A unique sample taken in 1944 of the Cretaceous–Palaeogene boundary succession at the UNESCO World Heritage Site Stevns Klint, Denmark

AF: FINN SURLYK & STEN LENNART JAKOBSEN

Surlyk, F. & Jakobsen, S.L.: A unique sample taken in 1944 of the Cretaceous–Palaeogene boundary at the UNESCO World Heritage Site Stevns Klint, Denmark. Geologisk Tidsskrift 2026, pp. 55–62. ISSN 2245-7097, København.

A large column-like block comprising the Cretaceous–Palaeogene boundary strata was cut out of the coastal cliff section at Stevns Klint, Denmark, in 1944 during World War II. Since then, it has been an eye-catching monument exhibited at the Geological Museum in Copenhagen until it was moved to the large storage building housing the collections of the new Natural History Museum of Denmark. The exact location of the excavation site has for a long time been quite uncertain, but old re-discovered colour slides show the location, the methods used to excavate the block and the transport away from the steep cliff. The block represents a unique evidence of the succession which made Stevns Klint a UNESCO World Heritage Site in 2014.

Keywords: Maastrichtian, Danian, Fiskeler, UNESCO World Heritage List 2014.

Finn Surlyk [finns@ign.ku.dk]. Department of Geosciences and Natural Resource Management, University of Copenhagen. Øster Voldgade 10, DK-1350 Copenhagen K, Denmark. Sten Lennart Jakobsen [KALK/Østsjællands Museer, Rådhusvej 2, DK-4640, Faxe, Denmark.

The 14.5 km long coastal cliff Stevns Klint is located about 40 km south of Copenhagen, Denmark, and became a UNESCO World Heritage Site in 2014 as the most prominent Cretaceous–Palaeogene boundary locality in the World (Fig. 1; Damholt & Surlyk 2012). This status was based on the complete nature of the fossiliferous boundary succession, the presence of the boundary clay containing the famous iridium anomaly, and the excellent exposure and accessibility. Exhibits of the succession in museums are thus of major importance for both scientific, educational and outreach purposes. In 1944 during World War II professor Alfred Rosenkrantz organized a meticulous excavation of a large, column-like block containing the boundary succession. The block was carefully hoisted to the top of the steep cliff by a primitive crane and transported to Copenhagen, where it became a central monument in the exhibition hall of the Geological Museum. The exact location of the sample site has since then been forgotten and both palaeontologists and amateur geologists have tried to find the place. The serendipitous re-discovery of a series of old colour slides taken during the excavation in 1944 has now allowed pinpointing the exact location where the block was cut out of the cliff.

Fig. 1. Map showing the sample location (arrowed) of the excavated column in the face of the coastal cliff, Stevns Klint. The cored Stevns-2 borehole is situated immediately adjacent to the sample location on the coast (marked with black dot). The core is described in Rasmussen & Surlyk (2012) and Surlyk *et al*. (2013). Inset: Map of Sjælland showing the position of the N–S-oriented seismic line immediately off the coast of the Stevns peninsula (Fig. 4). Red rectangle indicates the position of the map. FQ: Faxe Quarry, SK: Stevns Klint.

Stratigraphy of the Stevns Klint succession

Stevns Klint is a classical locality for the study of the Cretaceous–Palaeogene (K–Pg) boundary succession and together with the nearby Faxe limestone quarry it constitutes the type locality for the lowest Paleocene, Danian Stage. The total succession exposed along the coastal cliff of Stevns Klint is about 45 m thick and shows the stratigraphic evolution from the uppermost Maastrichtian across the Cretaceous–Palaeogene boundary and well into the lower Danian (Figs 2, 3; Surlyk *et al*. 2006; Surlyk *et al.* 2013). The altitude of the boundary which is defined at the base of the boundary clay with the famous iridium anomaly – the Fiskeler Member – varies from 5 m below to about 30 m above sea level (Fig. 4). The boundary strata thus show a long wavelength geometry of broad valleys and intervening ridges. This was for many years interpreted as reflecting folding into broad synclines and anticlines (Rosenkrantz 1937). Reflection seismic lines collected offshore the cliff, however, show that the wavy nature of the boundary in the long cliff profile reflects the irregular relief of the late Maastrichtian sea floor, caused by bottom-hugging contour currents (Fig. 4; Lykke-Andersen & Surlyk 2004). The whole of the thick Upper Cretaceous – Danian Chalk Group in northern Europe is now known to represent one of the largest fossil contourite complexes (Surlyk & Lykke-Andersen 2007; Esmerode *et al.* 2007a, b; Surlyk *et al*. 2008; Esmerode & Surlyk 2009).

A full description of the geology of Stevns Klint is presented in Surlyk *et al*. (2006). The lowest part of the succession exposed in the cliff belongs to the Sigerslev Member (Fig. 2) and comprises about 30 m of gently mound-bedded chalk (Anderskouv *et al*. 2007), passing gradually upwards into almost horizontally deposited chalk. This part is poorly fossiliferous and is interpreted to represent the deepest water chalk exposed in Denmark. The Sigerslev Member is topped by an incipient double hardground which is overlain by 2.5–6 m of mounded bryozoan chalk of the Højerup Member. The top of this member is wavy with shallow basins and intervening crests, reflecting the seafloor topography of the bryozoan mounds (Fig. 3). It is overlain by the basal Danian Fiskeler Member, a black to brownish clay, mainly about 5–10 cm thick. The base of the Fiskeler Member represents the Cretaceous–Palaeogene, Maastrichtian–Danian boundary. The clay passes gradationally upwards into the 30–60 m thick lowermost Danian Cerithium Limestone Member (Figs 2, 3). The clay wedges out towards the margins of the basins where it passes into a bedding plane where the Højerup Member is overlain directly by the Cerithium Limestone. This unit is truncated by an erosional hardground surface which also truncates the top of the intervening bryozoan mound crests of the Højerup Member (Fig. 3). The erosion surface is overlain

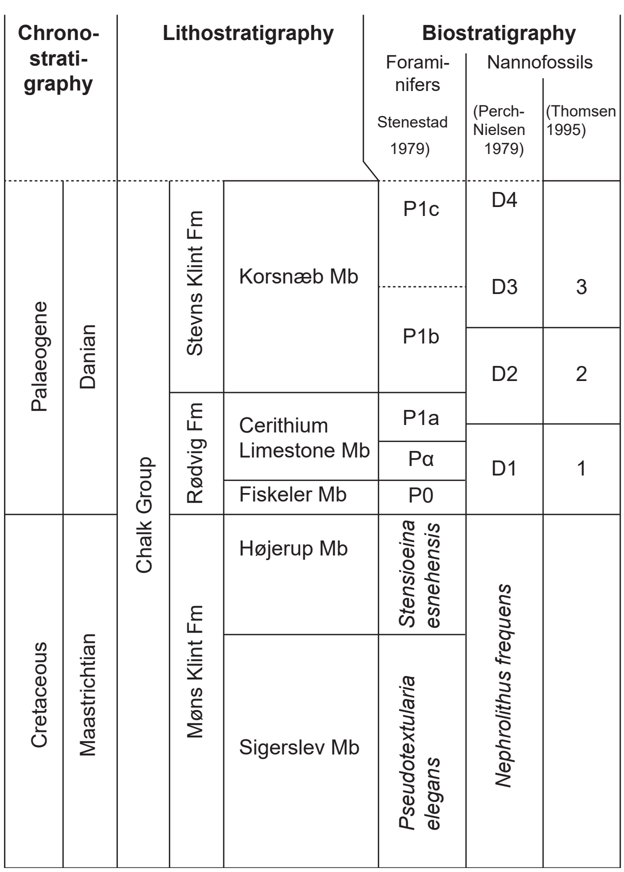

Fig. 2. Stratigraphic scheme covering the Maastrichtian–Danian succession exposed at Stevns Klint. Modified from Surlyk *et al.* (2006) and Rosenkrantz *et al.* (2021).

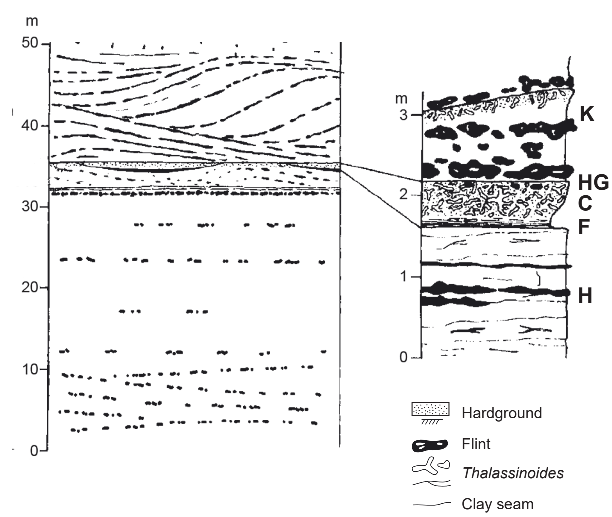

Fig. 3. Sketch illustrating the complex stratigraphy of the Cretaceous–Palaeogene boundary succession at Stevns Klint. The dark clay of the basal Danian Fiskeler Member with the famous iridium anomaly at the base is restricted to the central parts of the basins between the mounded tops of the uppermost Maastrichtian Højerup Member. The clay wedges out towards the margins of the basin where it passes into a sub-horizontal joint. The upper marly light brown parts of the Fiskeler Member reach farther out towards the margins of the basin and many boundary sections through a basin margin miss the lowermost part of the clay and do not show the Fiskeler proper and thus not the actual boundary This is the case with a prominent example shown in a local exhibition, Stevns Klint Experience. Key to code explained in caption to Figure 5.

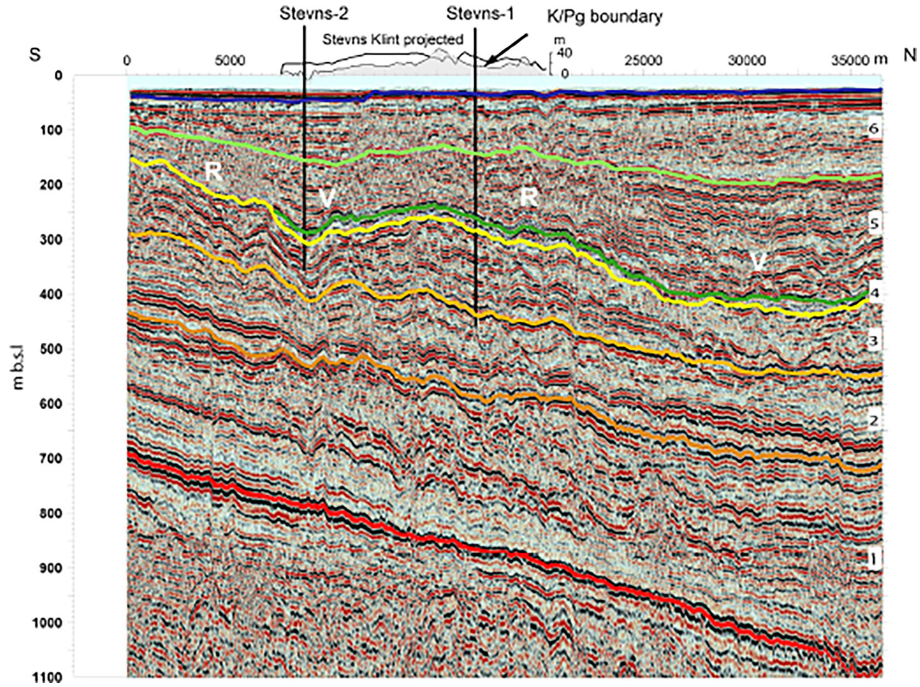

Fig. 4. N–S-oriented seismic line offshore Stevns Klint which is projected onto the top of the line. line. The sample location is situated where the vertical line of Stevns-2 cuts the cliff at the southern end of a small valley of the Maastrichtian seafloor where the boundary goes below sea level. Note the large-scale ridge-valley topography in the underlying chalk strata formed by bottom-hugging contour currents. The planar reflection shown in red is interpreted as the base-chalk. The position of the cored borehole S2 is shown. Modified from Lykke-Andersen & Surlyk (2004).

by relatively hard, mounded bryozoan limestone of the lower Danian Korsnæb Member (Figs 2, 3). The erosional hardground is thus complex, comprising the lower Danian Cerithium Limestone and the top of the uppermost Maastrichtian Højerup Member.

The adjacent beds of hardened Højerup Member and Cerithium Limestone are difficult to distinguish lithologically in the field. Fossils were thus commonly sampled from the complex hardground without distinguishing between the two limestones of different ages. This resulted in the notion that there was a gradual faunal transition across the boundary. The true nature of the faunal changes across the boundary was solved by Rosenkrantz (1924), who was the first to realise the complex nature of the boundary, taking great care in separating collections from the two units. This resulted for the first time in the recognition of a sharp faunal break at the Cretaceous–Palaeogene boundary (Rosenkrantz 1924, 1937, 1939, 1966), preceding the mass extinction debate with many years. This is probably one of the reasons for Rosenkrantz's project to cut out a big column-like block of the boundary succession for scientific and educational purposes and as a unique museum exhibition specimen.

The sampling project

Denmark was occupied by Germany in 1940–45 during World War II. As a side-effect geological studies were severely hampered. Old hunting grounds for Danish geologists in East and West Greenland, Iceland and the Faroe Islands were obviously out of reach. Lack of fuel for automobiles was a major hindrance for field work in Denmark outside the near reaches of Copenhagen where the geological university department and the Geological Survey of Denmark were situated. However, Stevns Klint could be reached by a small local train and by cars equipped with a gas generator.

Professor Alfred Rosenkrantz, who over many years had undertaken extensive field work along the coastal cliff initiated an ambitious sampling project in 1944 in the last year of the war. His idea was to cut out a large rock column across the Maastrichtian–Danian boundary from a place where the boundary clay, the Fiskeler Member was well exposed and the boundary succession well preserved and easy to examine. A useful sample location was, however, far from easy to find. Necessary requirements were:

1. Several metres of the top Maastrichtian Højerup Member should be exposed, and the boundary succession must be complete and show the central part of a Fiskeler basin where the full thickness of the clay was present. The lower Danian Cerithium Limestone, its top erosional hardground surface and several metres of the overlying bryozoan limestone of the Korsnæb Member should also be present (Figs 2, 3).
2. The succession should be located at a place where the cliff wall of the succession to be sampled was close to vertical to make it possible to saw out a column-like block.
3. The lower Danian bryozoan limestone of the Korsnæb Member is much harder and erosion-resistant than the Maastrichtian chalk. The cliff profile therefore shows a dramatic overhang of

Fig. 5. The sampling site was determined and the cleaning of the cliff face could begin. The wall in the upper right and in the background shows a characteristic pattern, reflecting the old quarrying method by sawing. The different stratigraphic levels are from below: **H**. The mound-bedded bryozoan-rich chalk of the uppermost Maastrichtian **H**øjerup Member; **F**. The basal Danian boundary clay, the **F**iskeler Member; **C**. The lowermost Danian **C**erithium Limestone Member; **HG**: the erosional **h**ard**g**round forming the top of the Cerithium Limestone; **K**. the lower Danian bryozoan limestone of the **K**orsnæb Member. Professor Alfred Rosenkrantz to the left.

Fig. 6. The column was marked up and sawing along the margins had begun. Note the saw placed vertically in the middle of the column.

Fig. 7. The column almost free, only the base needed to be sawn and the wooden board to the right ready to be packed around the column.

Fig. 8. The column sawn completely free, packed in a case of wooden boards and ready to be hoisted to the top of the cliff.

Fig. 9. A simple crane was constructed at the cliff top.

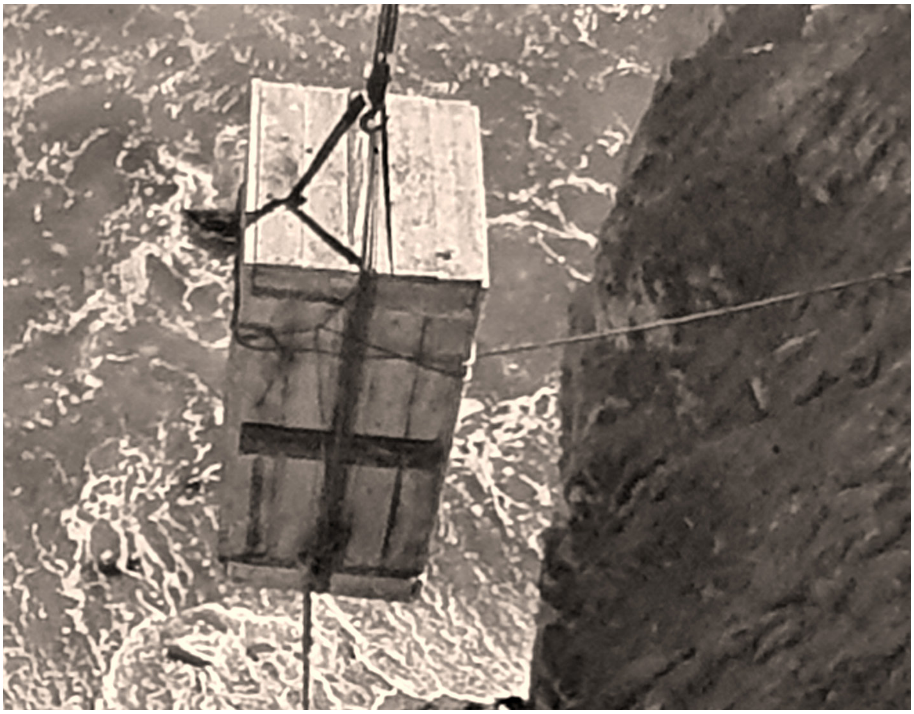

Fig. 10. Start of lifting the column to the flat surface at the top of the cliff.

Fig. 11. Sampling close to completion. The board-encased column close to the top of the cliff. In the background a truck is waiting to transport it to the Mineralogical Museum (later named the Geological Museum) in Copenhagen. A gas generator was mounted providing energy for driving by using wood or coke for fuel.

Fig. 12. Stevns Klint geo-tourists with long, dark leather coats and long black boots inspecting the Fiskeler Member at the time when the column was being excavated in the summer of 1944.

the limestone along much of the of the cliff, in many cases reaching several metres out in the air. Such places had to be avoided in part for safety reasons

4. The top of the cliff should be relatively easily accessible by car, allowing the column to be lifted to the top and loaded onto a truck. It would be close to impossible to transport it away from the sample site in other ways. The beach is narrow, commonly rather steep, and composed of flint cobbles and large fallen slabs of bryozoan limestone. In addition, access to the beach is only possible at a few places which are situated quite far from each other.

A suitable sample site was found by Rosenkrantz at the southern end of the cliff off the Boesdal limestone quarry (Fig. 1). The quarry is separated from the beach by an unquarried limestone wall some 20 m thick but with an opening to the beach in the north-eastern corner, allowing quarried limestone to be sailed away by ship. The wall north of and adjacent to the opening is vertical because the coastal side in earlier times had undergone quarrying undertaken with a large saw between holes drilled down through the succession at regular intervals. The Cretaceous–Palaeogene boundary strata disappear under the sea a few tens of metres farther north, reflecting its wavy nature along the cliff (Fig. 4). There is thus only a short stretch between this place and the coastal entrance to the quarry which could be used for sampling of the column-like block. Fortunately, the land above this place has not been quarried and is flat and stable, making it possible for a truck to pick up the column after it had been hoisted up with a crane. The Boesdal site was chosen by Rosenkrantz, being close to the only place along the whole length of the cliff where this kind of work could be undertaken.

Sampling of the column-like block

The sampling site being found, the actual work could now begin (Figs 5–11). These new-found pictures show all stages in the sampling process. First, the cliff surface was cleaned and evened out across the boundary strata to be sampled (Fig. 5). Then the outline of the column was marked and sawing could begin (Fig. 6). Big blocks next to the margins of the column were cut away and removed to allow the bottom and back side of the column to be sawn free (Fig. 7). A wooden board case was constructed like a coffin around the column (Fig. 8). A simple crane was made and placed on the top of the cliff (Fig. 9). It had to be quite solid, as the block weighs about 1 ton. The board case and its content was finally hoisted to the top of the cliff (Fig. 10) and safely placed on a truck powered by a war-time gas generator (Fig. 11). During all this work the Cretaceous–Palaeogene boundary strata in the cliff attracted close attention by a group of young men dressed in dark leather coats and equipped with black boots (Fig. 12). Subsequently, the block was transported to the Mineralogical Museum (later named the Geological Museum) where it enjoyed a prominent position for about 74 years until it was moved to its present location in the

Fig. 13. The column at its present location in the storehouse of the Natural History Museum of Denmark at Priorparken. Symbols as in Figure 5.

storehouse of the Natural History Museum at Priorparken in a Copenhagen suburb (Fig. 13).

The block is 150 cm high, 60 × 60 cm in widths and was fortified with cement along the back and lateral sides. It exposes 95 cm of the uppermost Maastrichtian white bryozoan chalk of the Højerup Member at the base. This is overlain by the basal Danian black clay of the Fiskeler Member, which passes gradationally over a few centimetres into the lowermost Danian Cerithium Limestone Member. This is topped by an erosional hardground which is somewhat difficult to see in the block because the very top of the Cerithium Limestone is developed as a band of black flint nodules. The irregular, burrowed erosion surface is overlain by 45 cm of bryozoan limestone of the lower Danian Korsnæb Member. Then follows another nodular flint band, 8 cm thick, followed by bryozoan limestone to the top (Fig. 13).

The block is obviously somewhat fragile after transport to Copenhagen in 1944, placement in the museum exhibition hall, followed by transport to and placement in the storehouse. At the time of writing the old Geological Museum is being closed down and some of the geological exhibits will be located at the new building of the Natural History Museum. It is our hope that the column will resume a prominent place in the new museum. It is a unique, solid example of one of the few UNESCO World Heritage sites in Denmark.

Acknowledgements

We are grateful to Peter Alsen for assistance with the illustrations and Ole Bennike for excellent editorial work. We thank Lotte M. Larsen and Gunver K. Pedersen for helpful comments.

References

Anderskouv, K., Damholt, T. & Surlyk, F. 2007: Late Maastrichtian chalk mounds, Stevns Klint, Denmark – combined physical and biogenic structures. Sedimentary Geology 200, 57–72.

Damholt, T. & Surlyk, F. 2012: Nomination of Stevns Klint for inclusion in the World Heritage List, 160 pp. St. Heddinge: Østsjællands Museum.

Esmerode, E.V., Lykke-Andersen, H., Surlyk, F., 2007a: Ridge and valley systems in the Upper Cretaceous chalk of the Danish Basin: contourites in an epeiric sea. In: Viana, A.R. & Rebesco, M. (eds): Economic and Palaeoceanographic Significance of Contourite deposits, Geological Society, London, Special Publications, 276, pp. 265–282.

Esmerode, E.V., Lykke-Andersen, H. & Surlyk, F. 2007b: Interaction between bottom currents and slope failure in the Late Cretaceous of the southern Central Graben, North Sea. Journal of the Geological Society, London 165, 55–72.

Esmerode, E.V. & Surlyk, F. 2009: Origin of channel systems in the Upper Cretaceous Chalk Group of the Paris Basin. Marine and Petroleum Geology 26, 1338–1349.

Lykke-Andersen, H. & Surlyk, F. 2004: The Cretaceous–Palaeogene boundary at Stevns Klint, Denmark: inversion tectonics or sea-floor topography. Journal of the Geological Society, London 161, 343–352. https://doi.org/10.1144/0016-764903-021

Perch-Nielsen, K. 1979: Calcareous nannofossil zonation at the Cretaceous/Tertiary boundary in Denmark. In: Birkelund, T. & Bromley, R.G. (eds): Symposium on the Cretaceous/Tertiary boundary events; I, The Maastrichtian and Danian of Denmark, 115–135. University of Copenhagen, Denmark.

Rasmussen, S.L. & Surlyk, F. 2012: Facies and ichnology of an Upper Cretaceous chalk contourite complex, eastern Denmark, and the validity of contourite facies models. Journal of the Geological Society 169, 435–447. https://doi.org/10.1144/0016-76492011-136

Rosenkrantz, A. 1924: Nye Iagttagelser over Cerithiumkalken i Stevns Klint med bemærkninger om Grænsen mellem Kridt og Tertiær. Meddelelser fra Dansk Geologisk Forening 6, 28–31.

Rosenkrantz, A. 1937: Bemærkninger om det østsjællandske Daniens stratigrafi og tektonik. Meddelelser fra Dansk Geologisk Forening 9, 199–212.

Rosenkrantz, A. 1939: Faunaen i Cerithiumkalken og det hærdnede Skrivekridt i Stevns Klint. Meddelelser fra Dansk Geologisk Forening 9, 4, 509–514.

Rosenkrantz, A. 1966: Die Senon/Dan Grenze in Dänemark. Berichte der Deutschen Gesellschaft für Geologische Wissenschaften A11, 721–727.

Rosenkrantz, A., Surlyk, F., Anderskouv, K., Frykman, P., Stemmerik, L. & Thibault, N. 2021: The K–T boundary strata north of Korsnæb, Stevns Klint, Denmark – evolution and geometry revealed in a long, horizontal profile. Bulletin of the Geological Society of Denmark 69, 233–244. https://doi.org/10.37570/bgsd-2021-69-10

Surlyk, F. & Lykke-Andersen, H. 2007: Contourite drifts, moats and channels in the Upper Cretaceous chalk of the Danish Basin. Sedimentology 54, 405–422. https://doi.org/10.1111/j.1365-3091.2006.00842.x

Surlyk, F., Damholt, T. & 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 54, 1–48. https://doi.org/10.37570/bgsd-2006-54-01

Surlyk, F., Jensen, S.K. & Engkilde, M. 2008: Deep channels in the Cenomanian–Danian Chalk Group of the German North Sea sector: Evidence of strong constructional and erosional bottom currents and effect on reservoir quality distribution. AAPG Bulletin 92, 1565–1586.

Surlyk, F., Rasmussen, S.L., Boussaha, M., Schiøler, P., Schovsbo, N.H., Sheldon, E., Stemmerik, L. & Thibault, N.R. 2013: Upper Campanian – Maastrichtian holostratigraphy of the eastern Danish Basin. Cretaceous Research 46, 232–256. https://doi.org/10.1016/j.cretres.2013.08.006

Thomsen, E. 1995: Kalk og kridt i den danske undergrund. In: Nielsen, O.B. (ed.): Danmarks Geologi fra Kridt til i dag 31–67. Aarhus: Århus Geokompendenier.