

# First record of *Epicymatoceras vaelsense* (Nautilida) from the Maastrichtian white chalk of northern Denmark

OKSANA MALCHYK & MARCIN MACHALSKI



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The atypical Late Cretaceous nautilid *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst, 1862) is described and illustrated on the basis of three specimens from the Maastrichtian white chalk of Denmark. One of these is probably from the lower/upper Maastrichtian boundary interval at Frejlev, while the other two originate from the uppermost Maastrichtian chalk as exposed in the Dania quarry; both localities are in Jylland, northern Denmark. These are first reports of *E. vaelsense* from Denmark; the species has previously been recorded from the uppermost Campanian and lower Maastrichtian of the Netherlands, Belgium, northern Germany and Poland. The presence of *E. vaelsense* in the topmost Maastrichtian white chalk in the Dania quarry is considered the youngest record of *Epicymatoceras* known to date, suggesting the persistence of the genus until the end of the Cretaceous. The diameter of the embryonic conch of the Danish *E. vaelsense* may be estimated at c. 30 mm, based on an individual from the Dania quarry, confirming earlier observations that the species possessed one of the largest embryonic conchs amongst Late Cretaceous nautilids.

**Keywords:** Upper Cretaceous, Cephalopoda, *Epicymatoceras*, Denmark, embryonic conch, K–Pg mass extinction.

Oksana Malchyk [omalcz@twarda.pan.pl], Marcin Machalski [mach@twarda.pan.pl], Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland.

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Fossil nautilids are uncommon in Maastrichtian and Danian deposits of Denmark. In addition, they are still rather poorly presented in the literature (e.g. Ravn 1902; Rosenkrantz 1944, 1960; Gravesen 2001). The following species have been described from the Maastrichtian and Danian of Denmark: *Eutrephoceras darupense* (Schlüter, 1876), *E. bellerophon* (Lundgren, 1867), *Cymatoceras? patens* (Kner, 1848), *Hercoglossa danica* (von Schlotheim, 1820) and *Danathuroidea fricator* (Beck, in Lyell 1835). Of these, *E. darupense* has been recorded from the lower/upper Maastrichtian interval at Frejlev (Jylland), *C.? patens* from the same interval and locality as well as from the lower Maastrichtian of Møns Klint, south-eastern Denmark, while *E. bellerophon*, *H. danica*, and *D. fricator* are on record from the middle Danian at Faxe and the upper Danian at Saltholm, both in Sjælland, eastern Denmark (Ravn 1902). Rosenkrantz (1944) reported on the presence of *Eutrephoceras* and *Hercoglossa* in the Maastrichtian chalk of Stevns Klint, south-eastern Sjælland. In addition, several specimens assigned to *Eutrephoceras*, *Cimomia*(?), *Cymatoceras* or “*Nautilus*”(?) have been recorded from Maastrichtian strata exposed at Møns Klint, Gedser Odde in south-eastern Denmark and in Jylland, northern Denmark (Gravesen & Jakobsen 2013), see Fig. 1A.

The aim of the present note is to describe and illustrate the first records of the nautilid *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst, 1862) from the Maastrichtian white chalk of Denmark. This material, three specimens in total, comes from two Maastrichtian sites in Jylland, northern Denmark (Fig. 1B). The specimens studied are stored in the collections of the Natural History Museum of Denmark, Copenhagen (registration numbers MGUH 33073, 33074 and 33075); they were briefly mentioned by Malchyk *et al.* (2017, p. 3). These new specimens contribute to a better understanding of regional and global patterns of nautilid turnover during the Late Cretaceous and early Paleogene interval, which is significant in the context of the ongoing debate on the nature of the Cretaceous–Paleogene (K–Pg) mass extinction (e.g. Goolaerts *et al.* 2014; Landman *et al.* 2014; Goolaerts 2018; Malchyk 2018).

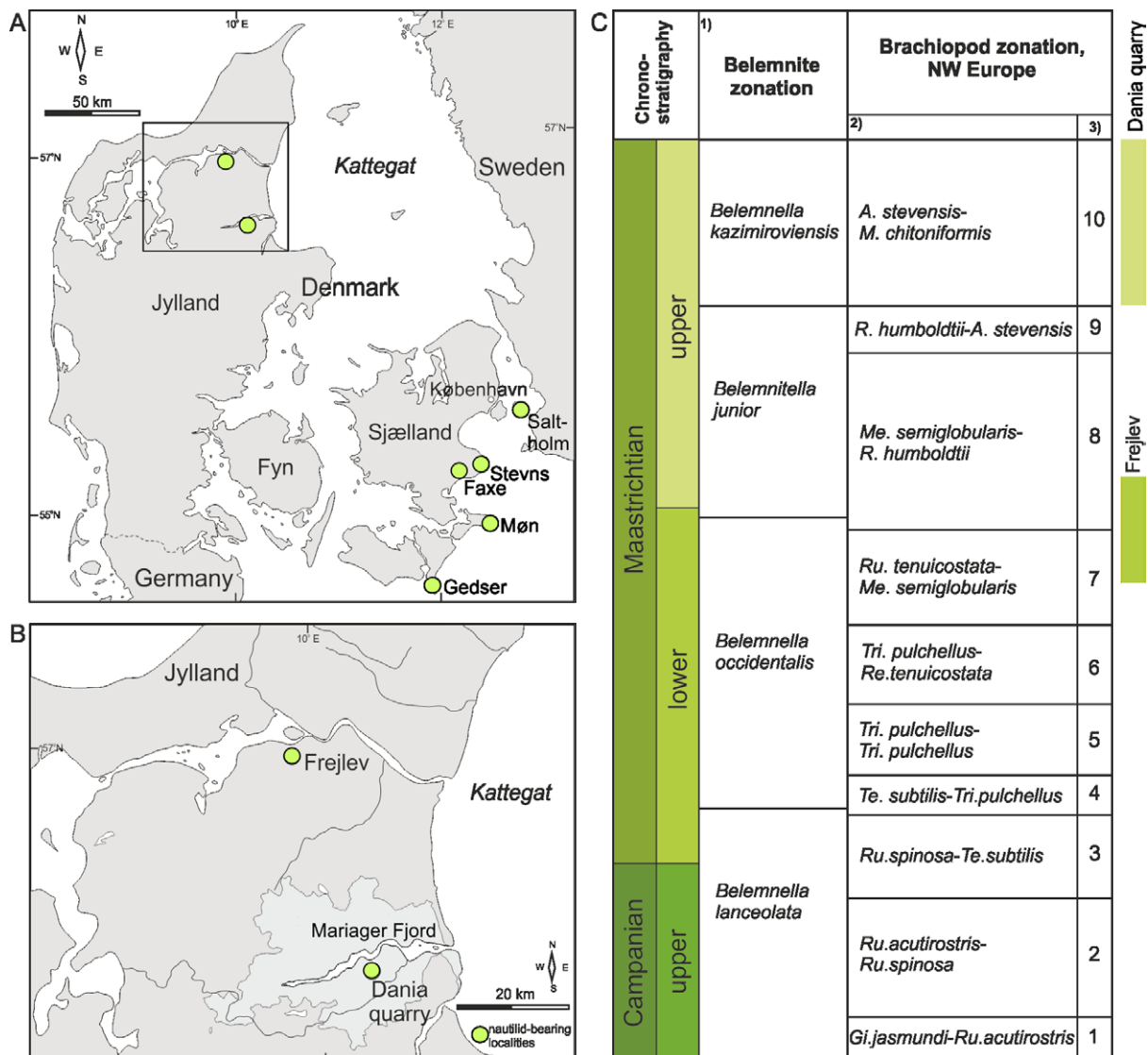
## Stratigraphy and localities

Traditionally, the upper Campanian to Maastrichtian chalk in Denmark has been subdivided into ten

microbrachiopod zones (Surlyk 1970, 1984). These were correlated with the conventional European belemnite zonal scheme, according to which the base of the Maastrichtian was defined by the first occurrence (FO) of *Belemnella lanceolata* (e.g. Birkelund 1957; Schulz & Schmid 1983; Christensen 1996, 1997). However, in recent years, the definition of the Campanian–Maastrichtian boundary has changed. The Global Stratotype Section and Point (GSSP) for the base of the Maastrichtian Stage is placed at the 115.2 m level at Tercis near Dax, south-west France (Odin 2001; Odin & Lamaurelle 2001). According to the Tercis definition, the base of the Maastrichtian

Stage is significantly higher than the level of the FO of *Belemnella lanceolata* (e.g. Walaszczyk 2004; Remin 2012; see also Machalski 2012). Therefore, the Campanian–Maastrichtian boundary as defined at Tercis is placed in Denmark within the *Rugia spinosa*–*Terebratulina subtilis* Zone of Surlyk (1970, 1984) (Fig. 1C).

The precise geographical provenance of one of the specimens studied (MGUH 33074) is unknown. However, as stated on the original label, it is most likely from Frejlev, northern Denmark (Fig. 1B). The Frejlev section spans the lower–upper Maastrichtian interval boundary, the *Rugia tenuicostata*–*Meonia semiglobularis* Zone to the *Meonia semiglobularis*–*Rue-*



**Fig. 1.** A: Map of Denmark with localities mentioned in the text. B: Location of the two sections that yielded the nautilid *Epicymatoceras vaelsense* in northern Denmark. C: Stratigraphy of upper Campanian and Maastrichtian strata in north-western Europe. Sources: 1) Birkelund (1957); 2) Surlyk (1984); 3) Surlyk (1970). Abbreviations: A.: *Argyrotheca*; Gi.: *Gisilina*; M.: *Magas*; Me.: *Meonia*; Rue.: *Ruegenella*; Ru.: *Rugia*; Te.: *Terebratulina*; Tri.: *Trigonosemus*. Chronostratigraphy modified according to the new definition of the base of the Maastrichtian Stage and subsequent correlations (Odin 2001; Odin & Lamaurelle 2001; Walaszczyk 2004; Remin 2012).

*genella humboldtii* Zone of Surlyk (1984) (Fig. 1C). In terms of belemnite zonation, this stratigraphic interval belongs to the lower part of the *Belemnitella junior* Zone and the upper part of the *Belemnella fastigata* Zone (Schulz 1979; Schulz & Schmid 1983). Therefore, MGUH 33074 is probably from either the uppermost lower Maastrichtian *Ru. tenuicostata*–*Me. semiglobularis* Zone, or from the lowermost upper Maastrichtian *Me. semiglobularis*–*Rue. humboldtii* Zone.

Specimens MGUH 33073 and MGUH 33075 are from the Dania limestone quarry. This is an abandoned chalk pit, currently overgrown by vegetation (S.L. Jakobsen, personal communication 2018), situated on the south side of Mariager Fjord (Fig. 1A). A Maastrichtian–Danian boundary succession of carbonate deposits, c. 30 m thick, was formerly available at this quarry (Håkansson & Hansen 1979). The Maastrichtian part of the Dania quarry succession corresponds to the *Argyrotheca stevensis*–*Magas chitoniformis* brachiopod Zone (Fig. 1C), which is the equivalent of the *Belemnella kazimiroviensis* Zone (Schulz 1979; Schulz & Schmid 1983; Surlyk 1984; Birkelund 1993) and can be correlated with the *Palynodinium grallator* dinoflagellate Zone of Hansen (1977). It should also be noted that the Maastrichtian part of the Dania succession yielded the topmost Maastrichtian zonal coccolith species *Micula prinsii* (Håkansson & Hansen 1979). The precise position of both nautilid specimens within the Dania section is unknown. However, they are safely assigned a latest Maastrichtian age, based on the data presented above. Specimen MGUH 33073 was collected by Mogens Steentoft Nielsen at the beginning of the 21<sup>st</sup> century and subsequently transferred to the collections of the Natural History Museum of Denmark (Copenhagen), having been declared Danekræ (catalogue number 886, see <http://www.danicafossils.dk/>).

## Systematic palaeontology

Order Nautilida Agassiz, 1847

Superfamily Nautiloidea de Blainville, 1825

Family Cymatoceratidae *sensu* Chirat and Bucher, 2006

Genus *Epicymatoceras* Kummel, 1956

*Type species.* *Nautilus vaelsensis* Binkhorst van den Binkhorst, 1862. p. 15, pl. 5, fig. 2.

*Diagnosis.* “Widely evolute, greatly compressed; whorl section subquadrate, nearly twice as high as wide; ventral shoulders angular, venter narrow and flattened; flanks only slightly inflated; umbilical shoulders broadly arched; suture with shallow ventral lobe and shallow lateral lobe; position of siphuncle unknown; surface bearing fine sinuous ribs that curve backward toward ventral shoulders and form slight sinus on venter” (Kummel 1964, p. K454).

*Epicymatoceras vaelsense* (Binkhorst van den Binkhorst, 1862).

1862 *Nautilus vaelsensis* Binkhorst van den Binkhorst, p. 15, pl. 5, fig. 2a–c.

1876 *Nautilus vaelsensis* Binkhorst van den Binkhorst – Schlüter, p. 177, pl. 51, fig. 3.

1887 *Nautilus vaelsensis* Binkhorst van den Binkhorst – Holzapfel, p. 68, pl. 4, fig. 4.

1956 *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst) – Kummel, p. 439, pl. 23, figs. 1–2.

2012 *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst) – Jagt, p. 141, pl. 30, figs G–H.

2017 *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst) – Malchuk *et al.*, p. 5, fig. 3.

*Material.* Three specimens in mould preservation (MGUH 33073, 33074 and 33075). Specimen MGUH 33074 probably originates from the lower/upper Maastrichtian boundary at Frejlev; specimens MGUH 33073 and 33075 come from the topmost Maastrichtian succession in the Dania limestone quarry.

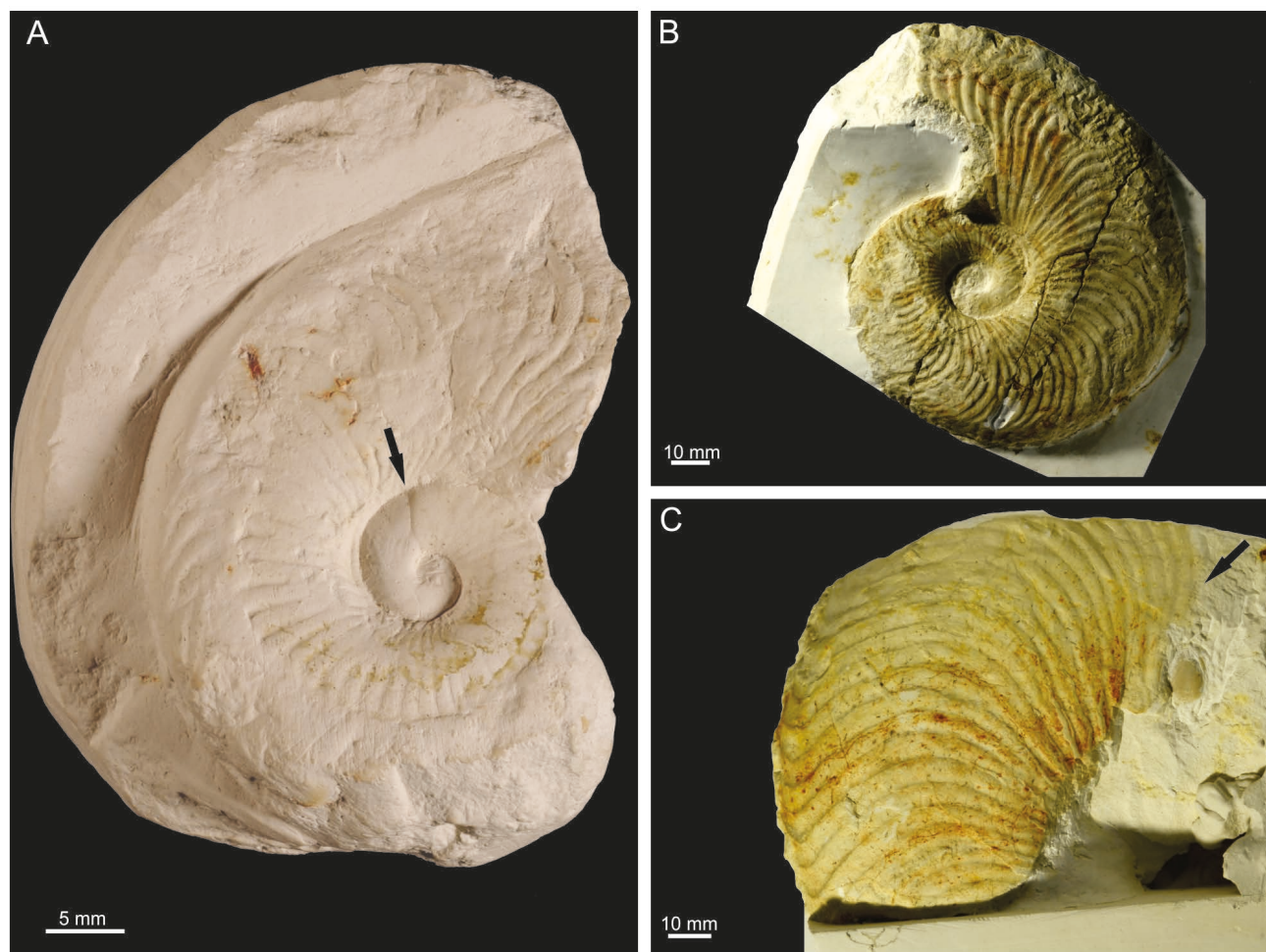
*Description.* Specimen MGUH 33073 (Fig. 2A) from the Dania quarry is an internal mould comprising the larger part of the phragmocone, measuring approximately 73 mm in maximum preserved diameter. The whorl section is compressed and subquadrate. Coiling is relatively evolute. The umbilicus is wide, c. 25 per cent of the diameter, with steeply inclined umbilical wall and broadly rounded umbilical shoulder. The flanks are flat. The ventrolateral shoulder of this specimen is angular in the early part of conch and seems to be more rounded in the latest stage, as preserved. The venter is generally flat; however, it seems to be slightly convex on the outermost part of the last preserved whorl of the phragmocone. The position of the siphuncle is uncertain. The ornamentation of MGUH 33073 consists of coarse radial ribs, up to 3 mm in maximum width and separated by narrow and deep grooves (> 1 mm). Ribs arise at the umbilical seam, broadening across the flank with a sigmoidal curve and suddenly curving backwards at the ventrolateral shoulder, forming a narrow ventral sinus. They are poorly expressed and almost

effaced on the higher flank and the early stages of the phragmocone, but are stronger and more convex at mid-flank and ventrolateral shoulder on the later part of the phragmocone.

A nepionic constriction delimiting pre- and post-hatching stages is well recognised as a narrow depression on the innermost whorl (Fig. 2A). The embryonic conch is characterised by a poorly expressed reticulate pattern dominated by longitudinal lirae and measures about 15 mm in visible diameter. Based on the assumption that in the early whorl stages in *Epicymatoceras* the height of every next whorl is half covered by the next one (see Malchyk *et al.* 2017), the total embryonic diameter is estimated to have been approximately 30 mm, thus matching the hatching diameter reported for specimens of *E. vaelsense* from the Upper Cretaceous of Poland.

MGUH 33074 (Fig. 2B) from Frejlev(?) is probably the most complete specimen of *E. vaelsense* ever to

have been recorded. It is an internal mould of the phragmocone and a large portion of the body chamber, extending to the aperture with a maximum preserved conch diameter of c. 128 mm. A partially preserved apertural margin is recognised on the right side of the specimen studied as a slightly curved outline (Fig. 2C). Unfortunately, the shape of the hyponomic and ocular sinuses could not be determined due to the fragmentary preservation of the specimen. One may note that the ribs tend to become weaker and less pronounced in the adapertural part of the shell, when compared to the main body of the individual (Fig. 2C). Conch shape is relatively evolute, gradually becoming more evolute towards the later whorl stages. The whorl section is compressed with generally flattened flanks. The umbilicus is large and comprises about 27 per cent of the diameter, the umbilical wall is inclined and the umbilical shoulder is broadly rounded. The ventrolateral shoulder is an-



**Fig. 2.** The cymatoceratid *Epicymatoceras vaelsense* from the Maastrichtian of northern Denmark (Jylland). **A:** Specimen MGUH 33073 from the Dania quarry. The arrow indicates the nepionic constriction between embryonic and post-embryonic parts of the shell. **B** and **C:** Specimen MGUH 33074, probably from Frejlev. **B:** Left view. **C:** Right view of a partially broken body chamber displaying the apertural margin (arrow).

gular, the venter is flat. The surface of MGUH 33074 is ornamented by very prominent ribbing. Ribs are about 1 mm in width at the umbilicus and become up to 4–5 mm wide towards the aperture, showing some bifurcation at mid-flank. Ribs are strongly expressed on the phragmocone and become less conspicuous on the adapertural part of the body chamber. The embryonic conch is not visible in this particular specimen.

MGUH 33075 from Dania is a fragmentary internal mould consisting of three fragments, not illustrated here. The largest piece comprises a portion of the umbilicus and flank and measures about 50 mm in length. One of the other remaining fragments is preserved as an external impression, probably of part of the lower and middle flank, and another one is the internal mould of a portion of the lower flank.

*Comparison.* *Epicymatoceras* Kummel, 1956 is an atypical Late Cretaceous nautilid genus that belongs to the family Cymatoceratidae Spath, 1927 (*sensu* Chirat & Bucher 2006; for a detailed discussion of the systematic position of *Epicymatoceras*, see Malchyk *et al.* 2017). Its relatively evolute conch coiling and prominent radial ribbing of the shell surface makes it easily recognisable (e.g. Kummel 1956; Goolaerts & Frank 2014; Malchyk *et al.* 2017). At present, it comprises only two species, namely *Epicymatoceras vaelsense* (Binkhorst van den Binkhorst, 1862) and *E. monstrum* Shimansky, 1975. The former has been recorded from the Netherlands, Belgium, Germany and Poland in Europe, with a stratigraphic range from the upper Campanian to the lower Maastrichtian (Binkhorst van den Binkhorst 1862; Schlüter 1876; Holzapfel 1887; Jagt *et al.* 1998; Jagt 2012; Goolaerts & Frank 2014; Malchyk *et al.* 2017). In the original description of Binkhorst van den Binkhorst (1862, p. 15), *Nautilus vaelsensis* is diagnosed as follows: “Testâ compressâ, discoïdali, striis numerosis, proximantibus, arcualis, ornatâ. Aperturâ subquadrilaterâ. Septis paululúm arcuatis”. The second species, *E. monstrum*, is known exclusively from the upper Maastrichtian of Mangyshlak, Kazakhstan (Shimansky 1975).

The morphological features of the present material allow it to be identified as *Epicymatoceras vaelsense*. However, the Danish specimens differ from the type material of *E. vaelsense* from the lower Maastrichtian of Vaals, province of Limburg, the Netherlands (Binkhorst van den Binkhorst 1862, pl. 5, fig. 2a–c), in having a slightly more convex venter and more strongly impressed ribbing. The specimens studied here are most closely similar to conspecific material from the upper Campanian and lower Maastrichtian of Poland (Malchyk *et al.* 2017, fig. 3A–B), but the Danish specimens show more rounded ventrolateral shoulders. These differences are most probably the

result of intraspecific variability of *E. vaelsense*.

*Epicymatoceras monstrum*, as described and figured by Shimansky (1975, p. 122, pl. 27, fig. 3), from the upper Maastrichtian of Mangyshlak is a generally similar form; however, it differs from the Danish specimens in having a much wider umbilicus (U ~ 30 per cent), more rounded umbilical and ventrolateral shoulders and more convex venter.

*Occurrence.* *Epicymatoceras vaelsense* is known from the upper Campanian to Maastrichtian of Belgium and the Netherlands (Binkhorst van den Binkhorst 1862; Jagt *et al.* 1998; Jagt 2012; Goolaerts & Frank 2014), Germany (Schlüter 1876; Holzapfel 1887), Poland (Malchyk *et al.* 2017) and Denmark (this work).

## Discussion and conclusions

The first record of the genus *Epicymatoceras* from the Upper Cretaceous white chalk deposits of northern Denmark (Jylland) is presented. The Danish occurrences include three specimens of *Epicymatoceras vaelsense*, one from the lower/upper Maastrichtian boundary interval, the other two from the top of the Maastrichtian. Previous data on the stratigraphic range of *E. vaelsense* across Europe extended from the upper Campanian to the lower Maastrichtian (see above). On the basis of these data, the specimens described from the Dania quarry represent the youngest known records of *Epicymatoceras* to date, indicating that the genus extended into the latest Maastrichtian. Nevertheless, despite the persistence of *Epicymatoceras* until the end of the Cretaceous, all ribbed Cretaceous nautilids within the family Cymatoceratidae became extinct prior to, or at, the Cretaceous–Paleogene boundary (e.g. Ward *et al.* 2016; Malchyk *et al.* 2017).

It is possible to recognise the adapertural margin of *Epicymatoceras* for the first time; it was observed as a slightly curved outline on the preserved portion of the body chamber in specimen MGUH 33074, probably from Frejlev.

The cast of the embryonic conch of *Epicymatoceras vaelsense* is observable in specimen MGUH 33073 from the Dania quarry; its diameter is estimated to have been *c.* 30 mm. These new data on *E. vaelsense* from Denmark and the previously recorded hatchling diameter of *Epicymatoceras* from the upper Campanian from Poland confirm that the hatching size in this genus is near the maximum known range recorded for Cretaceous, Cenozoic and Recent nautilids (Landman *et al.* 1983; Matsumoto *et al.* 1984; Arnold *et al.* 1987; Landman 1988; Saunders *et al.* 1996; Cichowolski

2003; Cichowolski *et al.* 2005; Wani and Ayyasami 2009; Wani *et al.* 2011; Malchyk *et al.* 2017; Landman *et al.* 2018).

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