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Late Campanian nostoceratid ammonites from the Lehrte West Syncline near Hannover, northern Germany

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In memory of my doctor father GUNDOLF ERNST and the impressive field works with him

ABSTRACT:

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The nostoceratid ammonites *Nostoceras* (*Didymoceras*) *postremum* (BŁASZKIEWICZ, 1980) and *Nostoceras* (*Didymoceras*) *varium* (BŁASZKIEWICZ, 1980) are described from northern Germany for the first time. They appear with the second occurrence of *Nostoceras* (*Bostrychoceras*) *polyplocum* (ROEMER, 1841) in the upper portion of the *Neancyloceras bipunctatum* / *Galerites roemeri* Zone of the Lehrte West Syncline (Lower Saxony, east of Hannover), which is equivalent to the upper *Belemnitella langei* Zone of the chalk of Lägerdorf-Kronsmoor (c. 50 km north of Hamburg). In northern Germany, this ammonite association appears c. 1 Ma earlier than *Belemnella lanceolata,* which marks the base of the Maastrichtian in belemnite terms, and c. 1.5 Ma earlier than the international base according to the first occurrences of *Diplomoceras cylindraceum* and *Pachydiscus neubergicus* at Lägerdorf-Kronsmoor. Assuming that the GSSP of the base of the Maastrichtian Stage at Tercis (southern France) equals the boundary of the U.S. Western Interior (radiometric age 71.3 ± 0.5 Ma), *Nostoceras* (*Bostrychoceras*) *polyplocum* first appears in Europe c. 75 Ma before present.

Key words: Cretaceous, Campanian, Ammonites, Taxonomy, Stratigraphy, Correlation, Germany.

INTRODUCTION

Among others, nostoceratid ammonites play a significant role for the stratigraphic subdivision of Campanian age. *Nostoceras* (*Bostrychoceras*) *polyplocum* (ROEMER) and *Nostoceras* (*Nostoceras*) *hyatti* STEPHENSON are used for the definition of Upper Campanian sections, in Europe and elsewhere.

The nostoceratid ammonites from the Lehrte West Syncline have been in the collection of the author since 1993. All of the specimens were found in the course of excavations in Ahlten. Since that time the absence of further exposures has meant that no nostoceratid ammonites have been added to the original material. Because the preservation is poor and no completely preserved helicoidal whorls were found, determination of the material has been open to discussion. Furthermore, the complete body chambers that were found are much larger than any previously seen in Campanian nostoceratid ammonites and they therefore can be compared only with difficulty with specimens from the important European localities Tercis, southwestern France (KÜCHLER & ODIN 2001; ODIN & *al*. 2001), northern Spain (KÜCHLER 2000a; KÜCHLER & *al*. 2001), and Poland (BŁASZKIEWICZ 1980).

LOCATION AND BIOSTRATIGRAPHY

The upper Upper Cretaceous of southern Lower Saxony crops out in several isolated secondary marginal depressions of salt structures and in the intervening rim synclines. The thickest and most complete Campanian succession is found in the Lehrte West Syncline east of Hannover (Text-fig. 1). The Campanian of Lehrte can be subdivided into fourteen macrobiozones, mostly by means of irregular echinoids, belemnites and ammonites (Ernst 1975; Niebuhr 1995; Niebuhr & *al*. 1997). The lowest two of them (*Gonioteuthis granulataquadrata* and *Sphenoceramus lingua* / *Gonioteuthis quadrata* zones) are characterized by unbedded Emscher marls. With the *Offaster pilula* transgression (middle Lower Campanian), there is a lithological change to c. 400 m thick marl-limestone rhythmites, encompassing 10 macrobiozones of Early, informal Middle (early Late) and Late (late Late) Campanian age. The two most important faunal events within the Lehrte marl-limestone rhythmites are the first occurrences (FOs) of *Belemnitella mucronata* (Schlotheim) and *Nostoceras* (*Bostrychoceras*) *polyplocum*, which are separated by c. 250 m of sediment (c. 5.3 Ma using accumulation rates of c. 47 m/Ma, Niebuhr 2004). Most of the terminal two macrobiozones following the *Nostoceras polyplocum* regression of early Late Campanian age (*Belemnitella minor* / *Nostoceras polyplocum* and *Neancyloceras bipunctatum* / *Galerites roemeri* zones) are characterized by a maximum of 200 m thick shallow-water spiculitic Ahlten opoka (Text-fig. 2).

The topmost 30 m of the Ahlten opoka bear the here presented nostoceratid ammonites. The accompanying fauna clearly indicates a middle Late Campanian age and comprises (modified after Niebuhr & *al*. 1997) the following:

- ammonites – *Menuites wittekindi* (Schlüter), *Menuites portlocki portlocki* (Sharpe), *Hauericeras fayoli* de Grossouvre, *Neancyloceras bipunctatum* (Schlüter), *Lewyites elegans* (Moberg), *Jeletzkytes compressus* (Roemer), *Hoploscaphites greenlandicus* (Donovan), *Hoploscaphites ikorfatensis* (Birkelund), *Trachyscaphites pulcherrimus* (Roemer);
- belemnites – *Belemnitella minor* Jeletzky;

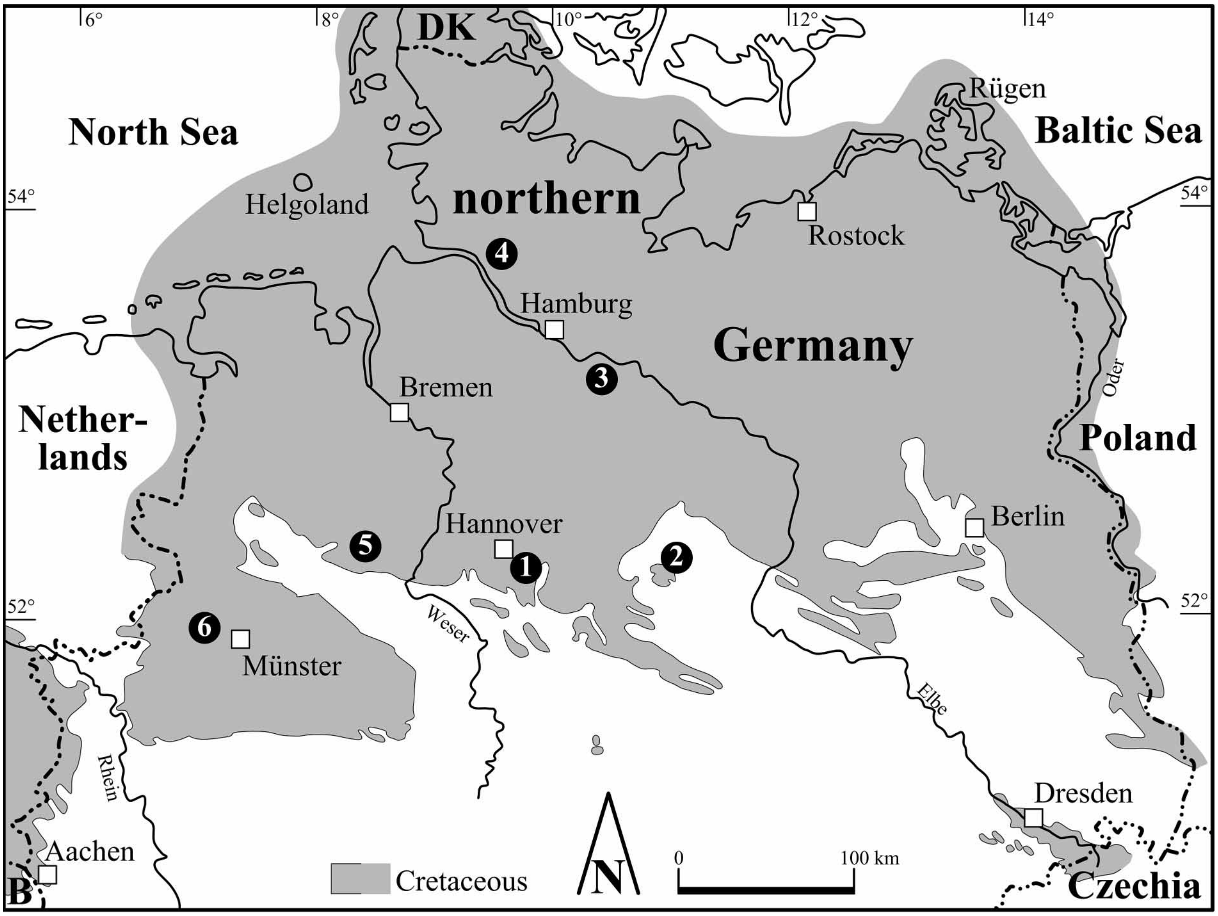

Fig. 1. Cretaceous of northern Germany, and *Nostoceras* (*Bostrychoceras*) *polyplocum* bearing sections: 1 – Lehrte West Syncline, 2 – Beienrode Basin, 3 – Lüneburg (Lower Saxony); 4 – Lägerdorf-Kronsmoor (Holstein); 5 – Stemweder Berg (Westphalia); 6 – Baumberge (Münsterland)

- echinoids – *Galerites roemeri* (DESOR), *Cardiaster cordiformes* (WOODWARD), *Echinocorys pyramidalis* SMISER, *Hemiaster* ex gr. *aquisgranensis* (SCHLÜTER); and
- inoceramid bivalves – *Cataceramus subcompressus* (MEEK & HAYDEN), *Cataceramus goldfussianus* (D'ORBIGNY), *Cataceramus pteroides* (GIERS).
- Stratigraphically relevant benthic foraminifers are *Neoflabellina rugosa* (D'ORBIGNY), *Bolivinoides delicatulus regularis* (REUSS), and *Bolivina incrassata* (REUSS).

Belemnitella langei JELETZKY is not proved in the Lehrte West Syncline, nevertheless, the benthic foraminifer assemblage enables correlation to the only Campanian-Maastrichtian boundary succession available in northern Germany. In Lägerdorf-Kronsmoor c. 160 km north of Lehrte (see Text-fig. 1), *Bolivina incrassata* first appears 1.3 m above the base of the *No. polyplocum* Zone and persists into the late Early Maastrichtian, while *Neoflabellina rugosa* and *Bolivinoides delicatus regularis* have an only 4.2 m thick overlap within the upper *Bt. langei* Zone (SCHÖNFELD 1990), 23.1-27.3 m below the FO of *Belemnella lanceolata* (SCHLOTHEIM) (comp. SCHULZ 1979; SCHULZ & *al*. 1984). According to the calculated accumulation rates of the chalk of Lägerdorf-Kronsmoor (24.5 m/Ma, EHRMANN 1986), in northern German sections the ammonite association documented here appears c. 1 Ma earlier than *Bn. lanceolata* and c. 1.5 Ma earlier

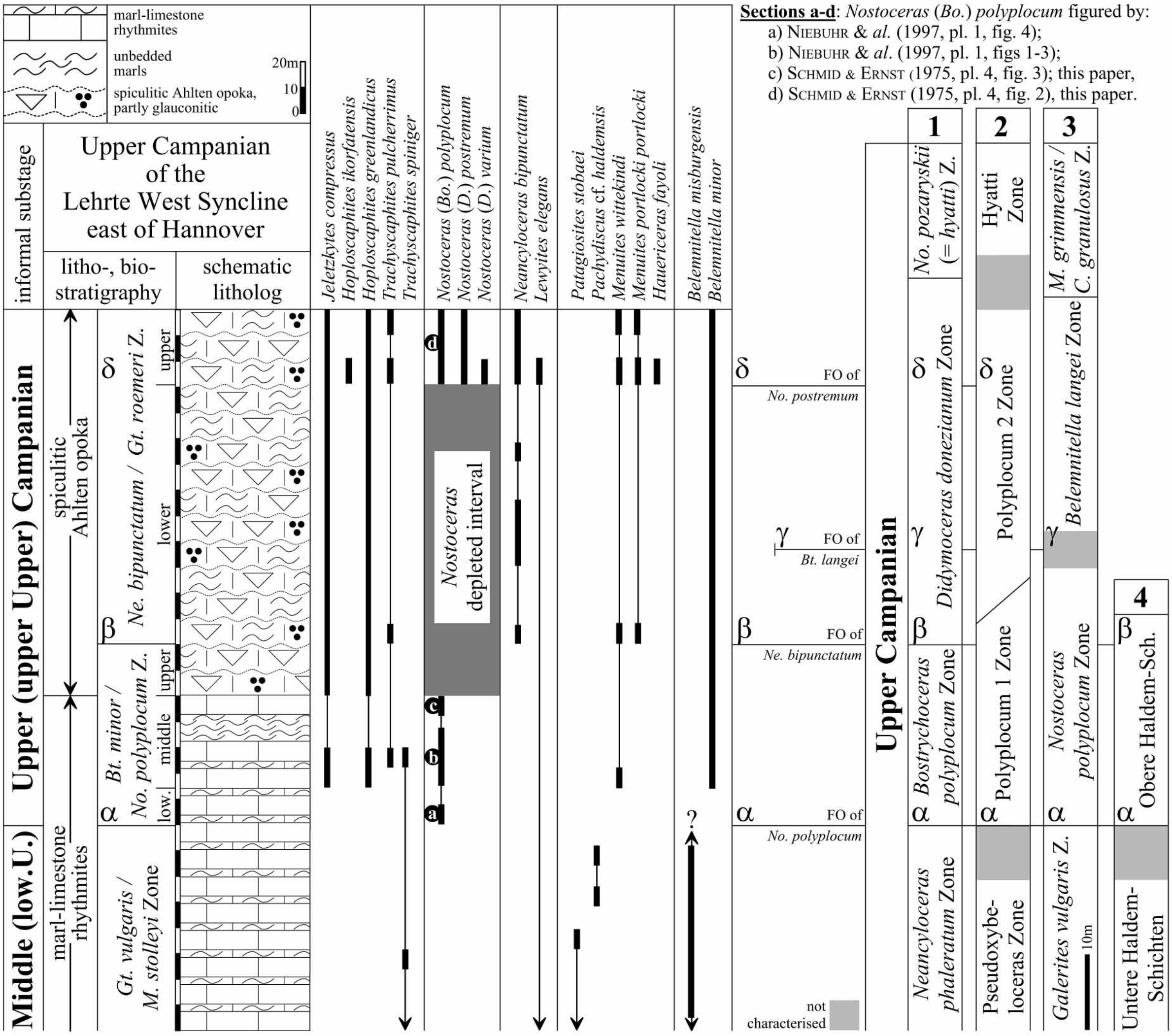

Fig. 2. Lithological log and cephalopod taxa of the upper portion of the Upper Campanian of the Lehrte West Syncline. The first occurrences of α – *Nostoceras* (*Bostrychoceras*) *polyplocum*, β – *Neancyloceras bipunctatum*, γ – *Belemnitella langei*, and/or δ – *Nostoceras* (*Didymoceras*) *postremum* can be used for correlation with 1 – Vistula river valley, Poland (BŁASZKIEWICZ 1980), 2 – Tercis, southwestern France (ODIN & *al*. 2001), 3 – Lägerdorf-Kronsmoor (NIEBUHR 2003), and 4 – Stemweder Berg (KENNEDY & KAPLAN 1997). The Vistula river valley sections are the only ones, where all four biomarkers occur. The biozones of Lägerdorf-Kronsmoor are in real scales

than the international base of the Maastrichtian Stage (GSSP at Tercis, southwestern France; see Odin & Maastrichtian Working Group members 2001) according to the FOs of *Diplomoceras cylindraceum* (Defrance) and *Pachydiscus neubergicus* (von Hauer) at Lägerdorf-Kronsmoor (Niebuhr 2003).

The underlying c. 100 m below the topmost 30 m of the Ahlten opoka (lower and middle *Ne. bipunctatum* / *Gt. roemeri* Zone) belong to the so-called '*Bostrychoceras*-freie Zwischenschichten' of Schmid & Ernst (1975, p. 335) or '*Nostoceras* depleted intervall' (Text-fig. 2), in which nostoceratid ammonites are absent. *Nostoceras*

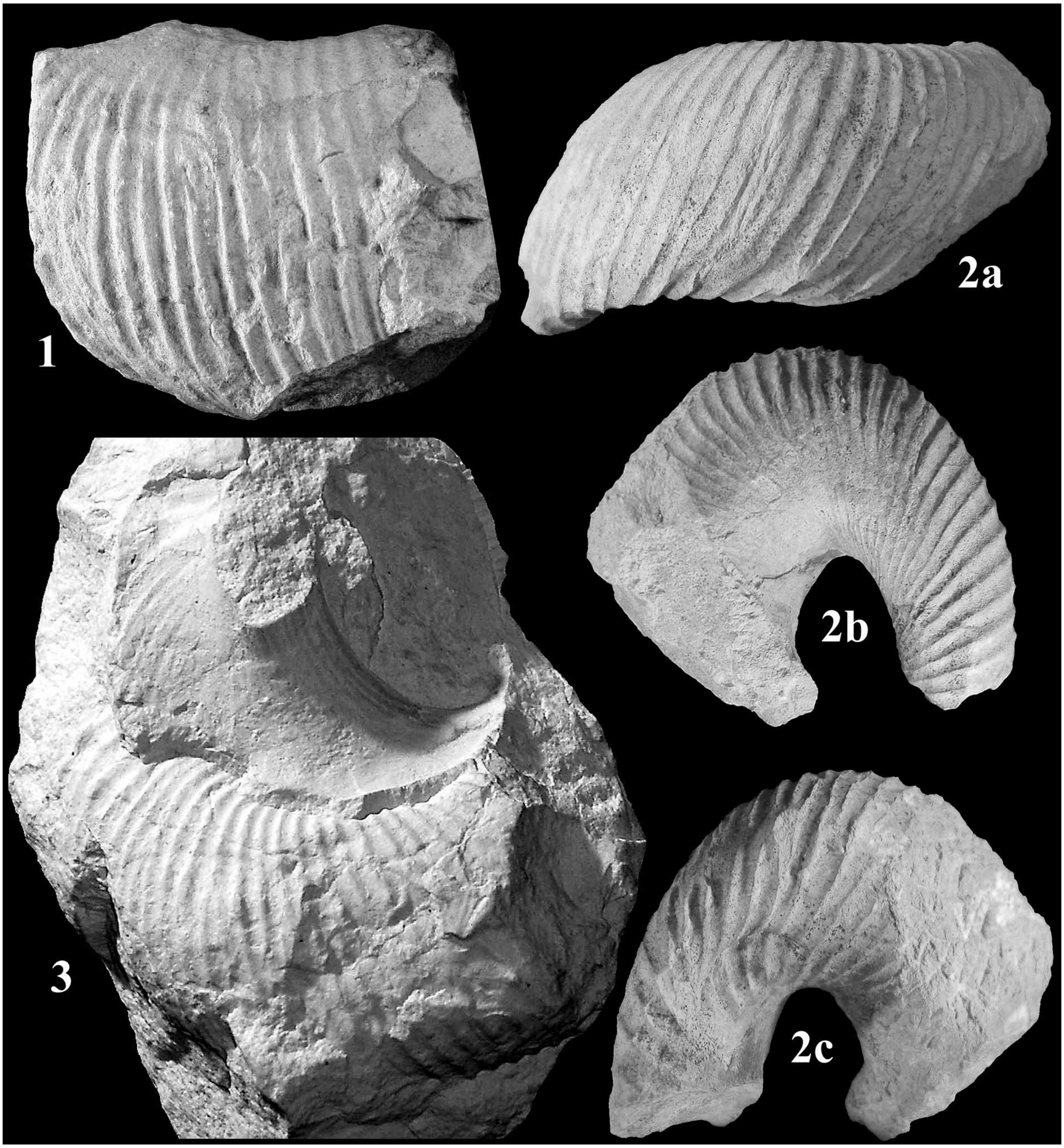

Fig. 3. *Nostoceras* (*Bostrychoceras*) *polyplocum* (Roemer, 1841) of Schmid & Ernst (1975). All figures are natural size. 1 – kca 31, Schmid & Ernst (1975, pl. 4, fig. 3). Lateral view. Marl-limestone rhythmites of the middle *Belemnitella minor* / *Nostoceras polyplocum* Zone below the *Nostoceras* depleted interval. 2 – kca 30, Schmid & Ernst (1975, pl. 4, fig. 2). Lateral, ventral, and dorsal views. Ahlten opoka of the upper *Neancyloceras bipunctatum* / *Galerites roemeri* Zone above the *Nostoceras* depleted interval. 3 – Ma13716, Schmid & Ernst (1975, not figured). External mould and lateral view of two helicoidal whorls in contact. Without exact stratigraphic level (? upper portion of Ahlten opoka). Gybsum carst found in the collection of the late G. Ernst, depository of the original is unknown

(*Bostrychoceras*) *polyplocum* first appears c. 170 m below the nostoceratid ammonite association described here, disappears with the facies change from marl-limestone rhythmites to Ahlten opoka, is absent for c. 1 Ma and reappears again together with the FOs of *Nostoceras* (*Didymoceras*) *postremum* and *Nostoceras* (*Didymoceras*) *varium*. It is difficult to understand why the nostoceratids disappear at the base of the interval in question, and then reappear at the top, while all the other stratigraphically important cephalopods, especially scaphitids and belemnites, range throughout (see Text-fig. 2).

MATERIAL

The Ahlten material presented here comprises twenty-one specimens, which are housed in the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, D-30655 Hannover, collection numbers Ma13592 to Ma13611, Ma13716, and kca 30 (a specimen from SCHMID & ERNST 1975). Six specimens are referred to *Nostoceras* (*Bostrychoceras*) *polyplocum*, a single specimen to *Nostoceras* (*Didymoceras*) *varium*, thirteen to *Nostoceras* (*Didymoceras*) *postremum*, one to *Nostoceras* sp. (Ma13610), and one fragment is indeterminate (Ma13602). All specimens are strongly compressed fragments of composite moulds.

SCHMID & ERNST (1975) have figured fragmentary helicoidal whorls of two specimens of *No.* (*Bo.*) *polyplocum* from the Lehrte West Syncline, which are refigured here (Text-fig. 3.1 and 3.2). One specimen is from the marl-limestone rhythmites of the middle *Bt. minor* / *No. polyplocum* Zone below (kca 31, level c of Text-fig. 2) and one is from the Ahlten opoka of the upper *Ne. bipunctatum* / *Gt. roemeri* Zone above the extensive *Nostoceras* depleted interval (kca 30, level d of Text-fig. 2). A gypsum cast of a further specimen of SCHMID & ERNST (1975) was found in the collection of the late Gundolf ERNST, which is without exact stratigraphic information and figured here for the first time (Ma13716, Text-fig. 3.3). Further specimens are figured by NIEBUHR & *al*. (1997, pl. 1, figs 1-4).

BIOMETRIC CHARACTERISTICS

By transition from the helicoidal whorls to the hook, nostoceratid ammonites change their growth direction. As defined for *Nostoceras* (*Didymoceras*) (see WRIGHT & *al*. 1996, p. 247) the middle and final portions of body chambers have their characteristic two rows of tubercles in a ventrolateral to ventral position. However, on the coiled phragmocone two rows of tubercules and the venter between them appear on the lower half of the outer whorl face (Text-fig. 4) which, therefore, should not be called the 'flank', as has been done by KENNEDY & KAPLAN (1997, p. 54).

Because the venter is located on the lower portion of the helicoidal whorl face, the measured whorl height of nostoceratid ammonites does not exactly correspond to the real one, which is the distant between venter and dorsum (comp. Text-fig. 4). However, the Ahlten material shows that measured and real whorl heights and breadths differ by less than 10 %. At body chambers the measured whorl heights and breadths are equal to the real ones because of the shift of the venter to the external side of the whorl.

In fragmentary material of nostoceratid ammonites, four portions of the shell or the composite mould can be distinguished (Text-fig. 4):

- helicoidal whorls – ventrolateral tuberculation on the lower portion of the outer whorl face, septa;
- transitional part – shifting of ventrolateral tuberculation, crowding of ribs at the dorsum;
- middle portion of body chamber – ventrolateral tuberculation on the external side of the whorl;
- final portion of body chamber – like middle portion but with adult aperture.

Based on this characterization, fourteen specimens can be defined as complete body chambers and transitional parts or portions of them. Body chambers are clearly distinguishable as to be sinistrally or dextrally coiled. Eight specimens belong to helicoidal whorls, but only three of which have visible septa. Sutures are not preserved. Unfortunately, there is no specimen showing both body chamber and the helicoidal whorls in contact. Therefore, the determination of the nostoceratid ammonites of Upper Campanian age gives many problems.

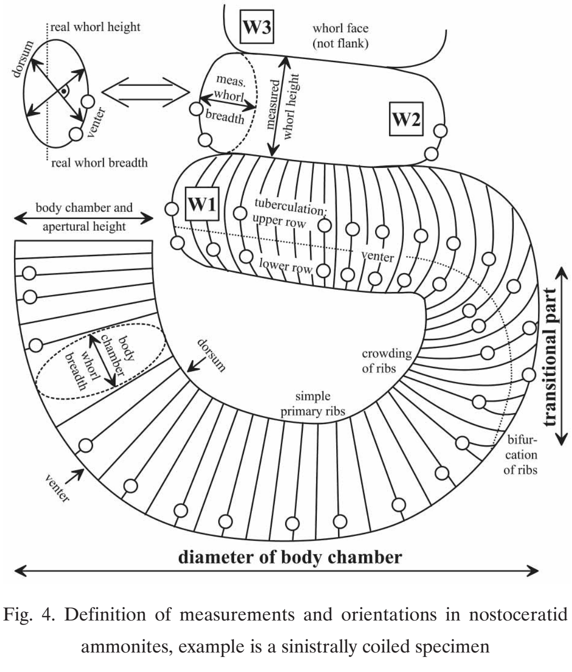

Fig. 4. Definition of measurements and orientations in nostoceratid ammonites, example is a sinistrally coiled specimen

All the dimensions below are quoted in millimetres. D = diameter; vL = ventral length measured between lower and upper row of tuberculation; Ah = apertural height; Wh = whorl height; Wb = whorl breadth; rib index = number of ribs in a distance equal to the whorl height; rib ratio = vL/ribs = ventral length divided by numbers of ribs; W1, W2 = first, second whorl counted from body chamber to the juvenile stage.

SYSTEMATIC DESCRIPTION

Suborder Ancyloceratina WIEDMANN, 1966
Superfamily Turrilitaceae GILL, 1871
Family Nostoceratidae HYATT, 1894
Genus *Nostoceras* HYATT, 1894

TYPE SPECIES: *Nostoceras stantoni* HYATT, 1894, p. 569; = *Ancyloceras* ? *approximans* CONRAD, 1855, p. 266.

DISCUSSION: Concerning the genus *Nostoceras*, the Ahlten material comprises forms intermediate between *Bostrychoceras* HYATT, 1900, and *Didymoceras* HYATT, 1894. Morphological variations in both are strong, and a clear distinction, using the criteria of HYATT (1894), e.g., type of tuberculation and phragmocone coiling, is impossible. Hence a simplification of the generic classification of these forms as applied by KENNEDY & SUMMESBERGER (1984) is adopted herein, with both *Bostrychoceras* and *Didymoceras* being regarded as subgenera of the genus *Nostoceras*. This agrees with the view of KÜCHLER (2000a).

Subgenus *Bostrychoceras* HYATT, 1900

TYPE SPECIES: *Turrilites polyplocum* ROEMER (1841, p. 92, pl. 14, figs 1, 2); by original designation of HYATT (1900, p. 588).

Nostoceras (*Bostrychoceras*) *polyplocum* (ROEMER, 1841)
(Pl. 2, Fig. 1; Text-figs 3, 5f)

pars *1841. *Turrilites polyplocum* ROEMER, p. 92, pl. 14, fig. 1, *non* fig. 2 [= *Eubostrychoceras saxonicum* (SCHLÜTER, 1876)].

pars 1872. *Heteroceras polyplocum* A. ROEMER sp.; SCHLÜTER, p. 112, pl. 33, figs 3-8; pl. 34, fig. 1, *non* figs 2-5 [= *Nostoceras* (*Didymoceras*) *varium* BŁASZKIEWICZ, 1980]; pl. 35, ? figs 1-7, fig. 8.

1975. *Bostrychoceras* (*Bostrychoceras*) *polyplocum* (F.A. ROEMER, 1841); SCHMID & ERNST, p. 339, pl. 4, figs 2, 3.

1980. *Bostrychoceras polyplocum polyplocum* (ROEMER, 1841); BŁASZKIEWICZ, p. 20, pl. 1, figs 1-9; pl. 2, figs 2, 3, 5, 6.

1980. *Bostrychoceras polyplocum schlueteri* BŁASZKIEWICZ, p. 20, pl. 2, figs 1, 4, 9-11.

1980. *Bostrychoceras unituberculatum* BŁASZKIEWICZ, p. 21, pl. 3, figs 1-8; pl. 4, figs 3-6.

1990. *Cirroceras polyplocum* (ROEMER); RIEGRAF, unnumbered figure p. 179.

pars 1997. *Bostrychoceras polyplocum* (ROEMER, 1841); KENNEDY & KAPLAN, p. 52, pl. 39, figs 1, 4, ? figs 2, 3; pl. 40, figs 1-5, 7-11, ? fig. 6; pl. 41, figs 1-4, fig. 9, ? figs 5-8; pl. 42, figs 1-6, ? fig. 7; pl. 43, figs 1-5; pl. 44, figs 1, 2; pl. 45, figs 1-4; pl. 46, figs 1, 2; pl. 47, figs 1-3, 7, 8, *non* figs 4-6 [= *Nostoceras* (*Didymoceras*) *varium* BŁASZKIEWICZ, 1980]; pls 48-50; *non* pl. 51, figs 1, 2 [= *Nostoceras* (*Euskadiceras*) *euskadiense* II KÜCHLER, 2000].

1997. *Bostrychoceras polyplocum* (ROEMER, 1841); NIEBUHR & *al*., pl. 1, figs 1-4.

2000a. *Nostoceras* (*Bostrychoceras*) *polyplocum polyplocum* (ROEMER); KÜCHLER, pl. 13, fig. 1; pl. 14, figs 1, 3, 5-7.

2001. *Nostoceras* (*Bostrychoceras*) *polyplocum polyplocum* (ROEMER, 1841); KÜCHLER & ODIN, p. 502, pl. 1, figs 3-6; pl. 2, figs 1-3.

2001. *Nostoceras* (*Bostrychoceras*) *polyplocum schlueteri* (BŁASZKIEWICZ, 1980); KÜCHLER & *al*., pl. 1, fig. 1.

? 2001. *Bostrychoceras polyplocum* (ROEMER, 1841); KENNEDY & COBBAN, p. 22, pl. 4, fig. 6; pl. 5, figs 1-3, 5-7.

2001. *Bostrychoceras polyplocum* (ROEMER, 1841); KENNEDY & COBBAN, p. 22, pl. 4, text-fig. 3 [= refigured neotype of *Bostrychoceras polyplocum* (ROEMER, 1841), KENNEDY & KAPLAN 1997, pl. 39, fig. 4].

2003. *Nostoceras* (*Bostrychoceras*) *polyplocum* (ROEMER, 1841); NIEBUHR, text-fig. 3.

TYPES: ROEMER's (1841) types from Dülmen, Lemförde and Weinböhlen, northern Germany, are lost. The neotype designated by KENNEDY & KAPLAN (1997, p. 53, pl. 39, fig. 4) is the lower portion of BMNH 37092 in the Natural History Museum, London, UK. Locus typicus is the Stemweder Berg, Haldem, Westphalia, northern Germany. Stratum typicum is the c. 50 m thick Obere Haldem-Schichten, *No. polyplocum* Zone, Upper Campanian.

MATERIAL: Six specimens (kca 30, Ma13597, Ma13600, Ma13605, Ma13606, Ma13716).

DESCRIPTION: *No.* (*Bo.*) *polyplocum* can be both sinistrally (Ma13605, Ma13606) and dextrally coiled (Ma13597, Ma13716). Ma13600 has visible septa, however, it shows less than $^1/_3$ of a single helicoidal whorl. This fragment has a Wh = 37 mm, dense simple nontuberculate primary ribs and a rib index of 13. Ma13605 shows the last septum and the early transitional part, has a Wh of 38-40 mm, Wb/Wh ratios of 0.55-0.58, and a rib index of 12. Mostly sinuous primaries may bifurcate at the juncture of the outer and lower whorl faces and show only a single tuberculate swelling at the position of the lower row. The helicoidal whorl of the Ahlten specimen of SCHMID & ERNST (1975; see Text-fig. 3.2: kca 30) reaches a Wh of 41 mm and a rib index of 11. Only a single tuberculate swelling is visible. Rib indices of 11-13 are indicated for helicoidal whorls of *No.* (*Bo.*) *polyplocum*.

Ma13716, the gybsum carst of SCHMID & ERNST (1975), figured for the first time on Text-fig. 3.3, shows two heliocone whorls in contact. Whorl heights, Wb/Wh, rib index, and rib ratio are similar to those of the other specimens (see Tab. 1). Ribbing consists of coarse simple primaries and few secondaries, which appear at the upper and lower whorl faces. Most of the ribs are nontuberculate, few weak tubercular swellings at the position of the upper row are visible.

The two body chambers of Ma13597 and Ma13606 with distinct collared adult aperture, an Ah of 47 mm, Wb/Wh ratios of 0.62 and 0.65 and rib indices of 7 and 8 (Tab. 1) are referred to macroconchs of *No.* (*Bo.*) *polyplocum*. In the best preserved specimen (Ma13597, Pl. 2, Fig. 1) two rows of tubercles or clavi appear, each of which is connected with two or three ribs. Ribbing consists of simple primaries and only once bifurcate at tuberculation. The body chamber is extremely short. At the dorsum, 25 mm before the adult aperture appears, the body chamber changes its growth direction at nearly a right angle, and shifting of tuberculation of the transitional part into the ventral position of body chambers appears c. 50 mm before the appearance of the adult aperture.

DISCUSSION: *No.* (*Bo.*) *polyplocum* shows a wide variation in ornament. One or two rows of tubercles can be present or absent in the early and middle growth stages. In contrast to the specimens from the Stemweder Berg, where all early growth stages with a Wh < 20 mm are bituberculate (KENNEDY & KAPLAN 1997, p. 54), those from below the *Nostoceras* depleted interval of Lehrte are non-, uni- or bituberculate (NIEBUHR & *al*. 1997, pl. 1, figs 1-3). Constrictions on the helicoidal whorls, which appear in the specimens of the Stemweder Berg with a Wh < 45 mm (KENNEDY & KAPLAN, p. 54, pl. 41, fig. 1), are not visible in the specimens presented here, but appear in the oldest *No.* (*Bo.*) *polyplocum* of the Lehrte marl-limestone rhythmites at a Wh of < 36 mm (NIEBUHR & *al*. 1997, pl. 1, fig. 4).

Some of the Stemweder Berg specimens seem to differ considerably from *No.* (*Bo.*) *polyplocum,* especially NMO Kr 429 of KENNEDY & KAPLAN (1997, pl. 51). Such specimens, which were determined as *Nostoceras* (*Euskadiceras*) *euskadiensis* II by KÜCHLER (2000b), also occur in Poland (original of *Didymoceras* sp. of BŁASZKIEWICZ 1980, pl. 4, figs 1, 2; refigured by KENNEDY & KAPLAN 1997, pl. 57, figs 4-6), Tercis (KÜCHLER & ODIN 2001, pl. 2, fig. 9), and northern Spain (KÜCHLER & *al.* 2001). *No.* (*E.*) *euskadiensis* II is bituberculate in all growth stages and differs from *No.* (*Bo.*) *polyplocum* in having a much coarser irregular rib-pattern with rib indices of < 10, and prominent spinose macro-tubercles. Likewise complete bituberculate *No.* (*Bo.*) *polyplocum* (see KENNEDY & KAPLAN 1997, pl. 40, fig. 11) are clearly different from *No.* (*E.*) *euskadiense* II.

Helicoidal whorls > 35 mm of *No.* (*Bo.*) *polyplocum* have high rib indices of > 10, which is also true for those of micro- and macroconchs of *Nostoceras* (*Didymoceras*) *postremum* (see Tab. 1). Nevertheless, only a single specimen out of thirty-one from the Stemweder Berg, figured by KENNEDY & KAPLAN (1997, pls 49, 50), reaches a Wh of 50 mm, which is reached in a helicoidal whorl of *No*. (*D.*) *postremum* of the Ahlten opoka (Ma136608, see below).

Likewise, the ornament of the transitional part and the body chamber gives only indirectly diagnostic criteria to distinguish *No.* (*Bo.*) *polyplocum* from microconchs of *No.* (*D.*) *postremum*. Both are characterized by irregular bituberculation of these portions (see Text-fig. 5). The body chamber of the macroconch Ma13597 is similar in size, ribbing, tuberculation and adult aperture and constriction in the final portion of the body chamber to a Stemweder Berg specimen figured by KENNEDY & KAPLAN (1997, pl. 48), which is also an adult macroconch. Likewise, the holotype of *Didymoceras postremum* BŁASZKIEWICZ, 1980, a microconch, refigured by KENNEDY & KAPLAN (1997, pl. 54, pl. 56, fig. 3) shows similarities, but developed the characteristically C-shaped body chamber of the subgenus *Didymoceras* (see below). However, in comparison to *No.* (*D.*) *postremum*, the body chambers of *No.* (*Bo.*) *polyplocum* are much shorter (see Tab. 1; Text-fig. 5f) and seem to be more strongly connected with the phagmocone. All figured specimens of *No.* (*Bo.*) *polyplocum* from the Stemweder Berg, including the holotype (*Bostrychoceras polyplocum* of KENNEDY & KAPLAN 1997, pl. 39, fig. 4) have such short body chambers, and in several specimens the change in growth direction at nearly a right angle (comp. Ma13597, Pl. 2, Fig. 1) a few centimetres before the adult aperture appears is visible.

According to BŁASZKIEWICZ (1980) and KÜCHLER & ODIN (2001), the stratigraphically oldest known specimens of *No.* (*Bo.*) *polyplocum* in the Vistula River Valley and at Tercis resemble the nontuberculate subspecies *schlueteri*, which should have a restricted occurrence in the lowermost portion of the *No. polyplocum* Zone. In the large suite of specimens from the Stemweder Berg KÜCHER & ODIN (2001, p. 502) have not found *No.* (*Bo.*) *polyplocum schlueteri*, and in the Upper Campanian of the Lehrte West Syncline KÜCHER & ODIN (2001) regarded the stratigraphically oldest *polyplocum* (NIEBUHR & *al*. 1997, pl. 1, fig. 4;

level a in Text-fig. 2), as well as the stratigraphically youngest one (Schmid & Ernst 1975, pl. 4, fig. 2; level d in Text-fig. 2) as ‘true’ *No.* (*Bo.*) *polyplocum polypolcum.* Likewise, *No.* (*Bo.*) *polyplocum* from the chalk of Lägerdorf-Kronsmoor (Niebuhr 2003, text-fig. 3) is similar to *No.* (*Bo.*) *polyplocum polyplocum* of Kücher & Odin (2001). According to Küchler & *al.* (2001, p. 730), however, this might indicate that the lower portion of the *No. polyplocum* Zone is missing in all northern German strata, which is definitely not the case. However, a splitting of *No.* (*Bo.*) *polyplocum* into two subspecies is not possible, relevant differences are not visible moreover, such a procedure would give rise to considerable stratigraphic complications.

Nostoceras (*Bo.*) *polyplocum* also occur in the Münsterland (Hiss 2001), and the upper Coesfelder Schichten, Billerbecker Grünsand and Baumberger Schichten yields an assemblage that consists almost entirely of individuals with a nontuberculate middle to early late growth stage (see Riegraf 1990). The specimens from Texas and Mexico (Kennedy & Cobban 2001) mostly have single ribs, or are irregular uni- and bituberculate, sometimes developed in the same specimen. In this ornament they cannot be differentiated from forms described from the Stemweder Berg (Kennedy & Kaplan 1997).

STRATIGRAPHY AND DISTRIBUTION: *Nostoceras* (*Bo.*) *polyplocum* is a widespread cosmopolitan species and the index fossil of the Upper Campanian *No. polyplocum* Zone of northern Germany (Lehrte West Syncline, Beienrode Basin, Lüneburg, Lägerdorf-Kronsmoor, Stemweder Berg, Münsterland; see Text-fig. 1), England, North Ireland, France, Spain, Poland, Russia and Ukraine, always associated with typical Upper Campanian species. However, only in the Lehrte West Syncline and Tercis does it co-occur with *No.* (*D.*) *postremum*. It also occurs in Armenia, Turkmenia, Kazakhstan, Iran, Bulgaria, North Africa, Texas and Mexico (comp. Kennedy & Kaplan 1997). However, it

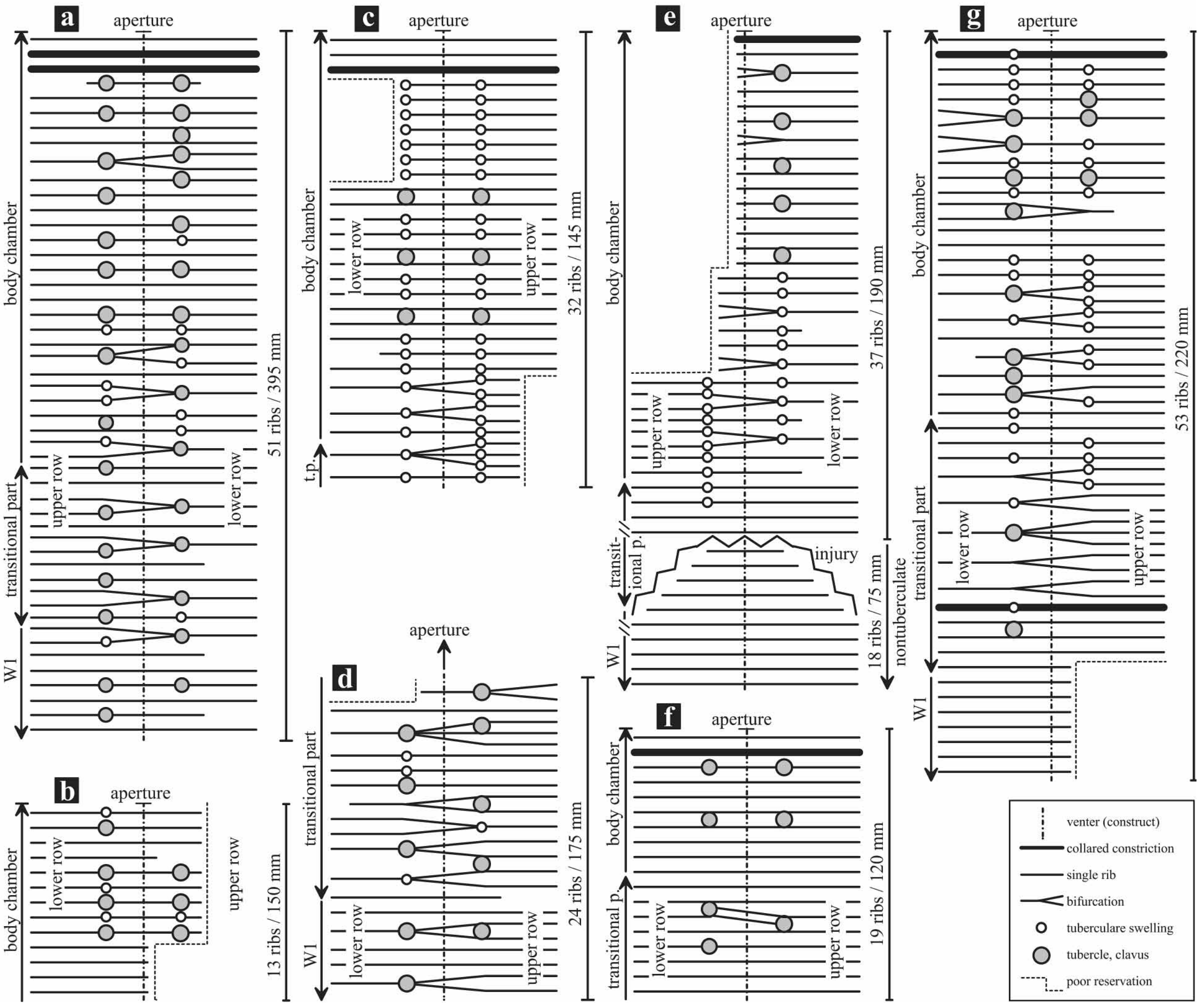

Fig. 5. Scheme of ribbing and tuberculation pattern of *Nostoceras* (*Didymoceras*) *postremum* (a = Ma13592, b = Ma13594, c = Ma13595, d = Ma13601, e = Ma13593), *Nostoceras* (*Bostrychoceras*) *polyplocum* (f = Ma13597), and *Nostoceras* (*Didymoceras*) *varium* (g = Ma13599) from the Ahlten opoka

must be emphasized that the occurrences in Texas (Kennedy & Cobban 2001) and North Africa (Jarvis & *al*. 2002) appear to be significantly older than those in Europe (see below chapter Stratigraphic Correlation).

Subgenus *Didymoceras* Hyatt, 1894

TYPE SPECIES: *Ancyloceras* ? *nebrascencis* Meek & Hayden, 1856, p. 71; by original designation of Hyatt, 1894, p. 574.

Nostoceras (*Didymoceras*) *varium* (Błaszkiewicz, 1980)

(Pl. 3, Fig. 1; Text-fig. 5g)

pars 1872. *Heteroceras polyplocum* Roemer, 1941; Schlüter, p. 112, pl. 34, figs 2-5.
*1980. *Didymoceras varium* Błaszkiewicz, p. 22, pl. 6, figs 1-7; pl. 7, figs 21, 22.
pars 1997. *Bostrychoceras polyplocum* (Roemer, 1941); Kennedy & Kaplan, p. 52, pl. 47, figs 4-6 (= refigured original of *Heteroceras polyplocum* Roemer, Schlüter, 1872, pl. 34, figs 4, 5).
2001. *Nostoceras* (*Didymoceras*) *varium* (Błaszkiewicz, 1980); Küchler & Odin, p. 505, pl. 1, fig. 7.

TYPES: The holotype is IG 1,310. II. 4 of Błaszkiewicz (1980, p. 22, pl. 6, figs 1, 2). Locus typicus is Dorotka, outcrop 43, middle Vistula River Valley, Poland. Stratum typicum is the *Nostoceras polyplocum* Zone, Upper Campanian.

MATERIAL: A single specimen (Ma13599).

DESCRIPTION: The dextrally coiled specimen consists of a part of the last whorl and a complete adult body chamber, which is perfectly C-shaped and shows an Ah of 36 mm. The whorl section has Wb/Wh ratios of 0.63 at the last helicoidal whorl to 0.78 near the aperture. Ribs are fine and dense, with a rib index of 9-10. In the last portions of the whorl, the ribs are mostly annular nontuberculate primaries, which pass over the slightly concave venter, and weaken considerably or disappear on the dorsum. On the final body chamber nearly every rib is connected to fine ventrolateral tubercular swellings or tubercles in two rows. The lower row appears earlier and is somewhat stronger than the upper one. Ribs frequently bifurcate at the lower row of tuberculation, secondaries are as a rule connected with the tubercular swellings of the upper row (Text-fig. 5g). Before the adult aperture appears ribbing crowd immediately.

No. coll. BGR:	taxon 1)	Ah	vL body chamber incl. transitional part	Wh body chamber incl. transitional part	Wh helicoidal whorl (+ septum)	Wb / Wh ratio	rib ratio (vL / ribs)	rib index
Ma13597	*No.* (*Bo.*) *polypolcum* (M)	47 mm	> 80 mm	47–49 mm	–	0.65	6.3	8
Ma13606	*No.* (*Bo.*) *polypolcum* (M)	47 mm	–	45 mm	–	0.62	–	7
Ma13605	*No.* (*Bo.*) *polypolcum*	–	–	39 mm	38 mm (+)	0.58	3.2	12
Ma13600	*No.* (*Bo.*) *polypolcum*	–	–	–	37 mm (+)	0.54	2.7	13
Ma13716	*No.* (*Bo.*) *polypolcum*	–	–	–	40-42 mm	0.68	3.2	12
kca 30	*No.* (*Bo.*) *polypolcum*	–	–	–	41 mm	0.54	3.3	11
Ma13599	*No.* (*D.*) *varium*	36 mm	> 100 mm	34–36 mm	–	0.63–0.78	4.2	9-10
Ma13592	*No.* (*D.*) *postremum* (M)	70 mm	> 300 mm	62–70 mm	–	0.68–0.78	7.7	8-9
Ma13594	*No.* (*D.*) *postremum* (M)	58 mm	–	58 mm	–	0.52–0.58	11.5	6-7
Ma13596	*No.* (*D.*) *postremum* (M)	–	–	52–58 mm	–	? 0.72	8.9	6-8
Ma13601	*No.* (*D.*) *postremum* (M)	–	–	54–56 mm	–	? 0.62	7.3	8
Ma13607	*No.* (*D.*) *postremum* (M)	–	–	57–60 mm	–	0.66	6.5	9
Ma13598	*No.* (*D.*) *postremum* (M)	–	–	48 mm	–	0.54	–	6
Ma13608	*No.* (*D.*) *postremum* (M)	–	–	–	50 mm	0.60	–	11
Ma13609	*No.* (*D.*) *postremum* (M)	–	–	–	–	–	–	–
Ma13593	*No.* (*D.*) *postremum* (m)	49 mm	> 200 mm	39–49 mm	39 mm	0.62	4.8	8-11
Ma13595	*No.* (*D.*) *postremum* (m)	49 mm	> 145 mm	39–49 mm	–	0.62–0.72	4.5	9
Ma13604	*No.* (*D.*) *postremum* (m)	41 mm	–	41 mm	–	–	–	7-9
Ma13611	*No.* (*D.*) *postremum*	–	–	–	27 mm	? 0.50	–	6-7
Ma13603	*No.* (*D.*) *postremum*	–	–	–	32 mm (+)	0.56	–	7-9
Ma13610	*Nostoceras* sp.	–	–	–	–	–	–	–
Ma13602	indeterminate	–	–	34–38 mm	–	0.54	7.8	5

Table 1. Dimensions of *Nostoceras* (*Bostrychoceras*) *polyplocum* (Roemer, 1841), *Nostoceras* (*Didymoceras*) *varium* (Błaszkiewicz, 1980), and *Nostoceras* (*Didymoceras*) *postremum* (Błaszkiewicz, 1980) from the Ahlten opoka. 1) M = macroconch, m = microconch

DISCUSSION: The single specimen of *Nostoceas* (*Didymoceras*) *varium* resembles the original of *Didymoceras varium* Błaszkiewicz (1980, pl. 6, figs 6, 7; refigured by Kennedy & Kaplan 1993, pl. 52, figs 2-4), which also consists of the last coiled portions and an adult body chamber. In the development of ornament, this specimen differs in a somewhat denser ribbing. Furthermore, the specimen lacks the pronounced collared constriction at the adult aperture, visible in the Polish material. Unfortunately, this is the only known body chamber of *No.* (*D.*) *varium* apart from the single Ahlten specimen.

Nostoceras (*D.*) *varium* differs from northern German *No.* (*Bo.*) *polyplocum* in having a pronounced C-shaped body chamber, which is delicate and much more densely ribbed. The Ah is much smaller than those of all other measured nostoceratids of Ahlten. In the large suite of *Bostrychoceras polyplocum* from the Stemweder Berg, micro- and macroconchs are more massive and their Ah are higher than 38.5 mm (Kennedy & Kaplan 1997, p. 54). *No.* (*D.*) *varium* is rare in northern Germany: in my opinion, only one of the thirty-one specimens of nostoceratid ammonites from the Stemweder Berg figured by Kennedy & Kaplan (1997) looks like *No.* (*D.*) *varium* (see Kennedy & Kaplan 1997, pl. 47, figs 4-6 = refigured of Schlüter, 1872, pl. 34, figs 4, 5).

STRATIGRAPHY AND DISTRIBUTION: Apart from this single specimen, *No.* (*D.*) *varium* is known from the *No. polyplocum* Zone, Upper Campanian, of the Stemweder Berg, Poland, and the Polyplocum 2 Zone at Tercis (Odin & *al*. 2001).

Nostoceras (*Didymoceras*) *postremum* (Błaszkiewicz, 1980)

(Pl. 1, Fig 1; Pl. 2, Fig. 2; Pl. 3, Fig. 2; Pl. 4, Figs 1-3;
Text-figs 5a-e)

*1980. *Didymoceras postremum* Błaszkiewicz, p. 25, pl. 8, figs 1-6; pl. 9, figs. 1-6.

2001. *Nostoceras* (*Didymoceras*) *postremum* (Błaszkiewicz, 1980); Küchler & Odin, p. 505, pl. 2, figs 4, 7, 10.

TYPES: The holotype is IG 1,310. II. 6 of Błaszkiewicz (1980, p. 25, pl. 8, figs 2, 5). Locus typicus is Ciszyca Górna, outcrop 107, middle Vistula River Valley, Poland. Stratum typicum is the *Didymoceras donezianum* Zone, Upper Campanian.

MATERIAL: Thirteen specimens (Ma13592, Ma13593, Ma13594, Ma13595, Ma13596, Ma13598, Ma13601, Ma13603, Ma13604, Ma13607, Ma13608, Ma13609, Ma13611). At least ten specimens show portions of the body chamber and the transitional part, five of them (Ma13592-Ma13595, Ma13604) also the adult aperture. Three specimens consist of helicoidal whorls (Ma1306, Ma13608, Ma13611) or the older portions of the transitional part, in a single specimen (Ma13603) the septa are visible.

DESCRIPTION: *Nostoceras* (*D.*) *postremum* is both sinistrally (Ma13592-Ma13594) and dextrally coiled (Ma13595). The whorl sections of all measured phragmocones and body chambers have Wb/Wh ratios of 0.5 to 0.78 (Tab. 1). Adult body chambers of the species are distinctly C-shaped and show strong dimorphism, herein interpreted as micro- and macroconchs. However, the Ahlten material shows much larger sizes than previously known from nostoceratid ammonites: body chambers of microconchs have maximum sizes of D = 110-120 mm (MA13593 and MA13595, Pl. 2, Fig. 2; Pl. 3, Fig. 2), lengths of body chambers more than 200 mm, and an Ah of 49 mm, while the largest macroconch (Ma13593, Pl. 1, Fig. 1) reaches D = 200 mm, a body chamber longer than 300 mm and an Ah of 70 mm. The distinctly C-shaped body chambers of both micro- and macroconchs enlarge towards the aperture and may become pipe-like (Ma13592, Pl. 1, Fig. 1a; Ma13593, Pl. 2, Fig. 2; Ma13595, Pl. 3, Fig. 2a). Collared constrictions are also visible in both macro- (Ma13592, Pl. 1, Fig. 1a; Ma13594, Pl. 4, Fig. 1) and microconchs (Ma13595, Pl. 3, Fig. 2a). The rib indices of the transitional part and the body chamber of microconchs are 7-9, and of macroconchs are 6-9, helicoidal whorls of both may reach 11 (Tab. 1; Ma13608 and Ma13593). The ventral length divided by numbers of ribs (rib ratio) gives a better differentiation between both: microconchs are finer ribbed with rib ratios of 4.5-4.8, while coarser ribbed macroconchs have rib ratios of much more than 6 (Text-figs 5a-e; Tab. 1).

The transitional parts and body chambers of macroconchs bear coarse, distant, sharp bituberculate ribs that are mostly annular or bifurcate, and may zig-zag a few times between separated tubercles, with occasional annular nontuberculate ribs. Tuberculation is irregular and coarsens towards the middle and final portion of the body chamber in both macro- and microconchs; the tubercles may become spines or clavi (Ma13598, Pl. 4, Fig. 2). Weak tubercles and tubercular swellings link only to a single rib, while coarse tubercles/spines/clavi are often connected with two or three ribs. On the final portions of the body chamber the last ribs in some specimens lose their tuberculation and crowd immediately before the adult aperture appears.

The ornament of the microconch Ma13595 (Pl. 3, Fig. 2; Text-fig. 5c) is regular and consists of simple primaries which pass across the flattened venter. Weak tubercular swellings appear in the transitional part and the final portion of the body chamber, while the middle portion of the body chamber bears three distinct tubercles in both the upper and lower row. The last helicoidal whorl and older portions of the transitional part of the microconch Ma13593 (Pl. 2, Fig. 2; Text-fig. 5e) are nontuberculate and have a rib index of 11. In the body chamber, tubercular swellings of the upper row first appear on the third rib after a non-fatal shell injury, towards the adult aperture spinose tuberculation coarsens strongly and the rib index reaches 8. It seems that the aperture of the pipe-like body chamber touches the last helicoidal whorl. Generally, tuberculation and ribbing of body chambers of microconchs is regular and denser in comparison to those of macroconchs.

Ornament of the early growth stage of the phragmocone fragments Ma13603 and Ma13611 is similar to the bituberculate body chambers of macroconchs; it shows coarse annular ribs which often bifurcate at the tubercles of the lower and upper row, and may loop or zigzag. Ribbing of the heliocone whorl with a Wh of 50 mm (probably of a macroconch, see Tab. 1) has simple primaries, only two tubercular swellings of the lower row are visible, at which the ribs bifurcate. The rib index is 11, similar to that of the last helicoidal whorl of microconch Ma13593 at a Wh of 39 mm (see Pl. 2, Fig. 2, right side).

DISCUSSION: *Nostoceras* (*D.*) *postremum* is the largest European nostoceratid ammonite. However, apart from the size, there are considerable similarities in ornament to *Nostoceras* (*Bostrychoceras*) *polyplocum* (for further discussion see above). Characteristic of the subgenus *Didymoceras* is the distinctly C-shaped body chamber, which seems only loosely connected with the phragmocone portions of *No.* (*D.*) *postremum* and *No.* (*D.*) *varium*. If one follows the view of KENNEDY & KAPLAN (1997), the holotype of *Didymoceras postremum* is similar to bituberculate specimens from the Stemweder Berg; hence the authors referred this species (and *Didymoceras varium* as well) to *Bostrychoceras polyplocum* with reservation. However, in the large suite of nostoceratid ammonites from the Stemweder Berg no specimen developed such a characteristically C-shaped body chamber as observable in specimens of the subspecies *Didymoceras*.

STRATIGRAPHY AND DISTRIBUTION: Apart from these specimens from the upper *Neancyloceras bipunctatum* / *Galerites roemeri* Zone (= upper *Belemnitella langei* Zone), *No.* (*D.*) *postremum* is known from the Polyplocum 2 Zone, Upper Campanian, of Tercis, and the middle portion of the *Didymoceras donezianum* Zone of the Vistula River Valley, Poland. *No.* (*D.*) *postremum* is unknown from the northern German sections of Lägerdorf-Kronsmoor, Stemweder Berg, and the Münsterland.

STRATIGRAPHIC CORRELATION

Lägerdorf-Kronsmoor (northern Germany)

The *Neancyloceras bipunctatum* / *Galerites roemeri* Zone of Ahlten is more or less equivalent to the *Belemnitella langei* Zone of Lägerdorf-Kronsmoor (Text-fig. 2). On the basis of the co-occurrence of the benthic foraminifers *Neoflabellina rugosa* and *Bolivinoides delicatulus regularis* the topmost c. 30 m of the Ahlten opoka correlates with the bioclastic chalk of the Grobkreide 2 Beds at Lägerdorf-Kronsmoor 28-34 m below the FO of *Diplomoceras cylindraceum* and 40-44 m below the FO of *Pachydiscus neubergicus* (see NIEBUHR 2003). Recently, a single specimen of *Nostoceras* sp. was found at the base of the Grobkreide 2 Beds (middle *Bt. langei* Zone). This find might correlate with the second occurrence of nostoceratid ammonites in the Lehrte West Syncline. The base of the *No. polyplocum* Zone of Lägerdorf-Kronsmoor is defined by the three *No. (Bo.) polyplocum* of SCHULZ (1978, p. 80; one of which was figured by NIEBUHR 2003, text-fig. 3) and further specimens in private collections from the same horizon.

Stemweder Berg (northern Germany)

It seems that the Obere Haldem-Schichten of the Stemweder Berg (see KENNEDY & KAPLAN 1997) do not reach the level of the FO of *No.* (*D.*) *postremum* (Text-fig. 2). This stratigraphic interpretation is also indicated by the single find of *Neancyloceras* cf. *bipunctatum* from the uppermost sections at the Stemweder Berg (KENNEDY & KAPLAN 1997, p. 61): this is a very common ammonite at Ahlten 100 m below the FO of *No.* (*D.*) *postremum*. The superbly preserved and common *No.* (*Bo.*) *polyplocum* as well as *No.* (*D.*) *varium* from the Stemweder Berg seem to belong to the lower level of *No.* (*B.*) *polyplocum* below the *Nostoceras*-depleted interval of Ahlten. In this interval, the FO of *No.* (*Bo.*) *polyplocum* close to the FOs of accompanying ammonites, especially of *Menuites wittekindi*, *Trachyscaphites pulcherrimus*, *Jeletzkytes compressus*, and *Hoploscaphites greenlandicus* (see KENNEDY & KAPLAN 1997, fig. 1), is similar to the Lehrte West Syncline.

Tercis (southwestern France)

In the Upper Campanian of Tercis, the GSSP of the base of the Maastrichtian Stage, the stratigraphic subdivision seems to be similar to that of the Lehrte West Syncline (Text-fig. 2). The FO of *No.* (*Bo.*) *polyplocum* at the basal *Belemnitella minor* / *Nostoceras polyplocum* Zone of Lehrte correlates with the FO of *No.* (*Bo.*) *polyplocum schlueteri* at Tercis (Polyplocum 1 Zone of ODIN & *al.* 2001). The second occurrence of *No.* (*Bo.*) *polyplocum*, co-occurring with *No.* (*D.*) *postremum* and *No.* (*D.*) *varium* in the upper *No. bipunctatum* / *Gt. roemeri* Zone of Ahlten correlates with the Polyplocum 2 Zone of ODIN & *al*. (2001), which is characterized by the FOs of the subgenus *Didymoceras* and of *No.* (*Bo.*) *polyplocum polyplocum.* Apart from Ahlten, the Tercis section is the only one where *No.* (*Bo.*) *polyplocum* and *No.* (*D.*) *postremum* co-occur. As in the Lägerdorf-Kronsmoor sections, the FOs of *No.* (*Bo.*) *polyplocum* and *Diplomoceras cylindraceum* at Tercis are separated by c. 3.6 Ma (according the accumulation rates given by EHRMANN 1986, and ODIN & TURIN 2001; see NIEBUHR 2003).

Vistula river valley (Poland)

Nostoceras (*Didymoceras*) *postremum* appears in the middle of the Upper Campanian *D. donezianum* Zone of Poland, as does *Bt. langei* (BŁASZKIEWICZ 1980) (Text-fig. 2). *Bt. langei* is not proved at Ahlten, but occurs in the time-equivalent *Bt. langei* Zone at Lägerdorf-Kronsmoor. Therefore, the Polyplocum 2 Zone at Tercis, the lower *Bt. langei* Zone at Lägerdorf-Kronsmoor, and the upper *Ne. bipunctatum* / *Gt. roemeri* Zone of Ahlten correlate with the middle of the *D. donezianum* Zone of BŁASZKIEWICZ (1980).

In Poland, *No.* (*D.*) *varium* is a species of the underlying *No. polyplocum* Zone, where it appears in its middle portion. In the *Bt. minor* / *No. polyplocum* Zone of the Lehrte West Syncline it was not found below the *Nostoceras* depleted interval. However, in my opinion, SCHLÜTER's specimens from the *No. polyplocum* Zone of the Stemweder Berg (SCHLÜTER 1872, pl. 34, figs 2-5) can be referred to *No.* (*D.*) *varium*. At Tercis, *No.* (*D.*) *varium* appears only a few metres below the FO of *No.* (*D.*) *postremum* in the uppermost Polyplocum 1 Zone (ODIN & *al*. 2001).

North America and North Africa

On condition that the nostoceratid ammonites of Texas (KENNEDY & COBBAN 2001) and North Africa (JARVIS & *al*. 2002) are 'true' *No.* (*Bo.*) *polyplocum* it must be emphasized that their occurrences appear to be significantly older than those in Europe. At El Kef (Tunisia, North Africa) *No.* (*Bo.*) *polyplocum* appears with the 'mid-Campanian event', which equals, according to carbon isotope data, with the *Bt. mucronata* transgression (Lower-Middle Campanian boundary interval) of northern Germany and England (NIEBUHR, submitted). The Texas occurrences are presumed to equate with the lower Middle Campanian *Baculites asperiformis* Zone of the Western Interior. This implies that *No.* (*Bo.*) *polyplocum* first appears in North America only c. 1 Ma later than the FO of the Middle (early Late) Campanian zonal index, *Bt. mucronata*, in northern Europe (e.g., HARDENBOL & *al*. 1998).

According to COMBEMOREL & CHRISTENSEN (in HARDENBOL & *al*. 1998) the FOs of *Bt. mucronata* and *Bt. minor* are separated by c. 6.3 Ma. However, these absolute ages are based on ^{40}Ar/^{39}Ar dating of bentonites from the Western Interior (OBRADOVICH 1993), but there are no comparable radiometric dates from Northwest Europe, Balto-Scandia and the Russian Platform. Cyclostratigraphic investigations of the Lehrte marl-limestone rhythmites show accumulation rates of c. 47 m/Ma (NIEBUHR 2004), and, according to orbital cycles demonstrated by variation of the carbonate contents of the sediment (c. thirteen long eccentricity cycles of 413 ky), *No.* (*Bo.*) *polyplocum* first appears c. 5.3 Ma later than *Bt. mucronata* and c. 0.2 Ma earlier than *Bt. minor.*

Stratigraphically relevant scaphitid ammonites, both appearing in the Campanian of Europe and North America, are *Trachyscaphites pulcherrimus* and *Jeletzkytes compressus* (e.g., BŁASZKIEWICZ 1980; NIEBUHR 1996; KENNEDY & COBBAN 1994a, 1994b, 1999; KÜCHLER & *al*. 2001), which occur in the Western Interior Middle and Upper Campanian, respectively, and co-occur with *No.* (*Bo.*) *polyplocum* in the Upper Campanian of Europe. In the Lehrte marl-limestone rhythmites *T. pulcherrimus* first appears with the last occurrence of *Trachyscaphites spiniger*, only c. 0.4 Ma (c. 20 m of sediment, see Text-fig. 2) later than *No.* (*Bo.*) *polyplocum*, and co-exists with *Jeletzkytes compressus* and *Hoploscaphites greenlandicus* up to the top of the Ahlten section. These ammonite occurrences are similar to those of the Stemweder Berg (KENNEDY & KAPLAN 1997, fig. 1). However, in the Western Interior the co-occurrence of *No.* (*Bo.*) *polyplocum* and *T. spiniger porchi* in the lower Middle Campanian *Baculites asperiformis* Zone (COBBAN & SCOTT 1964) is 2 to 3 Ma older (comp. COBBAN in HARDENBOL & *al*. 1998) than the occurrence of *T. pulcherrimus* in the upper Middle Campanian *Baculites gregoryensis* Zone (KENNEDY & COBBAN 1994a), and 4.8 to 6.6 Ma older than the occurrence of *Jeletzkytes compressus* in the middle Upper *Baculites cheyennensis* to *Baculites compressus* zones (KENNEDY & COBBAN 1994b). Likewise, the 2-3 Ma long lasting interval of the Western Interior *Baculites asperiformis* to *Baculites gregoryensis* zones yields the same inoceramid association that in Europe (WALASZCZYK 2004). Up to know, unfortunately, the differences in correlation between North America and Europe can not be resolved.

CONCLUSIONS

With respect to a three-fold subdivision of the Campanian age, which is followed according to the 2nd

International Symposium on Cretaceous Stage Boundaries (see HANCOCK & GALE 1996), the cosmopolitan *No.* (*Bo.*) *polyplocum* seems to be the ideal index species for the definition of the base of the Upper Campanian Substage in Europe and the Russian Platform. Apart from the occurrences in Texas (KENNEDY & COBBAN 2001) and North Africa (JARVIS & *al*. 2002), all other distributions seem to be restricted to the second youngest Campanian ammonite zone below that of *No.* (*No.*) *hyatti*. Assuming that the GSSP of the base of the Maastrichtian Stage at Tercis (southern France) equals the boundary of the U.S. Western Interior (radiometric age 71.3 ± 0.5 Ma; GRADSTEIN & *al*. 1994), *Nostoceras* (*Bostrychoceras*) *polyplocum* first appears in Europe c. 75 Ma before present [which is, according to HARDENBOL & *al*. (1998), the inexplicable top of the European Polyplocum Zone!].

In the Boreal realm, where belemnites are the most important index fossils, *No.* (*Bo*.) *polyplocum* spans the *Bt. minor* Zone and the lower to middle portions of the *Bt. langei* Zone. *Bt. mucronata,* which spans the *Goniothetis quadrata gracilis* / *Belemnitella mucronata* to basal *Galerites vulgaris* / *Micraster stolleyi* zones of Lehrte, might be the ideal index species for the definition of the Middle Campanian Substage.

In my opinion, a splitting of the species *polyplocum* into the subspecies *polyplocum* and *schlueteri* is taxonomically not possible and not practical. The subspecies concept of *No.* (*Bo.*) *polyplocum* according to BŁASZKIEWICZ (1980) and KÜCHLER & ODIN (2001) would imply the existence of hiatuses in most Campanian sections (e.g., northern Germany, Tercis) for which there is no evidence.

Because of the distribution of *No.* (*D.*) *postremum* and *No.* (*D.*) *varium* as well as problems with their taxonomic definitions, these species are not suitable for interregional correlation. Nevertheless, their FOs at Tercis and Ahlten are definitely more than 1 Ma younger than that of *No.* (*Bo*.) *polyplocum*. It is possible that, in some areas, an additional ammonite zone can be distinguished between those of *No.* (*Bo*.) *polyplocum* and *No.* (*No*.) *hyatti* that is characterised by the appearance of different species of the subgenus *Didymoceras*.

In the chalk of Lägerdorf-Kronsmoor the index ammonites *Diplomoceras cylindraceum* and *Pachydiscus neubergicus* indicate the base of the Maastrichtian Stage at the top of the *Bn. pseudobtusa* Zone in belemnite terms (NIEBUHR 2003). In contrast to the misleading illustration of ODIN (2001, fig. 3), *No.* (*No*.) *hyatti*, the last occurrence of which is the third ammonite marker for the boundary definition of the GSSP at Tercis, is not known in northern Germany.

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REFERENCES

BŁASZKIEWICZ, A. 1980. Campanian and Maastrichtian Ammonites of the Middle Vistula River Valley, Poland: a stratigraphic-paleontological study. *Prace Instytutu Geologicznego*, **92**, 1-63.

COBBAN, W.A. & SCOTT, G.R. 1964. Multinodose scaphitid cephalopods from the lower part of the Pierre Shale and equivalent rocks in the Conterminous United States. *Geological Survey Professional Paper*, **483-E**, E1-E13.

CONRAD, W.A. 1855. Description of eighteen new Cretaceous and Tertiary fossils. *Proceedings of the Academy of Natural Sciences of Philadelphia*, **7**, 265-268.

EHRMANN, W.U. 1986. Zum Sedimenteintrag in das zentrale nordwesteuropäische Oberkreidemeer. *Geologisches Jahrbuch*, **A 97**, 3-139.

ERNST, G. 1975. Stratigraphie, Fauna und Sedimentologie der Oberkreide von Misburg und Höver bei Hannover. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg*, **44**, 69-97.

GILL, T. 1871. Arrangement of the families of Mollusks. *Smithsonian Miscellaneous Collections*, **227**, xvi + 1-49.

GRADSTEIN, F.M., AGTERBERG, F.P., OGG, J.G., HARDENBOL. J., VEEN, P. VAN, THIERRY, J. & HUANG, Z. 1994. A Mesozoic time scale. *Journal of Geophysical Research*, **99** (B12), 24,051-24,074.

HANCOCK, J.M & GALE, A.G. 1996. The Campanian Stage. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, **66** - Supplement, 103-109.

HARDENBOL, J., THIERRY, J., FARLE, M.B., JACQUIN, T., GRACIANSKY, P.C. & VAIL, P.R. 1998. Mesozoic and Cenozoic Sequence Chronostratigraphic Framework of European Basins. Chart 5: Cretaceous Biochronostratigraphy. *In*: GRACIANSKY, P.C., HARDENBOL, J.M., JACQUIN, T. & VAIL, P.R. (*Eds*), Mesozoic and Cenozoic Sequence Stratigraphy of European Basins. *Society of Sedimentary Geology, Special Publication*, **60**, Tulsa.

HISS, M. 2001. Geologische Karte von Nordrhein-Westfalen 1:25 000. Erläuterungen zu Blatt 3909 Horstmar, 1-183.

HYATT, A. 1894. Phylogeny of an acquired characteristic. *Proceedings of the American Philosophical Society*, **32**, 349-647.

— 1900. Cephalopoda. *In*: ZITTEL, K.A. VON (1896-1900), Textbook of Palaeontology, transl. Eastman, C.R., 502-604. London–New York.

JARVIS, I., MABROUK, A., MOODY, R.T.J. & CABRERA, S. DE 2002. Late Cretaceous (Campanian) carbon isotope events, sea-level change and correlation of Tethyan and Boreal realms. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **188**, 215-248.

KENNEDY, W.J. & COBBAN, W.A. 1994a. Ammonite fauna from the Wenonah Formation (Upper Cretaceous) of New Jersey. *Journal of Paleontology*, **68** (1), 95-119.

— & — 1994b. Upper Campanian ammonites from the Mount Laurel Sand at Biggs Farm, Delaware. *Journal of Paleontology*, **68** (6), 1285-1305.

— & — 1999. Campanian (Late Cretaceous) ammonites from the Bergstrom Formation in Central Texas. *Acta Geologica Polonica*, **49** (1), 67-80.

— & — 2001. Campanian (Late Cretaceous) Ammonites from the upper part of the Anacacho Limestone in South-Central Texas. *Acta Geologica Polonica*, **51** (1), 15-30.

KENNEDY, W.J. & KAPLAN, U. 1997. Ammoniten aus dem Campan des Stemweder Berges, Dammer Oberkreidemulde, NW-Deutschland. *Geologie und Paläontologie in Westfalen*, **50**, 31-245.

KENNEDY, W.J. & SUMMESBERGER, H. 1984. Upper Campanian ammonites from the Gschliefgraben (Ultrahelvetic, Upper Austria). *Beiträge zur Paläontologie von Österreich*, **11**, 149-206.

KÜCHLER, T. 2000a. Upper Cretaceous of the Barranca (Navarra, northern Spain); integrated litho-, bio- and event stratigraphy. Part II: Campanian and Maastrichtian. *Acta Geologica Polonica*, **50** (4), 441-499.

— 2000b. *Nostoceras* (*Euskadiceras*) *euskadiense* a new ammonite subgenus and species from the higher Upper Campanian (Upper Cretaceous) of northern Spain. *Berliner Geowissenschaftliche Abhandlungen*, **E 34**, 291-307.

KÜCHLER, T. & ODIN, G.S. 2001. Upper Campanian-Maastrichtian ammonites (Nostoceratidae, Diplomoceratidae) from Tercis les Bains (Landes, France). *In*: ODIN, G.S. (*Ed*.), The Campanian-Maastrichtian Stage Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 500-549. *Elsevier*; Amsterdam.

KÜCHLER, T., KUTZ, A. & WAGREICH, M. 2001. The Campanian-Maastrichtian boundary in northern Spain (Navarra province): the Imiscoz and Erro sections. *In*: ODIN, G.S. (*Ed*.), The Campanian-Maastrichtian Stage Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 723-744. *Elsevier*; Amsterdam.

MEEK, F.B. & HAYDEN, F.V. 1856. Descriptions of new species of Gastropoda and Cephalopoda from the Cretaceous formation of Nebraska Territory. *Proceedings of the Academy of Natural Sciences of Philadelphia*, **8** (for 1856), 63-72.

NIEBUHR, B. 1995. Fazies-Differenzierungen und ihre Steuerungsfaktoren in der höheren Oberkreide von S-Niedersachsen/Sachsen-Anhalt (N-Deutschland). *Berliner geowissenschaftliche Abhandlungen*, **A 174**, 1-131.

— 1996. Die Scaphiten (Ammonoidea, Ancyloceratina) des höheren Obercampan der Lehrter Westmulde östlich Hannover (N-Deutschland). *Berliner geowissenschaftliche Abhandlungen*, **E 18**, 267-287.

— 2003. Late Campanian to Early Maastrichtian ammonites from the white chalk of Kronsmoor (northern Germany) – taxonomy and stratigraphy. *Acta Geologica Polonica*, **53** (4), 257-281.

— 2004. Geochemistry and time-series analyses of orbitally forced Upper Cretaceous marl-limestone rhythmites (Lehrte West Syncline, northern Germany). *Geological Magazine*, in press.

— Revision of Boreal Mid-Campanian to Lower Maastrichtian carbon isotope stratigraphy and proposed correlation into the Tethyan Realm. *Cretaceous Research*, submitted to press.

NIEBUHR, B., VOLKMANN, R. & SCHÖNFELD, J. 1997. Das *polyplocum*-Event der Lehrter Westmulde (Oberkreide, N-Deutschland): Bio-/ Litho-/ Sequenzsstratigraphie, Fazies-Entwicklung und Korrelation. *Freiberger Forschungsheft*, **C 468**, 211-243.

OBRADOVICH, J.D. 1993. A Cretaceous time scale. *In*: CALDWELL, W.G.E. & KAUFFMAN, E.G. (*Eds*), Evolution of the Western Interior Basin. *Geological Association of Canada, Special Paper*, **39**, 379-396.

ODIN, G.S. 2001. The Campanian-Maastrichtian boundary: correlation from Tercis (Landes, SW France) to Europe and other continents. *In*: ODIN G.S. (*Ed.*), The Campanian-Maastrichtian Stage Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 806-819. *Elsevier*; Amsterdam.

ODIN, G.S. & TURIN, L. 2001. Composition isotopique du strontium à la limite Campanien-Maastrichtien; étude à Tercis les Bains (Landes, France) et comparaison avec d'autres bassins. *In*: ODIN, G.S. (*Ed*.), The Campanian-Maastrichtian Stage Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 166-171. *Elsevier*; Amsterdam.

ODIN, G.S., COURVILLE, P., MACHALSKI, M. & COBBAN, W.A. 2001. The Campanian-Maastrichtian ammonite fauna from Tercis (Landes, France); a synthetic view. *In*: ODIN, G.S. (*Ed*.), The Campanian-Maastrichtian Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 550-567; *Elsevier*; Amsterdam.

ODIN, G.S. (comp.) and the Maastrichtian Working Group members 2001. The Campanian-Maastrichtian boundary: definition at Tercis (Landes, SW France) principle, procedure, and proposal. *In*: ODIN, G.S. (*Ed*.), The Campanian-Maastrichtian Stage Boundary. Characterisation at Tercis les Bains (France) and Correlation with Europe and other Continents. *Developments in Palaeontology and Stratigraphy*, **19**, 820-833. *Elsevier*; Amsterdam.

RIEGRAF, W. 1990. Baumberger Sandstein und Plattenkalke von Sendenhorst. *In*: WEIDERT, W.K. (*Ed*.), Klassische Fundstellen der Paläontologie, **2**, 175-189. *Goldschneck*, Stuttgart.

ROEMER, A. 1840-1841. Die Versteinerungen des norddeutschen Kreidegebirges. 1-145. Hannover.

SCHLÜTER, C.A. 1872. Cephalopoden der oberen deutschen Kreide. I. *Palaeontographica*, **21**, 1-120.

— 1876. Cephalopoden der oberen deutchen Kreide. II. *Palaeontolographica*, **24**, 1-144.

SCHMID, F. & ERNST, G. 1975. Ammoniten aus dem Campan der Lehrter Westmulde und ihre stratigraphische Bedeutung. 1. Teil: *Scaphites*, *Bostrychoceras* und *Hoploplacenticeras*. *Berichte der naturhistorischen Gesellschaft*, **119**, 315-359.

SCHÖNFELD, J. 1990. Zur Stratigraphie und Ökologie benthischer Foraminiferen im Schreibkreide-Richtprofil von Lägerdorf/Holstein. *Geologisches Jahrbuch*, **A 117**, 1-151.

SCHULZ, M.-G. 1978. Zur Litho- und Biostratigraphie des Obercampan-Untermaastricht von Lägerdorf und Kronsmoor (SW-Holstein). *Newsletters on Stratigraphy*, **7** (2), 73-89.

— 1979. Morphometrisch-variationsstatistische Untersuchungen zur Phylogenie der Belemniten-Gattung *Belemnella* im Untermaastricht NW-Europas. *Geologisches Jahrbuch*, **A 47**, 3-157.

SCHULZ, M.-G., ERNST, G., ERNST, H. & SCHMID, F. 1984. Coniacian to Maastrichtian stage boundaries in the standard section for the Upper Cretaceous white chalk of NW Germany (Lägerdorf-Kronsmoor-Hemmoor): Definitions and proposals. *Bulletin of the Geological Society of Denmark*, **33**, 203-215.

WALASZCZYK, I. 2004. Inoceramids and inoceramid biostratigraphy of the Upper Campanian to basal Maastrichtian of the Middle Vistula River section, central Poland. *Acta Geologica Polonica*, **54** (1), 95-168.

WIEDMANN, J. 1966. Stammesgeschichte und System der posttriadischen Ammonoideen; ein Überblick. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **125**, 49-79.

WRIGHT, C.W., CALLOMAN, J.H. & HOWARTH, M.K. 1996. Treatise on Invertebrate Paleontology, Part L, Mollusca 4: Cretaceous Ammonoidea. ii-xx + 1-362. *The Geological Society of America, Inc*. and *The University of Kansas*, Boulder, Colorado, and *Lawrence*, Kansas.

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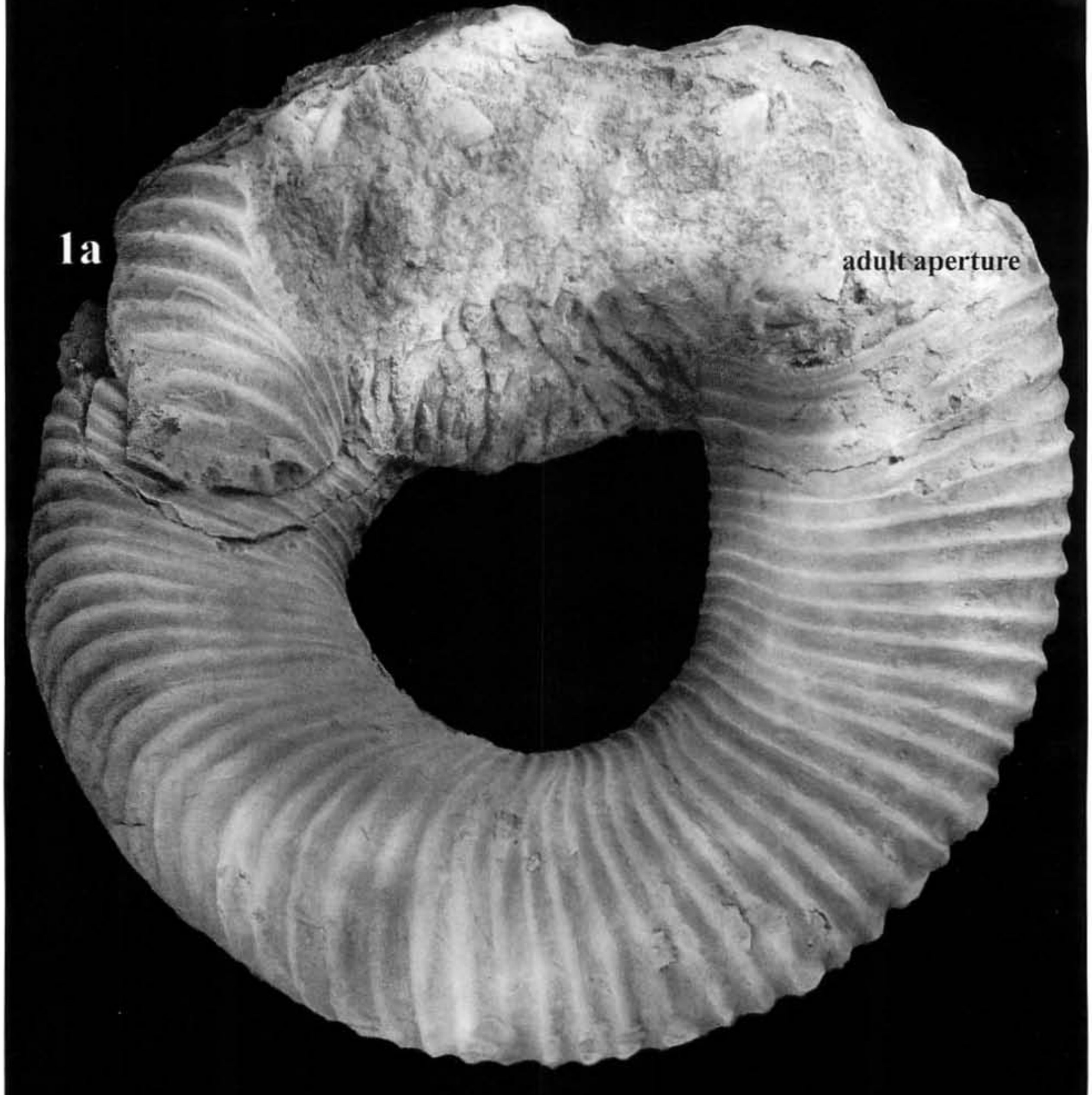
PLATE 1

Nostoceras (*Didymoceras*) *postremum* (BŁASZKIEWICZ, 1980). Ma13592. Lateral and ventral views. Complete C-shaped body chamber and younger portions of the last whorl. Macroconch with delicate regular ribbing and adult aperture. Gybsum carst in the collection of the BGR, original in the privat collection of W. DEMBSKI, Ahlten.

All figures × 0.75

1a



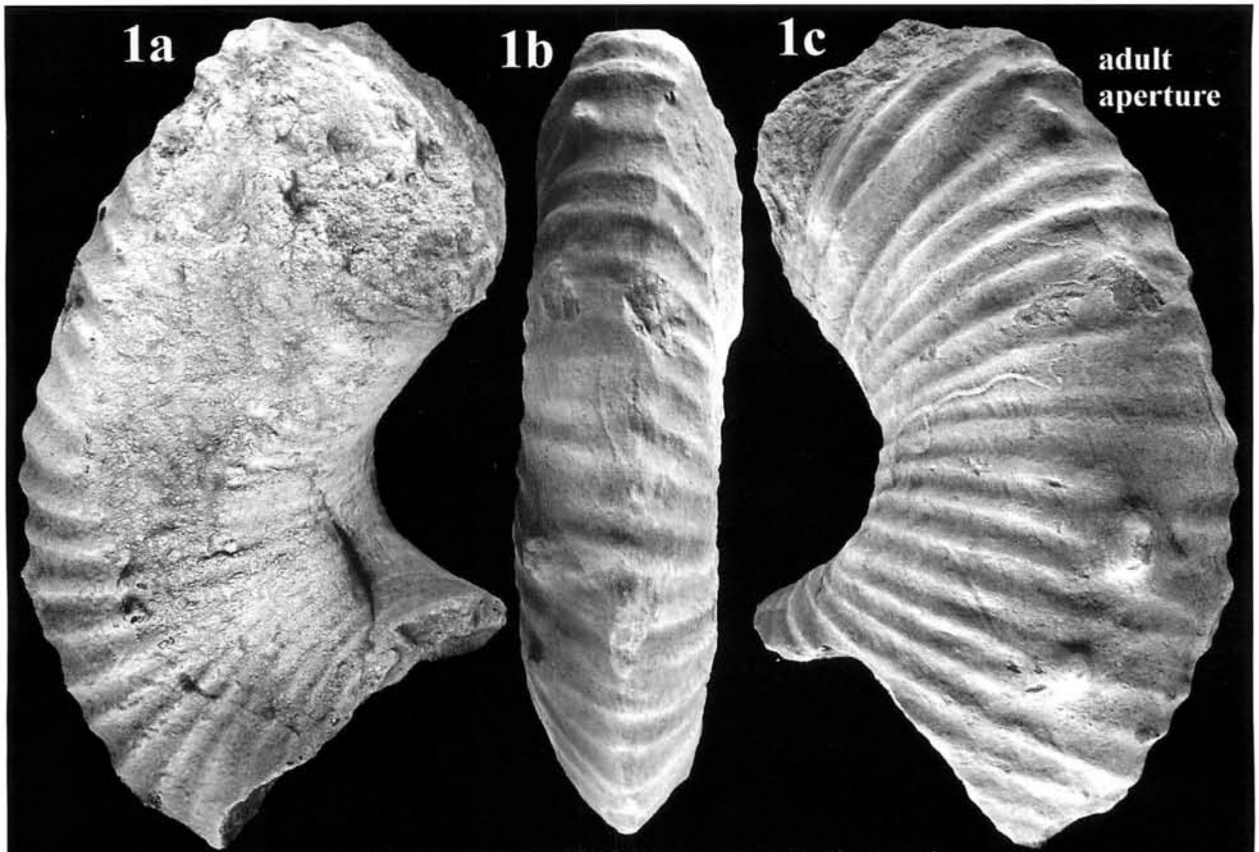
1b

PLATE 2

1 – *Nostoceras* (*Bostrychoceras*) *polyplocum* (ROEMER, 1841). Lateral, ventral, and dorsal views. Ma13597. Final portion of the body chamber. Macroconch with distinct collared constriction at the adult aperture.

2 – *Nostoceras* (*Didymoceras*) *postremum* (BŁASZKIEWICZ, 1980). Lateral view. Ma13593. Complete body chamber and younger portions of the last whorl. Microconch with non-fatal shell injury and adult aperture.

All figures are natural size


1a
1b
1c
adult aperture

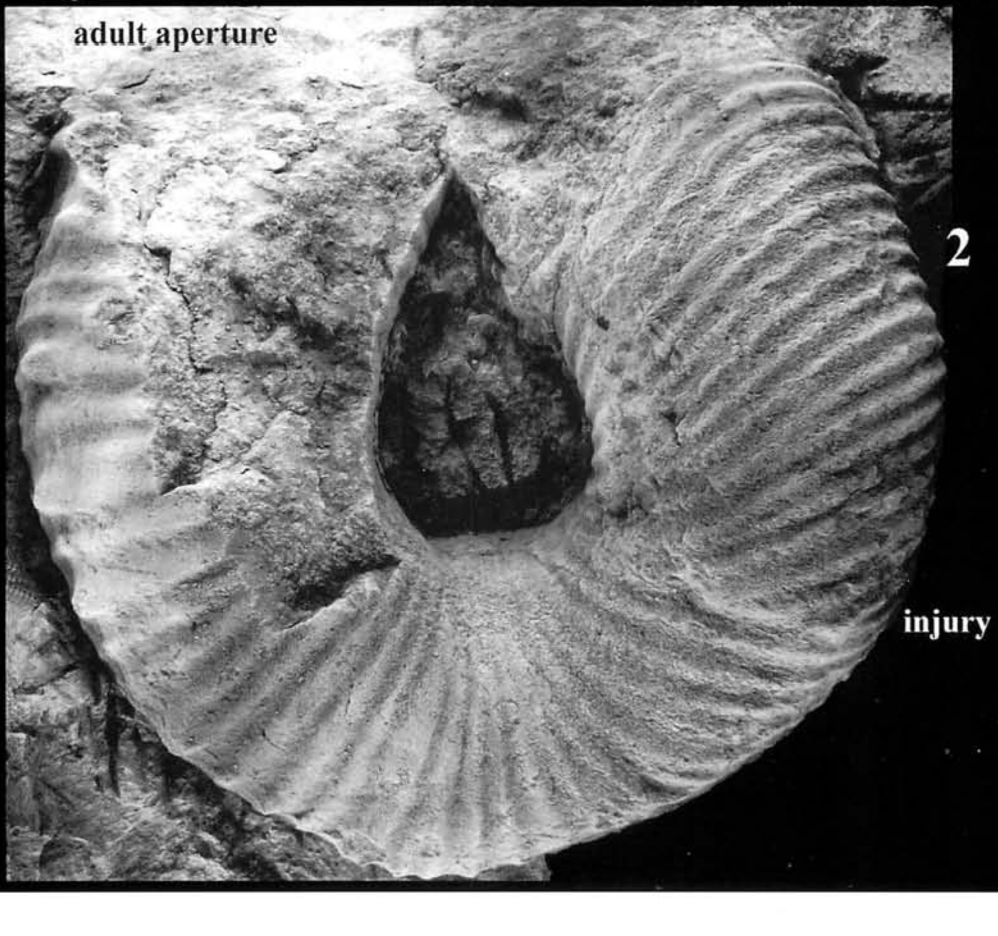

adult aperture
2
injury

PLATE 3

1 – *Nostoceras* (*Didymoceras*) *varium* (BŁASZKIEWICZ, 1980). Lateral and ventral views. Ma13599. Complete C-shaped body chamber and portions of the last whorl with delicate regular ribbing and adult aperture.

2 – *Nostoceras* (*Didymoceras*) *postremum* (BŁASZKIEWICZ, 1980). Lateral, ventral, and dorsal views. Ma13595. Complete body chamber of a microconch with adult aperture.

All figures are natural size


1a
adult aperture
1b
adult aperture
2a
2b
2c

PLATE 4

Nostoceras (*Didymoceras*) *postremum* (BŁASZKIEWICZ, 1980).

1 – Lateral view. Ma13594. Final portions of the body chamber. Macroconch with very coarse ribbing and adult aperture.
2 – Lateral view. Ma13598. Fragment of a macroconch with conspicuous ventrolateral clavi and spines.
3 – Lateral view. Ma13596. Portions of the body chamber of a macroconch.

All figures are natural size


adult aperture
1
2
3