

Late Campanian and Early Maastrichtian ammonites from the white chalk of Kronsmoor (northern Germany) – taxonomy and stratigraphy

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ABSTRACT:

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Hypophylloceras (*Neophylloceras*) *velledaeforme* (SCHLÜTER, 1872), *Anagaudryceras lueneburgense* (SCHLÜTER, 1872), *Saghalinites wrighti* BIRKELUND, 1965, *Pachydiscus* (*Pachydiscus*) *neubergicus* (VON HAUER, 1858), *Menuites* cf. *wittekindi* (SCHLÜTER, 1872), *Diplomoceras cylindraceum* (DEFRANCE, 1816), *Baculites vertebralis* LAMARCK, 1801, *Baculites knorrianus* DESMAREST, 1817, *Acanthoscaphites tridens* (KNER, 1848), and *Hoploscaphites constrictus* (J. SOWERBY, 1877) are described for the first time from Kronsmoor, the only continuous Campanian-Maastrichtian boundary succession of northern Germany. Combined with the slightly younger section at Hemmoor (30 km SW of Kronsmoor), thirteen ammonites species in all are known to date from the Maastrichtian. The material studied comprises species from the Upper Campanian *Belemnitella langei* to the Lower Maastrichtian *Belemnella sumensis* zones. Three species (*Baculites vertebralis*, *Baculites knorrianus*, *Hoploscaphites constrictus*) occur earlier here than elsewhere (e.g., Denmark). *Menuites* cf. *wittekindi*, formerly known only from the *Nostoceras polyplocum* Zone (Upper Campanian), occurs in the *Belemnella lanceolata* Zone at Kronsmoor. *Pachydiscus Neubergicus* and *Diplomoceras cylindraceum*, two of twelve markers for the base of the Maastrichtian at Tercis (GSSP, southwestern France), have their first occurrences at Kronsmoor significantly above that of *Belemnella lanceolata*, the belemnite marker for the base of the stage. Compared with Tercis, where the stage boundary was recommended between the FOs of both ammonite species, the Campanian – Maastrichtian boundary at Kronsmoor seems to be located within the *Belemnella pseudobtusa* Zone. Thus, the first occurrence of the genus *Belemnella* is of Late Campanian age, appearing c. 540 ky earlier than the base of the Maastrichtian as defined at the GSSP at Tercis.

Key words: Upper Cretaceous, Campanian-Maastrichtian boundary, Ammonites, Stratigraphy, Correlation, Northern Germany.

INTRODUCTION

The range of ammonite in the uppermost Campanian to Lower Maastrichtian successions of the Boreal Realm are still poorly known. In order to improve the data base, well-documented records of

ammonites in relation to other important index fossils, such as belemnites and nannoplankton, are needed in a sufficient number of sections, so that the ranges can be tested properly. Against this background, ammonite material from Kronsmoor has supplied important new stratigraphic data.

At the 'Second International Symposium on Cretaceous Stage Boundaries' (Brussels, 1995) the first occurrence of the ammonite *Pachydiscus neubergicus* (VON HAUER, 1858) was proposed as a potential marker for definition of the Campanian-Maastrichtian boundary at Tercis, southwestern France, the proposed boundary stratotype (ODIN 1996). This reflects the fact that this ammonite has a wide distribution outside the Boreal Realm (HANCOCK & KENNEDY 1993). However, in northern Germany *P. neubergicus* is rare and the biozonation of the Upper Campanian and Maastrichtian as well as the placement of the Campanian-Maastrichtian boundary itself rely on belemnites of the *Belemnitella* and *Belemnella* lineages (SCHULZ 1978, 1979; CHRISTENSEN 2000). Only in the Middle Vistula River valley in Poland have both ranges of ammonites and belemnites from the Campanian-Maastrichtian interval been recorded and documented in detail (BŁASZKIEWICZ 1980).

The potential of the Tercis section to act as a boundary stratotype was discussed by ODIN & Maastrichtian Working Group members (2001) and ODIN & LAMAURELLE (2001), who noted that it is of key importance in providing a section where Tethyan nannofossil and planktonic foraminiferal occurrences can be directly or indirectly related to Boreal index taxa. The Campanian-Maastrichtian Stage boundary was located where the most obvious biostratigraphic change is located. Twelve biostratigraphic criteria (biohorizons) were chosen, two of which are the first occurrences of ammonite taxa also represented at Krons Moor: the FO of *Pachydiscus neubergicus* lies c. 35 ky above and the FO of *Didymoceras cylindraceum* c. 165 ky below the arithmetic mean of the level 115.2 m at Tercis (ODIN & Maastrichtian

Working Group members 2001; ODIN & LAMAURELLE 2001). The Tercis section and the GSSP definition with twelve biohorizons was voted and ratified between 1999 and 2001. Therefore, a refined correlation between Tercis and Krons Moor is one of the main objectives of this paper.

HANCOCK & *al.* (1993) correlated the Tercis section with southeastern England, which in turn can be linked to the refined northern German Lower Maastrichtian *Belemnella* zonation of SCHULZ (1979), and demonstrated that the inferred first occurrences of *P. neubergicus* and *Hoploscaphites constrictus* at Tercis are at a level which is correlatable with a level within the *Belemnella obtusa* Zone. Tercis and Norfolk are correlated using echinoid ranges which suggest that the FO of *P. neubergicus* at Tercis would be contemporaneous (± 100 ky) with the FO of *Bn. lanceolata* in Norfolk (CHRISTENSEN & *al.* 2000), and in the same paper it was proposed to place the Campanian-Maastrichtian boundary at Krons Moor c. 8 m higher than the belemnite-based boundary. Based on geochemical evidence, ODIN & TURIN (2001) and ODIN (2001, figs 2, 3) even suggest a synchronicity of both levels. However, the recent discussion has turned and evidence starts to build that the first occurrence of *Belemnella* is of Late Campanian age and much older than the arithmetic mean level 115.2 m at Tercis (see for example: WALASZCZYK & *al.* 2002).

The complete Campanian-Maastrichtian boundary section at Krons Moor (Saturn quarry), about 50 km NW of Hamburg, is located on the Krempe diapir of the northern limb of the elongated salt structure 'Krempe-Hemmoor-Bevern' (Text-fig. 1). Ammonites have been collected bed by bed for the past forty years on the basis

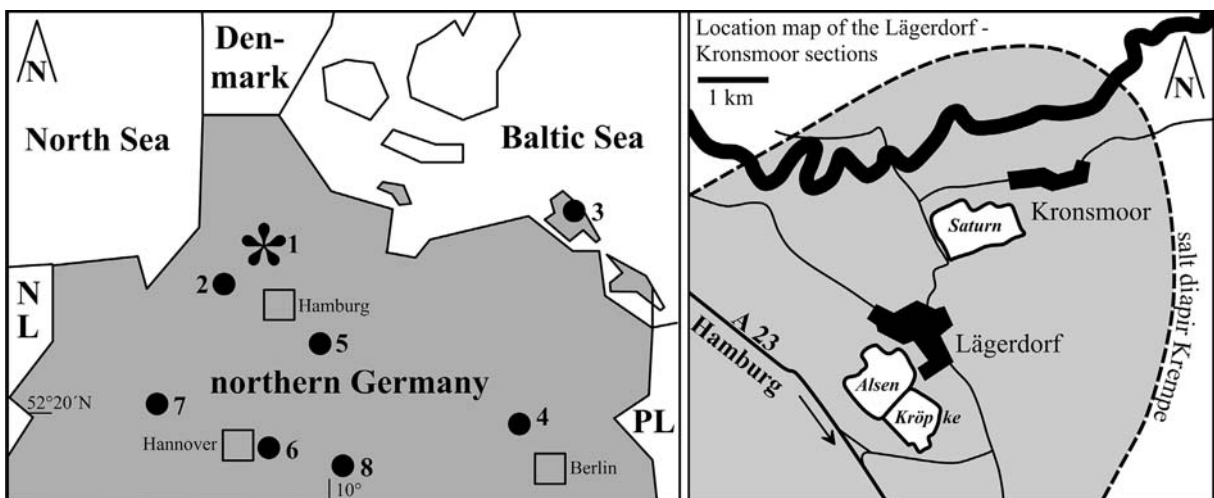


Fig. 1. Middle Campanian to Upper Maastrichtian sections in northern Germany (1 – Lägerdorf – Kronsmoor, 2 – Hemmoor, 3 – Rügen, 4 – borehole Nennhausen 2/63, 5 – Zeltberg / Lüneburg, 6 – Misburg + Ahlten + Ilten, 7 – Steweder Berg / Haldem, 8 – Beienrode Basin), and location map of the Lägerdorf-Krons Moor section (Middle Coniacian to Lower Maastrichtian)

of a detailed scheme of lithological marker beds and belemnite biozones. For the present paper, ammonites from three collections were studied:

- More than fifty specimens from the collection of Klaus ESSER, Pommernweg 4, D-25479 Ellerau, Germany. Owing to ongoing field work, the collection is permanently enlarged. Later, all macrofossils, which likewise include belemnites, nautiloids, echinoids, and brachiopods, will be completely transferred in a German natural history museum or a geoscience institute. Seventeen ammonites of the ESSER collection that are figured here (PIW2003VIII1 to PIW2003VIII17) are kept in the collection of the Institut für Paläontologie, Bayerische Julius-Maximilians-Universität, Pleicherwall 1, D-97070 Würzburg, Germany.
- The ammonite collection of the late Max-Gotthard SCHULZ, Kiel, was transferred to the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Stilleweg 2, D-30655 Hannover, Germany, and comprises two specimens from the Campanian of the

Alsen quarry at Lägerdorf (Ma13682 to Ma13683) and twenty-one specimens from the Saturn quarry at Krons Moor (Ma13684 to Ma13704).

- Four specimens from the collection of Christian NEUMANN, Museum für Naturkunde, Institut für Paläontologie, Invalidenstr. 43, D-10115 Berlin, Germany,

UPPER CAMPANIAN AND MAASTRICHTIAN SEQUENCES IN NORTHERN GERMANY

The Upper Campanian in northern Germany comprises different facies types representing shallow to deep marine environments (Text-fig 2). Deeper marine settings are characterised by white chalks ('Schreibkreide') and marl-limestone alternations. At the Steweder Berg (KAPLAN & RÖPER 1997), c. 180 km SW, and Lehrte West Syncline (NIEBUHR & *al.* 1997, 2000), c. 160 km S of Krons Moor, spiculitic opoka of shallower water origin crops out. In the Beienrode Basin, c. 220 km SE,

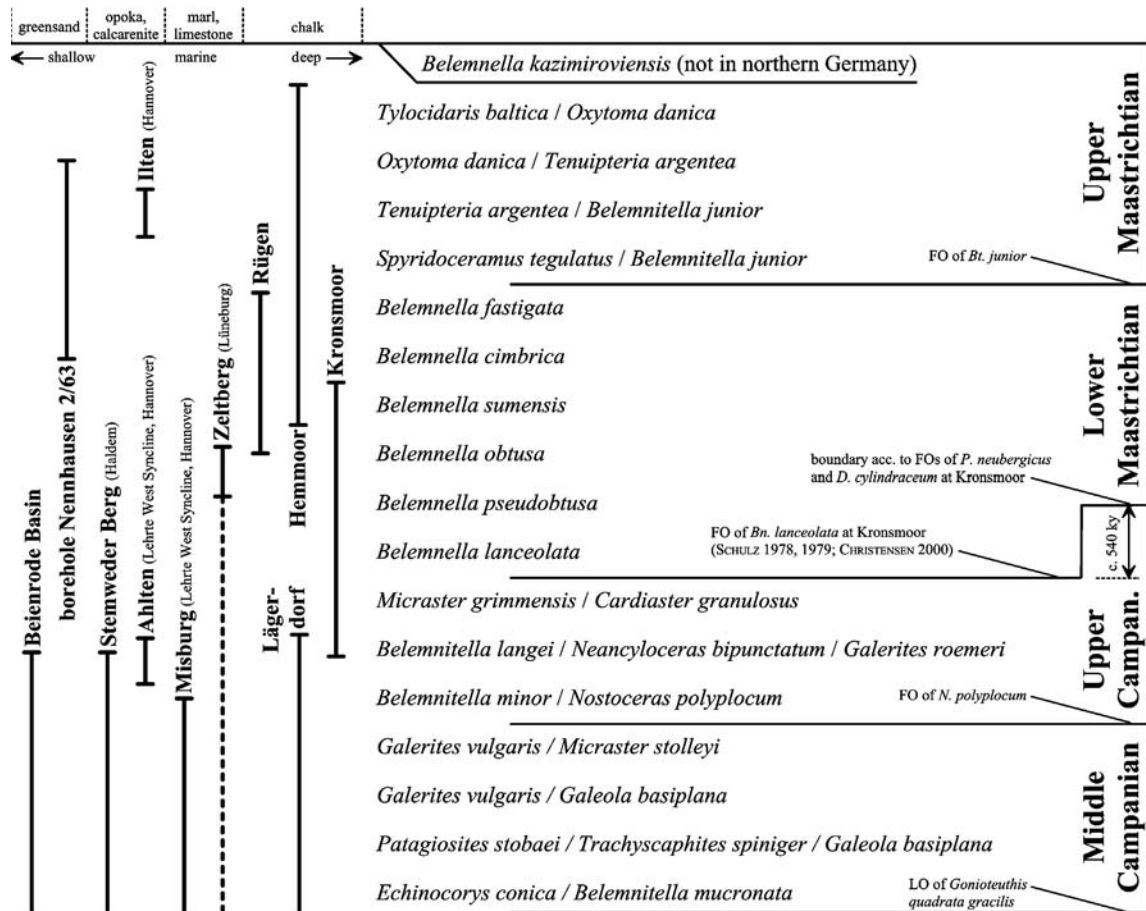


Fig. 2. Stratigraphic ranges and facies of Middle Campanian to Upper Maastrichtian sections in northern Germany. Beside of Ilten all sections bear ammonites. Different positions of the Campanian-Maastrichtian boundary are discussed in the text

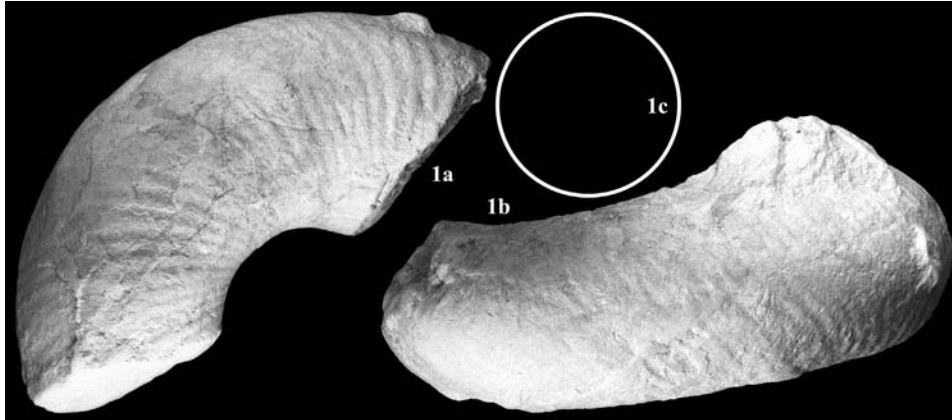


Fig. 3. *Nostoceras (Bostrychoceras) polyplacum* (ROEMER, 1841). Lateral and ventral views, and circular whorl section. Alsen quarry, Lägerdorf, F 100 - 9 m, basal *N. polyplacum* Zone. Coll. M.-G. SCHULZ. Ma13682

nearshore greensands were deposited (GRIEPENKERL 1889; NIEBUHR & ERNST 1991; NIEBUHR 1995). However, apart from the white chalk section of Lägerdorf-Kronsmoor (SCHULZ & al. 1984), marine sedimentation was terminated by the *Nostoceras polyplacum* Regression in the Late Campanian *Neancyloceras bipunctatum* / *Galerites roemeri* (= *Belemnitella langei*) Zone (NIEBUHR 1995; NIEBUHR & al. 1997).

The Alsen and Kröpke quarries at Lägerdorf, 2 km S of Kronsmoor (Text-fig. 1), comprise the Middle Coniacian to Upper Campanian (SCHULZ & al. 1984). The base of the Upper Campanian *Nostoceras polyplacum* Zone here was placed c. 90 m below the Campanian-Maastrichtian boundary in belemnite terms on the basis of three specimens of the index taxon from the same horizon (SCHULZ 1978, p. 80), only one of which was found in his collection (Ma13682) and is figured here for the first time (Text-fig. 3). Quarrying has progressed at the Alsen quarry, and the former gap in exposure between the Lägerdorf and Kronsmoor sections (SCHULZ & al. 1984) has recently been filled. Currently, the Lägerdorf (Alsen) and Kronsmoor (Saturn) quarries overlap stratigraphically within the *Belemnitella langei* Zone.

The Saturn quarry at Kronsmoor is the only Campanian-Maastrichtian boundary succession available in northern Germany. A total sediment thickness of c. 100 m (= c. 4 my using accumulation rates of 24.5 m/my, EHRMANN 1986) is exposed, comprising the Late Campanian *Belemnitella langei* to Early Maastrichtian *Belemnella sumensis* zones of SCHULZ (1978, 1979). The white chalk has average carbonate contents of 92 to 97 % (EHRMANN 1986). The lower 46 m of the section (Upper Campanian in belemnite terms) comprise a few thin marly beds and weak, discontinuous burrow horizons. Only a single flint bed in the lower part of the *Bt. langei* Zone is exposed. The fossil content is low and predomi-

nantly consists of belemnites (*Belemnitella langei*, *Bt. schulzi*) as well as irregular echinoids (*Galerites roemeri*, *Micraster grimmensis*, *Cardiaster granulosis*).

The nodular flint layer F 600 linked to the first occurrence of the belemnite genus *Belemnella*, especially *Bn. lanceolata*, marks the Campanian-Maastrichtian boundary in belemnite terms (SCHULZ 1978, 1979). Of the above-mentioned fossils, only *Galerites roemeri* crosses the boundary. In the upper 53 m of the section (Lower Maastrichtian in belemnite terms) three distinct marly packages with carbonate contents of c. 90 % appear, which can be traced across the quarry. The fossil content of the lowermost 3 to 4 m of the *Bn. lanceolata* Zone is extremely low. From the first marl package upwards, the index belemnite occurs more frequently. Ammonites, however, remain rare up to the middle *Belemnella obtusa* Zone. The *Belemnella sumensis* Zone is the most fossiliferous part of the section, having yielded belemnites, ammonites, nautiloids, irregular echinoids, crinoids, brachiopods, and a few bivalves (see SCHULZ & al. 1984). Only the topmost 14 m of the *Bn. sumensis* Zone contain more or less discontinuous nodular flint layers, one of them capped by an omission surface with abundant baculitids, topping weakly lithified chalk (see Pl. 3, Fig. 4).

The white chalk section at Hemmoor, c. 30 km SW of Kronsmoor, comprises the Lower to Upper Maastrichtian; however, the upper Upper Maastrichtian *Belemnella kazimiroviensis* Zone is missing (SCHMID 1982). Kronsmoor and Hemmoor overlap stratigraphically more than 20 m within the *Bn. sumensis* Zone (SCHULZ 1979). The Lower Maastrichtian chalk of Rügen (REICH & FRENZEL 2001), c. 280 km E of Kronsmoor, has been dated as the Early Maastrichtian *Bn. obtusa* to *Bn. fastigata* zones according to SCHULZ (1979). The Zeltberg section at Lüneburg, c. 100 km SE of Kronsmoor, has been referred to the 'Mucronaten-Schichten', ranging from

Middle (= lower Upper) Campanian to lower part of the Lower Maastrichtian according to SCHMID (1955). However, SCHULZ (1979) documented only the Early Maastrichtian *Belemnella obtusa* Zone. Borehole Nennhausen 2/63, 25 km NW of Berlin and c. 300 km SE of Kronsmoor, documents the *Belemnella cimbrica* to *Oxytoma danica* / *Tenuipteria argentea* zones, but in a shallow-marine greensand facies (AHRENS & al. 1965; NIEBUHR & al. 2000). The nearshore conglomerates and bryozoan calcarenites of Ilten near Hannover are of *Tenuipteria argentea* / *Belemnitella junior* Zone age (lower Upper Maastrichtian), however, ammonites are missing (VOIGT 1951; NIEBUHR & al. 2000).

SYSTEMATIC PALAEOONTOLOGY

The ranges of ammonites at Kronsmoor (Text-fig. 4) are indicated by metres below (-), above (+) or around (\pm) marly layers (mB), distinct burrow horizons (G), discontinuous burrow horizons (Gb), firm grounds (Fg), and flint beds (F). The flint layer F 600 marks the Campanian-Maastrichtian boundary in belemnite terms (SCHULZ 1978, 1979) and, thus, beds with numbers less than 600 belong to the Campanian, beds with numbers above 600 to the Maastrichtian as defined in belemnite terms. Where possible, specimens are interpreted as macroconchs (M) or microconchs (m), based on criteria mentioned below. All dimension of specimens given are in millimetres. Wb/Wh ratio = whorl breadth / whorl height ratio. The umbilical ratio of planispiral taxa is given in percent of the maximum shell diameter. The term *rib index* as applied to heteromorphs is the number of ribs in a distance equal to the whorl height.

Order Ammonoidea VON ZITTEL, 1884
 Suborder Phylloceratina ARKELL, 1950
 Family Phylloceratidae VON ZITTEL, 1884
 Subfamily Phylloceratinae VON ZITTEL, 1884

Genus *Hypophylloceras* SALFELD, 1924

TYPE SPECIES: *Phylloceras onoense* STANTON, 1896, p. 74; by monotypy.

Subgenus *Neophylloceras* SHIMIZU, 1934

TYPE SPECIES: *Ammonites (Scaphites?) ramosus* MEEK, 1857. For a discussion of the subgenus see BIRKELUND (1965).

Hypophylloceras (Neophylloceras) velledaeforme
 (SCHLÜTER, 1872)
 (Pl. 1, Figs 1-3)

1872. *Ammonites velledaeformis* SCHLÜTER, p. 60, pl. 18, figs 4-7.

1993. *Hypophylloceras (Neophylloceras) velledaeforme* (SCHLÜTER, 1872); BIRKELUND, p. 43, pl. 1, figs 1, 2.

TYPES: The original of SCHLÜTER (1872, pl. 18, fig. 7) was designated lectotype by BIRKELUND (1993). It is kept in the Museum des Geowissenschaftlichen Zentrums der Universität Göttingen, no. 65-3. Locus typicus is Lüneburg, Lower Saxony, northern Germany. Stratum typicum is the 'Mucronaten-Schichten', ranging from the Middle (= lower Upper) Campanian to lower part of the Lower Maastrichtian according to SCHMID (1955). At the Zeltberg section of Lüneburg, SCHULZ (1979) was able to document the Early Maastrichtian *Belemnella obtusa* Zone only.

MATERIAL: Three specimens – from mB 594 \pm 2 m (Ma13686), Gb 616 + 0.9 m (Ma13684), and G 620 + 1.3 m (Ma13685).

DESCRIPTION: All specimens are parts of phragmocones. The largest, but badly crushed specimen Ma13686 (Pl. 1, Fig. 3), which seems to have been over 80 mm in diameter, has visible septa. The two more complete specimens (Pl. 1, Figs 1, 2) show a very narrow umbilicus and Wb/Wh ratios of 0.45 and 0.47. Whorl section is strongly compressed and more or less lanceolate with the maximum whorl width at the inner flanks. The surface is covered by an extremely fine ribbing. Primary ribs arise at the umbilical wall, but get more distinct above the inner third of the flank. The ribs are narrow, biconcave and prorsiradiate, strengthened on the outer flanks and cross the venter in a convexity. Few secondaries appear first on the inner third of the flank and additional intercalated ribs arise at various points. Complex sutures, characteristic of this subgenus, are seen in both specimens. The small nucleus of specimen Ma13684 is smooth (Pl. 1, Fig. 1b).

DISCUSSION: Material from Kronsmoor is very similar to the Lüneburg specimen figured by SCHLÜTER (1872, pl. 18, figs 4, 5). According to him, septate phragmocones of *H. (N.) velledaeforme* may reach a size of 80 mm in diameter which is also the maximum size of the septate specimens of Kronsmoor. Comparisons of the sutures of the specimens with those of the lectotype (SCHLÜTER 1872, pl. 18, fig. 7; see also RAVN 1902, pl. 3, fig. 12) are difficult because of poor preservation, but show the great complexity with characteristic leaf-like lobes and saddles.

The smallest specimen with a diameter of 40 mm (Pl. 1, Fig. 2) is close to the largest *H. (N.) velledaeforme* from Denmark as figured by BIRKELUND (1993, pl. 1, fig. 1). It differs from that specimen in its more compressed whorl section and smaller Wb/Wh ratio.

STRATIGRAPHY AND DISTRIBUTION: This species appears to be rare and both the stratigraphic range and intraspecific variation are more or less unknown (see BIRKELUND 1993). Up to now, *Hypophylloceras (N.) velledaeforme* was known exclusively from the *Belemnella obtusa* Zone of Lüneburg (SCHLÜTER 1872) and the Upper Maastrichtian of Denmark (BIRKELUND 1993). Two specimens from Krons Moor correspond in stratigraphic position to records from Lüneburg, but Ma13686 suggests a first occurrence of the species in the upper *Micraster grimmensis* / *Cardiaster granulatus* Zone, c. 14 m below the Campanian-Maastrichtian boundary in belemnite terms.

Suborder Lytoceratina HYATT, 1889
Superfamily Tetragnostidae HYATT, 1900
Family Gaudryceratidae SPATH, 1927

Genus *Anagaudryceras* SHIMIZU, 1934

TYPE SPECIES: *Ammonites sacya* FORBES, 1846, p. 113, pl. 14, fig. 9; by original designation. For a discussion of the genus see KENNEDY & KLINGER (1979) and WRIGHT & KENNEDY (1984).

Anagaudryceras lueneburgense (SCHLÜTER, 1872)
(Pl. 1, Fig. 5)

1872. *Ammonites Lüneburgensis* SCHLÜTER, p. 62, pl. 18, figs 8, 9.
1986. *Anagaudryceras lueneburgense* (SCHLÜTER, 1872);
KENNEDY & SUMMESBERGER, p. 185, pl. 3, fig. 6; pl. 15, fig. 4 (with additional synonymy).
1993. *Anagaudryceras lueneburgense* (SCHLÜTER, 1872);
BIRKELUND, p. 44, pl. 1, figs 3-5.
2001. *Anagaudryceras lueneburgense* (SCHLÜTER, 1872);
COURVILLE & ODIN, p. 531, pl. 1, figs 1-3.

TYPES: Erroneously, BIRKELUND (1982) designated two specimens (SCHLÜTER 1872, pl. 18, figs 8, 9) as lectotypes. Thus, the original specimen of SCHLÜTER (1872, pl. 18, fig. 8) is herein re-designated lectotype. It is kept in the Museum des Geowissenschaftlichen Zentrums der Universität Göttingen, no. 65-4, where the paralec-

totype (SCHLÜTER 1872, pl. 18, fig. 9), the only other specimen belonging to the type series, is also kept. Locus typicus is Lüneburg, Lower Saxony, northern Germany. Stratum typicum is the 'Mucronaten-Schichten', ranging from lower Upper (= Middle) Campanian to lower part of the Lower Maastrichtian according to SCHMID (1955). At the Zeltberg section of Lüneburg, SCHULZ (1979) documented the Early Maastrichtian *Belemnella obtusa* Zone only.

MATERIAL: A single specimen – from mB 607 + 0.2 m (Ma13687).

DESCRIPTION: The specimen is a phragmocone > 39 mm in diameter, consisting of a partial internal mould, and an external mould. Portions of the youngest five whorls are visible, and only some of them show four irregularly spaced prorsiradiate, straight collar-ribs and associated constrictions.

DISCUSSION: The specimen is badly crushed and referred to *A. lueneburgense* with some hesitation. The lectotype as well as many other figured specimens (BIRKELUND 1993; HANCOCK & KENNEDY 1993) are fragments of body chambers that show the characteristic constrictions of the species much better than the Krons Moor specimen. However, the close similarity in ornament appears to substantiate the present assignment.

STRATIGRAPHY AND DISTRIBUTION: The Krons Moor specimen is from the *Belemnella lanceolata* Zone. Other occurrences in northern Germany are from the Lower Maastrichtian of Rügen (SCHLÜTER 1874), the *Belemnella obtusa* Zone of Lüneburg (SCHLÜTER 1872), and the Late Maastrichtian *Belemnella junior* Zone of Hemmoor (BIRKELUND 1982). Furthermore, it has been recorded from the Lower-Upper Maastrichtian boundary interval of Denmark (BIRKELUND 1993), the *Bn. sumensis* Zone of Neuberg, Austria (KENNEDY & SUMMESBERGER 1986) as well as the uppermost Campanian *Nostoceras hyatti* Zone at Tercis, southwestern France (HANCOCK & KENNEDY 1993; COURVILLE & ODIN 2001), which seems to document its lowermost occurrence.

Family Tetragnostidae HYATT, 1900

Genus *Saghalinites* WRIGHT & MATSUMOTO, 1954

TYPE SPECIES: *Ammonites cala* FORBES, 1846, p. 104, pl. 8, fig. 4; by original designation. For discussion of the genus see BIRKELUND (1965).

Saghalinites wrighti BIRKELUND, 1965
(Pl. 1, Fig. 4)

1876. *Ammonites* sp. n.? SCHLÜTER, p. 161, pl. 42, figs 6, 7.
1965. *Saghalinites wrighti* BIRKELUND, p. 30, pl. 1, fig. 5; pl. 2, figs 1-5; pl. 3, fig. 1; text-figs 14-25.
1993. *Saghalinites wrighti* BIRKELUND, 1965; BIRKELUND, p. 45, pl. 1, figs 6, 7; pl. 2, figs 1, 3, 4, 6.
1993. *Saghalinites wrighti* BIRKELUND, 1965; WARD & KENNEDY, p. 21, figs 19.3, 19.4, 19.8, 19.12, 20.1-20.3.
2001. *Saghalinites wrighti* BIRKELUND, 1969; COURVILLE & ODIN, p. 531, pl. 1, figs 6-9.

TYPES: Holotype is MGUH 9747 of BIRKELUND (1965, pl. 2, fig. 5, text-fig. 19), kept in the Geological Museum of Copenhagen. Locus typicus is Nûgssuaq, West Greenland. Stratum typicum is the 'Oyster-ammonite conglomerate', locality III, either upper Lower Maastrichtian or lower Upper Maastrichtian (see BIRKELUND 1993).

MATERIAL: A single specimen – from G 615 (PIW2003VIII).

DESCRIPTION: This small specimen is a phragmocone of 27 mm in diameter and an umbilical ratio of 44 %. The umbilicus is broad and shallow, with a low, flattened umbilical wall. The youngest 4 to 5 whorls are visible, the whorl section of which is rounded. Each whorl covers nearly half of the previous one. Constrictions and suture line are not visible.

DISCUSSION: The specimen is referred to *S. wrighti* on the basis of the characteristic umbilical ratio and the absence of constrictions, not visible in most of the Danish specimens either (SCHLÜTER 1876; BIRKELUND 1993).

STRATIGRAPHY AND DISTRIBUTION: The single specimen from Kronsmoor is from the *Belemnella obtusa* Zone. The single specimen from Hemmoor (BIRKELUND 1982) was collected from the upper Lower Maastrichtian, the exact level being unknown. The material from West Greenland and Denmark comes from the Lower-Upper Maastrichtian boundary interval (BIRKELUND 1993). The specimens from Neuberg, Austria, is *Belemnella sumensis* Zone age (KENNEDY & SUMMESBERGER 1986). In the coastal outcrops in the Biscay region of France and Spain, *Saghalinites wrighti* ranges from the Lower Maastrichtian into the upper Upper Maastrichtian (HANCOCK & KENNEDY 1993; WARD & KENNEDY 1993). Two specimens from the latest Campanian *Nostoceras hyatti* Zone at Tercis (COURVILLE & ODIN 2001) appear to document its lowermost occurrence.

Suborder Ammonitina HYATT, 1889
Superfamily Desmocerataceae VON ZITTEL, 1895
Family Pachydiscidae SPATH, 1922

Genus and Subgenus *Pachydiscus* VON ZITTEL, 1884

TYPE SPECIES: *Ammonites neubergicus* VON HAUER, 1858, p. 12, pl. 2, figs 1-3; non pl. 3, figs 1, 2; by subsequent designation of DE GROSSOUVRE (1894, p. 177). For a discussion of the genus and subgenera see KENNEDY & SUMMESBERGER (1986) and KENNEDY (1986b).

Pachydiscus (Pachydiscus) neubergicus (VON HAUER, 1858)
(Pl. 1, Figs 6, 7)

1858. *Ammonites Neubergicus* VON HAUER, p. 12 (*pars*), pl. 2, figs 1-3.
1872. *Ammonites Neubergicus* VON HAUER; SCHLÜTER, p. 59, pl. 18, figs 1-3.
1986. *Pachydiscus (Pachydiscus) neubergicus* (VON HAUER, 1858); KENNEDY & SUMMESBERGER, p. 189, pl. 2, figs 1, 2; pl. 3, figs 1-3; pl. 4, figs 1-5; pl. 5, figs 1, 4, 5; pl. 6, figs 1, 2; pl. 15, figs 7, 8; text-fig. 5 (with full synonymy).
1993. *Pachydiscus (Pachydiscus) neubergicus* (VON HAUER, 1858); BIRKELUND, p. 47, pl. 4, figs 1, 2; pl. 8, fig. 1; pl. 10, fig. 1.
2001. *Pachydiscus neubergicus* (VON HAUER, 1858); COURVILLE & ODIN, p. 533, pl. 6, figs 48-50.
2001. *Pachydiscus neubergicus* (VON HAUER, 1858); KÜCHLER & *al.*, pl. 3, figs 1-3, 6, 7.

TYPES: Lectotype is the original of VON HAUER (1858, p. 12, pl. 2, figs 1, 2) by the subsequent designation of DE GROSSOUVRE (1894, p. 209), kept in the collection of the Geologische Bundesanstalt, Wien, no. 1858.01.6. Locus typicus is Neuberg, Steiermark, Austria. Stratum typicum is the middle to possibly upper *Belemnella sumensis* Zone (see KENNEDY & SUMMESBERGER 1986, p. 200).

MATERIAL: Two specimens – between G 595 and G 610 (Ma13688), and G 615 (PIW2003VII2).

DESCRIPTION: Both specimens are nuclei. Coiling is relatively involute, with half to two-thirds of the previous whorl covered. The *ex situ* specimen Ma13688 (Pl. 1, Fig. 6) has an umbilical ratio of 27 % at a diameter of 75 mm, and the *in situ* specimen PIW2003VII2 (Pl. 1, Fig. 7) 26 % at a diameter of 47 mm. The whorl section appears to have been compressed with rounded inner

and convergent outer flanks, and a narrowly rounded venter. In both specimens, twelve distant primary ribs per whorl arise close to the umbilical seam and are nearly straight up to the outer portion of the flanks. The primaries are strengthened on the inner third of the flanks, giving rise to umbilical bullae, and bifurcate at mid-flanks, where secondaries and occasional intercalated ribs appear. Ventral and primary ribs have a ratio of 3.2. At the venter in both specimens, the siphonal line is visible. In the umbilicus of PIW2003VII2 portions of three inner whorls are seen (Pl. 1, Fig. 7).

DISCUSSION: The Krons Moor material is close to the Neuberg lectotype and the small topotypes of this species (see KENNEDY & SUMMESBERGER 1986). Both lectotype and topotypes seem to differ from the Krons Moor material only in having at least two primary ribs more and a slightly higher proportion of secondaries and occasional intercalated ribs. The ventral / primary rib ratio of 3.2 is nearly equivalent to that of the lectotype with 3.1 (50 ventral ribs / 16 primary ribs with umbilical bullae, see KENNEDY & SUMMESBERGER 1986), the topotypes having ratios of 2.8 to 4.3. The differences are probably due to the fact that both Krons Moor specimens are even smaller than the Neuberg material.

In diameter, number of primary ribs as well as the ventral / primary rib ratio, the Krons Moor specimens are extremely close to the specimen from Lüneburg figured by SCHLÜTER (1872, pl. 18, figs 1, 2). BŁASZKIEWICZ (1980) referred SCHLÜTER's specimen to his subspecies *raricostatus*. However, the holotype of *P. neubergicus raricostatus* BŁASZKIEWICZ (BŁASZKIEWICZ 1980, pl. 36, figs 3, 4, 8) is so close to topotypes of *P. neubergicus sensu stricto* that KENNEDY & SUMMESBERGER (1986) did not separate that subspecies. Furthermore, Danish specimens (see BIRKELUND 1993), especially the specimen in her pl. 10, fig. 1, unfortunately found *ex situ*, is closely comparable.

STRATIGRAPHY AND DISTRIBUTION: *Pachydiscus (Pachydiscus) neubergicus* has been described from a great number of localities in Europe, Russia, Africa, India and Australia. It is an index of the Lower Maastrichtian and its first occurrence seems to be the only biomarker on which consensus was reached for placing the Campanian-Maastrichtian boundary (see ODIN 1996). In general, the FO of this species at Tercis has been accepted as the base of the Maastrichtian, in fact, it is located 0.9 m above the arithmetic mean level of the GSSP (ODIN & Maastrichtian Working Group members 2001, tab. 1). Unfortunately, the exact provenance of the *ex situ* specimen from around the Campanian-Maastrichtian boundary at Krons Moor cannot be established unequivocally (see 'Stratigraphic results').

However, PIW2003VII2 (Pl. 1, Fig. 7) is fairly well constrained at the base of the *Belemnella obtusa* Zone. Furthermore, in northern Germany SCHULZ & al. (1984) referred *P. neubergicus* from Lüneburg to the *Bn. obtusa* Zone, but it is worthy of note that SCHMID (1955, tab. 2) recorded only a single *in situ* specimen of this species, found c. 2 m above the first occurrence of *Bn. lanceolata*. The SCHLÜTER specimens from Lüneburg (1872, pl. 18, figs 1-3) were found *ex situ*. The type material of *P. (P.) neubergicus* from Neuberg is dated as *Bn. sumensis* Zone (KENNEDY & SUMMESBERGER 1986), while BŁASZKIEWICZ (1980) referred Polish material of *P. neubergicus raricostatus* to the lower Lower Maastrichtian and *P. n. neubergicus* to the upper Lower Maastrichtian. In the Biscay region of France and Spain, *P. (P.) n. neubergicus* ranges from low in the Lower Maastrichtian to low in the Upper Maastrichtian (WARD & KENNEDY 1993), while at Tercis the first occurrence of *P. neubergicus* is not younger than 20-40 ky than the time of deposition of the recommended level of the Campanian-Maastrichtian boundary (ODIN & al. 2001; ODIN & LAMAURELLE 2001). In the Maastrichtian type area the species is restricted to the basal *Bn. sumensis* to lower *Bn. cimbrica* zones (JAGT & FELDER 2003). The FO of *P. neubergicus* in Denmark is much higher in comparison to other sections: the three stratigraphically located specimens cover the Lower-Upper Maastrichtian boundary (BIRKELUND 1993). In Boreal sections the *Bn. pseudobtusa* (probably find of the *ex situ* specimen, see 'Stratigraphic Results') to basal *Bn. obtusa* zones are taken here to be the maximum age of *P. neubergicus*.

Genus *Menuites* SPATH, 1922

TYPE SPECIES: *Ammonites menu* FORBES, 1846, p. 111, pl. 10, fig. 1; by original designation. For a discussion of the genus see COBBAN & KENNEDY (1993) and KENNEDY & KAPLAN (1997).

Menuites cf. wittekindi (SCHLÜTER, 1876) (Pl. 2, Fig. 1)

- cf. 1872. *Ammonites robustus* SCHLÜTER, p. 67 (*pars*), pl. 21, figs 5, 6 and ?7, 8; pl. 22, figs 1-3.
- cf. 1876. *Ammonites Wittekindi*; SCHLÜTER, p. 160 (*pars*).
- cf. 1980. *Anapachydiscus wittekindi* (SCHLÜTER); BŁASZKIEWICZ, p. 50, pl. 42, figs 1, 2; pl. 43, fig. 2; pl. 44, figs 1-6; pl. 45, figs 1-6; pl. 46, figs 1-3; pl. 47, figs 1, 2; pl. 48, figs 3, 4; pl. 49, figs 1, 3; pl. 50, figs 2, 3; pl. 51, figs 1, 2; pl. 52, figs 1, 2; pl. 53, figs 1, 2.
- cf. 1997. *Menuites wittekindi* (SCHLÜTER, 1872); KENNEDY & KAPLAN, p. 47, pl. 16, fig. 1; pl. 20, figs 2, 3; pl. 21, fig. 1;

pl. 29, figs 1-4; pls 30-32; pls 33, 34; pl. 35, fig. 1; pl. 36, fig. 1; pl. 38, fig. 3 (with synonymy).

? 2001. *Pachydiscus* sp. ou *Menuites* sp.; COURVILLE & ODIN, p. 535, pl. 2, fig. 13.

TYPES: Lectotype is one of SCHLÜTER's specimens (1872, pl. 22, figs 1, 2) designated by BŁASZKIEWICZ (1980). It was illustrated by KENNEDY & KAPLAN (1997, pl. 36) and is kept at the Institut für Paläontologie, Rheinische Friedrich-Wilhelms-Universität at Bonn, Germany. Locus typicus is the Steweder Berg ('Haldem'), Dammer Oberkreidemulde, Lower Saxony, northern Germany. Stratum typicum is the 'Obere Haldem-Schichten' which have been referred to the *Belemnitella minor* / *Nostoceras polyplacum* Zone, Upper Campanian (KENNEDY & KAPLAN 1997).

MATERIAL: A single specimen between mB 603 and mB 607 (Ma13689).

DESCRIPTION: This macroconch is 140 mm in diameter and represents a growth stage of a comparatively young individual with ribs and umbilical bullae as well as the beginning of a later (middle) growth stage, in which ornament effaces. The specimen is wholly septate with complex intricate sutures. Coiling is involute, more than two thirds of the previous whorl covered; the umbilical ratio has a mean of 22 % (see Table 1). Flanks and venter are broadly rounded, with the greatest breadth at the inner flank. Wb/Wh ratios are between 0.97 in the early and 1.12 in the middle growth stage.

In the early growth stage (diameter < 105 mm), twelve weak primary ribs appear at the umbilical wall and are strengthened at the umbilical shoulder, giving rise to long umbilical bullae, and bifurcate in most cases at the greatest breadth of the flanks. Occasionally intercalated ribs appear at the outer flanks. The ribs are distant, rounded, straight to weakly prorsiradiate, and cross the venter in broad convexity interrupted on the mould by a narrow groove marking the siphonal line. Ventral and primary ribs have a ratio of c. 3. Ribbing shows a very regular pattern.

In the middle growth stage (diameter > 105 mm), the ornament starts to efface, the inner and middle flanks becoming more or less smooth. Between 105 to 130 mm in diameter, eight very weak ventral ribs appear. At the last half whorl of the specimen (diameter > 130 mm), flanks and venter are completely smooth and only the siphonal line is visible.

DISCUSSION: This specimen relates to the *Anapachydiscus-Menuites* morphogroup in showing

massive, involute whorls and umbilical bullae giving rise to paired ribs. This morphogroup has been referred to the genus *Menuites* by HANCOCK & KENNEDY (1993), following the view expressed by WARD & KENNEDY (1993) that *Anapachydiscus* and *Menuites* represent a sexually dimorphic pair, with the latter name having priority.

From the Upper Campanian of northern and central Europe, three important species of *Menuites* have been described: *Menuites wittekindi*, *M. portlocki* and *M. vistulensis*. *Menuites wittekindi* differs from *M. portlocki* and *M. vistulensis* in showing a more or less smooth middle growth stage (see BŁASZKIEWICZ 1980) and ribbing with more than 30 ribs per inner whorl of nuclei, i.e. much denser than that of *M. portlocki* (24 ribs, see KENNEDY & KAPLAN 1997). Macroconchs of *M. wittekindi* seem to have the densest ornament of these three species, microconchs are unknown in the large suite of specimens from Haldem (see KENNEDY & KAPLAN 1997, p. 49).

Two small specimens of '*Pachydiscus*' *wittekindi* from Rügen have diameters of less than 95 mm and show the early growth stage with ribs and umbilical bullae (WOLANSKY 1932). However, these specimens are poorly preserved and display only the early growth stages; thus, they can be compared only with reservation. Similarities exist in the early growth stage of the specimen presented here and one from Haldem (KENNEDY & KAPLAN 1997, pl. 38, fig. 3).

KENNEDY & SUMMESBERGER (1986) described the sole specimen of *Menuites costatus* from the *Bn. sumensis* Zone of Neuberg, Austria, which is readily distinguished from all other *Menuites*, including the specimen presented here. It is a crushed body chamber of 70 mm diameter with prominent finger-like ventral tubercles in the older portion. The specimen is a microconch and macroconchs of *M. costatus* are unknown.

Furthermore, two species of *Menuites* appear in the Maastrichtian: *Menuites fresvillensis* (Lower-Upper Maastrichtian boundary interval) and *M. terminus* (*Belemnella kazimiroviensis* Zone, upper Upper Maastrichtian). In growth stages < 110 mm in diameter (see WARD & KENNEDY 1993; MACHALSKI & JAGT 1998), *M. fresvillensis* does not differ substantially from *M. terminus*, which appears to be its closest ally. In comparison to *M. wittekindi*, both species have denser ribbing. In the early and middle growth stages *M. fresvillensis* has 40 ribs per whorl (KENNEDY 1986b), while *M. terminus* can reach 60 or more ribs per whorl (KENNEDY 1986b; WARD & KENNEDY 1993), which is nearly twice as much as in the specimen described herein. Because of similarities to *Menuites wittekindi* and *M. fresvillensis*, the relevant characteristics of the speci-

	<i>Menuites wittekindi</i> (<i>N. polyplacum</i> Zone)	<i>M. cf. wittekindi</i> (Ma13689, <i>Bn. lanceolata</i> Zone)	<i>Menuites fresvillensis</i> (up. Lower to low. Upper Ma.)
maximum diameter (with portion of body chamber)	> 580 mm Ø (L.)	140 mm Ø, wholly septate	> 160 mm Ø
Wb/Wh ratio (at mm Ø)	0.87 (at 100.3 mm Ø) 1.07 (at 220 mm Ø)	1.10 (at 78 mm Ø) 1.12 (at 105 mm Ø) 0.97 (at 135 mm Ø)	1.12 (at 67.8 mm Ø) 1.01 (at 106 mm Ø) 0.94 (at 148 mm Ø)(L.)
umbilical ratio (% of Ø)	23.4-23.9 %	21.5-22.2 %	19.8-24 %
umbilical bullae (> 60mm Ø – loss of flank ornament)	9-11 per whorl	12 per whorl	10-14 per whorl
ribs (> 60 mm Ø – loss of flank ornament)	34-35 per whorl	36 per whorl	up to 42 per whorl
loss of umbilical bullae and flank ribs	beyond 120 mm Ø	beyond 105 mm Ø	beyond 100-120 mm Ø
ventral ribs (after loss of flank ornament)	–	8 weak ventral ribs between 105-130 mm Ø, (= 1/5 whorl)	40-48 per whorl (phragmocone and body chamber)
complete smooth growth stage	beyond 120 – ? 300 mm Ø (L.)	beyond 130 mm Ø	no complete smooth growth stage up to 160 mm Ø
primary ribs (after complete smooth growth stage)	19 per whorl between ? 300- > 580 mm Ø (L.)	–	–

Table 1. Comparison of relevant characteristics of *Menuites wittekindi* (KENNEDY & KAPLAN 1997), the specimen presented here (*Menuites cf. wittekindi*, Ma13689), and *Menuites fresvillensis* (KENNEDY 1986b; KENNEDY & HANCOCK 1993). L = lectotype, Ø = diameter

men here presented have been compared to both of them (Table 1).

There is no doubt that the specimen under consideration is a representative of *Menuites*. Ribbing pattern and measurements show close similarity to macroconchs of *M. wittekindi* in their early to middle growth stages, as illustrated by KENNEDY & KAPLAN (1997), especially their pl. 21, fig. 1. Due to slight differences between the lecto- and paralectotypes in the SCHLÜTER collection and the Krons Moor specimen, the latter is here, the specimen assigned to *Menuites wittekindi* with a query.

STRATIGRAPHY AND DISTRIBUTION: *Menuites wittekindi* is a typically Late Campanian ammonite of the *Belemnitella minor* / *Nostoceras polyplacum* and *Nancyloceras bipunctatum* / *Galerites roemeri* (= *Belemnitella langei*) zones (see NIEBUHR & al. 1997). Apart from Lägerdorf (SCHULZ & al. 1984), it occurs at several localities of northern Germany in shallow to deep marine environments (Stemweder Berg, Münsterland Basin, Ahlten near Hannover, Beienrode Basin near Helmstedt) as well as in Poland (BŁASZKIEWICZ 1980), always associated with characteristic Late Campanian cephalopods. Up to now, neither the species nor the genus is known from the Campanian-Maastrichtian boundary interval in the Boreal Realm. The two specimens from the 'Mucronatenkreide von Rügen' (WOLANSKY 1932) are of

Bn. obtusa to *Bn. fastigata* Zone age. The genus *Menuites* re-appears with *M. fresvillensis* in the upper Lower Maastrichtian of the Biscay region (WARD & KENNEDY 1993) and in the Upper Maastrichtian of the The Netherlands (KENNEDY 1986a; MACHALSKI & JAGT 1998); later, in the uppermost Maastrichtian, *M. terminus* appears also in Denmark (BIRKELUND 1993) and Poland (MACHALSKI & JAGT 1998).

At Krons Moor, 3.5-7 m above the Campanian-Maastrichtian boundary in belemnite terms, *Menuites cf. wittekindi* co-occurs with typically Early Maastrichtian cephalopods. If the specimen here presented is a 'true' *M. wittekindi*, this record might give it the longest range of any ornamented Campanian ammonite by far. The reason behind the long absence of the genus *Menuites* in the uppermost Campanian remains enigmatic.

Suborder Ancyloceratina WIEDMANN, 1960
Superfamily Turritaceae GILL, 1871
Family Diplomoceratidae SPATH, 1926
Subfamily Diplomoceratinae SPATH, 1926

Genus *Diplomoceras* HYATT, 1900

TYPE SPECIES: *Baculites cylindracea* DEFRANCE, 1816, p. 160; by original designation.

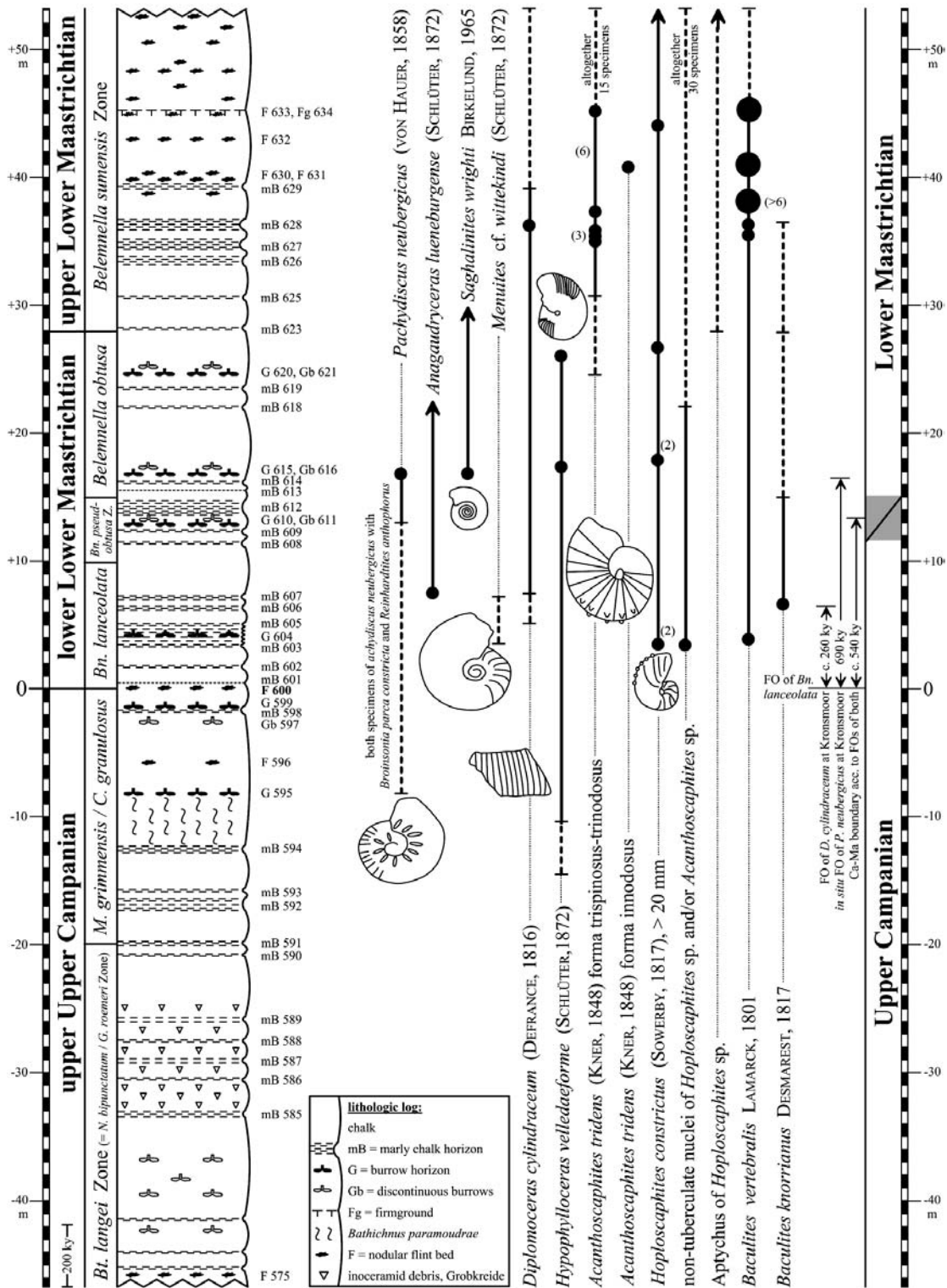


Fig. 4. Stratigraphic distribution of ammonites collected *in situ* (dots), within a well-defined part of the section (stippled line), or ascertained occurrence of several specimens at the Kronsmoor section (full line) and also at Hemmoor (full line with arrow). Numbers of specimens is indicated, where more than a single specimen is known from the same level. Lithological log of the white chalk section of Kronsmoor modified according to SCHULZ (1978) and SCHULZ & al. (1984). Left-hand column: belemnite zonation of SCHULZ (1979), right-hand column: possible Campanian-Maastrichtian boundary definition based on FOs of *Pachydiscus neubergicus* and *Diplomoceras cylindraceum* at Kronsmoor. Bottom left: scale of accumulation rate after EHRMANN (1986)

Diplomoceras cylindraceum (DEFRANCE, 1816)
(Pl. 1, Fig. 8; Pl. 4, Fig. 1)

1816. *Baculites cylindracea* DEFRANCE, p. 160.
1872. *Hamites* cf. *cylindraceus* DEFRANCE sp.; SCHLÜTER, p. 103, pl. 29, figs 8, 9; pl. 31, figs 10-14.
1986b. *Diplomoceras cylindraceum* (DEFRANCE, 1816); KENNEDY, p. 51, pl. 4, figs 1, 2; pl. 9, figs 8-10, pl. 10; text-figs 3I-L, 6, 7G-M (with full synonymy).
1987. *Diplomoceras cylindraceum* (DEFRANCE, 1816); KENNEDY, p. 181, pl. 17, fig. 3; pl. 18, fig. 5; pl. 21, figs 2, 3, 5, 6; pl. 22, fig. 6; pl. 23, figs 1, 2; pl. 24, figs 1-3; pl. 25, figs 1-8; pl. 26, fig. 18; pl. 33, fig. 16; pl. 36, fig. 6; text-figs 9, 10 (with full synonymy).
1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); BIRKELUND, p. 51, pl. 3, figs 3, 4; pl. 9, fig. 1; pl. 11, figs 1-5; pl. 12.
1993. *Diplomoceras cylindraceum* (DEFRANCE, 1816); WARD & KENNEDY, p. 49, figs 42, 43.16, 43.17.
2001. *Diplomoceras cylindraceum* (DEFRANCE, 1816); KÜCHLER & ODIN, p. 521, pl. 6, figs 12-13.
2001. *Diplomoceras cylindraceum*; ODIN & al., p. 567, fig. 2.
2002. *Diplomoceras cylindraceum* (DEFRANCE, 1816); REICH & FRENZEL, pl. 24, figs 2, 3.

TYPES: DEFRANCE (1816) provided no illustrations of the species, but a description that was considered a perfectly valid diagnosis by KENNEDY (1986b, p. 52). According to KENNEDY (1986b), DEFRANCE's specimens have not been traced, therefore, a neotype was designated (KENNEDY 1987, p. 183, pl. 24, figs 1-3), no. IRSNB 10511 at the Institut Royal des Sciences naturelles de Belgique, Brussels. Locus typicus is the St Pietersberg, Maastrichtian type area, the Netherlands. Stratum typicum is the Nekum Member or Meerssen Member, Maastricht Formation, upper Upper Maastrichtian.

MATERIAL: Three specimens – from mB 606 ± 1 m, between mB 626 and F 630 (PIW2003VII5), and above mB 629.

DESCRIPTION: All specimens are composite moulds, showing external ornament. Distinct ribs are annular, narrow, sharp, and separated by much wider interspaces. They are regularly spaced and vary from almost rectiradial to slightly prorsiradial. Whorl section is oval-compressed, the venter only slightly narrower than the dorsum. The specimen Pl. 1, Fig. 8 has a rib index of 14 by a whorl height of 47 mm. The largest specimen (Pl. 4, Fig. 1) is 230 mm long and Wb/Wh ratios vary from 0.85 to 0.96 by whorl heights between 28 and 43.5 mm. It is slightly finer ribbed with a rib index of 15

at its younger portions. At all specimens, there are no constrictions visible.

DISCUSSION: In the suite of Campanian-Maastrichtian ammonites, *Diplomoceras cylindraceum* is easy to identify. The specimens here presented are similar to distinctly ribbed specimens from France (KENNEDY 1986b), Maastricht (KENNEDY 1987), and Denmark (BIRKELUND 1993). High rib indices >10 (e.g., 11-13, see KENNEDY 1986b; KENNEDY & SUMMESBERGER 1986) indicate that these fragments belong to *Diplomoceras cylindraceum*.

STRATIGRAPHY AND DISTRIBUTION: *Diplomoceras cylindraceum* has a world-wide distribution (see KENNEDY 1986b) and ranges throughout most of the Maastrichtian. At Tercis, the lowermost occurrence of this species is reported a few metres below the Campanian-Maastrichtian boundary (KÜCHLER & ODIN 2001; ODIN & al. 2001) and c. 200 ky earlier than that of *Pachydiscus neubergicus* (ODIN & Maastrichtian Working Group members 2001; ODIN & LAMAURELLE 2001). Another European Upper Campanian occurrence is reported by MACHALSKI (1996a) from the *Nostoceras hyatti* Zone at Piotrawin, Poland. In Denmark, this species first appears in the *Belemnella lanceolata* Zone and extends to the top of the *Bn. kazimiroviensis* Zone (BIRKELUND 1993). In northern German localities (Lüneburg, Rügen) it is known from Lower Maastrichtian strata. At Krons Moor it appears c. 6.5 m higher than *Bn. lanceolata* and c. 10.5 m below the first *in situ* occurrence of *Pachydiscus neubergicus*. In European sections the upper portions of the *Nostoceras hyatti* Zone are taken here to be the maximum age of *D. cylindraceum*.

Family Baculitidae GILL, 1871
Genus *Baculites* LAMARCK, 1799

TYPE SPECIES: *Baculites vertebralis* LAMARCK, 1801, p. 103; by subsequent designation of MEEK (1876, p. 391). For a discussion of the family and the genus see KLINGER & KENNEDY (2001).

Baculites vertebralis LAMARCK, 1801
(Pl. 3, Figs 1-4)

1801. *Baculites vertebralis* LAMARCK, p. 103.
1986b. *Baculites vertebralis* LAMARCK, 1801; KENNEDY, p. 57, pl. 11, figs 6-11; pl. 12, figs 1-6; text-figs 3a-d, 7d-f, 8 (with synonymy).
1987. *Baculites vertebralis* LAMARCK, 1801; KENNEDY, p. 187, pl. 19, figs 1-4, 7-10, pl. 20, figs 3-5; pl. 28, figs 2, 7-10, 14-16;

pl. 29, figs 1-15; pl. 30, figs 1-9; text-figs 11a-b, 12 (with synonymy).

1993. *Baculites vertebralis* LAMARCK, 1801; BIRKELUND, p. 53, pl. 13, figs 1-11; pl. 16, figs 1-5.

2001. *Baculites vertebralis* LAMARCK, 1801; KLINGER & KENNEDY, p. 215, figs 31B, 160, 161 (with full synonymy).

TYPES: Lectotype, designated by KENNEDY (1986b, p. 57), is the original of FAUJAS-SAINT-FOND (1799, pl. 21, figs 2, 3). Locus typicus is Maastricht, the Netherlands. Stratum typicum is the Upper Maastrichtian.

MATERIAL: Numerous specimens – one from mB 603 + 0.2 m, one from mB 628 - 1 m (Ma13703), one from mB 628 - 0.6 m, and acmes in three distinct and conspicuous layers between mB 628 and Fg 634 (PIW2003VII3, PIW2003VII4).

DESCRIPTION: The shell is small and smooth. PIW2003VII3, the largest specimen seen (Pl. 3, Fig. 1), is 130 mm long and still septate at a whorl height of 27 mm. The whorl section is ovate and compressed, with a Wb/Wh ratio of 0.7. The venter is more narrowly rounded and dorsum is slightly flattened (Pl. 3, Fig. 1b). Small specimens (Pl. 3, Figs 2, 4) have regular oval to elliptical whorl sections with Wb/Wh ratios of 0.67. The flanks are rounded. Suture is rather complex (Pl. 3, Fig. 1c), moderately incised, with rectangular elements. Assignment of the specimen Pl. 3, Fig. 3 is with some hesitation, because the suture is not visible.

DISCUSSION: *Baculites vertebralis* lacks the tear-shaped whorl section of *Baculites anceps*, another species commonly recorded from the Boreal Maastrichtian. The venter of *Ba. vertebralis* is rounded, that of *Ba. anceps* sharp and flanked by grooves (KENNEDY 1986b). The suture (Pl. 3, Fig. 1c) is similar to that figured by KENNEDY (1986b, text-fig. 7E). *Baculites knorrianus* (described below) is much larger and much more compressed.

STRATIGRAPHY AND DISTRIBUTION: In Denmark (BIRKELUND 1993) and France (KENNEDY 1986b), *Baculites vertebralis* occurs in upper Upper Maastrichtian strata. Further records of Late Maastrichtian age are from Belgium, Sweden, Poland, southern Russia, U.S.A., and possibly North Africa and Palestine (KLINGER & KENNEDY 2001). In Zumaya, northern Spain, the species starts possibly in the Lower Maastrichtian, recorded as *Ba. cf. vertebralis* by WARD & KENNEDY (1993). Apart from the questionable *Ba. vertebralis* from the *Belemnella lanceolata* Zone (Pl. 3, Fig. 3), the occurrence at Kronsmoor is restricted to the *Belemnella sumensis* Zone.

Baculites knorrianus DESMAREST, 1817
(Pl. 4, Figs 2, 3)

1817. *Baculites knorrianus* DESMAREST, p. 48, pl. 1, fig. 3.

1876. *Baculites knorrianus* DESM. GEIN.; SCHLÜTER, p. 146 (*pars*), pl. 39, figs 16-18.

1987. *Baculites knorrianus* DESMAREST, 1816; KENNEDY & SUMMESBERGER, p. 32, pl. 4, figs 4-6; pl. 5, figs 1-14; text-fig. 2 (with full synonymy).

1993. *Baculites knorrianus* DESMAREST, 1817; BIRKELUND, p. 52, pl. 13, figs 12-14.

2001. *Baculites knorrianus* DESMAREST, 1817; KLINGER & KENNEDY, p. 174, figs 132, 133 (with full synonymy).

2002. *Baculites* sp.; REICH & FRENZEL, pl. 24, fig. 5.

TYPES: Neotype designated by KENNEDY & SUMMESBERGER (1987, p. 33) is 7459a in the collection of the Naturhistorisches Museum, Wien. Locus typicus is Nagoryan̄ near Lvov, the Ukraine. Stratum typicum is the lower Lower Maastrichtian (*Bn. lanceolata* and *Bn. pseudobtusa* zones *sensu* SCHULZ 1979).

MATERIAL: Three specimens – from mB 606 + 0.4 m (Ma13704), between mB 613 and mB 623 (PIW2003VII6), and between mB 623 and mB 628.

DESCRIPTION: All specimens are crushed internal moulds, reaching a large size and expanding slowly, with whorl heights up to 72 mm (Pl. 4, Fig. 3). The whorl section is very compressed and ovoid to elliptical with a Wb/Wh ratio of 0.47. The venter is more narrowly rounded than the dorsum, the mid-lateral region is slightly flattened. The specimens are completely smooth. The suture is complex with broad bifid lobes and saddles (Pl. 4, Fig. 3), but only visible in few specimens.

DISCUSSION: Large, smooth *Baculites* from the Campanian and Maastrichtian have commonly been referred to *Ba. knorrianus*, but KENNEDY (1986b) included only the very compressed Maastrichtian representatives with characteristic whorl section and suture. The suture of an adult specimen figured by KENNEDY & SUMMESBERGER (1987, text-fig. 2B) is very similar than that of the specimen Pl. 4, Fig. 3 at a whorl height of 66 mm. The specimen of Rügen (REICH & FRENZEL 2002, pl. 24, fig. 5) is c. 800 mm long with a whorl height of c. 90 mm (pers. comm. M. REICH 2003). The other Maastrichtian baculite species, *Ba. vertebralis* and *Ba. anceps*, are much smaller. *Ba. anceps* has a tear-shaped whorl section with a sharp venter. For *Ba. vertebralis*, see above.

STRATIGRAPHY AND DISTRIBUTION: *Baculites knorrianus* has a more limited palaeobiogeographic dis-

tribution and stratigraphic range than *Baculites vertebralis* (see below). It occurs in the Lower Maastrichtian of northern Germany, northeastern Belgium, and the Ukraine (see KLINGER & KENNEDY 2001). In Denmark, the species straddles the Lower-Upper Maastrichtian boundary (BIRKELUND 1993). The three specimens from Kronsmoor are from the *Belemnella lanceolata* to basal *Bn. sumensis* zones.

Superfamily Scaphitaceae GILL, 1871

Family Scaphitidae GILL, 1871

Subfamily Scaphitinae GILL, 1871

Genus and Subgenus *Acanthoscaphites* NOWAK, 1911

TYPE SPECIES: *Scaphites tridens* KNER, 1848, p. 10, pl. 2, fig. 1; by subsequent designation of DIENER (1925, p. 205). For a discussion of the genus see KENNEDY & SUMMESBERGER (1987) and JAGT & *al.* (1999).

Acanthoscaphites (Acanthoscaphites) tridens (KNER, 1848) forma *trispinosus*(M)-*trinodosus*(m)
(Pl. 5, Figs 1-9; Pl. 6, Fig. 1)

1848. *Sc. tridens*, m. KNER, p. 10, pl. 2, fig. 1.
 1848. *Scaphites trinodosus* KNER; KNER, p. 11, pl. 2, fig. 2.
 1872. *Scaphites tridens* KNER; SCHLÜTER, p. 94, pl. 28, figs 1-4 (with additional synonymy and discussion).
 1911. *Acanthoscaphites tridens-trinodosus* KNER; NOWAK, p. 576, pl. 33, figs 25, 26; text-fig. 13.
 1911. *Acanthoscaphites tridens-trispinosus* GEINITZ; NOWAK, p. 578, pl. 32, figs 5, 6.
 1911. *Acanthoscaphites tridens-variens* ŁOPUSKI; NOWAK, p. 578 (*pars*), pl. 33, fig. 29 (*non* ŁOPUSKI).
 1987. *Acanthoscaphites tridens* (KNER, 1848); KENNEDY, p. 205, pl. 37, figs 1-4.
 1987. *Acanthoscaphites tridens* (KNER, 1848); KENNEDY & SUMMESBERGER, p. 36 (*pars*), pl. 6, figs 25-28; pls 7, 8; pl. 9, figs 3, 4; pl. 10; pl. 11, figs 1, 2; pl. 12; pl. 13, fig. 4; pl. 14 (with full synonymy and discussion).
 1993. *Acanthoscaphites tridens* (KNER, 1848); BIRKELUND, p. 55 (*pars*), pl. 8, figs 2, 3; pl. 9, fig. 2.
 1999. *Acanthoscaphites (Acanthoscaphites) tridens* (KNER, 1848); JAGT & *al.*, p. 134, pls 1, 2; text-figs 1, 2 (with discussion).
 2002. *Acanthoscaphites tridens* (KNER, 1848); REICH & FRENZEL, pl. 24, fig. 4.

TYPES: The whereabouts of KNER's (1848) material is not known. The original of his pl. 2, fig. 1 should be designated lectotype, if found. Locus typicus is Nagoryan̄

near Lvov, the Ukraine. Stratum typicum is the *Belemnella lanceolata* and *Bn. pseudobtusa* zones *sensu* SCHULZ (1979; see KENNEDY & SUMMESBERGER 1987, p. 40, text-fig. 3).

MATERIAL: Fifteen specimens – one from G 620 to mB 625 (Ma13690), two from mB 627 to mB 628 (PIW2003VII8), one from mB 628 - 1 m (Ma13695), one from mB 628 - 0.7 m (Ma13691), one from mB 628 - 0.55 m (Ma13702), one from mB 628 + 1 m (Ma13692), one from F 633, six *ex situ* specimens from the *Bn. sumensis* Zone (Ma13693, PIW2003VII7, PIW2003VII9, PIW2003VII10), and one specimen, which lacks stratigraphic data (Ma13694).

DESCRIPTION: All specimens are crushed to varying degrees, only five of them are more complete showing the whole diameter of the phragmocone. PIW2003VII10 is larger than the minimum size of adult macroconchs, given by JAGT & *al.* (1999, p. 134), but misses the apertural part of the body chamber (Pl. 6, Fig. 1). Furthermore, there are two microconchs of 52 and 55 mm (Ma13694 and PIW2003VII8; Pl. 5, Figs 6, 8) and two nearly complete nuclei of 28 and 30 mm (Ma13693 and Ma13695; Pl. 5, Figs 4, 7).

All *A. (A.) tridens* forma *trispinosus*(M)-*trinodosus*(m) from Kronsmoor have siphonal tubercles and ventrolateral tubercles or clavi. This tuberculation appears and disappears at variable growth stages, even the nucleus PIW2003VII9 with a diameter < 25 mm shows this pattern (Pl. 5, Fig. 9). Some ventrolaterals are stronger in comparison to the siphonal tubercles, appear earlier and persist longer. Both ventrolaterals and the intermittend siphonal tubercle are mostly confined to the same rib. The tuberculate ribs are separated by one to three nontuberculate ribs.

The largest macroconch (PIW2003VII10; Pl. 6, Fig. 1) is 145 mm in diameter, but misses the middle and late portions of the body chamber. On phragmocone eighteen primary ribs arise at the umbilical seam and pass straight across the umbilical wall. The umbilicus is small and deep, conical, the umbilical shoulders are rounded. Flanks are somewhat flattened and venter is broadly rounded, with the greatest breadth at the outer flank. On the inner flanks, the ribs are narrow, rounded, straight and rectiradiate to prorsiradiate, variably to feebly concave on the outer flanks. A total of 52 ribs per whorl crosses the venter in a convexity. The Wb/Wh ratios shift from 0.83 at the older to 0.65 at the younger part of the ultimate whorl. The macroconch has nine weak umbilico-lateral nodes and seven or more groups of ventrolateral and siphonal tubercles to the outer whorl, but loses tuberculation on the body chamber.

Microconchs of *A. (A.) tridens* forma *trispinosus*(M)-*trinodosus*(m) are much smaller and also more finely ribbed than the macroconch PIW2003VII10. On the younger portion of the phragmocone of the larger microconch (PIW2003VII8; Pl. 5, Fig. 8), the umbilical bullae migrate out to an umbilicolateral position and nodes appear on them. The bullae give rise to two or more ribs, while intercalated ribs arise at various points on the flank and occasionally branch. Tuberculation is fairly regular. Microconch Ma13694 (Pl. 5, Fig. 6) has a near-square whorl section with a Wb/Wh ratio of 1 and shows a somewhat atypical ornament. Typical are the umbilical bullae that migrate out to an umbilicolateral position, and give rise to groups of two or three ribs with occasional non-tuberculate ribs, which loop between umbilicolateral and ventral tubercles and across the venter. Ventral clavi are present, varying from weak to strong, and are separated by one or two non-tuberculate ribs. Atypical are additional ventrolateral, radially drawn-out nodes, which are either linked to the ventral tubercles or are isolated. The atypical sixth and seventh rows vary in position on either side in the present microconch. The nodes appear to start as swellings and rapidly become stronger, but disappear altogether at a diameter of 45 mm. Siphonal tubercles appear and disappear more or less fused, and consist of two unequal coalesced nodes, in position corresponding either to pairs of ventral tubercles or occurring in between.

Likewise the phragmocone of the nucleus Ma13693 (Pl. 5, Fig. 4) has a near-square whorl section, with a Wb/Wh ratio of 1. There are thirteen primary ribs which strengthen into umbilical bullae. Siphonal and ventrolateral tubercles appear to be distinct and robust. Nucleus Ma13695 resembles a very small and finely ribbed, juvenile microconch (Pl. 5, Fig. 7).

DISCUSSION: *Acanthoscaphites (Acanthoscaphites) tridens* is the largest scaphitid ammonite known from the European Maastrichtian, and shows a strong sexual dimorphism (see KENNEDY & SUMMESBERGER 1987). The diameter of microconchs varies from 80 to 130 mm and of macroconchs from 130 to 250 mm (JAGT & *al.* 1999). The giant *Acanthoscaphites* of the Lower Maastrichtian have been treated in very different ways by previous authors. Already SCHLÜTER (1872) regarded *Scaphites tridens*, *S. trinodosus* and *S. quadrispinosus* as synonyms. NOWAK (1911) recognised no fewer than five varieties of *Acanthoscaphites tridens*, named var. *trinodosus* KNER, var. *quadrispinosus* GEINITZ, var. *bispinosus* NOWAK, var. *trispinosus* GEINITZ, and var. *varians* ŁOPUSKI and regarded *A. tridens* var. *trinodosus* as the basic stock of the species. Later, BIRKELUND (1979) and BŁASZKIEWICZ (1980) treated *varians*, *quadrispinosus* and *bispinosus* as

separate species. On the basis of a large suite of specimens from the type locality Nagoryanĭ KENNEDY & SUMMESBERGER (1987) described and discussed *Acanthoscaphites tridens* at length, and showed that *Scaphites tridens* KNER, *S. tridens* var. *trispinosus* GEINITZ, and *Acanthoscaphites tridens* var. *bispinosus* NOWAK were macroconchs, whereas *S. trinodosus* KNER, and *S. quadrispinosus* GEINITZ were microconchs of a single species.

However, with the exception of Nagoryanĭ (KENNEDY & SUMMESBERGER 1987) and Rügen (WOLANSKY 1932; REICH & FRENZEL 2002), not all of the above mentioned forms occur in other sections that have yielded *A. (A.) tridens*. Specimens from northern and western Germany (Aachen, Krons Moor, Lüneburg), and Denmark have siphonal tubercles, but all Polish forms (*A. bispinosus* and *A. quadrispinosus* of BŁASZKIEWICZ 1980) lack them. KENNEDY & SUMMESBERGER (1987, p. 39) regarded the presence or absence of siphonal tuberculation to be within the range of intraspecific variation. If it is a characteristic feature, two macroconch(M)-microconch(m) pairs *sensu* KENNEDY & SUMMESBERGER (1987) appear likely: *trispinosus*(M)-*trinodosus*(m) with siphonal tubercles and *bispinosus*(M)-*quadrispinosus*(m) without. I interpret these two macroconch-microconch pairs as forms of a single species, for which SCHLÜTER (1872) selected the name *tridens*, and I prefer to refer to them as *Acanthoscaphites (A.) tridens* forma *trispinosus-trinodosus* and *Acanthoscaphites (A.) tridens* forma *bispinosus-quadrispinosus*. This enables a discussion of the different forms of *A. (A.) tridens* with respect to palaeobiogeographic and/or stratigraphic distribution without further splitting. However, further work is needed to satisfactorily resolve this complex taxonomic problem.

Both macro- and microconchs of *A. (A.) tridens* forma *trispinosus-trinodosus* have in the literature been shown to be extremely variable in details of ornament. The discontinuous ventrolateral rows of nodes in the atypical microconch (Pl. 5, Fig. 6) seem to be an expression of pathology. With the exception of these, all elements of ornament of this specimen are in agreement with regular microconchs of *A. (A.) tridens* forma *trispinosus-trinodosus*. One specimen from Nagoryanĭ even has seven rows of tubercles (NOWAK 1911, pl. 33, fig. 29), but the additional rows are produced by the development of new umbilical bullae on the outer whorl as the umbilical tubercles of the inner whorl migrate out to an umbilicolateral position (KENNEDY & SUMMESBERGER 1987, p. 39). Except for the additional sixth and seventh row of nodes and the fact that the alleged microconchs of *Acanthoscaphites (Euroscaphites) varians blaszkiewiczii* (see JAGT & *al.* 1999) are much smaller, the atypical specimens from Krons Moor and Nagoryanĭ are referable to *A.*

(*A.*) *tridens* forma trispinosus-trinodosus. It appears that in *A.* (*A.*) *tridens* forma trispinosus-trinodosus rare specimens with seven rows of tubercles occur from time to time. Also in other species of scaphitid, duplication or coalescence of nodes are known (see e.g., *Hoploscaphites constrictus* in JAGT 1995, p. 33, pl. 7, figs 13, 14).

Likewise some nuclei of *Acanthoscaphites tridens* forma trispinosus-trinodosus from Krons Moor seem to be atypical, revealing distinct and robust siphonal and ventrolateral tubercles (see Pl. 5, Figs 4, 9). The nuclei from Nagoryan̄ (KENNEDY & SUMMESBERGER 1987, pl. 6, figs 1-5) and from Aachen (JAGT & al. 1999, pl. 1, figs 3, 7) still lack tuberculations at even greater diameters. Small scaphitids with multiple tuberculation are known from an enigmatic group of phragmocones from the Upper Maastrichtian of Cotentin, northern France, which were assigned by KENNEDY (1986b) to *Acanthoscaphites verneuillianus*, *A.* cf. *verneuillianus*, and *Acanthoscaphites* sp. In his view, the absence of inner ventrolateral tubercles immediately distinguishes *A. verneuillianus* from *Scaphites trinodosus* (*Acanthoscaphites* (*A.*) *tridens* forma trispinosus-trinodosus), the latter of which has non-tuberculate nuclei. Except for the smaller size, the venter of the holotype of *A. verneuillianus* (see KENNEDY 1986a, pl. 16, figs 15-17) is closely similar to that of *A.* (*A.*) *tridens* forma trispinosus-trinodosus of Pl. 5, Fig. 1 and that of the nucleus of Pl. 5, Fig. 4b, bearing siphonal and ventrolateral tubercles. The tuberculate nuclei of Krons Moor show close similarities to the species representing late growth stages, especially of macroconchs. Therefore, they were assigned to *A.* (*A.*) *tridens* forma trispinosus-trinodosus. Non-tuberculate nuclei of *Hoploscaphites* sp. and/or *Acanthoscaphites* sp. (Pl. 7, Figs 6-10) are described and discussed below.

STRATIGRAPHY AND DISTRIBUTION: At Krons Moor, *Acanthoscaphites* (*A.*) *tridens* forma trispinosus-trinodosus is known from the upper *Belemnella obtusa* and *Bn. sumensis* zones. Likewise, the two specimens of SCHLÜTER (1872, pl. 28, figs 1, 2, 4) from the Zeltberg section of Lüneburg have been referred to the *Bn. obtusa* Zone. In the Aachen area, *A.* (*A.*) *tridens* (forma trispinosus-trinodosus) is confined to the lower-middle Vijlen Member (Gulpen Formation) which corresponds to the *Bn. sumensis* Zone (JAGT & al. 1999). In Denmark, *A. tridens* or *A. tridens trispinosa* (see BIRKELUND 1979, 1993) likewise ranges through the *Belemnella obtusa* and *Bn. sumensis* zones. The top of the *Bn. sumensis* Zone thus appears to represent the youngest occurrence of *Acanthoscaphites* (*A.*) *tridens* forma trispinosus-trinodosus.

The record of *Acanthoscaphites* (*A.*) *tridens* forma bispinosus-quadriscopinosus in Poland is without exact age assignment, except '*Bn. lanceolata* and *Bn. occidentalis*

zones' (BŁASZKIEWICZ 1980), which are equivalent to the Lower Maastrichtian.

At the type locality of *A. tridens*, the species is restricted to the *Belemnella lanceolata* to *Bn. pseudobtusa* zones (see KENNEDY & SUMMESBERGER 1987). The 'Mucronatenkreide von Rügen' (WOLANSKY 1932) refers to the *Bn. obtusa* to *Bn. fastigata* zones. At both localities, *Acanthoscaphites* (*A.*) *tridens* forma trispinosus-trinodosus co-occurs with *A.* (*A.*) *tridens* forma bispinosus-quadriscopinosus. For further records of *A. tridens* in the literature see KENNEDY & SUMMESBERGER (1987).

In summary, the documented stratigraphic range of *A.* (*A.*) *tridens* forma trispinosus-trinodosus would appear to be the Lower Maastrichtian (*Bn. lanceolata* to upper *Bn. sumensis* zones). All localities at which this siphonally tuberculate form is not associated with the non-siphonally tuberculate *Acanthoscaphites* (*A.*) *tridens* forma bispinosus-quadriscopinosus, are of *Bn. obtusa* and *Bn. sumensis* zone age. It is speculated that in the upper *Bn. pseudobtusa* to early *Bn. obtusa* zones a palaeobiogeographic splitting into two different forms occurred: *A.* (*A.*) *tridens* forma trispinosus-trinodosus seems to characterise Denmark as well as northern and western Germany whereas *A.* (*A.*) *tridens* forma bispinosus-quadriscopinosus characterises Poland. In the *Bn. obtusa* to *Bn. sumensis* zones of Rügen (northeastern Germany) both, siphonally and non-siphonally tuberculated forms of *A. tridens* are present.

Acanthoscaphites (*Acanthoscaphites*) *tridens* (KNER, 1848) forma innodosus (M)
(Pl. 7, Fig. 1)

1974. *Acanthoscaphites innodosus* NAIDIN, p. 178, pl. 62, fig. 1.
1987. *Acanthoscaphites tridens* (KNER, 1848); KENNEDY & SUMMESBERGER, p. 36 (pars), pl. 4, figs 1-3; pl. 16, figs 1-6.
1993. *Acanthoscaphites tridens* (KNER, 1848); BIRKELUND, p. 55 (pars), pl. 8, fig. 4.
2002. *Acanthoscaphites* sp.; REICH & FRENZEL, pl. 24, fig. 1.

MATERIAL: A single specimen – from F 631 + 0.5 m (PIW2003VII11).

DESCRIPTION: PIW2003VII11 is a phragmocone with the early portions of the body chamber preserved (Pl. 7, Fig. 1). It is a macroconch, 152 mm in diameter, and much finer ribbed than macroconch PIW2003VII10. Twenty-six primary ribs per whorl arise at the umbilical seam and pass straight across the high and rounded umbilical wall. Intercalated ribs arise at various points on the flank and eventually branch. A total of 84 ribs per whorl cross the venter in a broad convexity. Flanks and

venter are broadly rounded, with the greatest breadth just below mid-flank, the Wb/Wh ratio is 1. The specimen has no umbilical tubercles on the outer whorl of the phragmocone and the early portions of the body chamber, nor siphonal nor ventral tubercles.

DISCUSSION: *Acanthoscaphites* (*Acanthoscaphites*) *tridens* forma *innodosus* is developed in macroconchs, but seems to be rare within the range of intraspecific variation of *A. tridens*. The non-tuberculate *Acanthoscaphites innodosus* NAIDIN 1974 (p. 178, pl. 62, fig. 1), also a macroconch, seems to be a synonym of *A. (A.) tridens* (KENNEDY & SUMMESBERGER 1987; JAGT & al. 1999). On the basis of a large suite of specimens from Nagoryanŷ, KENNEDY & SUMMESBERGER (1987, p. 37) noted that ‘all macroconchs of *Acanthoscaphites tridens* develop prominent ventral tubercles’, but their specimen on pl. 16, fig. 6, a finely-ribbed macroconch with the same diameter than the Kronsmoor specimen, also lacks any tuberculation on the phragmocone and the early portions of the body chamber. In most adult Nagoryanŷ specimens, ribbing gets significantly coarser at the transition to the final section of the body chamber before tuberculation appears (e.g. KENNEDY & SUMMESBERGER 1987, pl. 15). In the largest known European scaphitid, the specimen from Rügen (see REICH & FRENZEL 2001, pl. 24, fig. 1), ribbing gets coarser towards the final section of the body chamber, but the specimen is non-tuberculate at a diameter of more than 350 mm (pers. comm. M. REICH 2003), and the phragmocone shows dense ribbing similar to that in the Kronsmoor specimen. Probably PIW2003VII11 is merely an incomplete macroconch that lacks the final section of body chamber where the tubercles may appear. The formae of *Acanthoscaphites* (*Acanthoscaphites*) *tridens* are only of descriptive character, showing the large suite of morphological variation in this species.

STRATIGRAPHY AND DISTRIBUTION: The specimen is from the *Belemnella sumensis* Zone which has yielded most of the Kronsmoor *Acanthoscaphites* (*A.*) *tridens* forma *trispinosus-trinodosus*. The type locality of *A. tridens* (Nagoryanŷ, the Ukraine) is of *Belemnella lanceolata* to *Bn. pseudobtusa* zone age (see KENNEDY & SUMMESBERGER 1987). The chalk of Rügen spans the *Bn. obtusa* to *Bn. fastigata* zones.

Acanthoscaphites (*A.*) *tridens* forma *innodosus* co-occurs with *A. (A.) tridens* forma *trispinosus-trinodosus*.

Genus *Hoploscaphites* NOWAK, 1911

TYPE SPECIES: *Ammonites constrictus* J. SOWERBY, 1817, p. 189, pl. A, fig. 1; by original designation.

Hoploscaphites constrictus (J. SOWERBY, 1817)
(Pl. 7, Figs 2-5)

1817. *Ammonites constrictus* J. SOWERBY, p. 189, pl. A, fig. 1.
1872. *Scaphites constrictus* SOWERBY sp.; SCHLÜTER, p. 92; pl. 28, figs 5-9.
1965. *Hoploscaphites constrictus* SOWERBY var. *vulgaris* NOWAK; HALLER, p. 138; pl. 10, figs 5-7.
1982. *Hoploscaphites constrictus* (J. SOWERBY, 1818); BIRKELUND, p. 19 (*pars*), pl. 3, figs 1-11, 13-14 (with selected synonyms, including subspecies, macroconchs and microconchs).
1986b. *Hoploscaphites constrictus* (J. SOWERBY, 1817); KENNEDY, p. 64, pl. 13, figs 1-13, 16-24; pl. 14, figs 1-38; pl. 15; text-figs 9, 11A-11H (with additional synonymy).
1987. *Hoploscaphites constrictus* (J. SOWERBY, 1817); KENNEDY, p. 197, pl. 31, figs 1, 8-26; pl. 32, figs 1-12, 18-21 (with full synonymy).
1993. *Hoploscaphites constrictus* (J. SOWERBY, 1817); BIRKELUND, p. 57, pl. 14, figs 1-7, 12; pl. 15, figs 1-14; pl. 16, figs 6-16; pl. 17, figs 5-23.
1996b. *Hoploscaphites constrictus* (J. SOWERBY, 1817); MACHALSKI, p. 372, figs 2A-G, 3A-C.
2002. *Hoploscaphites constrictus* (J. SOWERBY, 1818); REICH & FRENZEL, pl. 22, figs 5, 6.

TYPE: BMNH C.36733, kept in the Natural History Museum at London, is the original of J. SOWERBY (1817, pl. A, fig. 1), designated lectotype by KENNEDY (1986b, p. 68). Paralectotypes are BMNH C.70645 - C.70647. Locus typicus is St. Colombe, Cotentin Peninsula, Manche, France. Stratum typicum is the ‘Calcaire à *Baculites*’, Upper Maastrichtian.

MATERIAL: Six specimens – one from mB 603 ± 0.3 m (Ma13698), one from G 604 - 0.6 m (Ma13696), two from G 615 + 1 m (PIW2003VII12), one from G 620 + 2 m (Ma13697), one from F 632 to F 633.

DESCRIPTION: *Hoploscaphites constrictus* shows a marked sexual dimorphism of the general type discussed by MAKOWSKI (1962) and COBBAN (1969), and demonstrated for this species by BIRKELUND (1982), KENNEDY (1986b, 1987) and MACHALSKI (1996b).

The lengths of the three more or less complete macroconchs (Ma13696, PIW2003VII12, and Ma13698; Pl. 7, Figs 2, 4, 5) vary from 31 to 49 mm. Ma13698, the lowermost occurrence of this species according to SCHULZ (1978, p. 83) c. 3.5 m above the FO of *Belemnella lanceolata*, is strongly damaged and can only be determined as *Hoploscaphites* cf. *constrictus*. The body chamber of the best specimen Ma13696 (Pl. 7, Fig. 2), the next-lowest occurrence of this species c. 4 m above the FO of

Belemnella lanceolata, is high-whorled, with a straight to feebly convex umbilical wall that conceals a portion of the umbilicus of the phragmocone. The venter and ventrolateral shoulders are rounded. Ribbing of the early portion of the phragmocone appears to have been relatively typical of the species: narrow, straight primary ribs occasionally bifurcate, secondaries and intercalated ribs arise at the middle and outer flank, and all ribs pass straight across the venter. The ratio of primaries and intercalatories is c. 1:3. Weak ventral clavi appear at the end of phragmocone, cover the straight part of the body chamber and disappear well before the aperture. They are linked across the venter by groups of two or three delicate riblets. Macroconch PIW2003VII12 (Pl. 7, Fig. 4) shows the prominent umbilical bulge at the beginning of the shaft, which is broad and short. On the straight part of the body chamber, ribbing is weaker, but there are traces of broad prorsiradiate primary ribs on the inner flank, arising in pairs from two or three umbilical bullae, increasing by branching and intercalation and linked to the ventral clavi. On the apertural part of the body chamber, ribbing is much finer than on the phragmocone, and the number of ribs per 10 mm on the venter close to the aperture is 12-14.

Only one most complete microconch has been found (Ma13697; Pl. 7, Fig. 3), with a length of 28 mm. The body chamber is slender and finely ribbed in comparison to the macroconchs of this species, reflecting sexual dimorphism. The ventral clavi first appear on the straight part of the body chamber.

DISCUSSION: This species or species group shows a wide range of variation and certain varieties have been separated at the subspecies or species level (BIRKELUND 1982). Among these, it is more appropriate to treat *Hoploscaphites tenuistriatus* as a short-living species with a distinct range around the Lower-Upper Maastrichtian boundary rather than yet another subspecies of *H. constrictus*. It differs from the present species in having a relatively coarsely ribbed phragmocone but very finely ribbed body chamber with 16-27 ribs per cm on the venter close to the aperture, lacking nodes (BIRKELUND 1993). *Hoploscaphites pumilus*, a species from the Campanian-Maastrichtian boundary interval, differs from *H. constrictus* in having sharply defined ventrolateral and umbilical shoulders and a trapezoidal cross section of the shaft, especially in microconchs (MACHALSKI & ODIN 2001). *H. constrictus* has been originally defined based on a macroconch, and the Krons Moor specimen of Pl. 7, Fig. 2 is an unquestionable macroconch of this species well comparable to the type material.

The Danish *H. constrictus* (BIRKELUND 1979, 1993) show a progressive evolutionary decrease in ribbing den-

sity on the last 10 mm of the body chamber in mature macroconchs from 12-13 ribs at the Lower-Upper Maastrichtian boundary to 6-11 ribs in the uppermost Maastrichtian. *H. constrictus* of the *Bn. lanceolata* Zone of Krons Moor have 12-14 ribs per 10 mm such as the lowermost macroconch of BIRKELUND (1979) from the Lower-Upper Maastrichtian boundary. Similar trends are described by MACHALSKI (1996b) from the Upper Maastrichtian of Poland. The decrease in ribbing density in *Hoploscaphites constrictus* first starts with the Upper Maastrichtian, in Lower Maastrichtian the number of ribs on the last 10 mm of the body chamber in mature macroconchs seems to be more or less constant.

STRATIGRAPHY AND DISTRIBUTION: *Hoploscaphites constrictus* has been described from a great number of localities in Europe and Russia. It is the classic index fossil and one of the commonest ammonites in shallow to deep marine environments of the Maastrichtian Stage. In Denmark this species ranges throughout all of the Maastrichtian (BIRKELUND 1993). However, in the lower Lower Maastrichtian, *H. constrictus* is rare. At Tercis, the FO of this species was not selected to locate the level of the GSSP because of 'most commonly the taxon first occurs at a younger level than the stage boundary' defined by a multi-bio-events approach (ODIN & Maastrichtian Working Group members 2001, p. 827), but this is not true for northern Germany. At Krons Moor, its lower limit is well documented with two adult specimens from the SCHULZ collection (Ma13696 and Ma13698; Pl. 7, Figs 2, 5) as well as a nucleus (see Ma13700; Pl. 7, Fig. 11) c. 4 m above the Campanian-Maastrichtian boundary in belemnite terms.

Non-tuberculate nuclei of *Hoploscaphites* sp. and/or
Acanthoscaphites sp.
(Pl. 7, Figs 6-11)

MATERIAL: Thirty specimens with < 20 mm in diameter, one from mB 603 (Ma13700), twenty-nine from above mB 618 (PIW2003VII13, PIW2003VII14, PIW2003VII15, PIW2003VII16, PIW2003VII17, Ma13699, Ma13701).

DESCRIPTION: Non-tuberculate nuclei of scaphitid ammonites are common in the Krons Moor material. Ribbing varies strongly. Ma13699 with a diameter of 13 mm has 13 primary ribs (Pl. 7, Fig. 9), and PIW2003VII16 has 17 primary ribs at a diameter of 17 mm (Pl. 7, Fig. 10), both with a ratio of primaries to intercalatories of 1:3, but this can only be seen in very few

specimens on account of poor preservation. Most of the fragments show fine, narrow, straight primary ribs occasionally bifurcating at the middle flank, and all ribs pass straight across the rounded venter (e.g., Ma13700; Pl. 7, Fig. 11). The greatest breadth of Ma13699 (Pl. 7, Fig. 9) is reached at the umbilical shoulders, on the flanks primaries are stronger developed than on the broadly rounded venter and intercalatories first appear on the ventral shoulders. PIW2003VII13 (Pl. 7, Fig. 6) shows a somewhat atypical ribbing with some strengthened primaries and bundles of intercalatories appearing between them.

DISCUSSION: The specimens discussed here are small phragmocones which are indeterminable at the genus and species level. Nevertheless, Ma13700 is from the same interval where the lowermost adult *Hoploscaphites constrictus* was found (lower *Bn. lanceolata* Zone, c. 4 m above the Campanian-Maastrichtian boundary in belemnite terms). This is much lower than the FO of *Acanthoscaphites (A.) tridens* forma *trispinosus-trinodosus* at Kronsmoor and, therefore, it is highly likely that Ma13700 is a nucleus of *H. constrictus* (J. SOWERBY, 1817). Twenty-nine specimens, some of which look very similar to Ma13700, are even associated with adult *H. constrictus* and *A. tridens* (upper *Belemnella obtusa* and *Bn. sumensis* zones) and a determination is impossible.

Early phragmocone whorls of *Hoploscaphites constrictus* (KENNEDY 1986b) as well as nuclei of *Acanthoscaphites tridens* from Nagoryan̄ (KENNEDY & SUMMESBERGER 1987, pl. 6, figs 1-5) and from Aachen (JAGT & al. 1999, pl. 1, figs 3, 7) are devoid of tuberculation. That is also true for most of the scaphitid nuclei of Kronsmoor with < 20 mm in diameter. Apart from ventrolateral tubercles, the tuberculate nuclei of Kronsmoor even bear distinct siphonal tuberculation which is a characteristic feature of *Acanthoscaphites (A.) tridens* forma *trispinosus-trinodosus* (see above). Non-tuberculate nuclei can even refer to *Hoploscaphites* sp. or *Acanthoscaphites* sp. and poor preservation precludes further determination.

Aptychus of *Hoploscaphites* sp.
(Pl. 7, Fig. 11)

1982. Aptychi of *Hoploscaphites* sp.; BIRKELUND, pl. 2, figs 6, 7.
1993. Aptychus of *Hoploscaphites*; BIRKELUND, p. 60 (*pars*), pl. 17, figs 2-4.
2002. Aptychen von *Hoploscaphites* sp.; REICH & FRENZEL, pl. 23, figs 4, 5.

MATERIAL: A single specimen – from the *Bn. sumensis* Zone (PIW2003VII17).

DESCRIPTION: This is a small (20 by 11 mm), rather broad, paired element, with more than 15 delicate, concentric ribs per cm. The calcitic shell is partially preserved.

DISCUSSION: Aptychi (calcitic ammonite jaws) occur throughout most of the Campanian and Maastrichtian outcrops of northern Germany. PIW2003VII17 from Kronsmoor closely resembles jaws found *in situ* in Late Campanian *Trachyscaphites spiniger* of Haldem (see SCHLÜTER 1872, pl. 25, figs 5-7) and *Hoploscaphites greenlandicus* of Ahlten near Hannover (see SCHLÜTER 1872, pl. 42, figs 4, 5; re-figured by KENNEDY & KAPLAN 1997, pl. 78, figs 5, 6), the latter referred to as *Striptychus roemeri*. The aptychi of *Hoploscaphites* from the chalk of Rügen (REICH & FRENZEL 2002) are similar to that of Kronsmoor. The Late Campanian ‘*Aptychus*’ *portlocki* from Belgium (KENNEDY 1993, p. 114, pl. 7, figs 18-24), also known to be associated with scaphitids, is much larger and more coarser ribbed than the German material.

STRATIGRAPHIC RESULTS

AMMONITE ASSOCIATION: Scaphitids are the most common ammonites. However, except for the late Early Maastrichtian *Belemnella sumensis* Zone, ammonites are rare in the chalk facies of Lägerdorf and Kronsmoor. The *Bn. sumensis* Zone also appears to be the most fossiliferous unit in the Lower Maastrichtian of the extended type area of the Maastrichtian Stage (pers. comm. J.W.M. JAGT 2003). Of significance in terms of a supra-regional level of correlation are the first occurrences of *Nostoceras polyplacum*, *Pachydiscus neubergicus*, *Diplomoceras cylindraceum*, and *Hoploscaphites constrictus*.

Similar to Tercis, the typical ‘Maastrichtian’ ammonites *Anagaudryceras lueneburgense*, *Saghalinites wrighti* and *Hypophylloceras velledaeforme* appear much earlier than at other localities (ODIN & al. 2001). At Kronsmoor, *A. lueneburgense*, *H. constrictus*, *Baculites vertebralis* and *Baculites knorriani* seem to have their lowermost occurrences within the *Belemnella lanceolata* Zone. Of special importance is the occurrence of *Menuites* cf. *wittekindi* in the *Bn. lanceolata* Zone, formerly known only from the c. 2 my older Late Campanian *Belemnitella minor* / *Nostoceras polyplacum* to *Neancyloceras bipunctatum* / *Galerites roemeri* zones. At Kronsmoor, the Maastrichtian index ammonite *P. neubergicus* first appears (*ex situ*) in the Campanian-Maastrichtian boundary succession; the first *in situ* occurrence is at the base of the *Belemnella obtusa* Zone.

Most ammonite taxa identified are well known from the Boreal Realm. Combined with the ammonites from the Lower to Upper Maastrichtian chalk of Hemmoor, a

total of thirteen taxa is recorded from the Maastrichtian of northern Germany (Table 2). The overlap in composition of the ammonite assemblages in northern Germany and Denmark is great, probably related to the same pelagic white chalk environment in both regions. With the exception of *Menuites* cf. *wittekindi* and *Hoploscaphites schmidi*, eleven taxa are also known from the Danish Maastrichtian (see BIRKELUND 1993). However, in Denmark four of these (*A. lueneburgense*, *S. wrighti*, *P. neubergicus*, *Ba. knorrianus*) first appear much later, in the topmost Lower Maastrichtian. In particular, the FO

of *Pachydiscus neubergicus* coincides with that of *Acanthoscaphites varians* (BIRKELUND 1993), which is c. 2 my later than the FO of *Belemnella lanceolata*.

The Upper Campanian and Lower Maastrichtian strata of Lägerdorf-Kronsmoor and Tercis share only six ammonite taxa (*N. polyplacum*, *A. lueneburgense*, *S. wrighti*, *P. neubergicus*, *D. cylindraceum*, *H. constrictus*). During this time interval, Tercis belonged to the 'North Transitional Subprovince' of ERNST & al. (1996), more strongly influenced by Tethyan ammonite genera such as *Pseudokosmaticeras* and *Desmophyllites* (see ODIN & al.

Species, occ. at Lägerdorf (1), Kronsmoor (2), Hemmoor (3)	biozones at Lägerdorf, Kronsmoor, Hemmoor	occ. at further northern German localities	occ. at Denmark	occ. at Tercis, southwestern France
<i>Nostoceras (B.) polyplacum</i> (1)	basal <i>N. polyplacum</i> Z.	<i>Bt. minor</i> / <i>N. polyplacum</i> + <i>N. bipunctatum</i> / <i>G. roemeri</i> / <i>Bt. langei</i> Z.	(? hiatus in Denmark)	<i>N. polyplacum</i> Z.
<i>Hypophylloceras (N.) velledaeforme</i> (2)	<i>M. grimmensis</i> / <i>C. granulatus</i> - <i>B. obtusa</i> Z.	<i>Bn. obtusa</i> Z.	<i>Bn. fastigata</i> - <i>Bn. kazimiroviensis</i> Z.	
<i>Anagaudryceras lueneburgense</i> (2, 3)	<i>Bn. lanceolata</i> - <i>T. argentea</i> / <i>Bt. junior</i> Z.	<i>Bn. obtusa</i> Z.	<i>Bn. fastigata</i> - <i>T. argentea</i> / <i>Bt. junior</i> Z.	<i>N. hyatti</i> Z.
<i>Saghalinites wrighti</i> (2, 3)	<i>Bn. obtusa</i> - <i>Bn. fastigata</i> Z.	<i>Bn. obtusa</i> Z.	<i>Bn. fastigata</i> - <i>T. argentea</i> / <i>Bt. junior</i> Z.	<i>N. hyatti</i> - lowermost <i>P. neubergicus</i> Z.
<i>Pachydiscus (P.) neubergicus</i> (2)	<i>Bn. obtusa</i> Z.	<i>Bn. obtusa</i> Z.	<i>Bn. fastigata</i> + <i>S. tegulatus</i> / <i>Bt. junior</i> Z.	<i>P. neubergicus</i> Z. - ?
<i>Menuites</i> cf. <i>wittekindi</i> (2)	<i>Bn. lanceolata</i> Z.	<i>Bt. minor</i> / <i>N. polyplacum</i> + <i>N. bipunctatum</i> / <i>G. roemeri</i> / <i>Bt. langei</i> Z.		
<i>Diplomoceras cylindraceum</i> (2)	<i>Bn. lanceolata</i> - <i>Bn. sumensis</i> Z.	<i>Bn. obtusa</i> - <i>Bn. fastigata</i> Z.	<i>Bn. lanceolata</i> - <i>Bn. kazimiroviensis</i> Z.	uppermost <i>N. hyatti</i> - lower <i>P. neubergicus</i> Z.
<i>Baculites vertebralis</i> (2)	<i>Bn. lanceolata</i> - <i>Bn. sumensis</i> Z.	<i>Bn. obtusa</i> - <i>Bn. fastigata</i> Z.	<i>Bn. kazimiroviensis</i> Z.	
<i>Baculites knorrianus</i> (2)	<i>Bn. lanceolata</i> - <i>Bn. sumensis</i> Z.	<i>Bn. obtusa</i> - <i>Bn. fastigata</i> Z.	<i>Bn. fastigata</i> Z.	
<i>Acanthoscaphites (A.) tridens</i> forma <i>trispinosus</i> - <i>trinodosus</i> + forma <i>inodosus</i> (2)	<i>Bn. obtusa</i> + <i>Bn. sumensis</i> Z.	<i>Bn. obtusa</i> - <i>Bn. fastigata</i> Z.	<i>Bn. obtusa</i> + <i>Bn. sumensis</i> Z.	
<i>Acanthoscaphites (E.) varians</i> (3)	<i>Bn. cimbrica</i> - <i>S. tegulatus</i> / <i>Bt. junior</i> Z.		<i>Bn. fastigata</i> + <i>T. argentea</i> / <i>Bt. junior</i> Z.	
<i>Hoploscaphites schmidi</i> (3)	<i>S. tegulatus</i> / <i>Bt. junior</i> + <i>T. argentea</i> / <i>Bt. junior</i>			
<i>Hoploscaphites constrictus</i> (2, 3)	<i>Bn. lanceolata</i> - <i>T. argentea</i> / <i>Bt. junior</i> Z.	<i>Bn. obtusa</i> - <i>O. danica</i> / <i>T. argentea</i> Z.	<i>Bn. lanceolata</i> - <i>Bn. kazimiroviensis</i> Z.	<i>P. neubergicus</i> Z. - ?
<i>Hoploscaphites tenuistriatus</i> (3)	<i>Bn. fastigata</i> + <i>S. tegulatus</i> / <i>Bt. junior</i> Z.	<i>S. tegulatus</i> / <i>Bt. junior</i> - <i>O. danica</i> / <i>T. argentea</i> Z.	<i>Bn. fastigata</i> + <i>T. argentea</i> / <i>Bt. junior</i> Z.	

Table 2. Occurrences of ammonites in the Upper Campanian and Maastrichtian white chalk standard section of Lägerdorf, Kronsmoor and Hemmoor, additional northern German localities (Zeltberg, Rügen, Nennhausen, Lehrte West Syncline, Stenwedder Berg), Denmark (BIRKELUND 1993, text-figs 1,3) and Tercis, southwestern France (KÜCHLER & ODIN 2001; ODIN & al. 2001). Species from Hemmoor (3) according to BIRKELUND (1982)

2001), which are completely missing from the Boreal region of northern Germany and Denmark.

REMARKS ON THE CAMPANIAN-MAASTRICHTIAN BOUNDARY: It is the appearance of *Pachydiscus neubergicus* which is likely to be the most useful ammonite standard for the definition of the base of the Maastrichtian Stage, because it is a geographically widely distributed species, found in both Boreal and Tethyan regions. However, the indications are that its first appearance is higher than that of *Belemnella lanceolata*, the Boreal marker for the base of the Maastrichtian. At both German localities where *P. neubergicus* was found (Lüneburg: SCHMID 1955; SCHULZ & al. 1984; and Krons Moor: this paper), *in situ* records are from the *Belemnella obtusa* Zone. In order to refine the stratigraphic resolution, matrix samples of both specimens of *P. neubergicus* from the Krons Moor section were analysed for nannofossils by M.J. HAMPTON and L.T. GALLAGHER (Network Stratigraphic Consulting Ltd., Hertfordshire). Both samples have broadly the same nannofossil composition with *Broinsonia parca constricta* and *Reinhardtites anthophorus*, which characterise nannofossil zone CC23A and its equivalent UC16 (see BURNETT 1990, 1998).

According to BURNETT (*in* HANCOCK & al. 1993), *Br. parca*, the last occurrence of which marks the top of CC23A, at Krons Moor ranges up to the interval between Gb 621 and mB 623, uppermost *Bn. obtusa* Zone. In SCHÖNFELD & BURNETT (1991, p. 492), the last occurrence of *Br. parca* lies at the top of the *Bn. lanceolata* Zone and data in BURNETT (1998, LO of *Br. parca constricta* = top of *Bn. pseudobtusa* Zone) suggest that *Br. parca constricta* and *P. neubergicus* should be mutually exclusive. However, from the samples analysed herein it appears that they in fact do overlap and *Br. parca constricta* does range into the *Bn. obtusa* Zone, where *P. neubergicus* was found *in situ*.

Furthermore, the results are interesting as matrix samples of both *Pachydiscus neubergicus* contain specimens of *Reinhardtites anthophorus*. The LO of *R. anthophorus* marks the base of CC23A equivalent to the lower part of the *M. grimmensis* / *C. granulosis* Zone (cf. BURNETT 1990, 1998; SCHÖNFELD & BURNETT 1991; BURNETT *in* SCHÖNFELD & SCHULZ 1996), but *P. neubergicus* was found *in situ* c. 35 m higher (= c. 1.4 my later). If the identification is correct, *R. anthophorus* also seems to range up into the *Bn. obtusa* Zone and, therefore, the Campanian-Maastrichtian boundary at Krons Moor cannot be placed within CC23A (cf. BURNETT *in* HANCOCK & al. 1993; SCHÖNFELD & BURNETT 1991) or within the lower part of UC17 (BURNETT 1998).

Unfortunately, the two finds of *Pachydiscus neubergicus* presented herein do not much improve the biostratigraphic correlation of the Campanian-Maastrichtian boundary between the Boreal belemnite standard and the international ammonite standard zonation. If one accepts the calculated accumulation rates of the chalk at Krons Moor (24.5 m/my, EHRMANN 1986), *P. neubergicus* appears *in situ* c. 690 ky later and *Diplomoceras cylindraceum* c. 260 ky later than *Belemnella lanceolata* (see Text-fig. 4). *Nostoceras polyplacum* is another ammonite quoted from the underlying beds of the Alsen quarry at Lägerdorf (see Text-fig. 3) and its FO is c. 3.6 my and c. 4 my older than the FOs of *D. cylindraceum* and the *in situ* found *P. neubergicus*. In contrast to the misleading illustration of ODIN (2001, fig. 3), *Nostoceras hyatti*, the last occurrence of which is the third ammonite marker for the boundary definition of the GSSP at Tercis, is neither known from Krons Moor nor in northern Germany.

At Tercis the FOs of *D. cylindraceum* and *P. neubergicus* are separated by c. 200 ky (calculated accumulation rates at Tercis: 25 m/my, ODIN & TURIN 2001) and the Campanian-Maastrichtian boundary is situated between them (ODIN & Maastrichtian Working Group members 2001; ODIN & LAMAURELLE 2001), c. 3.6 and c. 3.8 my above the FO of *Nostoceras polyplacum*. This would indicate that the FOs of *N. polyplacum* and *D. cylindraceum* at Lägerdorf and Krons Moor are nearly isochronous compared with Tercis. At Krons Moor the base of the Maastrichtian in ammonite terms seems to be located within the *Belemnella pseudobtusa* Zone (see Text-figs 2, 4) and, therefore, the FO of *Belemnella* is definitely of Late Campanian age. This agrees with WALASZCZYK & al. (2002, p. 57) who favour the view, based on inoceramid evidence, that 'the base of the *Bn. lanceolata lanceolata* Zone, the traditional basal zone of the Maastrichtian in northern Europe, may appear to be stratigraphically much lower' (than the GSSP at Tercis). The view of correlation between the GSSP at Tercis and Krons Moor by CHRISTENSEN (2001) is that 'the FO of *Bn. lanceolata* at Krons Moor virtually corresponds to the Campanian-Maastrichtian Stage boundary at level 115.2 m at Tercis, as defined by a multi-bioevents approach'. However, for Krons Moor it must be pointed out that – based on the Campanian-Maastrichtian boundary definition by the FOs of *P. neubergicus* and *D. cylindraceum* – the FO of *Bn. lanceolata* is c. 540 ky older (and not only c. 200 ky, as assumed by CHRISTENSEN & al. 2000). The problem is still far from its final solution. Further investigations on the Campanian-Maastrichtian boundary interval of Krons Moor by means of nannofossil and foraminiferal records in relation to carbon and oxygen isotopic data are in hand by NIEBUHR, WEISS, HAMPTON & GALLAGHER.

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PLATE 1

- 1-3** – *Hypophylloceras* (*Neophylloceras*) *velledaeforme* (SCHLÜTER, 1872) ; 1 – Lateral views of outer whorl and associated nucleus. G 616 + 0.9 m, *Bn. obtusa* Zone. Coll. M.-G. SCHULZ, Ma13684; 2 – Lateral view. G 620 + 1.3 m, *Bn. obtusa* Zone. Coll. M.-G. SCHULZ, Ma13685; 3 – Lateral view, fragment with visible septa. mB 594 ± 2 m, *M. grimmensis* / *C. granulosus* Zone. Coll. M.-G. SCHULZ, Ma13686.
- 4** – *Saghalinites wrighti* BIRKELUND, 1965. Lateral view. G 615, *Bn. obtusa* Zone. *Ex* Coll. J.W.M. JAGT, now Coll. K. ESSER, PIW2003VIII1.
- 5** – *Anagaudryceras lueneburgense* (SCHLÜTER, 1872). External mould of outer whorl and lateral view of inner whorl. mB 607 + 0.2 m, *Bn. lanceolata* Zone. Coll. M.-G. SCHULZ, Ma13687.
- 6-7** – *Pachydiscus* (*Pachydiscus*) *neubergicus* (VON HAUER, 1858); 6 – Lateral and ventral views. Between G 595 and G 610, *M. grimmensis* / *C. granulosus* to *Bn. pseudobtusa* zones. Coll. M.-G. SCHULZ, Ma13688; 7 – Lateral view. G 615, *Bn. obtusa* Zone. Coll. K. ESSER, PIW2003VII2.
- 8** – *Diplomoceras cylindraceum* (DEFRANCE, 1816). Lateral view. Above mB 629, *Bn. sumensis* Zone, exact horizon unknown. Coll. C. NEUMANN.

All figures are natural size

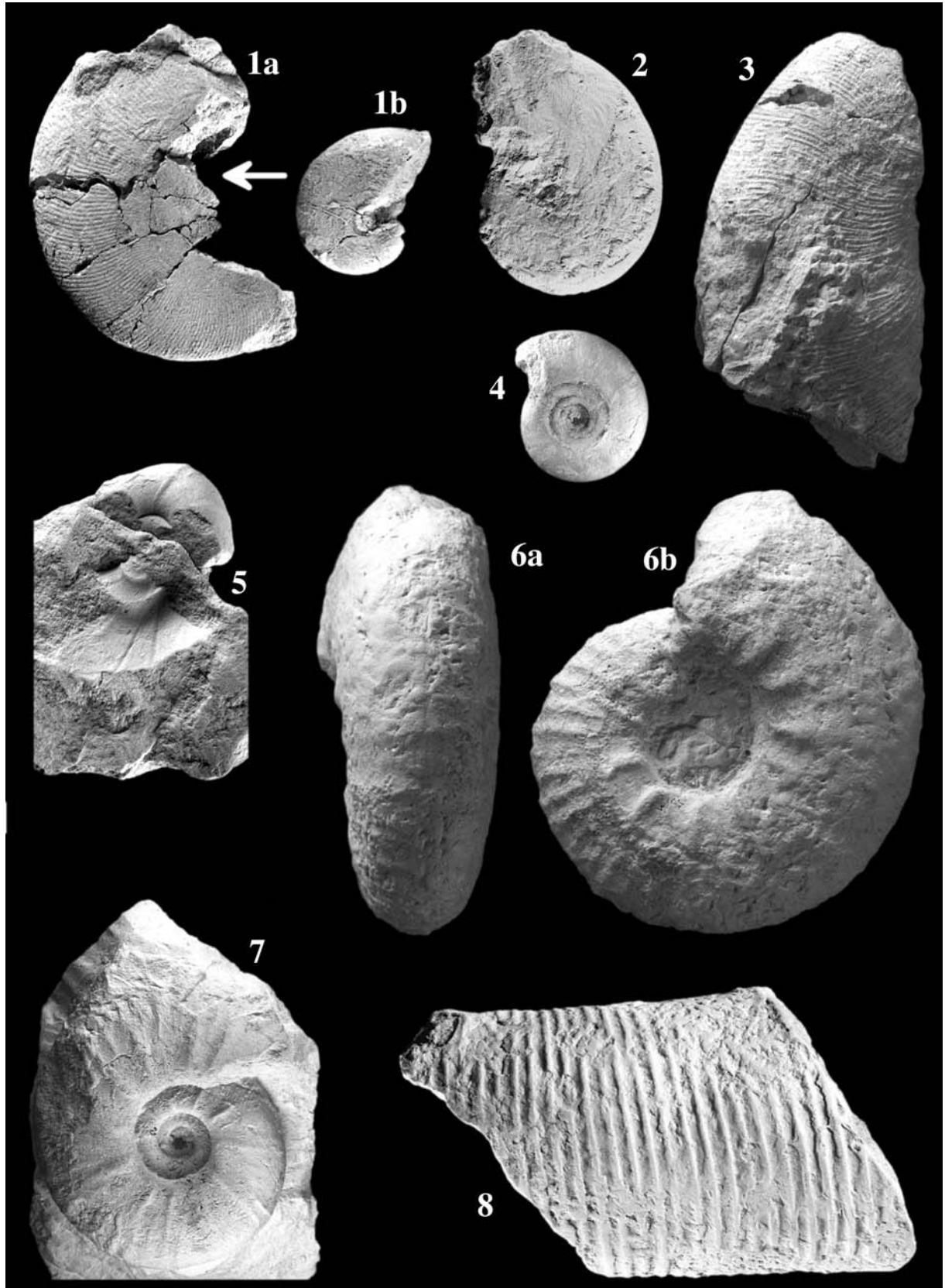


PLATE 2

Menuites cf. *wittekindi* (SCHLÜTER, 1872)

Lateral and ventral views of a macroconch (M) phragmocone. Between mB 603 and mB 607, *Bn. lanceolata* Zone. Coll. M.-G. SCHULZ, Ma13689.

All figures are natural size

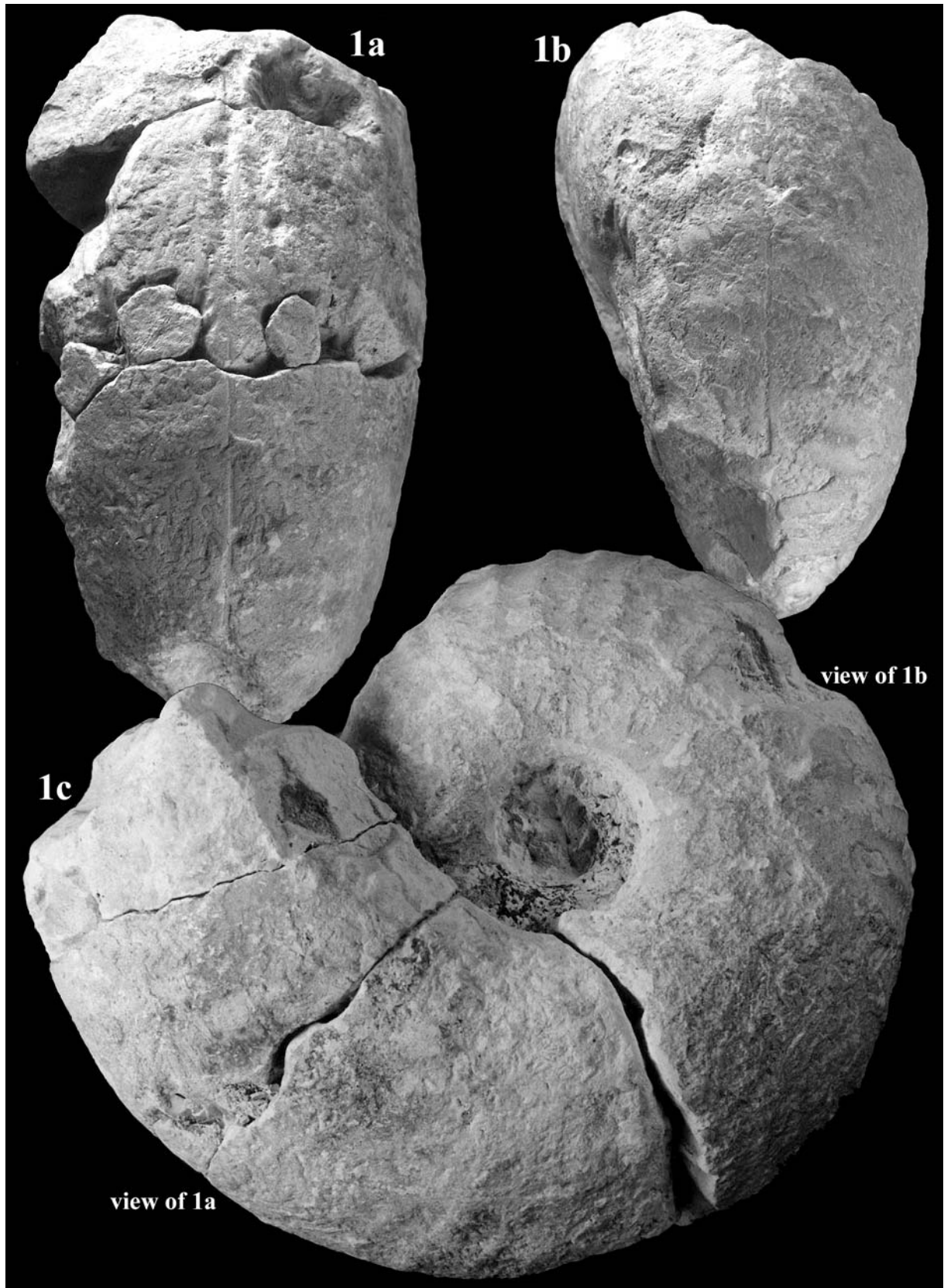


PLATE 3

Baculites vertebralis LAMARCK, 1801

- 1 – Lateral view, cross section, and suture. I = internal lobe, U = umbilical lobe, L = lateral lobe, E = external lobe. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VII3;
- 2 – Lateral view with visible suture lines. mB 628 - 0.6 m, *Bn. sumensis* Zone. Coll. C. NEUMANN;
- 3 – Lateral view; mB 603 + 0.2 m, *Bn. lanceolata* Zone. Coll. C. NEUMANN;
- 4 – Event bed with six specimens. Between mB 628 and F 630, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VII4.

All figures are natural size

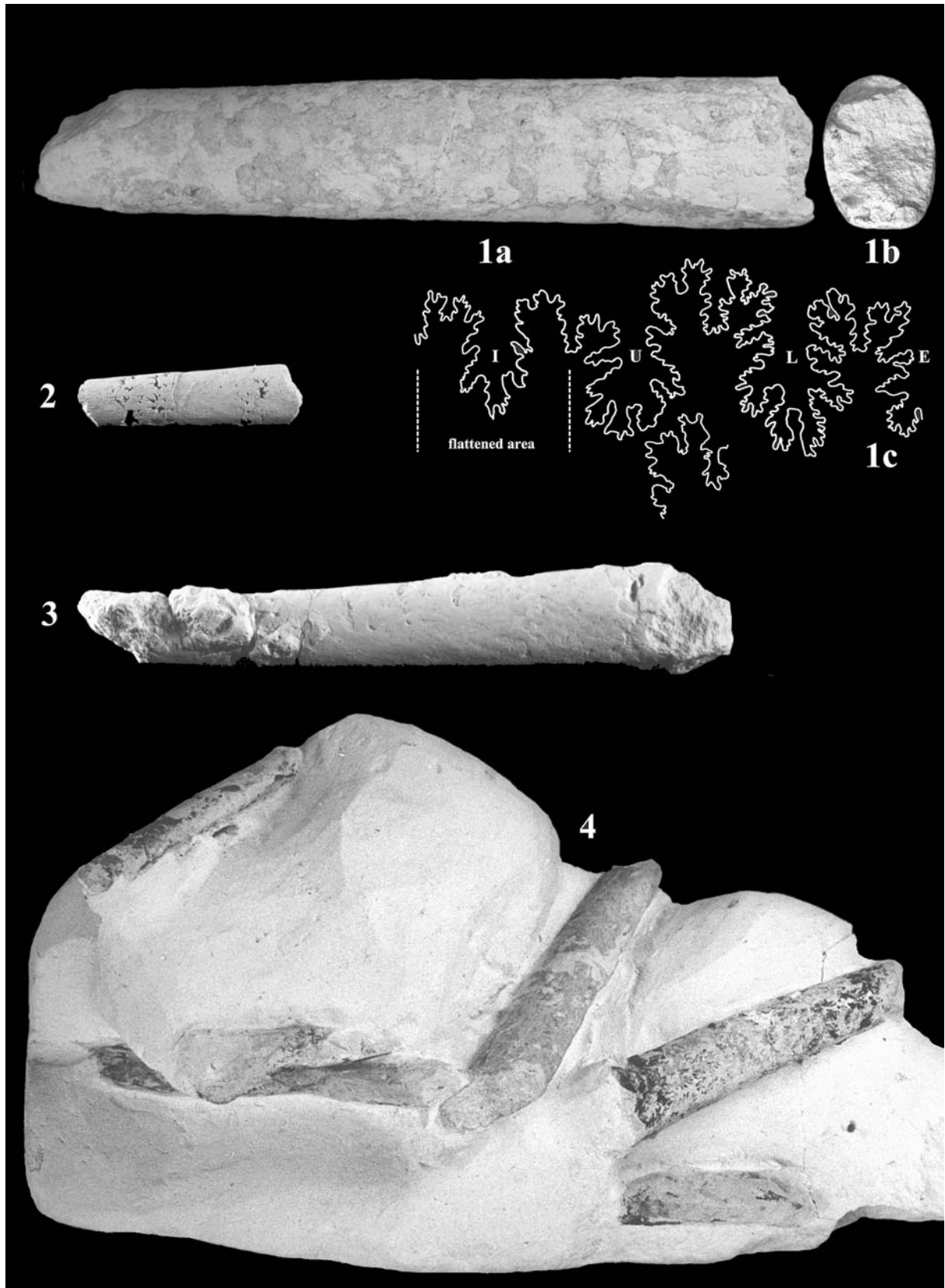


PLATE 4

- 1 – *Diplomoceras cylindraceum* (DEFRANCE, 1816). Lateral view. Between mB 626 and F 630, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VII5.
- 2 – *Baculites knorrianus* (DESMAREST 1817). Lateral view. *Bn. obtusa* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VII6.
- 3 – *Baculites knorrianus* (DESMAREST 1817). Lateral view with suture line marked. U = umbilical lobe, L = lateral lobe. Between mB 623 and mB 628, *Bn. sumensis* Zone. Coll. C. NEUMANN.

All figures $\times 0.75$

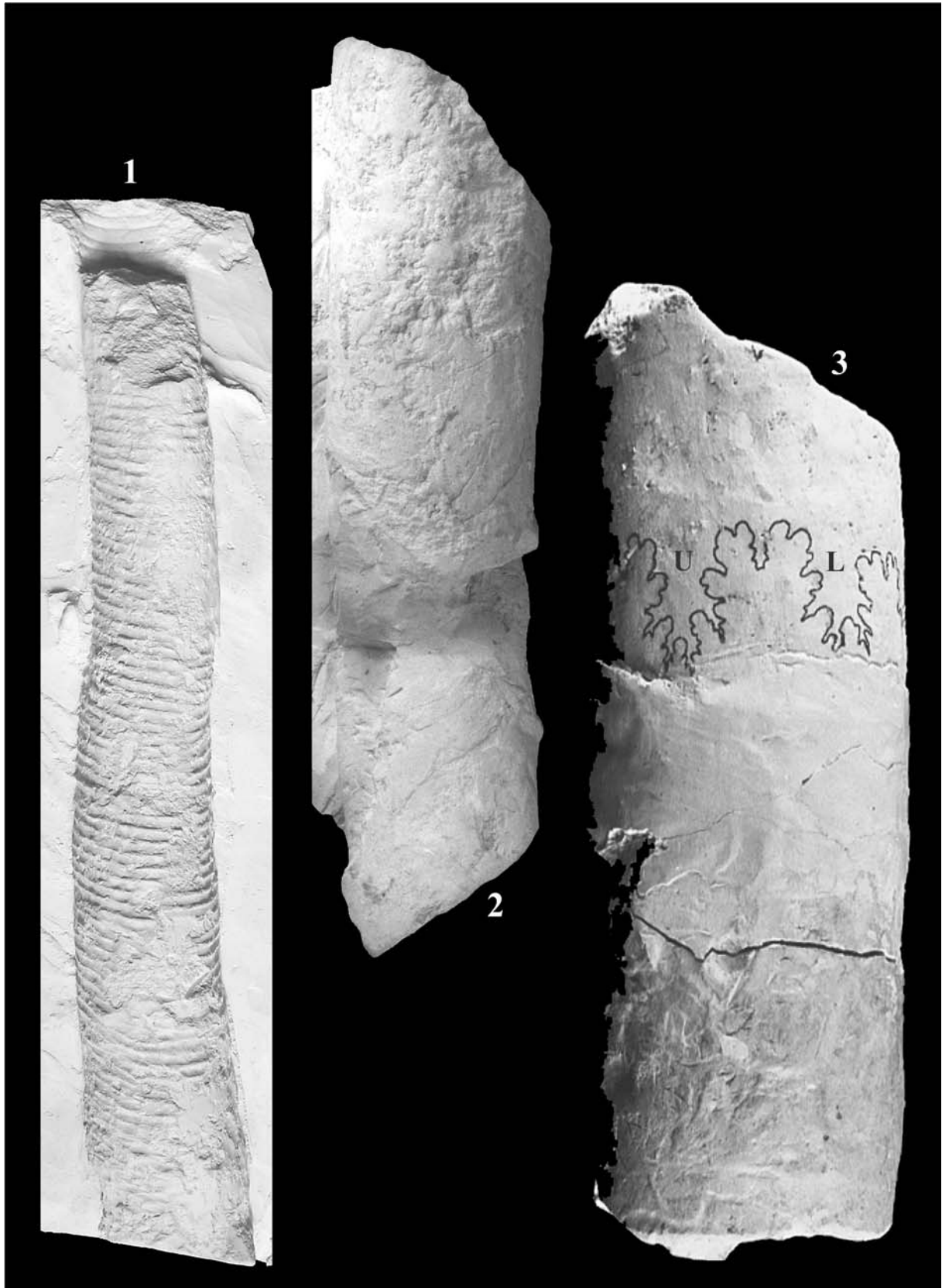


PLATE 5

Acanthoscaphites (Acanthoscaphites) tridens (KNER, 1848) forma *trispinosus* (M) - *trinodosus* (m).

- 1 – Ventral view, fragment of a microconch (m). Between G 620 and mB 625, *Bn. obtusa* to *Bn. sumensis* zones. Coll. M.-G. SCHULZ, Ma13690;
- 2 – Lateral view of a fragment of a microconch (m). mB 628 - 0.7 m, *Bn. sumensis* Zone. Coll. M.-G. SCHULZ, Ma13691;
- 3 – Lateral view of a nearly complete body chamber of a macroconch (M). mB 628 + 1 m, *Bn. sumensis* Zone. Coll. M.-G. SCHULZ, Ma13692;
- 4 – Lateral and ventral views of a complete nucleus. Above G 620, *Bn. sumensis* Zone, exact horizon unknown. Coll. M.-G. SCHULZ, Ma13693;
- 5 – Ventral and lateral views of a fragment of a body chamber. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VII7;
- 6 – Ventral and lateral views of a microconch (m) with atypical ornament, lacking stratigraphic information. Coll. M.-G. SCHULZ, Ma13694;
- 7 – Lateral and ventral views of a near-complete nucleus. mB 628 - 1 m, *Bn. sumensis* Zone. Coll. M.-G. SCHULZ, Ma13695;
- 8 – Lateral view of a microconch (m). Between mB 627 and mB 628, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VII8;
- 9 – Ventral and lateral views of a fragment of a nucleus. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VII9.

All figures are natural size

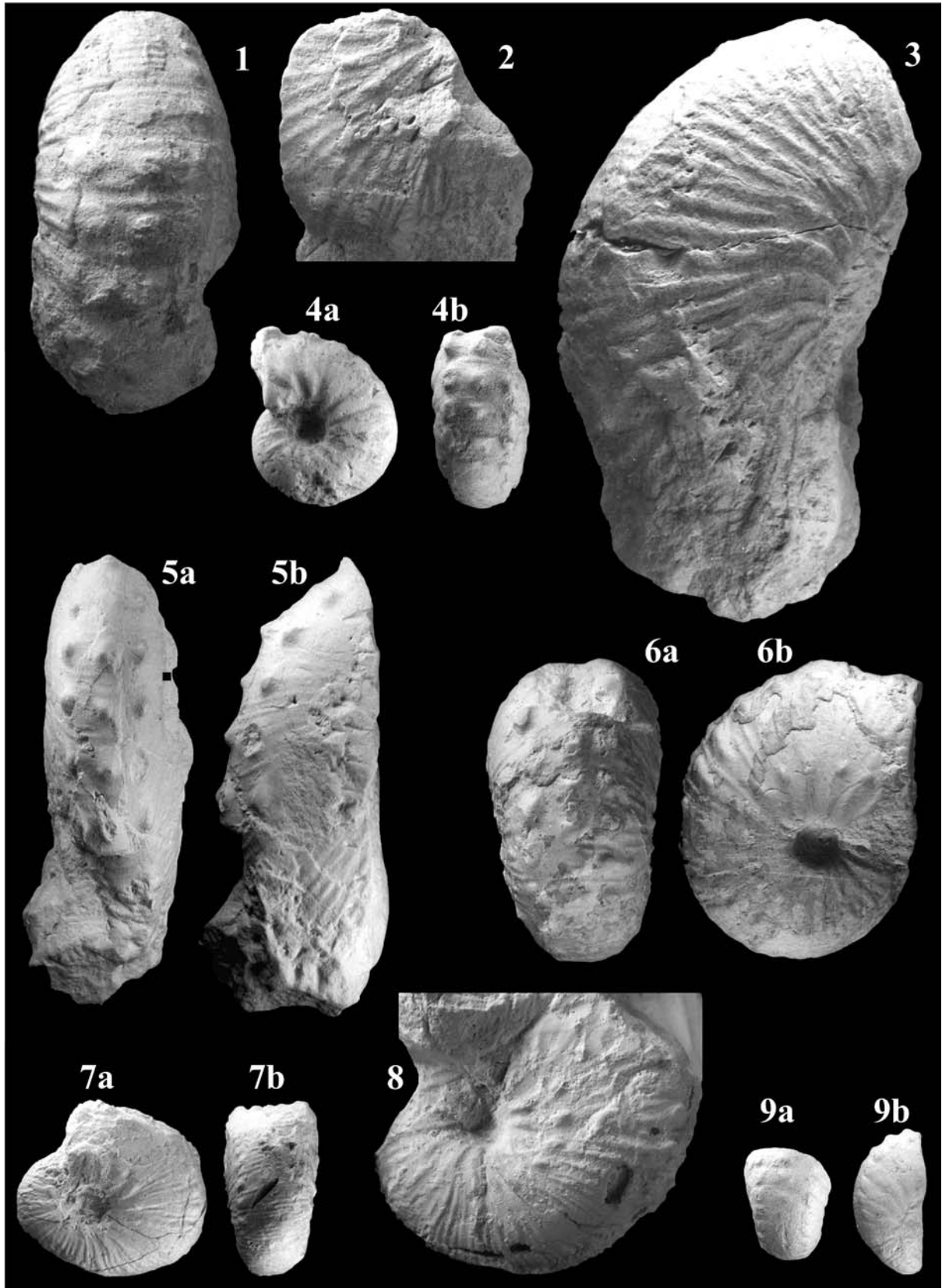


PLATE 6

Acanthoscaphites (Acanthoscaphites) tridens (KNER, 1848) forma *trispinosus* (M) -
trinodosus (m).

Lateral and ventral views of a macroconch (M) with very coarse ribbing and ventral tuberculation on the phragmocone. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VII10.

All figures are natural size.

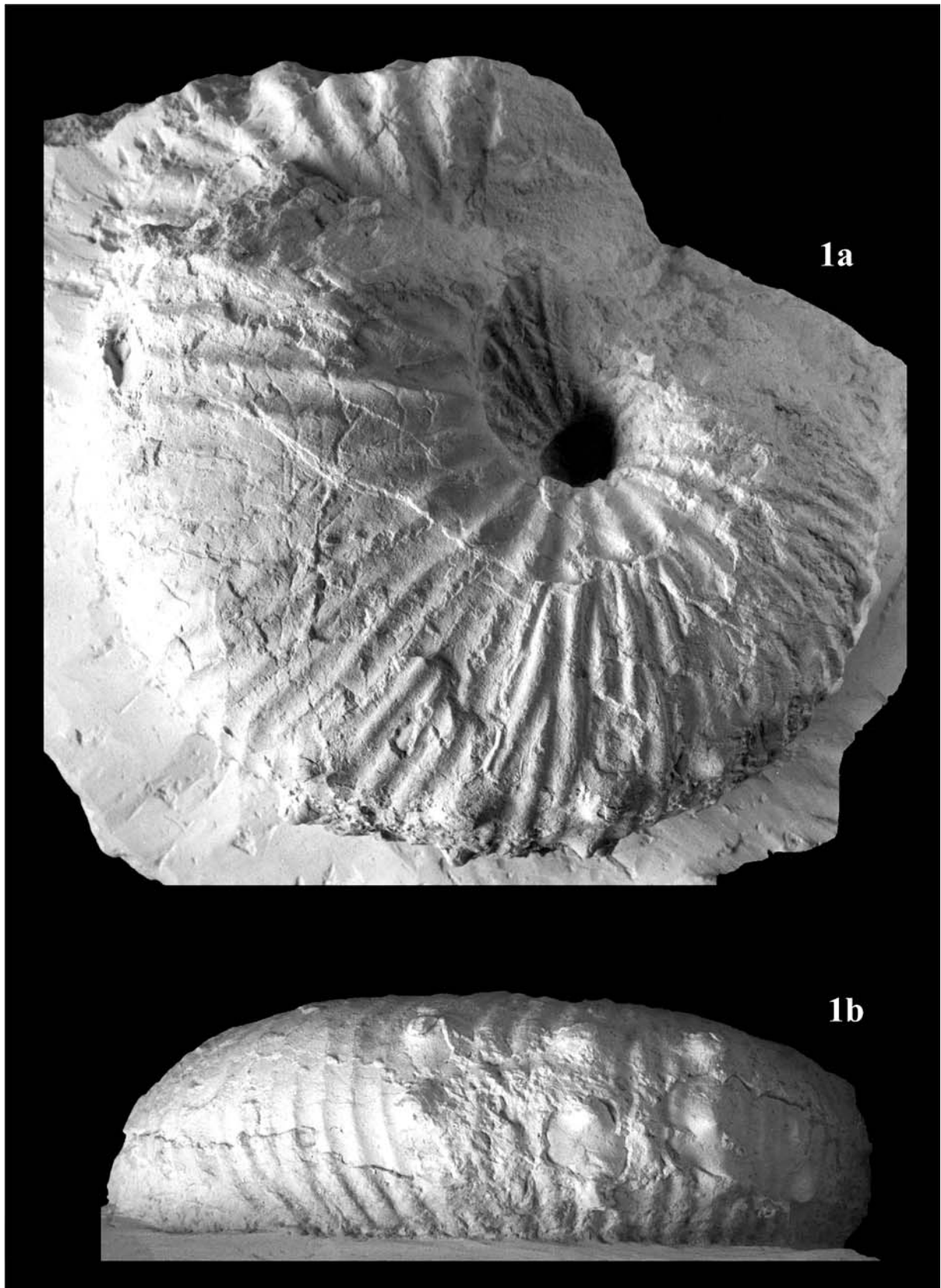


PLATE 7

- 1** – *Acanthoscaphites* (*Acanthoscaphites*) *tridens* (KNER, 1848) forma *innodosus*(M). Lateral view of a macroconch (M) with dense ribbing and lacking tuberculation. F 631 + 0.5 m, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VIII11.
- 2-4** – *Hoploscaphites constrictus* (J. SOWERBY, 1817); 2 – Lateral view of a macroconch (M). G 604 - 0.6 m, *Bn. lanceolata* Zone. Coll. M.-G. SCHULZ, Ma13696; 3 – Lateral view of a microconch (m). G 620 + 2 m, *Bn. obtusa* Zone. Coll. M.-G. SCHULZ, Ma13697; 4 – Lateral view of a macroconch (M). G 615 + 1 m, *Bn. obtusa* Zone. Coll. K. ESSER, PIW2003VIII12.
- 5** – *Hoploscaphites* cf. *constrictus* (J. SOWERBY, 1817). Lateral view of a strongly damaged macroconch (M). mB 603 ± 0.3 m, *Bn. lanceolata* Zone. Coll. M.-G. SCHULZ, Ma13698.
- 6-10** – Non-tuberculate nuclei of *Hoploscaphites* sp. and/or *Acanthoscaphites* sp.; 6 – Lateral view. Between mB 627 and mB 628, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VIII13; 7 – Lateral and ventral views of a deformed specimen. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VIII14; 8 – Lateral view. Between F 632 and F 633, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VIII15; 9 – Lateral and ventral views. mB 626 + 1.5 m, *Bn. sumensis* Zone. Coll. M.-G. SCHULZ, Ma13699; 10 – Lateral and ventral views of a complete juvenile specimen. Between mB 626 and mB 628, *Bn. sumensis* Zone. Coll. K. ESSER, PIW2003VIII16.
- 11** – Nucleus of *Hoploscaphites constrictus* (J. SOWERBY, 1817). Lateral views. mB 603, *Bn. lanceolata* Zone. Coll. M.-G. SCHULZ, Ma13700.
- 12** – Aptychus of *Hoploscaphites* sp.. *Bn. sumensis* Zone, exact horizon unknown. Coll. K. ESSER, PIW2003VIII17.

All figures are natural size

