The highest records of North American scaphitid ammonites in the European Maastrichtian (Upper Cretaceous) and their stratigraphic implications

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ABSTRACT:

MACHALSKI, M., JAGT, J.W.M., LANDMAN, N.H. & MOTCHUROVA-DEKOVA, N. 2007. The highest records of North American scaphitid ammonites in the European Maastrichtian (Upper Cretaceous) and their stratigraphic implications. *Acta Geologica Polonica*, **57** (2), 169-185. Warszawa.

The uppermost lower to upper Maastrichtian records of North American scaphitid ammonites in Europe are discussed in terms of taxonomy and significance for transatlantic correlation. A previous record of a U.S. Western Interior scaphitid ammonite, *Jeletzkytes dorfi*, from the lower part of the upper Maastrichtian in northeast Belgium, is demonstrated to have been based on specimens which reveal features typical of the indigenous European *Hoploscaphites constrictus* lineage. However, one of the individuals in this collection combines distinct mid-ventral swellings, characteristic of the *H. constrictus* stock, with irregular flank ornament, typical of *J. dorfi*. It is speculated that this specimen may be a product of interspecies hybridization. *Hoploscaphites* sp., allied to *H. nicolletii* or to *H. comprimus*, previously known only from the U.S. Western Interior, is recorded from the lower upper Maastrichtian of Austria, and *Discoscaphites gulosus*, hitherto regarded to be confined to the U.S. Western Interior, Gulf Coast, and Atlantic Seaboard, has been recognised in the upper Maastrichtian of Bulgaria. Additionally, poorly preserved material referred to as *Discoscaphites*? sp. is recorded from the uppermost lower Maastrichtian of Denmark, and from the upper Maastrichtian of southern Sweden. These records of scaphitids support earlier conclusions that the base of the European upper Maastrichtian roughly corresponds to the base of the *Hoploscaphites birkelundae* Zone in the U.S. Western Interior.

Key words: Maastrichtian, Cretaceous, Europe, North America, Ammonites, Scaphitids, Correlation.

INTRODUCTION

The level of precision in correlation between marine uppermost Cretaceous successions in Europe and North America is still far from satisfactory. This precludes detailed synchronisation of biotic changes on both sides of the Atlantic predating the Cretaceous-Palaeogene (K-Pg) event (e.g. JELETZKY 1960, 1962; KENNEDY & *al*. 1998). The weakest ties are between upper Maastrichtian successions of Europe and the U.S. Western Interior of North America, which can be ascribed to a high level of endemism amongst biota of both regions. However, rare transatlantic occurrences of scaphitid ammonites (JAGT & KENNEDY 1994) and inoceramid bivalves (WALASZCZYK & COBBAN 2006) provide biostratigraphic data for correlation of upper Maastrichtian deposits between the U.S. Western Interior and Europe (JAGT & KENNEDY 1994; KENNEDY & *al*. 1998; WALASZCZYK & COBBAN 2006).

As far as scaphitids are concerned, JAGT & KENNEDY (1994) reported the occurrence of *Jeletzkytes dorfi* LANDMAN & WAAGE, 1993 at the CPL SA quarry, Haccourt (northeast Belgium; see Text-fig. 1 for location of this and other localities mentioned in the text). That species had previously been known only from the *Hoploscaphites birkelun-dae* Zone of the U.S. Western Interior (LANDMAN & WAAGE 1993). The level in the Belgian succession which yielded *J. dorfi* was assigned by JAGT & KENNEDY (1994) to the lower portion of the upper Maastrichtian *Belemnitella junior* Zone (see Text-fig. 2 for stratigraphic scheme of the European Maastrichtian). On this basis, those authors suggested that the European, belemnite-based, boundary between the lower and upper Maastrichtian roughly corresponded to the base of the *Hoploscaphites birkelundae* ammonite zone in the U.S. Western Interior. This allowed, in turn, the conclusion that the lower/upper Maastrichtian boundary was 'slightly younger than 69.42 ± 0.37 myr' (JAGT & KENNEDY 1994, p. 240).

Until now, the Belgian record of *J. dorfi* was regarded as the highest, well-substantiated record of a North American scaphitid ammonite from Europe. Other 'mid' to upper Maastrichtian records from Hemmoor (northern Germany) and Lviv (western Ukraine; see Text-fig. 1), presumed to represent the U.S. Western Interior species *Hoploscaphites nicolletii* (MORTON, 1842) (JELETZKY 1962; NAIDIN 1974), were questioned by subsequent authors (BIRKELUND 1965; WAAGE 1968; LANDMAN & WAAGE 1993; MACHALSKI 2005).

In the present paper, we reinterpret the material previously reported from Belgium as *J. dorfi* and

Fig. 1. Location of uppermost lower to upper Maastrichtian successions which have yielded scaphitids discussed in the present paper

provide some additional examples of scaphitids conspecific or closely allied to the North American taxa from uppermost lower and upper Maastrichtian strata in Europe. These include specimens from Austria, Bulgaria, Denmark, and southern Sweden (Text-fig. 1), most of them previously considered to be representatives of indigenous European scaphitid lineages.

Although both preservation and stratigraphic constraint of part of the material discussed herein leave much to be desired, we hope the present study will stimulate others to look for better-preserved scaphitids of North American affinity in higher levels of the European Maastrichtian.

TAXONOMY

Specimens studied are housed in the following collections: ANSP, the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA; EMP, École des Mines collections, formerly in Paris, but now in the Université Claude-Bernard, Lyon, France; GBA, Geologische Bundesanstalt, Vienna, Austria; MGUH, Geological Museum of Copenhagen University, Copenhagen, Denmark; NHMM, Natuurhistorisch Museum Maastricht, the Netherlands; NHMW, Naturhistorisches Museum, Vienna, Austria; NLfB, Niedersächsisches Landesamt für Bodenforschung, Hannover, Germany; PMUS, Paleontological Museum of the University of Sofia "St Kliment Ohridski", Bulgaria; SGU, Sveriges Geologiska Undersökning, Uppsala, Sweden; YPM, Yale Peabody Museum of Natural History, New Haven, Connecticut, USA.

Jeletzkytes dorfi sensu JAGT & KENNEDY (1994) from northeast Belgium

The material studied comprises three specimens: NHMM 1993070, NHMM 1993071, and NHMM 1993072 (all ex JAGT Collection), described and illustrated by JAGT & KENNEDY (1994, fig. 3A-E). These specimens come from interval 6 of the Vijlen Member (Gulpen Formation), as exposed at the CPL (Ciments Portland Liégeois) SA quarry at Haccourt (province of Liège, northeast Belgium) (Text-fig. 1).

Interval 6 of this member was assigned to the

lower part of the lower upper Maastrichtian *Belemnitella junior* Zone by JAGT & KENNEDY (1994). It was subsequently reassigned to the upper lower Maastrichtian *Belemnella cimbrica* Zone by KEUTGEN (1996), on the basis of the occurrence of the eponymous belemnite species. However, no early Maastrichtian belemnites have been recorded from interval 6 at Haccourt, but only from presumably correlative strata at other localities, e.g., the nearby CBR-Lixhe quarry and temporary exposures in the Aachen city area (N. KEUTGEN, pers. comm., November 2006). Moreover, early Maastrichtian belemnites from the upper part of the Vijlen Member have recently been interpreted as reworked material, and a late Maastrichtian date in terms of belemnite stratigraphy has now been firmly established for intervals 4, 5, and 6 of this member (KEUTGEN, JAGT and FELDER, in preparation).

The specimens from Haccourt, all composite moulds, were assigned by JAGT & KENNEDY (1994) to *Jeletzkytes dorfi*, a scaphitid known previously only from the *Hoploscaphites birkelundae* Zone of the Fox Hills Formation and upper part of the Pierre Shale in South Dakota, Wyoming, and Colorado (U.S. Western Interior) (see LANDMAN & WAAGE 1993; LANDMAN & COBBAN 2003).

NHMM 1993070 (JAGT & KENNEDY 1994, fig. 3C) is a body chamber with preserved aperture. It is the smallest individual in this collection, with a maximum length of 29 mm. The concave umbilical wall of the body chamber indicates that it is an adult microconch (cf. JAGT & KENNEDY 1994). The ornament is significantly different from that of microconchs of *Jeletzkytes dorfi* as illustrated by LANDMAN & WAAGE (1993, e.g. fig. 146). Moreover, microconchs of *J. dorfi* from the U.S. Western Interior are usually much larger than the Haccourt individual, averaging 57 mm in maximum length, and ranging from 49 to 65 mm (LANDMAN & WAAGE 1993, table 16). In contrast, both size and ornament of NHMM 1993070 fall within the range of variation of microconchs in populations of the indigenous European scaphitid, *Hoploscaphites constrictus* (J. SOWERBY, 1817). Microconchs almost identical to that from Haccourt occur amongst topotypical material of *H. constrictus* from the lower upper Maastrichtian "Calcaire à *Baculites*" of Cotentin (Manche, France) (compare KENNEDY 1986, pl. 15, figs 4-9). MACHALSKI (2005, fig. 7A) illustrated a similar microconch from the upper Maastrichtian of

Chronostratigraphy		1) Faunal zones, NW Germany	2) Belemnite zones, NW Germany	3) Conventional belemnite zones	Brachiopod zones, NW Europe 4)	5)	6) Inoceramid zones
MAASTRICHTIAN U	U	*baltica/danica*		*Belemnella kazimiroviensis*	*stevensis-chitoniformis*	10	
MAASTRICHTIAN U	U	*danica/argentea*	*Belemnitella junior*	*Belemnitella junior*	*humboldtii-stevensis*	9	
MAASTRICHTIAN U	L	*argentea/junior*			*semiglobularis-humboldtii*	8	
MAASTRICHTIAN U	L	*tegulatus/junior*					*"Inoceramus" morgani*
MAASTRICHTIAN L U	U	*fastigata*	*fastigata*		*tenuicostata-semiglobularis*	7	*Cataceramus* sp.
MAASTRICHTIAN L U	U	*cimbrica*	*cimbrica*	*Belemnella occidentalis*	*pulchellus-tenuicostata*	6	
MAASTRICHTIAN L	L	*sumensis*	*sumensis* (*Belemnella*)		*pulchellus-pulchellus*	5	*Trochoceramus radiosus*
MAASTRICHTIAN L	L				*subtilis-pulchellus*	4	
MAASTRICHTIAN L	L	*obtusa*	*obtusa*	*Belemnella lanceolata*	*spinosa-subtilis*	3	*Endocostea typica*
MAASTRICHTIAN L	L						*"Inoceramus" redbirdensis*
MAASTRICHTIAN L	L	*pseudobtusa*	*pseudobtusa*		*acutirostris-spinosa*	2	
MAASTRICHTIAN L	L	*lanceolata*	*lanceolata*		*jasmundi-acutirostris*	1	*Trochoceramus costaecus*

Fig. 2. Stratigraphical correlation diagram of the European Maastrichtian to show macrofaunal (including belemnite) zones in northwest Germany, conventional belemnite zonation for northwest Europe, brachiopod zones for the same area and inoceramid zones for the lower Maastrichtian of northwest Europe (columns 1-5 based on CHRISTENSEN 1996, fig. 3). Sources are as follows - column 1: SCHULZ & SCHMID (1983); column 2: SCHULZ (1979), SCHULZ & SCHMID (1983); column 3: JELETZKY (1951), BIRKELUND (1957); column 4: SURLYK (1984); column 5 (SURLYK, 1970); column 6 (I. WALASZCZYK, pers. comm. 2007, see also WALASZCZYK & *al.* 2002; WALASZCZYK 2004). T – position of GSSP for the base of the Maastrichtian Stage as accepted in 2001 (ODIN 2001; ODIN & LAMAURELLE, 2001). Z – proposed position of the lower/upper Maastrichtian boundary, based on the first appearance of *Menuites fresvillensis* (ODIN 1996; FATMI & KENNEDY 1999; KLINGER & *al.* 2001). Figure from MACHALSKI 2005 (slightly modified)

Rejowiec, Lublin Upland (eastern Poland). We thus regard NHMM 1993070 as a microconch of *H. constrictus*.

NHMM 1993071 is crushed, and consists of the adapertural part of the phragmocone and a complete body chamber with preserved aperture (JAGT & KENNEDY 1994, fig. 3A, B; Text-fig. 3.1-3.5 herein). Its maximum length is estimated at c. 40 mm. NHMM 1993071 was regarded as a microconch by JAGT & KENNEDY (1994); however, we consider it to be an adult macroconch on account of the high whorl of the shaft (Text-fig. 3.1, 3.2). It does not show much resemblance to the type material of *Jeletzkytes dorfi* as described by LANDMAN & WAAGE

(1993), and cannot be regarded as conspecific. NHMM 1993071 is also much smaller than the macroconchs of *J. dorfi* from the U.S. Western Interior, which average 79 mm, and range from 67 to 105 mm in maximum length (LANDMAN & WAAGE 1993, table 16). NHMM 1993071 also departs from typical macroconchs of *H. constrictus*, e.g., those from the *stratum typicum* of this species, the "Calcaire à *Baculites*" of Cotentin (KENNEDY 1986). In contrast, it resembles some specimens from that unit which were referred to as *Hoploscaphites* sp. by KENNEDY (1986). In particular, specimen EMP 'A' (ex Deshayes Collection) from Orglandes is a good match to NHMM 1993071
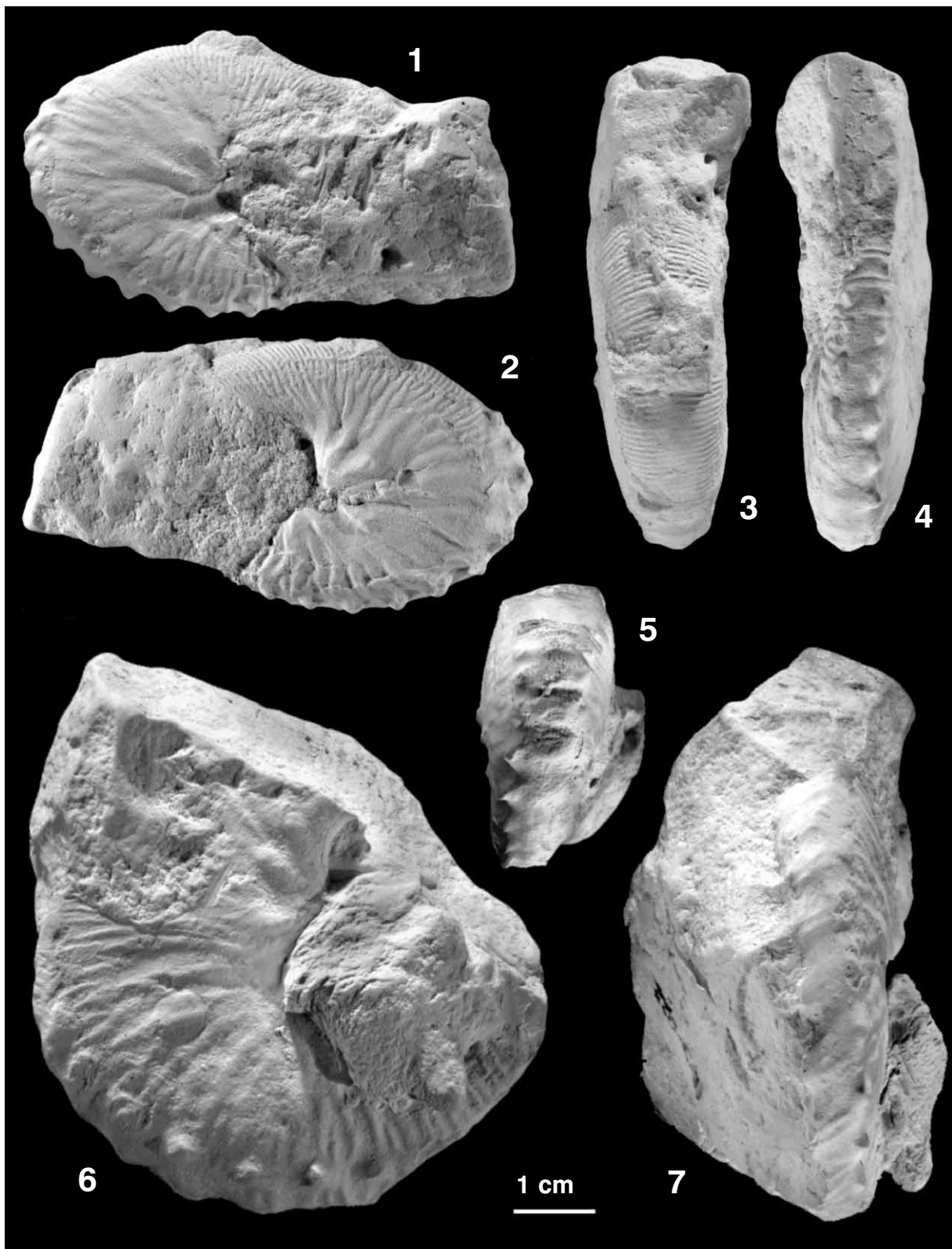
Fig. 3. **1-5** – *Hoploscaphites* sp. 1, NHMM 1993071; 1-2 – lateral views; 3 – postero-ventral view; 4 – postero-dorsal view; 5 – posterior view (terminology of photographic views based on LANDMAN & WAAGE 1993, fig. 11); **6-7**– *Hoploscaphites* sp. 2, NHMM 1993072; 6 – lateral view; 7– postero-dorsal view

(compare KENNEDY 1986, pl. 16, figs 1, 4, 13 and Text-fig. 3.1-3.5 herein). KENNEDY (1986, p. 76) compared his *Hoploscaphites* sp. from Cotentin to giant *H. schmidi* BIRKELUND, 1982 from Hemmoor (see MACHALSKI 2005 for the most recent review of the latter species) and regarded the former as "a significantly later parallel departure in ornament from typical *H. constrictus*". We share this view and extend it to NHMM 1993071, regarding it as a further offshoot of the main *H. constrictus* lineage. The scarcity of material available prevents us from any firm taxonomic decisions and we provisionally refer to NHMM 1993071 as *Hoploscaphites* sp. 1.

NHMM 1993072 (JAGT & KENNEDY 1994, fig. 3D, E; Text-fig. 3.6-3.7 herein) is a macroconch as indicated by the high whorl of the shaft and suggestion of an umbilical bulge (cf. JAGT & KENNEDY 1994). This is the largest specimen in the present lot, measuring approximately 60 mm in maximum original length. It is crushed, partially obliterated by a silex nodule, and consists of the adapertural part of the phragmocone and most of the body chamber with no hook preserved (Text-fig. 3.6-3.7).

We support JAGT & KENNEDY (1994) in their observation that there is a striking resemblance between NHMM 1993072 and some individuals of *Jeletzkytes dorfi* from the U.S. Western Interior as illustrated by LANDMAN & WAAGE (1993). In particular, these specimens share the same pattern of outer flank ribbing on the adapical portion of the body chamber (compare the relevant portions in NHMM 1993072 [Text-fig. 3.6] and the macroconch YPM 23175, the holotype of *J. dorfi*, as illustrated by LANDMAN & WAAGE 1993, fig. 141A-E). However, none of the U.S. Western Interior specimens of *J. dorfi*, neither micro- nor macroconchs, has siphonal swellings, which are well developed in NHMM 1993072 (Text-fig. 3.7). In contrast, siphonal swellings are characteristic of many members of the *H. constrictus* lineage, including the more robust individuals in populations of the eponymous species as well as in representatives of its short-lived offshoots (e.g. KENNEDY 1986; MACHALSKI 2005).

The strange combination of characters in NHMM 1993072 is difficult to explain with a single specimen at hand. However, some speculation is possible on the nature of NHMM 1993072. One possibility is that it may belong to an unknown species of the *Hoploscaphites constrictus* lineage, homeomorphic to North American *Jeletzkytes dorfi*

with respect to flank ornament. However, it is extremely unlikely that a near-identical pattern of flank ribbing evolved independently, yet simultaneously, on both sides of the Atlantic (according to WALASZCZYK & COBBAN 2006, non-tegulated inoceramids indicate that the *Hoploscaphites birkelundae* Zone in the U.S. Western Interior roughly corresponds to interval 6 of the Vijlen Member in northeast Belgium). Another possibility is that NHMM 1993072 is a pathological specimen of *Jeletzkytes dorfi* which acquired siphonal swellings due to malformation or parasitic infection. However, the pattern of swellings on the venter in NHMM 1993072 is too regular to be interpreted as pathologic.

Another possibility is that NHMM 1993072 is a hybrid, the result of interbreeding between an indigenous specimen of an unidentified species from the *H. constrictus* lineage and an immigrant *J. dorfi*. We favour the latter hypothesis, although are unable to prove it. Interbreeding has been suggested by SAUNDERS & WARD (1987) for extant *Nautilus pompilius* and *N. stenomphalus*. As far as we know, it has never been postulated for ammonites. Only a few studies have considered hybridization in fossil invertebrates (see AUSICH & MEYER 1994 for examples). The fact that two species possibly involved in interbreeding are traditionally assigned to different genera is not a serious obstacle for the hybridization hypothesis as the separation of these genera was considered invalid by WRIGHT (1996), who treated *Jeletzkytes* RICCARDI, 1983 as a junior synonym of *Hoploscaphites* NOWAK, 1911.

We provisionally refer to specimen NHMM 1993072 as *Hoploscaphites* sp. 2 and hope that additional finds from the Vijlen Member or elsewhere will throw more light on its status.

Hoploscaphites sp. from Austria

Material assigned here comprises two specimens, GBA 1858.01.2c and GBA 1858.01.2d, previously described and illustrated by KENNEDY & SUMMESBERGER (1986, pl. 16, figs 8, 9; pl. 16, fig. 13, respectively). Both specimens are from the Krampen section near Neuberg (Steiermark) which yielded a classic ammonite fauna revised by KENNEDY & SUMMESBERGER (1986).

In terms of lithostratigraphy, the Neuberg section belongs to the Gosau Group (KENNEDY & SUMMESBERGER 1986). Its chronostratigraphic posi-

tion is in dispute. According to KENNEDY & SUMMESBERGER (1986, p. 200), the Neuberg fauna "probably falls around the lower/upper Lower Maastrichtian (*lanceolata/occidentalis* Zone) boundary", as based on ammonite evidence. KENNEDY & SUMMESBERGER (1986, p. 201) also discussed nannofossil data which allowed them to conclude that the Neuberg fauna was "middle *sumensis* Zone and younger, but possibly not younger than upper *sumensis* Zone" in terms of the belemnite zonation of SCHULZ (1979). Contrary to this, Wagreich & *al*. (2003) assigned the Neuberg section to the upper Maastrichtian CC 25b of SISSINGH (1977) and PERCH-NIELSEN (1985), modified by WAGREICH & KRENMAYR (1993), and to the UC 20a nannofossil zone in the scheme of BURNETT (1998).

Specimen GBA 1858.01.2c is an internal mould of the adapertural part of the body chamber with the hook preserved (Text-fig. 4.1-4.2). In contrast, GBA 1858.01.2d is an external cast of a complete individual (KENNEDY & SUMMESBERGER 1986, pl. 16, fig. 13). Both specimens were regarded by KENNEDY & SUMMESBERGER (1986) as microconchs, possibly on account of their small size. However, the shaft of GBA 1858.01.2d is high (KENNEDY & SUMMESBERGER 1986, pl. 16, fig. 13) and seems to possess an umbilical bulge typical of adult macroconchs of many scaphitid taxa (MAKOWSKI 1962; COBBAN 1969; KENNEDY 1989; LANDMAN & WAAGE 1993; MACHALSKI 2005). In contrast, specimen GBA

Fig. 4. **1-2** – *Hoploscaphites* sp. 3; GBA 1858.01.2c; 1 – the hook in ventral view; 2 – lateral view

1858.01.2c cannot be assigned to either of the dimorphs due to its strong *post-mortem* deformation and fragmentary preservation.

Specimens GBA 1858.01.2c and GBA 1858.01.2d were referred by KENNEDY & SUMMESBERGER (1986) to *Hoploscaphites constrictus*. This view was supported by MACHALSKI (2005), who regarded specimen GBA 1958.01.2d as a possible member of a population of *H. constrictus*, ancestral to another European scaphitid, *Hoploscaphites tenuistriatus* (KNER, 1848). However, a closer examination of GBA 1858.01.2c and GBA 1858.01.2d has now revealed the presence of a strong adapertural projection of the ventral ribs in both specimens. Moreover, GBA 1858.01.2c shows a pronounced ventral rostrum at the aperture which conforms to the anterior projection of the ventral ribbing (Text-fig. 4.1-4.2). The preservation of GBA 1858.01.2d does not allow us to state if a rostrum was originally present at the aperture.

The adapertural inflection of the ribbing is absent from members of the European *H. constrictus* lineage, as well as from other, coeval scaphitids in Europe. In contrast, this character is regarded as distinctive for Maastrichtian representatives of the genus *Hoploscaphites* that are endemic to the U.S. Western Interior (LANDMAN & WAAGE 1993). The latter include four species, *Hoploscaphites nicolletii* (MORTON, 1842) (LANDMAN & WAAGE 1993, figs 48-68), *H. comprimus* (OWEN, 1852) (LANDMAN & WAAGE 1993, figs 60, 69-81), *H. melloi* LANDMAN & WAAGE, 1993 (figs 60, 82-84), and *H. birkelundae* LANDMAN & WAAGE, 1993 (originally described as *H. birkelundi*; figs 60, 85-90; subsequently corrected to *H. birkelundae* by LANDMAN & COBBAN 2003). Amongst these species, only two, *H. nicolletii* and *H. comprimus*, possess a pronounced ventral rostrum, which is present both in micro- and macroconchs (LANDMAN & WAAGE 1993, p. 46). We suggest that specimens GBA 1858.01.2c and, tentatively, GBA 1858.01.2d are allied to these two U.S. Western Interior species.

Fine sinuous ribbing of the shaft and hook, visible on both specimens from Neuberg, also recalls the ornament in *H. nicolletii* and *H. comprimus* from the U.S. Western Interior. However, the Neuberg specimens are much smaller than their North American counterparts. GBA 1858.01.2d is 17 mm in maximum length, and GBA 1858.01.2c, although incomplete, must have been of similar size. According to LANDMAN & *al*. (2003, table 6),
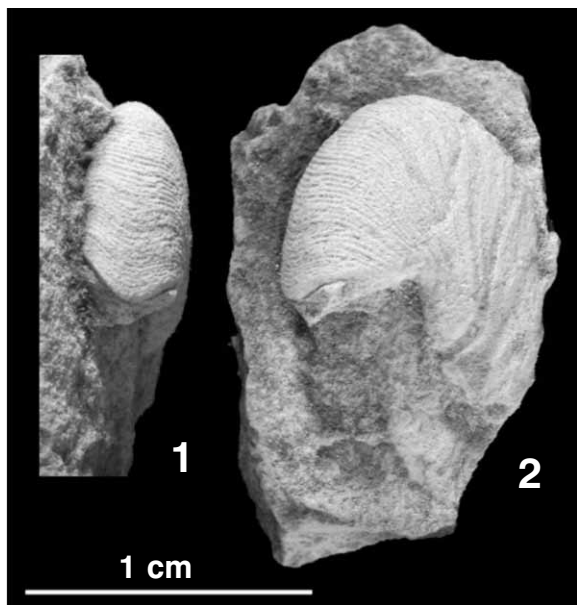
adult macroconchs of *H. nicolletii* average 62 mm, and range from 42 to 91 mm in maximum length, whereas the same parameter in adult microconchs averages 50 mm, and ranges from 39 to 62 mm. Adult specimens of *H. comprimus* show a similar range of dimensions (LANDMAN & WAAGE 1993).

Obviously, the maximum and average size of conspecific ammonite specimens could vary along geographical and/or temporal gradients, but in view of the enormous size differences between the Neuberg material and their North American counterparts it is difficult to believe that these are conspecific. In summary, we suggest that the Neuberg specimens represent a new species, provisionally referred to as *Hoploscaphites* sp. 3, which is best regarded as a miniaturised descendent of either *H. nicolletii* or *H. comprimus*. Nothing more can be stated, based on the material at hand.

NHMW 1977.1924.9 from Neuberg, identified by KENNEDY & SUMMESBERGER (1986, pl. 16, figs 6, 7) as *Hoploscaphites*? sp., may be conspecific with GBA 1858.01.2c and GBA 1858.01.2d. It is an internal mould of the adapertural part of the body chamber with the hook preserved; the latter is so low that the specimen can be convincingly regarded as a microconch. Its ribbing and tuberculation recall strongly that of microconchs of various U.S. Western Interior *Hoploscaphites* species as described and illustrated by LANDMAN & WAAGE (1993) and differs significantly from that of the European *H. constrictus*. However, NHMW 1977.1924.9 cannot be presently located in the collections of NHMW.

Three specimens from Neuberg assigned to *H. constrictus* by KENNEDY & SUMMESBERGER (1986, pl. 16, figs 1, 2, 3-5, 10) have also been reexamined. These are small adult macroconchs which conform to the general characteristics of *H. constrictus* macroconchs from various levels and localities in Europe. Consequently, the identification of these specimens by KENNEDY & SUMMESBERGER (1986) as *H. constrictus* can be fully confirmed. In particular, the ventral ribs on the hook of these specimens are straight or slightly convex adaperturally. Thus, it seems reasonable to conclude that two species, *Hoploscaphites constrictus* and *H.* sp. 3 in the sense of the present paper, were present in the Neuberg area.

Hoploscaphites nicolletii was previously reported from the upper lower Maastrichtian of Hemmoor (northern Germany; JELETZKY 1962) and from the lower upper Maastrichtian of Lviv (western Ukraine; NAIDIN 1974). Both records were questioned by subsequent authors (BIRKELUND 1965; WAAGE 1968; LANDMAN & WAAGE 1993; MACHALSKI 2005). The Ukrainian specimen is better interpreted as a tuberculate end-member (in terms of intrapopulation variation) of the European *H. tenuistriatus* (see MACHALSKI 2005). As far as the Hemmoor specimen is concerned, we have studied a cast in the NLfB collections, and concur with BIRKELUND (1965) and WAAGE (1968) that it is too poorly preserved to be identified at the species level. However, we wish to note that the umbilical diameter of the Hemmoor individual is much greater than in European *H. constrictus* (cf. JELETZKY 1962, p. 1015).

Discoscaphites gulosus (MORTON, 1834) from Bulgaria

TZANKOV (1982, p. 25, pl. 7, figs 9, 10) erected a new species, *Discoscaphites acutituberculatus*, on the basis of a single individual, preserved as a part (PMUS Cr_2 1113) and counterpart (PMUS Cr_2 1112), from the 'upper Maastrichtian *Hoploscaphites constrictus* Zone' near the village of Drandar (Drândar in TZANKOV 1982), Provadia region (northeast Bulgaria). Interestingly, TZANKOV (1982, fig. 25) designated only Cr_2 1113 (a part) as holotype of his new species.

According to JOLKIČEV (1989, p. 69), the deposits which yielded *D. acutituberculatus* belong to the Kajlâka Formation, which comprises mostly organodetritic limestones (JOLKIČEV 1986, 1989). The Kajlâka Formation is a unit widely distributed in the Fore-Balkan and Moesian Platform of northern Bulgaria and usually the highest Cretaceous unit in outcrops in this area.

The section near Drandar in particular and the Kajlâka Formation in general are relatively poorly constrained in terms of chronostratigraphy. JOLKIČEV (1989, p. 68) recorded only two fossil taxa from Drandar, namely the pycnodonteine oyster, *Pycnodonte vesicularis*, and the holasteroid echinoid, *Hemipneustes striatoradiatus*. The first is typical of the 'Senonian' worldwide (e.g. DHONDT 1985, 1999; MALCHUS 1990; DARRAGH & KENDRICK 1991). In contrast, *He. striatoradiatus*, which is widely distributed in the Kajlâka Formation (JOLKIČEV 1989, 2006) is

much more informative in terms of chronostratigraphy. This is a typically Tethyan element, known to range throughout the Maastrichtian, but particularly distinctive of the upper part of the stage, with records from the Netherlands, northeast Belgium, French Pyrenees, Navarra and Alicante (Spain), Bulgaria, Georgia, Kazakhstan, northern Caucasus and Tadzhikistan (SMITH & JEFFERY 2000). In Bulgaria, it always occurs above strata with typical lower Maastrichtian fossils (e.g. JOLKIČEV 2006, fig. 2). In the Maastrichtian type area, *He. striatoradiatus* first appears in the lower Lanaye Member (Gulpen Formation), of late Maastrichtian age (*Belemnitella junior* Zone of authors; equivalents of *tegulatus*/*junior* Zone *sensu* SCHULZ & SCHMID 1983) and ranges to the top of the Meerssen Member (Maastricht Formation, IVf-7; *Belemnella* (*Neobelemnella*) *kazimiroviensis* Zone).

Elsewhere in Bulgaria, the age of the Kajlâka Formation is late Maastrichtian as based on records of the upper Maastrichtian ammonite *Sphenodiscus binckhorsti* (see TZANKOV 1982; KENNEDY 1987; JAGT 2002, 2005), as well as on the basis of regular superposition with underlying lower Maastrichtian sediments. The Kajlâka Formation was recently proved to range in places into the highest Maastrichtian as indicated by the occurrence of the pachydiscid ammonite, *Anapachydiscus* cf. *terminus* WARD & KENNEDY, 1993 in the 'quarry type' limestones of the Kajlâka Formation as exposed at the village of Varbeshnitsa, northwest of Mezdra, northwest Bulgaria (JOLKIČEV 2006, pl. 1, fig. 5E = *Pachydiscus gollevillensis gollevillensis sensu* JOLKIČEV 1982). *Anapachydiscus terminus* is known from the uppermost Maastrichtian of the Bay of Biscay sections (France, Spain), the Netherlands, Denmark, central Poland, eastern Bulgaria (IVANOV 1995), Azerbijan, and Zululand and Natal, South Africa (see MACHALSKI & JAGT 1998 and KENNEDY & KLINGER 2006 for reviews of this species). In summary, the age of the section near Drandar may safely be regarded as late Maastrichtian, but we are not able to specify which part of the upper Maastrichtian is represented there.

Material described by TZANKOV (1982) consists of two parts, an internal mould of the spire, numbered PMUS Cr_2 1113 (Text-fig. 5.1-5.2), and a fragmentary external cast of the spire and of the adapical part of the shaft (Text-fig. 5.3), the latter numbered PMUS Cr_2 1112. There is no doubt that both specimens belong to a single individual (Text-fig. 5.4).

PMUS Cr_2 1113 (Text-fig. 5.1-5.2) is 34 mm in maximum preserved diameter, with a suboval intercostal cross section at this diameter. The umbilicus is obliterated by a matrix plug on both sides. At a diameter of c. 15 mm, the spire shows prorsiradiate ribs with tubercles, one row of ventrolaterals, and two rows of adjacent flank tubercles, all rows of tubercles being of subequal size. There are feeble indications of straight ribs linking the ventrolateral tubercles on both sides of the venter. More details of ornament are visible on one side of the spire, starting approximately at a diameter of 23 mm. The ribbing is rectiradiate to prorsiradiate and weakens towards the adapertural part of the spire.

Tubercles in PMUS Cr_2 1113 are coarse and conical, except for umbilical bullae. The most prominent tubercles are those which form the ventrolateral row and two adjacent rows on the flank. The tubercles in these rows are subequal in strength; additionally, a fourth row of laterals is present, which are much weaker than the tubercles in the two remaining rows on the flank. Distinct umbilicolateral bullae are also present. These are of similar strength to the adjacent flank tubercles. All rows of tubercles, four in total plus the umbilical bullae, strengthen adaperturally.

Ventral ribbing in PMUS Cr_2 1113 is preserved only on the last centimetre of the spire and is composed of ribs linking tubercles on both sides of the venter. These ribs are arranged in a zigzag pattern. The portion of external cast PMUS Cr_2 1112 corresponding to the spire as described above shows the same details of ornament, although better accentuated.

The external cast of PMUS Cr_2 1112 (Text-fig. 5.3) corresponds in part to the spire, and in part to the periumbilical area of the lower portion of the shaft. The umbilical wall is high and straight with distinct plicae. There are distinct umbilical bullae on the umbilical shoulder which migrate outwards adaperturally. Additionally, three rows of flank tubercles are visible, the innermost row being the weakest.

In all its preserved characters, the specimen from Drandar matches well the North American scaphitid *Discoscaphites gulosus* (MORTON, 1834). Based on a comparison with North American material, the Drandar specimen may confidently be regarded as a macroconch on account of the

straight course of, and the presence of plicae on the umbilical wall. *Discoscaphites gulosus* is widely known from North America; in the U.S. Western Interior, it was described from the Fox Hills Formation in North and South Dakota (LANDMAN & WAAGE 1993, figs 156, 157, 159, 160, 167-180). In the Gulf Coastal Plain, it is present in the Prairie Bluff Chalk of Alabama and Mississippi (MORTON 1834, pl. 16, fig. 1, pl. 16, fig. 2, pl. 19, fig. 4; JELETZKY & WAAGE 1978, pl. 2, figs 8-10, 16-19, pl.

3, figs 1-3; COBBAN & KENNEDY 1995, figs 10.4, 10.5, 19.20-19.24, 20.8-20.12, 20.14-20.17, 21.18-21.21), and probably also in the Corsicana Formation in Texas (STEPHENSON 1941, pl. 90, figs. 5, 6; KENNEDY & *al*. 2001, fig. 4f). On the Atlantic Coastal Plain, *Discoscaphites gulosus* is present in the Severn Formation of Maryland (KENNEDY & *al*. 1997, figs 20K-0, 21D, E), in the Peedee Formation in North Carolina (LANDMAN & *al*. 2004, figs 12C-J, 16), and in the Navesink, New Egypt and Tinton
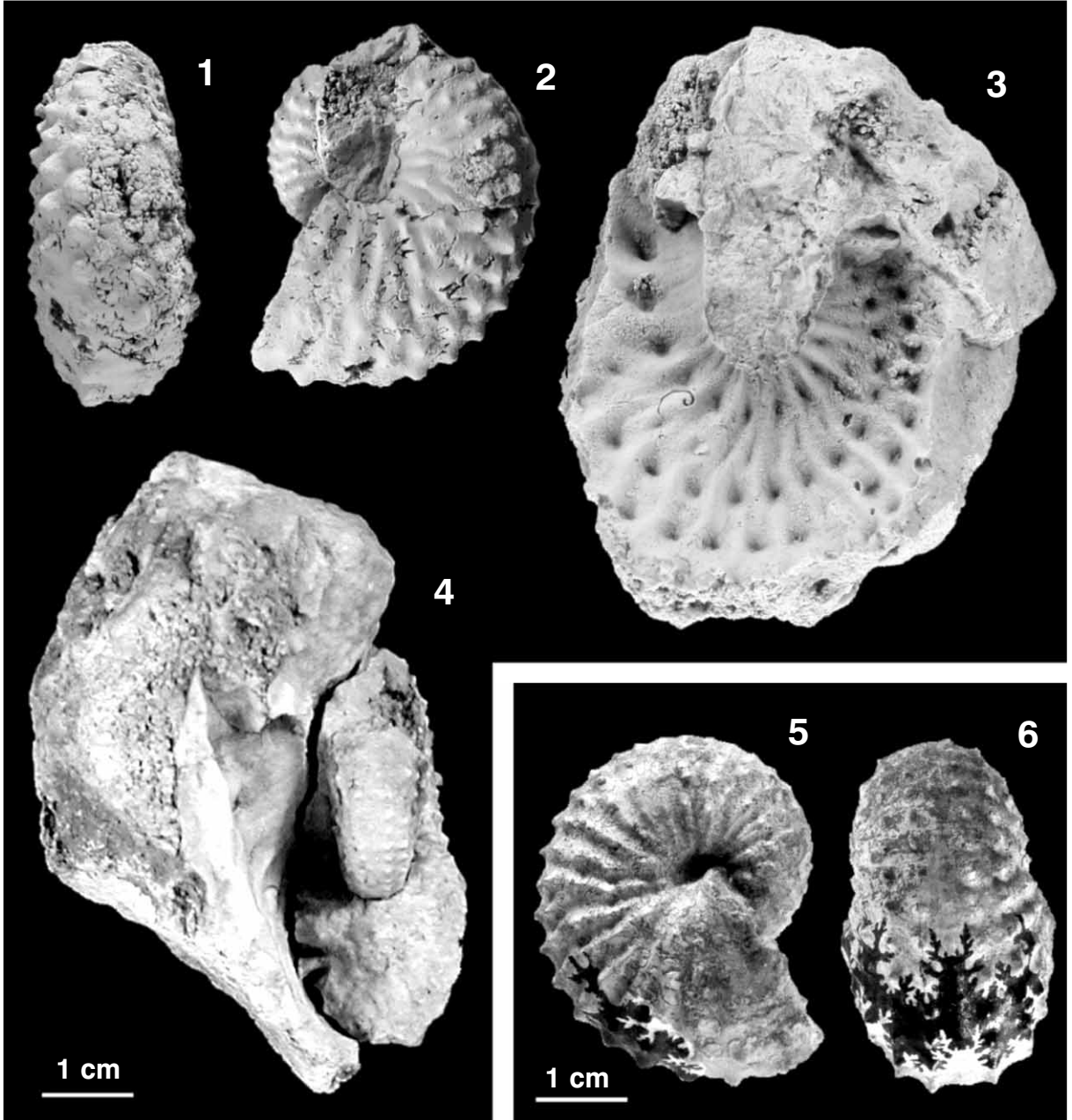

Fig. 5. **1-6** – *Discoscaphites gulosus* (MORTON, 1834); 1-2 – PMUS Cr_2 1113; 1 – ventral view; 2 – lateral view; 3 – PMUS Cr_2 1112 in lateral view; 4 – PMUS Cr_2 1113 and PMUS Cr_2 1112 in match; 5-6 – ANSP 51553; 5 – lateral view; 6 – ventral view

formations of New Jersey (KENNEDY & *al*. 2000, fig. 9G-I; LANDMAN & *al*. 2007, fig. 5I).

As far as ornament is concerned, the Drandar specimen is particularly close to ANSP 51553 from the Prairie Bluff Chalk, Alabama, a fragment of a large phragmocone, which is Morton's type of his variety *petechialis* (MORTON 1834, pl. 16/1; JELETZKY & WAAGE 1978, pl. 2, figs 16-19; refigured herein Text-figs 5.5, 5.6). The maximum lenght of the Drandar specimen may be estimated to have been c. 60 mm, as based on proportions of North American macroconchs. Thus, the Drandar specimen matches North American material also in size: the Fox Hills macroconchs average 77 mm and range from 58 to 94 mm in maximum length (LANDMAN & WAAGE 1993, table 19), the Prairie Bluff specimens are considerably smaller (LANDMAN & WAAGE 1993, p. 230). Prior to the present study, *Discoscaphites gulosus* was not known outside North America.

Discoscaphites? sp. from Denmark and southern Sweden

Two specimens are assigned here. Specimen SGU unregistered is the original of *Scaphites tridens* Kner in Ødum (1953, pl. 1, fig. 4; see also KENNEDY & CHRISTENSEN 1997, fig. 40, and Text-fig. 6 herein, based on photographs kindly supplied by Professor W.J. KENNEDY). It was found in upper Maastrichtian deposits, at a depth of 314. 5 m in the Höllviken-1 borehole, southern Sweden. Another specimen is MGUH 28375, from Rørdal quarry, Ålborg (northern Jylland, Denmark). According to the label, it originates from the bottom of the quarry, thus from the highest lower Maastrichtian *Rugia tenuicostata-Meonia semiglobularis* microbrachiopod zone of SURLYK (1984).

SGU unregistered (Text-fig. 6.1-6.2) is a fragmentary composite mould consisting of a partially preserved phragmocone and adapical part of the body chamber. It is 37 mm in maximum preserved length. There are no indications whether it is macro- or microconch. It has a small, shallow umbilicus and flat flanks of the shaft. The shaft and the adapertural portion of the visible spire is ornamented with delicate, straight and prorsiradiate ribs, intercalated with numerous growth lines. The adapical portion of the visible spire is ornamented with indistinct flexuous ribs which double by intercalation or by splitting on the outer flank. Each rib on the shaft and on the adapertural part of the spire has a tubercle adventrally. These tubercles are clavate on the spire and conical on the preserved part of the shaft; there are also faint indications of tubercles in similar positions on the adapical part of the visible spire. More rows of tubercles can be seen on the ventral region of the shaft, but the venter is partially concealed (Text-fig. 6.1) and it cannot be determined whether there were three or five rows
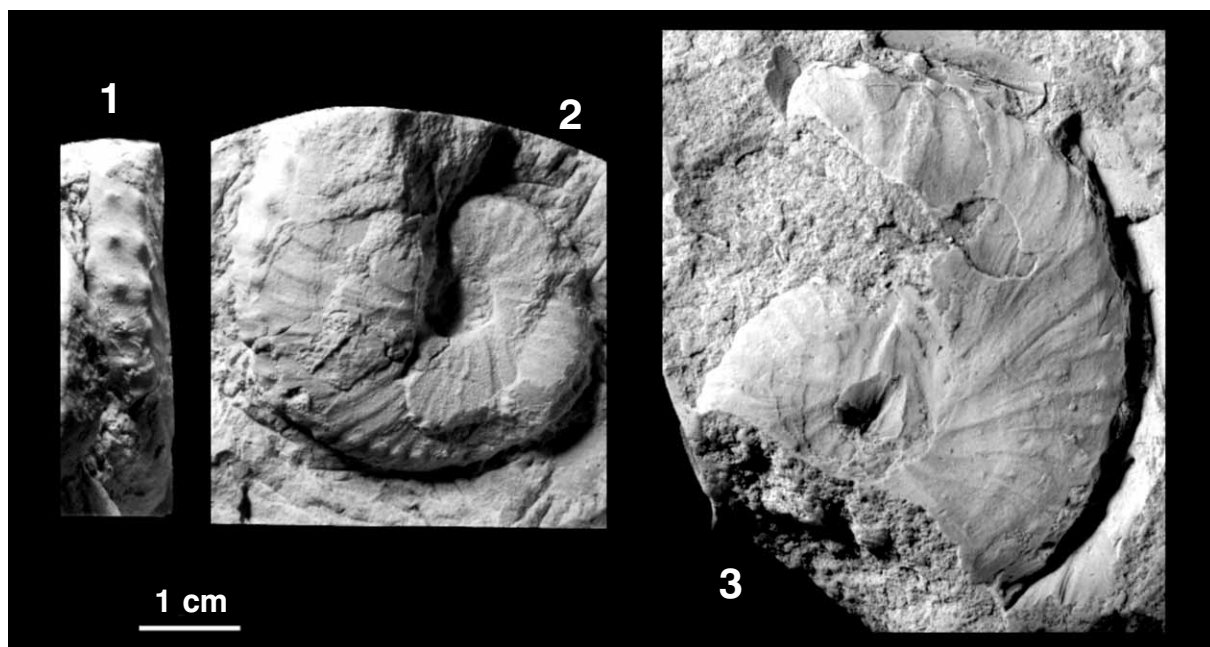

Fig. 6. **1-3** – *Discoscaphites*? sp.; 1-2 – SGU unregistered; 1– ventral view; 2 – lateral view; 3 – plaster cast of MGUH 28375, lateral view

of tubercles in total (KENNEDY & CHRISTENSEN 1997, p. 124). We have tried to borrow this specimen for further preparation of its venter, but it cannot be currently located in the collections of the Geological Survey of Sweden at Uppsala (Linda WICKSTRÖM, pers. comm., November 2006).

MGUH 28375 (Text-fig. 6.3) is a fragmentary composite mould of the phragmocone and body chamber with no hook preserved. The umbilical part of the specimen is damaged, thus preventing detailed measurement of umbilical diameter. Due to the damage to the umbilical wall, it is impossible to decide whether it is a macro- or microconch. MGUH 28375 seems to match well SGU unregistered in style of ornament on its preserved parts of its visible spire and shaft (compare Text-fig. 6.1-6.2 with Text-fig. 6.3). The only exception is that the delicate ribs on the flanks of the shaft commonly double by intercalation at midflank in MGUH 28375, whereas only primaries are visible in the same position on SGU unregistered. The venter of MGUH 28375 is not preserved, but there are tiny clavate tubercles in a ventrolateral or outer lateral position on each rib. There are some indications that more rows of tubercles were present near the venter.

Both specimens show remarkable similarities and are probably closely related, if not conspecific. No scaphitids with this kind of ornament are known to date from Maastrichtian strata in Europe. The presence of straight prorsiradiate and delicate ribs that intercalate with distinct growth lines, plus presence of tiny tubercles on every rib near the ventral side of the conch suggest affinity to *D. rossi* LANDMAN & WAAGE, 1993 (figs 181-189), known exclusively from the Fox Hills Formation of South Dakota. In contrast to other species of the genus *Discoscaphites*, which show several rows of tubercles, *D. rossi* is decidedly paucituberculate, having just a single one, or a maximum of two, rows of tubercles near the venter (LANDMAN & WAAGE 1993). Moreover, *D. rossi* recalls European specimens discussed herein in that its ribbing is composed of riblets and intervening growth lines. However, there are also differences. First, *D. rossi* is a micromorphic species with macroconchs averaging 26 mm and ranging from 21 to 33 mm in maximum length, the microconch being smaller (LANDMAN & WAAGE 1993, table 21). Thus, *D. rossi* is much smaller than both European specimens. Moreover, the lateral ribs in *D. rossi* are distinctly biconcave, being concave on

the inner flank, convex on midflank, and again concave on the outer flank. In contrast, the ribs in both specimens under consideration are straight. Taking into account the above-mentioned differences, plus the fact that the exact number of tubercle rows cannot be discerned either in MGUH 28375 or SGU unregistered, we content ourselves in referring to them as *Discoscaphites*? sp., awaiting additional finds, which might verify such an assignment.

PALAEOBIOGEOGRAPHIC AND STRATIGRAPHIC IMPLICATIONS

Unfortunately, of scaphitid records documented above, but a single one could be identified at the species level, i.e. that of *Discoscaphites gulosus* from the upper Maastrichtian of Bulgaria. As preserved, the morphology of this individual does not differ appreciably from that of North American material, recorded from the U.S. Western Interior, Gulf Coast, and Atlantic Seaboard.

In the past, isolated ammonite occurrences beyond their 'normal' geographic ranges, such as that of *D. gulosus* from Bulgaria documented herein, were usually interpreted to represent drift shells (KENNEDY & COBBAN 1976). This assumption was based on the presumed great extent of *post-mortem* dispersal of Recent *Nautilus* shells (e.g. HAMADA 1964; STENZEL 1964; TEICHERT 1970). However, a subsequent study (CHAMBERLAIN & *al*. 1981) has shown that extensive necroplanktonic floating in modern *Nautilus* is rather infrequent. CHAMBERLAIN & *al*. (1981, p. 508) also calculated the tempo of *post-mortem* phragmocone flooding in ammonites and argued that conchs of these cephalopods with diameters in the range of 10-50 mm would not usually become necroplanktonic drifters. Rather, such shells would settle directly onto the seafloor in the general area inhabited by their living relatives. Larger shells, especially those with diameters in excess of 150 mm, were deduced to have been more prone to *post-mortem* ascent, surface floating and long-distance transport (CHAMBERLAIN & *al*. 1981).

The maximum length of the Bulgarian specimen of *D. gulosus* is estimated to have been 60 mm; thus, it would have fallen into the category of shells for which *post-mortem* drift was regarded unlikely by CHAMBERLAIN & *al*. (1981). Thus, we prefer to

U S Western Interior	N W Europe	Substage
(Triceratops Beds : non-marine) *Jeletzkytes nebrascensis* *Hoploscaphites nicolletii* *Hoploscapites birkelundae*	*Belemnella kazimiroviensis* *Belemnitella junior*	UPPER MAASTRICHTIAN
Baculites clinolobatus *Baculites grandis* *Baculites baculus* *Baculites eliasi*	*Belemnella fastigata* *Belemnella cimbrica* *Belemnella sumensis* *Belemnella obtusa* *Belemnella pseudobtusa* *Belemnella lanceolata*	LOWER MAASTRICHTIAN

Fig. 7. The Maastrichtian zonation recognised in the northern part of the U.S. Western Interior and its correlation with the northwest European zonal scheme (after KENNEDY & *al*. 1998, modified)

interpret the Bulgarian record of *D. gulosus* as representing a member of an immigrant population from North America and not as a drift shell carried to Europe by ocean currents, although we cannot exclude the latter possibility. For the other scaphitids discussed here, the drift hypothesis is considered extremely unlikely, as they show significant morphologic differences from their North American allies. Would they have been drift shells, they would have matched the range of variation displayed by North American populations.

Regardless of the taphonomic intricacies of the Bulgarian specimen of *D. gulosus*, we may draw some biostratigraphic conclusions. According to LANDMAN & WAAGE (1993) and KENNEDY & *al*. (1998, fig. 4), *D. gulosus* occurs in the *Hoploscaphites nicolletii* and *Jeletzkytes nebrascensis* zones of the U.S. Western Interior. These are the highest marine Maastrichtian ammonite zones in this region, being overlain by largely continental deposits of the so-called *Triceratops* Zone (Text-fig. 7). In the Gulf Coast and Atlantic Seaboard, *D. gulosus* also occurs in upper Maastrichtian strata, ranging up into the highest Maastrichtian *Discoscaphites iris* Zone in both regions (LANDMAN & *al*. 2004). In general, it may be concluded that the upper Maastrichtian horizon with *D. gulosus* in Bulgaria is not older than the *Hoploscaphites nicolletii* Zone of the U.S. Western Interior. More detailed correlations between the North American and European Maastrichtian cannot be established in this case in view of the poor stratigraphic constraint of the Bulgarian specimen against the European zonal subdivision of the Maastrichtian Stage.

The other scaphitid records discussed here are based on specimens which cannot be directly assigned to any of the North American species, due to morphologic differences and the generally poor state of preservation. However, their close affinity to North American species is deduced from their morphologic traits. Most peculiar in this respect is the single macroconch from the basal *Belemnitella junior* Zone in northeast Belgium, identified as *Jeletzkytes dorfi* by JAGT & KENNEDY (1994), but interpreted herein as an interspecies hybrid between *J. dorfi* and an unidentified species from the endemic European *Hoploscaphites constrictus* lineage. Obviously, this hybrid cannot be younger or older than either of the species involved. *Jeletzkytes dorfi* is known exclusively from the *Hoploscaphites birkelundae* Zone of Wyoming and South Dakota (LANDMAN & WAAGE 1993; KENNEDY & *al*. 1998, fig. 4). Thus, the correlation of the base of the *Belemnitella junior* Zone in Europe with the *Hoploscaphites birkelundae* Zone in the U.S. Western Interior as proposed by JAGT & KENNEDY (1994, figs 1, 2) is still valid.

Two specimens from the lower upper Maastrichtian of Neuberg (Austria), referred to as *Hoploscaphites* sp. 3 herein, are considered to be allied to *H. nicolletii* or *H. comprimus*, known from the *Hoploscaphites nicolletii* and *Jeletzkytes nebrascensis* zones in the U.S. Western Interior, respectively (LANDMAN & WAAGE 1993; KENNEDY & *al*. 1998, fig. 4; Text-fig. 7 herein). The Austrian specimens are much smaller than their North American relatives and are regarded as descendants of either *H. nicolletii* or *H. comprimus*. The record of descendants cannot be older than that of their precursors,

which means that the lowest possible equivalent position for the Neuberg succession in Austria in terms of North American biozonation, is the U.S. Western Interior *Hoploscaphites nicolletii* Zone.

Finally, poorly preserved material referred to as *Discoscaphites*? sp. is recorded from the uppermost lower Maastrichtian of Denmark, and from the upper Maastrichtian of southern Sweden. The status of this material is too ambiguous to allow any stratigraphic conclusions.

In summary, if all scaphitid records documented herein have been interpreted correctly, they do indicate that the base of the upper Maastrichtian in Europe roughly corresponds to the base of the *Hoploscaphites birkelundae* Zone in the U.S. Western Interior as suggested earlier by JAGT & KENNEDY (1994, figs 1-2), KENNEDY & *al*. 1998 (fig. 1, refigured herein as Text-fig. 7) and LANDMAN & COBBAN (2003, p. 7).

Acknowledgements

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