

# AN UNUSUAL TAPHOCOENOSIS OF A SEA URCHIN AND A RECTALLY INSERTED TURRIFORM GASTROPOD FROM THE LOWERMOST PALEOCENE OF STEVNS KLINT, DENMARK

JESPER MILÀN<sup>1,2</sup>, BO W. RASMUSSEN<sup>2</sup> and LOTHAR H. VALLON<sup>1</sup>

<sup>1</sup>Geomuseum Faxe, Østervej 2, DK-4640 Faxe, Denmark -email: jesperm@oesm.dk;

<sup>2</sup>Natural History Museum of Denmark, Øster Voldgade 5-7, DK-1350 Copenhagen K, Denmark

**Abstract**— A specimen of the common irregular echinoid *Echinocorys sulcata* (Goldfuss, 1826), recovered from the lowermost Paleocene Stevns Klint Formation, at Stevns Klint, Denmark, is of note in revealing a perfect external mold of the turriiform gastropod *Cerithiella fenestrata* (Ravn, 1902) in the anal opening. The gastropod penetrated over a length of 21 mm perpendicularly into the echinoid test, and impressions in the surrounding matrix show the gastropod to have protruded over a length of 8 mm out of the test, being tightly lodged in the periproctal opening. It is assumed that this unusual combination resulted from the activities of bioturbators which, by chance, pushed the empty gastropod shell into the anal opening of the test of the dead echinoid, although other, more colorful, explanations cannot be excluded.

## INTRODUCTION

Occasionally, fossils are recovered in strange associations and orientations that can be difficult to explain by reference to common taphonomic processes. Here we present an unusual combination of a sea urchin (*Echinocorys sulcata*) that preserves a perfect imprint of a turriiform gastropod *Cerithiella fenestrata* (Ravn, 1902), lodged over a length of 21 mm into the echinoid's periproctal opening. The specimen was recovered by local collector Peter Bennike from a loose block of bryozoan-rich limestone at a small cliff fall on the beach at Stevns Klint, approximately 1 kilometer north of Stevns Lighthouse (Fig. 1).

## GEOLOGICAL SETTING

The cliff sections at Stevns Klint in eastern Denmark preserve a complete succession across the Cretaceous/Paleogene (K/Pg) boundary. The outcrop is famous for its extensive record, especially of invertebrate fossils of which about 450 species have been documented (see Damholt and Surlyk, 2012 for a complete faunal list), in addition to an extensive ichnofauna (e.g., Bromley and Ekdale, 1984; Ekdale and Bromley, 1984). The stratigraphic section exposed at the cliff north of Stevns Lighthouse comprises the late Maastrichtian Møns Klint Formation, represented by the lying Sigerslev Member and the hanging Højerup Member. The Sigerslev Member is here developed as a soft, white chalk with gently wavy to almost horizontal bedding. Mound-like structures may occur. The bedding is reflected by thin bands of flint nodules. At its top, this member is characterized by two closely spaced, incipient hardgrounds exhibiting nodular hardening and a small-scale irregular erosional surface. The Sigerslev Member is poor in benthic body fossils, but the trace fossil *Zoophycos* is common and *Thalassinoides* burrows are reflected by a band of flint nodules at about 30-50 cm below the upper incipient hardground (Surlyk et al., 2006, 2013).

The overlying Højerup Member is only 4-5 m thick and consists of a benthos-rich wackestone-chalk (mainly bryozoans). The sediment was deposited in small mounds that shifted their position toward the south during growth/accumulation. The mounds are contoured by flint nodules and *Thalassinoides*-boxworks occur throughout the entire unit (Surlyk et al., 2006).

The K/Pg boundary is exposed approximately in the middle of the cliff where the Fiskeler ("Fish-Clay") and Cerithium Limestone Members of the Rødvig Formation occur in small depressions between crests of the mounds of the Højerup Member. Toward its top the Fiskeler Member becomes richer in carbonate content and it eventually grades into the Cerithium Limestone Member. The top of the latter unit is marked by an erosional surface and associated hardground (Surlyk et al., 2006).

The succession is overlain by the lower Danian bryozoan limestone mounds of the Stevns Klint Formation (Fig. 2). These mounds are asymmetrical, their southern flanks being steeper than the northern. Depending on the position within the mounds four different facies types can be distinguished: (1) the initial mound association, consisting

mainly of bryozoan packstone-rudstone, (2) the steep flank-mound crest association, consisting of mainly bryozoan rudstone; (3) the gentle-flank association, characterized by bryozoan packstone, and incipient to fully developed hardgrounds; and (4) the intermound association, consisting predominantly of echinoid rudstone to packstone (Bjærgager

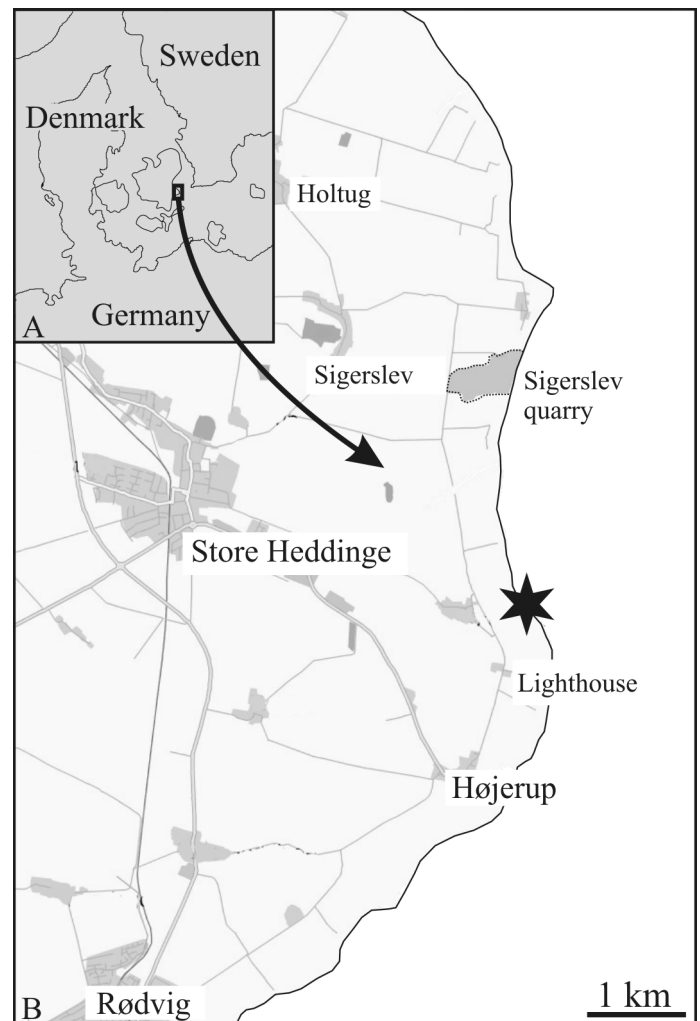


FIGURE 1. **A**, Stevns Klint in eastern Denmark. **B**, map of the Stevns peninsula. The specimen was collected from a small cliff fall, about 1 kilometer north of Stevns Lighthouse (marked by a star).

Chronostratigraphy			Lithostratigraphy	
LOWER PALEOCENE	DANIAN	MIDDLE		
		LOWER		
			Rødvig Fm	Cerithium Limestone Mb
CRETACEOUS	MAASTRICHTIAN		Møns Klint Fm	Højerup Mb
				Sigerslev Mb
				Fiskeler Mb

FIGURE 2. Stratigraphic scheme of the Upper Cretaceous–lower Paleocene section in the Danish Basin. The specimen originates from the lowermost part of the Paleocene Stevns Klint Formation (modified after Lauridsen et al., 2012; Surlyk et al., 2006, 2013).

and Surlyk, 2007). Similar to those within the Højerup Member, these mounds migrated during growth and over time toward the south; they are outlined by flint nodules (Surlyk et al., 2006; Bjerager and Surlyk, 2007).

**MATERIAL AND METHODS**

The specimen illustrated and discussed here (Fig. 3) is housed in the collections of the Østsjælland Museum (OESM, Store Heddinge) and consists of (a) the test of *Echinocorys sulcata* with the imprint of the rectally inserted gastropod (OESM-10062a) and (b) the surrounding matrix with the external mold of the posterior test portion and the protruding part of the gastropod (OESM-10062b). The casts are not numbered.

In order to obtain a detailed overview of the three-dimensional orientation of the specimen, a silicone mold was produced of the gastropod imprint in the echinoid and the imprint in the surrounding matrix. Furthermore, the entire specimen was CT scanned at the Department of Forensic Medicine, University of Copenhagen, Denmark, using a Siemens Definition Flash scanner. A reconstruction kernel of 90 was used, which is normally applied to high-density objects. Scanning parameters were set at 140kV and 220mAs, with a (X,Y)-matrix of 0.63 x 0.63 mm and a reconstruction (Z) of 0.63 mm. With these settings the object can be displayed with isometric voxels and reconstructed in true proportions.

**DESCRIPTION**

The specimen of *Echinocorys sulcata* (Goldfuss, 1826) measures 48 mm in length, 40 mm in width and 35 mm in height. It is three-

dimensionally preserved without any sign of tectonic deformation, flattening or damage to the test (Fig. 3a). The echinoid test is encrusted by bryozoans on all exposed sides. A closer inspection of the periproctal opening has revealed the imprint of the turriiform gastropod, *Cerithiella fenestrata* (Ravn, 1902) which enters the test perpendicularly, apex first, to a depth of 21 mm (Fig. 3b-d). The diameter of the opening is 5 mm, and the imprint of the gastropod can be traced all around its circumference (Fig. 3b). An imprint of the protruding part of the gastropod is preserved in the surrounding matrix. The gastropod extended over a length of 8 mm from the echinoid test, meaning that the shell had a total length of 29 mm. The largest diameter measured was 6 mm, but no details of aperture of the gastropod were preserved (Fig. 3d).

There is no sign of mechanical breakage neither of test plates nor of pressure-induced solution around the periproctal opening. The sediment infill of the test consists of structure-less, fine-grained limestone; the CT scans did not reveal any layering or other features in that infill that could have helped determine the *post-mortem* orientation of the echinoid test. Similar to all originally aragonitic hard body parts in the Danish chalk, the gastropod shell was dissolved and is preserved merely as an imprint in the surrounding matrix.

The matrix still surrounding parts of the specimen is composed of a bryozoans-rich, coarse-grained limestone, and also contains a single, isolated primary spine of the regular sea urchin *Tylocidaris oedumi* Brünnich Nielsen, 1938, which is an index fossil for the lower part of the Stevns Klint Formation.

**DISCUSSION**

The specimen was recovered from loose blocks of bryozoan-rich limestones from a minor cliff fall. At the site, the complete K/Pg boundary succession, ranging from the upper Maastrichtian to the lower Danian is exposed in the cliff section (compare Surlyk et al., 2006). The stratigraphic range of *Echinocorys sulcata* encompasses the entire Danian (Ravn, 1927), but the co-occurrence of the primary spine of *Tylocidaris oedumi*, implies a provenance from the lowermost meters of the Stevns Klint Formation (Brünnich Nielsen, 1938; Gravesen, 1993).

The orientation of the gastropod, pointing with its apex inward, almost perpendicularly through the anal opening, suggests that the shell must have been pushed in until it became lodged and remained in this position until the surrounding sediment had hardened. However, the absence of fractures or any other damage to the test plates around the periproct and the perfectly circular imprint of the gastropod within the anal opening proves that insertion was not forceful.

There are several scenarios to explain the unusual association of these specimens; however, some of these appear less likely than others.

1) In life position, a test of *Echinocorys* rests on its flat underside, the periproct facing downward under an angle of about 45°. For the gastropod shell to enter the test in such a position it must have moved upward through the sediment, which is highly unlikely as members of the Cerithiidae are grazers and scavengers, and not burrowers (e.g., Houbriek, 1992). In addition, the calcareous platelets of the periproctal membrane and the inner organs of the echinoid would have precluded penetration of the gastropod shell, unless this was pushed in with considerable force.

2) The empty echinoid test lay on its side, half buried in the sediment, next to the empty gastropod shell. The latter was then pushed into the anal opening of the echinoid by the activity of some bioturbating or surface-bulldozing organism (e.g., echinoids or decapod crustaceans). The presence of encrusting bryozoans on the echinoid test (Fig. 3a,b) supports that the empty test has been exposed on the seafloor for a considerable time. A few rare cases are described where echinoid tests are found preserved within other, partially broken, echinoid tests, from the Maastrichtian of Holland. In these cases the associations are interpreted as the result of fossils being rolled around by currents on the seafloor (Jagt, 2013).

3) The empty test lay upside down (top down) in the sediment. The living, grazing gastropod was grabbed by a predator and lifted up into the water column. The predator bit off the ultimate whorl which contained most of the soft body of the animal, after which the empty shell sank to the sea floor, apex first and by chance landed into the anal opening of the echinoid test. Belemnites are known to have been deposited apex down in the sediment (compare Schweigert, 1999). However, as far as we know, there are no records of similar occurrences of turriiform gastropods.

4) A hermit crab that inhabited the empty gastropod shell could

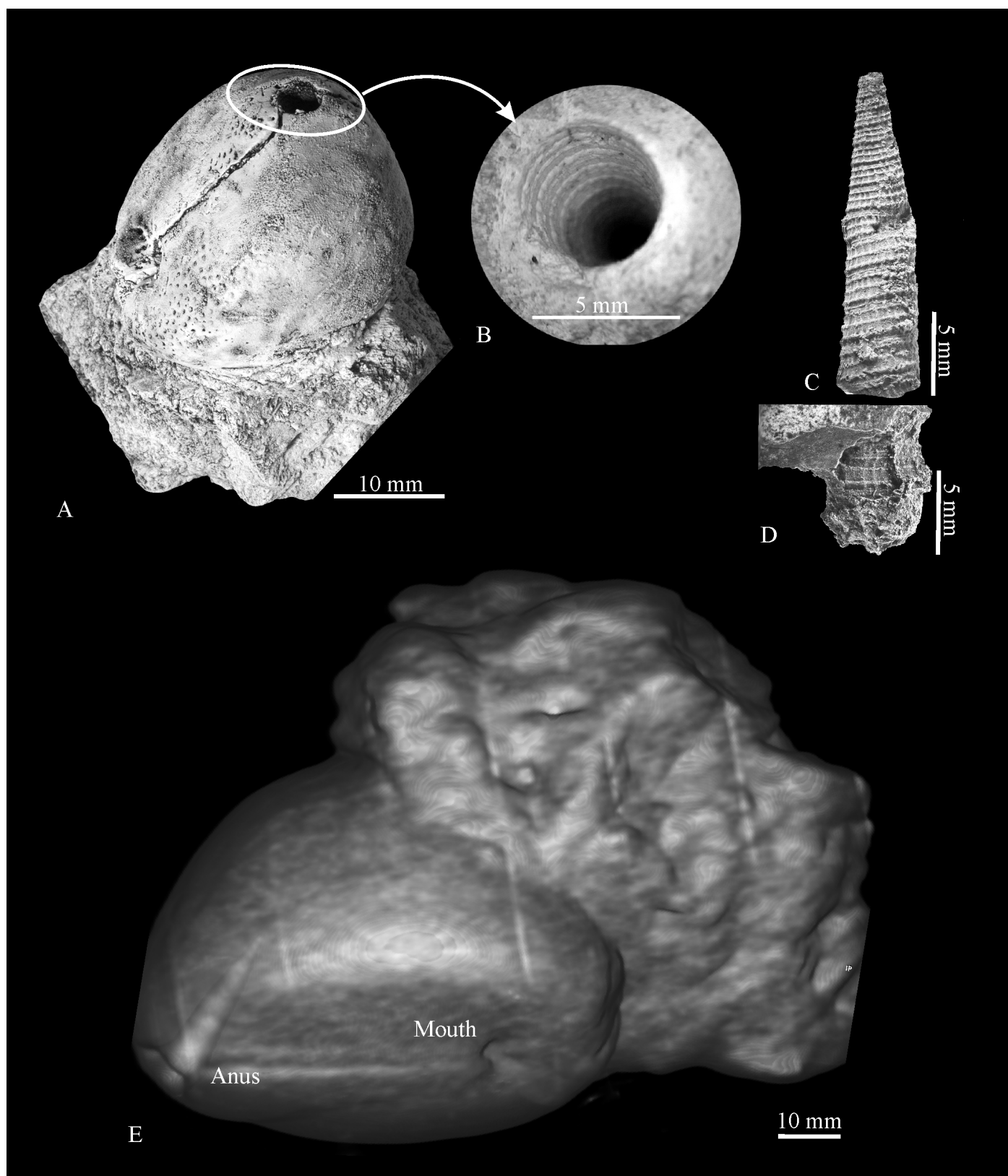


FIGURE 3. **A**, test of *Echinocorys sulcata* (OESM 10062a), in part still embedded in original matrix; **B**, close-up of the anal opening showing the perfect imprint of the turritiform gastropod *Cerithiella fenestrata*; **C**, silicone cast of the imprint, documenting that it penetrated over a length of 21 mm into the echinoid test; **D**, silicone cast of the imprint in the surrounding matrix, which originally extended over a length of 8 mm from the echinoid test; and **E**, transparent image of the echinoid generated by CT scanning, showing the internal orientation of the gastropod shell within. The parallel stripes on the image are from the plastic tray on which the specimen was mounted prior to scanning.

accidentally have backed up its abode into the periproctal opening of the empty test, becoming lodged in the process. Hermit crabs and other decapod arthropods are known to back away from rivals or predators. Undescribed isolated claws, attributed to paguroids, are on record from the Danian limestones of Denmark and are present in the collections of the Østsjælland Museum.

Of these scenarios we consider the ones where the shell was accidentally pushed into the test by burrowing or browsing organisms the most plausible. However, we cannot totally rule out other, more colorful, explanations.

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#### REFERENCES

- Bjerager, M., and Surlyk, F., 2007, Danian cool-water bryozoan mounds at Stevns Klint, Denmark – a new class of non-cemented skeletal mounds: *Journal of Sedimentary Research*, v. 77, p. 634–660.
- Bromley, R.G., and Ekdale, A.A., 1984, Trace fossil preservation in flint in the European Chalk: *Journal of Paleontology*, v. 58, p. 298–311.
- Brünnich Nielsen, K., 1938, Faunaen i Ældre Danium ved Korporalskroen: *Meddelelser fra Dansk Geologisk Forening*, v. 9 (for 1937), p. 117–126.
- Damholt, T., and Surlyk, F., 2012, Stevns Klint for inclusion in the World Heritage List: Store Heddinge, Østsjælland Museum, 160 p.
- Ekdale, A.A., and Bromley, R.G., 1984, Sedimentology and ichnology of the Cretaceous-Tertiary boundary in Denmark; implications for the causes of the terminal Cretaceous extinction: *Journal of Sedimentary Research*, v. 54, p. 681–703.
- Goldfuss, G. A., 1826, *Petrefacta Germaniae. I. Abbildungen und Beschreibungen der Petrefacten Deutschlands und der angränzenden Länder*. Düsseldorf, 234 pp.
- Gravesen, P., 1993, Early Danian species of the echinoid genus *Tylocidaris* (Cidaridae, Psychocidarinae) from eastern Denmark: *Contributions to Tertiary and Quaternary Geology*, v. 30, p. 41–73.
- Houbriek, R.S., 1992, *Monograph of the genus Cerithium Bruguiere in the Indo-Pacific (Cerithiidae--Prosobranchia)*. Smithsonian Institution Press, Washington, D.C., 211 p.
- Jagt, W.M.J., 2013, *Opmerkelijke Luiks-Limburgse Krijtfossielen, deel 18. Een Kans van éénop de miljoen: Natuurhistorisch Maandblad*, v. 102(8), p. 195–196.
- Lauridsen, B.W., Bjerager, M., and Surlyk, F. 2012, The middle Danian Faxe Formation – new lithostratigraphic unit and a rare taphonomic window into the Danian of Denmark. *Bulletin of the Geological Society of Denmark*, v. 60, p. 47–60.
- Ravn, J.P.J., 1902, *Molluskerne i Danmarks Kridtaflejringer II. Scaphopoder, Gastropoder og Cephalopoder: Det Kongelige Danske Videnskabernes Selskabs Skrifter*, 6. Naturvidenskabelig og Mathematisk Afdeling, v. 11, p. 5–66.
- Ravn, J.P.J., 1927, *De irregulære Echinider i Danmarks Kridtaflejringer: Det Kongelige Danske Videnskabernes Selskabs Skrifter, Naturvidenskabelig og Mathematisk Afdeling*, 8. Række, (11)4, p. 1–48.
- Schweigert, G., 1999, *Erhaltung und Einbettung von Belemniten im Nusplinger Plattenkalk (Ober-Kimmeridgium, Beckeri-Zone, Schwäbische Alb): Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie)*, v. 273, p. 1–35.
- Surlyk, F., Damholt, T., and Bjerager, M., 2006, Stevns Klint, Denmark: uppermost Maastrichtian chalk, Cretaceous–Tertiary boundary and lower Danian bryozoan mound complex: *Bulletin of the Geological Society of Denmark*, v. 54, p. 1–48.
- Surlyk, F., Rasmussen, S.L., Boussaha, M., Schiøler, P., Skovsbo, N.H., Sheldon, E., Stemmerik, L., and Thibault, N., 2013, Upper Campanian-Maastrichtian holostratigraphy of the eastern Danish Basin: *Cretaceous Research*, v. 46, p. 232–256.