücker Landstr. 159, D – 01109 Dresden, Germany.
E-mail: markus.wilmsen@senckenberg.de; niebuhr.birgit@googlemail.com

2GeoZentrum Nordbayern, Fachgruppe PaläoUmwelt, Loewenichstr. 28, D – 91054 Erlangen, Germany.
E-mail: patrick.chellouche@gzn.uni-erlangen.de

ABSTRACT:


The belemnite records of the lower Danubian Cretaceous Group (DCG, northeastern Bavaria, southern Germany) are compiled, taxonomically described and placed within the new integrated stratigraphic framework of the group. Three specimens from the lower Regensburg Formation (Saal Member) south of Regensburg can be assigned to Neohibolites cf. ultimus (d’Orbigny) and are dated as late Early Cenomanian (Mantelliceras dixoni Zone). Eight specimens represent Praeactinocamax plenus (Blainville) and occur in an event (plenus Event) in the lower Eibrunn Formation (Regensburg area) or basal Regensburg Formation (Roding area in the Bodenwöhrer Senke). Biostratigraphy and carbon stable isotopes suggest that the belemnite horizon with P. plenus in the DCG has strictly the same chronostratigraphic position (mid-Late Cenomanian, middle Metoicoceras gelsinianum Zone) as elsewhere in Central and NWEurope. The lithostratigraphic units of the lower Danubian Cretaceous Group (i.e., the Regensburg and Eibrunn formations), however, are characterized by a pronounced diachronism based on their time-transgressive (i.e., onlapping) deposition during the Cenomanian–Early Turonian transgression. The distribution of P. plenus around the Mid-European Island can be easily explained by migration around the positive area without the necessity of a marine strait across the Bohemian Massif.

Key words: Upper Cretaceous; Belemnitida; Taxonomy; Integrated stratigraphy; Palaeogeography.

INTRODUCTION

The Cretaceous of northeastern Bavaria (formerly often termed “Regensburger”, “Oberpfälzer” or “Fränkische albüberdeckende Kreide”, now formalized within the Danubian Cretaceous Group by Niebuhr et al. 2009) is one of the classic regions for early geological investigations in Germany (e.g., Gümbel 1854, 1868a, b, 1891). However, despite its key position between the well studied Boreal successions in the north and the Tethyan Alpine Cretaceous in the south, knowledge concerning the stratigraphy, macrofossil palaeontology and depositional environments of the Danubian Cretaceous Group remained in a somewhat undeveloped state throughout the 20th century. The few detailed macro-palaeontological monographs date back to Lehner (1937a, b) and Dacqué (1939), followed by short taxonomic accounts on the Upper Cenomanian
cephalopod fauna of the Eibrunn Formation from the Regensburg area (Förster et al. 1983; Röper and Rothgaenger 1995) or Middle Cenomanian siliceous sponges (Kauffman et al. 2000). Cenomanian belemnites were recorded in some of the aforementioned works but never discussed in taxonomic and stratigraphic detail. This is surprising and a waste of important information, as the occurrence of belemnites in the Cenomanian of NW Europe has a considerable stratigraphic and palaeo-ecologic significance (e.g., Christensen 1990a; Gale and Christensen 1996; Košták et al. 2004; Mitchell 2005; Wilmsen et al. 2007; Wilmsen and Rabe 2008; Wiese et al. 2009).

Thus, the scope of the present paper is a compilation of the belemnite records of the lower Danubian Cretaceous Group based on the examination of collection material of the Bayerische Staatsammlung für Paläontologie in Munich (BSP), new finds (PrNW) from the successions around Regensburg and Roding (Bodenwöhrrer Senke), and a re-logging and chronostratigraphic re-interpretation of classic sections of the Danubian Cretaceous Group such as the Mühlberg section near Bad Abbach. Apart from the short taxonomic treatment, the significance of the belemnite occurrences is discussed within an integrated stratigraphic framework. Furthermore, the occurrence of one taxon (i.e., *Praeactinocamax plenus*) around the Mid-European Island is used to evaluate controversial palaeogeographic reconstructions.

Text-fig. 1. Map showing the regional framework of the study area with main structures and distribution of the Danubian Cretaceous Group (light-grey shading). The sections of Text-fig. 2 and localities mentioned in the text are indicated.
GEOLOGICAL SETTING AND LITHOSTRATIGRAPHY

The study area is located in northeastern Bavaria (southern Germany), specifically around Regensburg and Roding in the Bodenwöhrer Senke (Text-fig. 1). Lithostratigraphically, the investigated successions are part of the Danubian Cretaceous Group (DCG) of Niebuhr et al. (2009). The DCG represents non-marine to neritic environments of a peri-continental shelf system at the northern margin of the Neotethys, south of the Mid-European Island (MEI), developing in response to the transgression of the early Late Cretaceous. The litho- and biostratigraphic revision of the DCG was carried out recently by Niebuhr et al. (2009), Tröger et al. (2009), Wilmsen et al. (2009) and Wilmsen and Niebuhr (2010).

The DCG comprises conglomerates, sands and sandstones, clays, marls and marlstones, calcarenites, siliceous opoka and limestones, with a maximum thickness of a few hundred metres. Marine deposition started in the Early Cenomanian and persisted into the Coniacian, comprising a nearly symmetrical trans-/regressive mega-cycle with a maximum flooding interval during the late Middle to early Late Turonian (Niebuhr et al. 2009; Wilmsen and Niebuhr 2010).

The marine lithostratigraphic units of the lower DCG are the Regensburg, Eibrunn and Winzerberg formations (Text-fig. 2). The Regensburg Formation (Cenomanian—lowermost Turonian) unconformably overlies various older rock units, mainly Upper Jurassic limestones of the Franconian Alb (Frankenalb) or the terrestrial Lower Cretaceous Schutzfels Formation (preserved only in

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Text-fig. 2. Correlation of sections from the lower Danubian Cretaceous Group in a SW–NE transect from south of Regensburg to Grub (Bodenwöhrer Senke; intermediate Benberg section modified after Förster et al. 1983). Belemnite occurrences are indicated. Note diachronism of lithostratigraphic units and facies-breaking stratigraphic pattern of the Praeactinocamax plemus Event (Eib. F. = Eibrunn Formation; Winz./Winzerb. F. = Winzerberg Formation; Reinh. Mb = Reinhauen Member)
Towards the northeast, the Regensburg Formation transgresses onto older Mesozoic strata or the Variscan basement of the Bohemian Massif (Text-fig. 2). The Regensburg Formation consists of mixed, more-or-less glauconitic siliciclastic-calcareous sediments. It is subdivided into a lower Saal Member consisting of thickly bedded glauconitic sandstones with a shallow-water fauna of bivalves, brachiopods, echinoids and siliceous sponges, and an upper Bad Abbach Member of interbedded sandy-silty marls and siliceous limestones (see Trusheim 1935; Kauffman et al. 2000; Niebuhr et al. 2009). The uppermost Cenomanian—lower Lower Turonian silty marls of the Eibrunn Formation document a first maximum flooding interval during the early Late Cretaceous transgression. Their faunal content (cephalopods, inoceramid bivalves and planktonic foraminifera) was the subject of papers by Förster et al. (1983), Hilbrecht (1986), Röper and Rothgaenger (1995) and Hilbrecht et al. (1996). The Eibrunn Formation is overlain by the spiculitic, calcareous silt-to marlstones (Reinhausen Member) and sandstones (Knollen-sand Member) of the Lower Turonian Winzerberg Formation. A conspicuous sequence boundary in the Lower–Middle Turonian boundary interval terminates this first (i.e., Cenomanian—Early Turonian) trans-/regressive cycle of the Danubian Cretaceous Group (Niebuhr et al. 2009). The Regensburg and Eibrunn formations are characterized by pronounced diachronism from southwest to towards the northeast due to the transgressive onlap onto the Bohemian Massif (Wilmsen et al. subm.).

In the DCG, belemnites occur in the upper Lower Cenomanian of the Saal Member of the Regensburg Formation south of Regensburg, in the Upper Cenomanian of the lower Eibrunn Formation both south and north of Regensburg, and in the Upper Cenomanian of the lower Regensburg Formation near Roding in the Bodenwöhrer Senke (Text-fig. 2). These occurrences are taxonomically briefly described below, followed by a discussion of their stratigraphic and palaeogeographic significance.

SHORT SYSTEMATIC ACCOUNT

Descriptive terminology of the belemnite rostrum follows Košťák (2004).

Family Belemnospideidae Naef, 1922
Genus Neohibolites Stolley, 1911

TYPE SPECIES: Belemnites ultimus d’Orbigny, 1845, pl. 75, figs 9–13.

Neohibolites cf. ultimus (d’Orbigny, 1845)
(Text-fig. 3A)


cf. 1971. Neohibolites ultimus (d’Orbigny 1845); Spaeth, p. 72, pl. 9, figs 7–12 (see for synonymy).

cf. 1999. Neohibolites ultimus (d’Orbigny); Wilmesen, p. 301, figs 4a–c, 5a, b (see for synonymy).


MATERIAL: 3 incomplete specimens (BSP 1887 VI, BSP 1887 VI 10; PrNW), including the original of Dacqué (1939, p. 69, pl. 4, fig. 14), described and figured as “Actinocamax cfr. plenus Blainville”, from the “Cenomaner Grünsandstein, Brandlerberg bei Kelheim”.

DESCRIPTION: The shape of the relatively small, slender rostra is conical, subspherical in the area of maximum diameter, with stronger lateral compression in the (alveolar) area of minimum diameter. Thus, the rostrum is slightly claviform in ventrodorsal view. Due to the incomplete preservation, the ventral furrow is only weakly visible. The alveolus is relatively deep and the alveolar end show the typical concentric defoliation described by Spaeth (1971, p. 73).

REMARKS: Even in this incomplete preservation, the specimens from the Regensburg Formation do not differ significantly from Neohibolites ultimus (d’Orbigny) as described and figured in the literature (e.g., Spaeth 1991; Wilmsen 1999). However, due to the incomplete preservation, they are kept in open nomenclature. Representatives of the Cenomanian to Lower Santonian belemnite genus Praeactinocamax Naidin (one of the few other belemnite genera present in the Cenomanian of Europe) are clearly differentiated from the present specimens by different shapes of their guards (which are subcylindrical to lanceolate) and the morphology of the alveolar parts of the rostra (Christensen 1990b; Košťák 2004; Wilmsen et al. 2007; Košťák and Wiese 2008; Wilmsen and Rabe 2008; Wiese et al. 2009). The very rare, small Cenomanian belemnite Belemnocamax Crick has short and ventrally strongly flattened rostrum with a distinct ventral groove and a heart-shaped anterior end (Christensen 1993; Wilmsen and Rabe 2008).

Family Belemnitellidae Pavlov, 1914

Taxonomy, palaeobiogeography and migration of the Late Cretaceous belemnite family Belemnitellidae were intensively discussed by Christensen (1997a, b), Košťák (2004) and Košťák et al. (2004).
Genus *Praeactinocamax* Naidin, 1964

**TYPE SPECIES**: *Belemnites plenus* Blainville, 1825-1827, p. 376 (1825), pl. 11, fig. 3 (1827).

*Praeactinocamax plenus* (Blainville, 1825) (Text-fig. 3C–J)

1825. *Belemnites plenus* Blainville, p. 376. 1974. *Actinocamax plenus* (Blainville); Christensen, p. 4–12, pl. 1, figs 1–3, pl. 2, figs 1–5, pl. 3, figs 1–6, pl. 4, figs 1–5 (see for older synonymies).

1995. *Actinocamax plenus* (Blainville); Röper and Rothgaenger, p. 182.

1997. *Praeactinocamax plenus* (Blainville); Košták and Pavliš, p. 2, text-figs 3, 4, pl. 1, figs 1–4, pl. 2, figs 1–6 (see for synonymy).

2005. *Praeactinocamax plenus* (Blainville); Mitchell, p. 367, fig. 1.14, 1.15.

2006. *Praeactinocamax plenus* (Blainville); Svoboda, p. 170, fig. 3b.

2009. *Praeactinocamax plenus* (Blainville, 1827); Wiese et al., p. 314, fig. 6a–c (see for some recent synonymies).

Text-fig. 3. Belemnites from the lower Danubian Cretaceous Group. All figures in natural size except B, D1, I1 and J1. – A1, A2 – *Neohibolites* cf. *ultimus* (d’Orbigny). BSP 1887 VI 10, original of Dacqué (1939, p. 69, pl. IV, fig. 14), from the "Cenomaner Grünsandstein, Brandl-berberg bei Kelheim" (=Lower Cenomanian Saal Member of the Regensburg Formation). A1, alveolar view. A2, ventral view. – B – *Neohibolites* sp. (× 2). PrNW, lateral view of alveolar fragment from ca. 4.5 m above the base the Saal Member of the Regensburg Formation, Fels-Werke, Kalkwerk Saal an der Donau. C-J – *Praeactinocamax plenus* (Blainville) showing different growth stages. C1-3, adult specimen BSP AS XVII 6, original of Dacqué (1939, p. 90, pl. 1, fig. 21), from the “Plenuszone, Eybrunner Mergel, Hainsacker bei Regensburg" (= Upper Cenomanian Eibrunn Formation). C1, ventral view; C2, dorsal view; C3, broken alveolar end. D1-3, adolescent specimen BSP AS XVII 7, original of Dacqué (1939, p. 90, pl. 1, fig. 22), from the “Plenuszone, Eybrunner Mergel, Hainsacker bei Regensburg" (= Upper Cenomanian Eibrunn Formation). D1, alveolar view (× 2); D2, dorsal view; D3, apical view (apex missing). E, alveolar fragment of an adult specimen from sample BSP 1982 XIX 96 from the Upper Cenomanian Eibrunn Formation of the Benberg motorway roadcut 6 km north of Regensburg. E1, dorsal view; E2, mid-guard cross-section at terminal end of rostrum. F, apical fragment of an adolescent specimen from sample BSP 1982 XIX 96 from the Upper Cenomanian Eibrunn Formation of the Benberg motorway roadcut 6 km north of Regensburg. F1, mid-guard cross-section at terminal end of rostrum; F2, dorsal view. G, alveolar fragment (ventral view) of adolescent specimen PrNW-1 from the lower Regensburg Formation (lower part of the Lower Greensand Bed) at Haimerl quarry near Grub (Bodenwöhrer Senke). H, left-lateral view of the complete adult specimen from sample BSP 1982 XIX 96 from the Upper Cenomanian Eibrunn Formation of the Benberg motorway roadcut 6 km north of Regensburg. I, juvenile specimen PrNW-2 from the lower Regensburg Formation (top of the basal black clay) at Haimerl quarry near Grub (Bodenwöhrer Senke). I1, alveolar view (× 2); I2, ventral view; I3, dorsal view. J, adolescent specimen PrNW-3 from the lower Regensburg Formation (top of the basal black clay) at Haimerl quarry near Grub (Bodenwöhrer Senke). J1, alveolar view (× 2); J2, lateral view.
MATERIAL: Five complete or nearly complete specimens (BSP AS XVII 6, BSP AS XVII 7, BSP 1982 XIX 96, and PrNW-2 and -3), including the two originals of Dacqué (1939, p. 90, pl. 1, figs 21, 22), described and figured as “Actinocamax plenus Blainville”, from the “Eybrunner Mergel” (= Eibrunn Formation) at the Winzerberg in Regensburg as well as three fragmentary specimens (alveolar and apical fragments from sample BSP 1982 XIX 96, alveolar fragment PrNW-1).

DESCRIPTION: The complete or nearly-complete guards are medium-sized and between 65–85 mm long with maximum lateral diameters (MLD) of 7–12 mm. MLD is situated approximately one third of the length of the guard from the apical end. The dimensions of the alveolar end of the fragmentary specimen BSP 1982 XIX 96 (Text-fig. 3E) with a length of 55 mm and a lateral diameter of 13.5 mm (without reaching the point of MLD) suggest a length of the complete rostrum of well above 100 mm. The general shape of the rostra is lanceolate in dorsoventral to subcylindrical in lateral view, caused by lateral compression of the alveolar end. Smaller specimens tend to have subcylindrical to only slightly lanceolate shapes (e.g., Text-fig. 3I, J) of their rostra due to allometric growth. Dorsolateral compressions / furrows are well developed in some rostra (Text-fig. 3D, J) at the alveolar end, resulting in somewhat triangular cross-sections. Alveolar ends (when fully preserved) show a cone-shaped alveolar fracture. The apex is placed centrally; however, in most cases the expected mucro is not preserved. The apical angle varies between 20° in juvenile (i.e., subcylindrical) and 35° in adult (i.e., lanceolate) specimens.

REMARKS: The present specimens do not differ from P. plenus as described and figured extensively in the literature (e.g., Christensen 1974; Košťák and Pavliš 1997; Košťák 2004; Wiese et al. 2009) and can, thus, be securely assigned to Blainville’s (1825) species, without any need for further taxonomic comments. The fauna from the Danubian Cretaceous Group shows the typical range of morphological variation in P. plenus as for example demonstrated by Gale and Christensen (1996, p. 73, fig. 5) for a fauna from les Lattes (Alpes de Haute-Provence, southeastern France): juveniles, adolescent and adult specimens are present (Text-fig. 3). Košťák (2004) gives a length range from 55–92 mm, but adult rostra can be well above 100 mm (Christensen 1974).

DISCUSSION

Belemnites are generally rare in the Danubian Cretaceous Group and restricted to the Regensburg and Eibrunn formations. However, the event-like occurrences of belemnites in the Cenomanian of central and NW Europe result in a considerable stratigraphic and palaeoecologic significance of the finds (cf. Ernst et al. 1983; Mitchell 2005).

Neohibolites ultimus occurs in the Lower and basal Middle Cenomanian (Mantelliceras mantelli to lower Acanthoceras rhetomagenese zones) of the Tethyan Realm as well as in contemporaneous rocks of the Russian Platform and the southern part of the Central European Subprovince (Christensen 1976, 1990a; Combémorel et al. 1981; Wilmsen 1999; Mitchell 2005). N. ultimus is particularly common in the lower Lower Cenomanian [e.g., N. ultimus is represented by fine specimens in the British Geological Survey (BGS) collections from the N. carcitane Subzone Rye Hill Sands of the Wessex Basin, southern England; it also occurs in the Inoceramus cripsi Event in eastern England; pers. comment C.J. Wood] and is one of the last representatives of the genus Neohibolites Stolley, which became extinct in the upper part of the A. rhetomagenese Zone (Combémorel et al. 1981). Dacqué’s (1939) specimens from the “Cenomaner Grünsandstein, Brandlerberg bei Kelheim” (Text-fig. 3A) can be stratigraphically allocated to the Saal Member of the lower Regensburg Formation. However, an in-situ record of an alveolar fragment of Neohibolites sp. (Text-fig. 3B) from the middle part of the Saal Member at the type section (Saal an der Donau) from beds with abundant Inoceramus virgatus virgatus Schlüter can be unequivocally assigned to the upper Lower Cenomanian Mantelliceras dixoni Zone. This fits the stratigraphic position of the single specimen of N. ultimus from the Saxonian Cretaceous Basin which was recorded from contemporaneous nearshore sediments of the Meissen Formation by Spaeth and Köhler (1997) and Köhler and Spaeth (1998). Also Ernst and Rehfled (1997) and Mitchell (2005, N. ultimus biohorizon III) recorded belemnite horizons with N. ultimus from the M. dixoni Zone of the Lower Saxony and Anglo-Paris basins. However, the complete stratigraphic range of N. ultimus is more extended, comprising the Early and early Middle Cenomanian (Combémorel et al. 1981).

Praeactinocamax plenus is known from the Late Cenomanian Metoicoceras geslinianum Zone of the Russian Platform and adjoining areas (e.g., Christensen 1997a; Košťák 2004; Košťák et al. 2004; Wiese et al. 2009). In Central and northwest Europe, its tem-
poral distribution is even more limited, being stratigraphically restricted to a short interval within the middle part of the *Metoicoceras gesslinianum* Zone. This interval defines a stratigraphic event in Europe named the *plenus* Event (Ernst et al. 1983; Mitchell 2005). The specimens from the Regensburg area all come from a thin, nodular calcareous bed in the lower part of the Eibrunn Formation ("Kalkmergelbank" of Förster et al. 1983); three specimens were recorded from Benberg (north of Regensburg) and nine specimens from Bad Abbach (south of Regensburg; Förster et al. 1983; Röper and Rothgaenger 1995). An interval with intensive *Chondrites*, below the *plenus* bed, is interpreted as an equivalent of the *Chondrites* Event of northern Germany (see Ernst et al. 1983). The stratigraphic position of the "Kalkmergelbank" within the *M. gesslinianum* Zone and, thus, the isochrony of the *plenus* Event, is supported by a rich *M. gesslinianum* zonal ammonoid assemblage directly below the "Kalkmergelbank" (Förster et al. 1983; Röper and Rothgaenger 1995), the co-occurrence with the inoceramid bivalve *Inoecamus pictus bohemicus* Leonhardt (Tröger et al. 2009), and carbon stable isotope stratigraphy (Hilbrecht and Hoefs 1986).

In the Bodenwöhrer Senke (Grub section), the *plenus* Event occurs in the lower Regensburg Formation, i.e. in the upper part of a black marine clay which rests transgressively on top of a Variscan granite and at the base of the overlying gauconitic sandstone (Lower Greensand Bed; Chellouche 2008; Niebuhr et al. 2009; see Text-fig. 2). Interestingly, the two levels with *P. plenus* in Grub are separated by an erosion surface at the base of the Lower Greensand Bed which yields mainly fragmented guards of *P. plenus*. The stratigraphic observations from the Grub section correlate very well with the situation in the Plenus Marl's Member in southern England, where *P. plenus* likewise occurs in two beds [Jefferies' (1963) beds 3 and 4] separated by an erosion surface representing a parasequence boundary (see Wiese et al. 2009 for details). Carbon stable isotope stratigraphy (Chellouche 2008; Wilmsen et al. subm.) again supports a strictly isochronous nature of the *plenus* Event within the *M. gesslinianum* Zone and highlights the chronostratigraphical significance of (bio-)event stratigraphy (e.g., Wiese et al. 2004). On the other hand, it reveals the highly diachronous nature of the lithostratigraphic units of the lower Danubian Cretaceous Group (Text-fig. 2).

*Praeactinocamax plenus* is widely distributed along the shelves of the northern Tethyan margin, from Turkestan-Tadzhikistan in the east to the Anglo-Paris Basin in the west (e.g., Christensen 1997b; Košťák 2004; Košťák et al. 2004). The species (reported as *P. aff. plenus*) probably persisted into the early Turonian in NW Siberia (Košťák and Wiese 2008). The species generally occurs north of the palaeobiogeographic boundary of the Tethyan Realm albeit the record from Ies Lattes (southeastern France) can be regarded as northern Tethyan (Gale and Christensen 1996; Text-fig. 4). Like many other Cretaceous belemnites, *P. plenus* probably had a nektobenthic mode of life and avoided deeper marine environments, being particularly common in inner to mid-shelf settings (e.g., Christensen 1976; Košťák et al. 2004; Mitchell 2005; Wilmsen et al. 2007; Wiese et al. 2009). It is thus also very common around the Mid-European Island (MEI) which provided extensive shallow-marine environments in its periphery (Text-fig. 4). Records of *P. plenus* come from the Bohemian Cretaceous Basin (e.g., Košťák and Pavliš 1997), the Saxonian Cretaceous (e.g., Hänitzschel 1933), the Polish Jura Chain (Marcinowski 1972), Lower Saxony (e.g., Wiese et al. 2009), the Münsterland Cretaceous Basin (e.g., Christensen et al. 1992), southern England (e.g., Jefferies 1962, 1963; Christensen 1974; Mitchell 2005), eastern (Cleveland Basin) and western England (Wessex Basin; see Mortomore et al. 2001 and Wiese et al. 2009), southeastern France (e.g., Gale and Christensen 1996) and northeastern Bavaria (this study and references above). Faunal similarities, especially the occurrence of *P. plenus* on both sides of the Bohemian Massif (forming the eastern part of the MEI) led Dorn (1958) and Svoboda (1985, 2006) to the inference of a direct marine connection of the Bohemian and the Danubian Cretaceous basins across the Bohemian Massif (Text-fig. 4). However, in the absence of clear geological evidence [i.e., marine Upper Cenomanian sediments from the course of the inferred strait across the Bohemian Massif], a simple migration of *P. plenus* in shallow-marine environments around the MEI would be a much more straightforward explanation for the occurrence of the species in the Danubian Cretaceous (Text-fig. 4). Based on its much more extended stratigraphic range on the Russian Platform (where *P. plenus* appears earlier and disappears later; e.g., Christensen 1997a), the species must have invaded Central Europe as a pulse fauna from the (north-)east. Commonly, this is explained by a short-term cooling ("plenus Cold Event" of Gale and Christensen 1996). However, the find of a breeding population as far south as southeastern France (i.e., in a north Tethyan setting; Gale and Christensen 1996) suggest that, during the incursion of the species into Central and NW Europe, water temperature was not an ecological barrier during its migration around the MEI on both its northern and southern margins (it may have even passed the Upper Silesian/East-Sudetic blocks on their southern flanks;
Text-fig. 4). After entering the Saxonian and Bohemian Cretaceous basins, migration of *P. plenus* into the Danubian Cretaceous Basin may have continued around the southern margin of the Bohemian Massif, or counterclockwise along the northern margin of the MEI and via the Anglo-Paris Basin (the latter scenario was also favoured by Košťák et al. 2004, p. 517). From studies of the rapid dispersal of Recent marine benthic molluscs along coasts and even across oceans (see e.g. Scheltema 1977) it is apparent that the duration of migration of nektic *P. plenus* across central Europe would be far beyond the resolution of integrated stratigraphy and, thus, must appear as an isochronous event in the stratigraphic record.

CONCLUSIONS

The belemnite records of the lower Danubian Cretaceous Group (DCG, northeastern Bavaria, southern Germany) are compiled (including collection material of the Bayerische Staatssammlung für Paläontologie in Munich and new finds) and placed within the new integrated stratigraphic framework of the group (Niebuhr et al. 2009). Three specimens from the lower Regensburg Formation (Saal Member) south of Regensburg can be assigned to *Neohibolites cf. ultimus* (d’Orbigny) and are dated as late Early Cenomanian (*Mantelliceras dixoni* Zone). Eight specimens represent *Praeactinocamax plenus* (Blainville) and occur in an event (*plenus* Event) in the lower Eibbrunn Formation (Regensburg area) or basal Regensburg Formation (Bodenwöhrer Senke). Independent stratigraphic data (ammonoids, inoceramid bivalves, carbon stable isotopes) suggest that the *P. plenus* belemnite bioevent in the DCG has exactly the same chronostratigraphic position (mid-Late Cenomanian, middle *Metoicoceras gesslinianum* Zone) as elsewhere in central and NW Europe. The lithostratigraphic units of the lower Danubian Cretaceous Group (i.e., the Regensburg and Eibbrunn formations), however, are characterized by a pronounced diachronism based on their time-transgressive (onlapping) deposition during the Cenomanian–Early Turonian transgression. The dis-
tribution of *P. plenus* around the Mid-European Island can be easily explained by migration around the positive area without the necessity of a marine strait across the Bohemian Massif.

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