Stevns Klint, Denmark: Uppermost Maastrichtian chalk, Cretaceous–Tertiary boundary, and lower Danian bryozoan mound complex

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Stevns Klint is a 14.5 km long coastal cliff south of Copenhagen, Denmark. It is a classical Cretaceous–Tertiary boundary locality and constitutes the type locality of the Danian Stage together with the nearby Faxe quarry. The irregular coastal topography, the presence of numerous old quarries in the upper, Danian part of the cliff section, and the inaccessibility of parts of the coast makes it difficult to construct an exact geological profile of the whole length of the cliff. Until now the only profile is a fine engraved pen drawing from a boat by Puggaard in 1853. We present a new profile of the cliff constructed on the basis of multi-model photogrammetric mapping of a long series of overlapping photographs taken from a small airplane. This was supplemented by photography and observations from a boat and from the beach. The exposed succession is about 45 m thick and is subdivided into a series of new lithostratigraphic units. It shows the stratigraphic evolution from the uppermost Maastrichtian, across the Cretaceous–Tertiary boundary and into the lower Danian. The position of the boundary varies from about 5 m below to about 30 m above present day sea level. The irregular relief has been interpreted as due to Paleogene folding but it actually represents a depositional sea-floor topography. The lower part of the succession comprises about 25 m of upper Maastrichtian benthos-rich chalk of the new Sigerslev Member showing irregular low-amplitude mounded bedding outlined by thin layers of nodular flint, passing upward into benthos-poor, gently wavy to almost horizontally bedded chalk poor in flint. The member is capped by a double incipient hardground and a prominent marker band of nodular flint, occurring 30–50 cm beneath the upper hardground can be followed along the length of the cliff. The upper hardground is overlain by uppermost Maastrichtian bryozoan chalk wackestone deposited in low asymmetrical mounds of the new Højerup Member. It is 4–5 m thick in the southern part of the cliff, thins gradually to the north, and has wedged out almost completely at the northern end of the cliff. The new Sigerslev and Højerup Members form the top part of the Maastrichtian Tor Formation in the Stevns Klint area. It is overlain by the new lowermost Danian Fiskeler Member (P0 foraminifer Zone) which drapes the troughs between the mound crests and wedges out gradually towards the margins of the troughs. It is generally about 5–10 cm thick and passes gradually upwards into the strongly burrowed new Cerithium Limestone Member (Pα–P1a Zones), which is up to 60 cm thick. The Fiskeler and Cerithium Limestone Members form the new Rødvig Formation. An erosional hardground surface truncates the top of the Cerithium Limestone Member and the intervening crests of the uppermost Maastrichtian mounds of the Højerup Member. The surface is overlain by lower Danian bryozoan packstone–rudstone mound complexes (foraminifer zones P1b–P1c , local coccolith zones 2–3, Nannoplankton Zones D2–D3). The internal architecture of the mounds is outlined by thick black flint layers and the mounded bryozoan limestone belongs to the new Korsnæb Member of the new Stevns Klint Formation. Up to 20 m of bryozoan limestone are preserved beneath the Quaternary deposits, forming the top of the cliff succession. The new photogrammetric profile may serve as an excursion guide, as a basis for detailed sedimentological study, and for biostratigraphical, geochemical and palaeomagnetic sampling. Finally, it illustrates the geometry, dimensions and architecture of one of the finest carbonate mound complexes known.

Keywords: Stevns Klint, Maastrichtian, Danian, Cretaceous–Tertiary boundary, multi-model photogrammetry, chalk, bryozoan mound complex

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The coastal cliff Stevns Klint in eastern Denmark is 14.5 km long and is possibly the most famous, and easily the most attractive, scenic and best exposed Cretaceous–Tertiary boundary locality in the World (Figs 1, 2). It is visited by scores of geologists, student excursions, school classes and tourists every year and is one of the localities at which the iridium enrichment in the boundary clay was first described (Alvarez *et al.* 1980). It is within easy reach, situated only about one hour drive from Copenhagen Airport. The stratigraphy, sedimentology and palaeontology of the succession exposed in the cliff are highly fascinating. Part of the cliff is inaccessible except by boat in calm weather, and other parts are or have until recently been military property. The topography of the cliff face is irregular, with marked bends of the coastline, and the upper, Danian part of the cliff section is dissected by numerous old, small quarries, whereas the Maastrichtian chalk is or has been exploited in a few larger quarries. Most of the cliff exposes soft Maastrichtian chalk at the base and hard Danian bryozoan limestone at the top, resulting in a characteristic, overhanging cliff profile (Fig. 2 and cover photograph). The basic configuration of the succession exposed in the cliff was recognized already by Abildgaard (1759), but hitherto the only published profile of the complete cliff section is an excellent pen drawing made from a small boat by Puggaard (1853).

Stevns Klint has its first written record in Latin in Saxo Grammaticus 'History of Denmark', written between approximately 1190 and 1210. The area must originally have been called Stevn. The final 's' is a result of the name's frequently appearing in genitival composition. The name Stevn results from a compound of Old Danish stæth meaning 'anvil', which is often used in a transferred sense of topographical features, with Old Danish hem, cognate with German heim and English ham, a word referring to a 'settlement' or 'settled area'. Names of this type would seem to belong to the period of the folk migrations. The pronunciation of Stevns Klint is sdewn¿s klin¿d using the International Phonetic Alphabet (and *not* Stevens). The ¿ indicates a glottal stop, Danish 'stød'. This account was kindly provided by Gillian Fellows-Jensen (pers. comm. 2002). 'Klint' is Danish for cliff. Stevns is the name for the whole peninsula, and Stevns Klint is the name for the coastal cliff, bordering the peninsula on the east.

The aims of this paper are to provide a length-profile of the famous Cretaceous–Tertiary boundary succession exposed in the cliff which may serve as a guide for excursions and sampling, to demonstrate the application of the multi-model photogrammetric method, and to illustrate one of the finest ancient carbonate mound complexes known.

Geological setting

The 14.5 km long and up to 41 m high coastal cliff, Stevns Klint is situated about 45 km south of Copenhagen on the east coast of the Danish island of Sjælland (Fig. 1). The upper Maastrichtian – lower Danian succession exposed in the cliff was deposited over the eastern end of the Ringkøbing–Fyn High, which forms the southern border of the Danish Basin (Fig. 1). The chalk and bryozoan limestone are thus relatively thinner and of an overall shallower-water nature than the correlative deposits of the Danish Basin and the North Sea (see Surlyk *et al.* 2003 for an overview of the Chalk Group, and Thomsen 1995, for a detailed account of the Danian stratigraphy, palaeogeography and facies distribution). The area has experienced uplift close to a total of 600 m by combined Late Cretaceous and Cenozoic basin inversion and regional Neogene uplift, and the succession was originally buried beneath Cenozoic deposits (Liboriussen *et al.* 1987; Japsen 1992, 1993; Vejbæk 1997; Japsen & Bidstrup 1999; Japsen *et al.* 2002; Vejbæk & Andersen 2002). The succession exposed in Stevns Klint belongs to the top part of the Chalk Group which is about 1 km thick as seen in seismic sections obtained immediately onshore and offshore of the cliff (Fig. 3; Lykke-Andersen & Surlyk 2004; new onshore seismic lines of H. Lykke-Andersen, F. Surlyk and L. Stemmerik collected in November 2005).

Stratigraphy

The Danian Stage was introduced by Désor in 1847 on the basis of the successions exposed in the upper part of Stevns Klint and the nearby Faxe quarry (see Gravesen 2001 for an overview). Until the 1950s the Danian was regarded as the uppermost stage in the Cretaceous System. The recognition of a mass extinction of marine calcareous plankton at the Maastrichtian–Danian Stage boundary (e.g. Bramlette & Martini 1964) prompted many authors to suggest a transfer of the stage from the top of the Cretaceous to the bottom of the Tertiary. Rosenkrantz (1966) reviewed the palaeontological evidence and included the Danian in the Tertiary with a base at the base of the Fiskeler Member. Since 1960 the Danian has been considered the lowermost stage in the Tertiary System, which in 1989 was split into the Paleogene and Neogene Systems. The International Commission on Stratigraphy has suggested that the Tertiary should be eliminated (see review by Salvador 2006). We agree with Salvador (2006) in that the Tertiary should be retained as a system with the Paleogene and Neo-

Fig. 1. Map of Denmark showing major structural elements, from Lykke-Andersen & Surlyk (2004). Inset map of Stevns Klint, showing place names mentioned in the text, position of boreholes (S1 and S2), lithostratigraphic type localities (in brackets), and projected lines of the photogrammetrical profile (red lines). The map is printed with permission from the National Survey and Cadastre (© Kort og Matrikelstyrelsen (A. 49-05)).

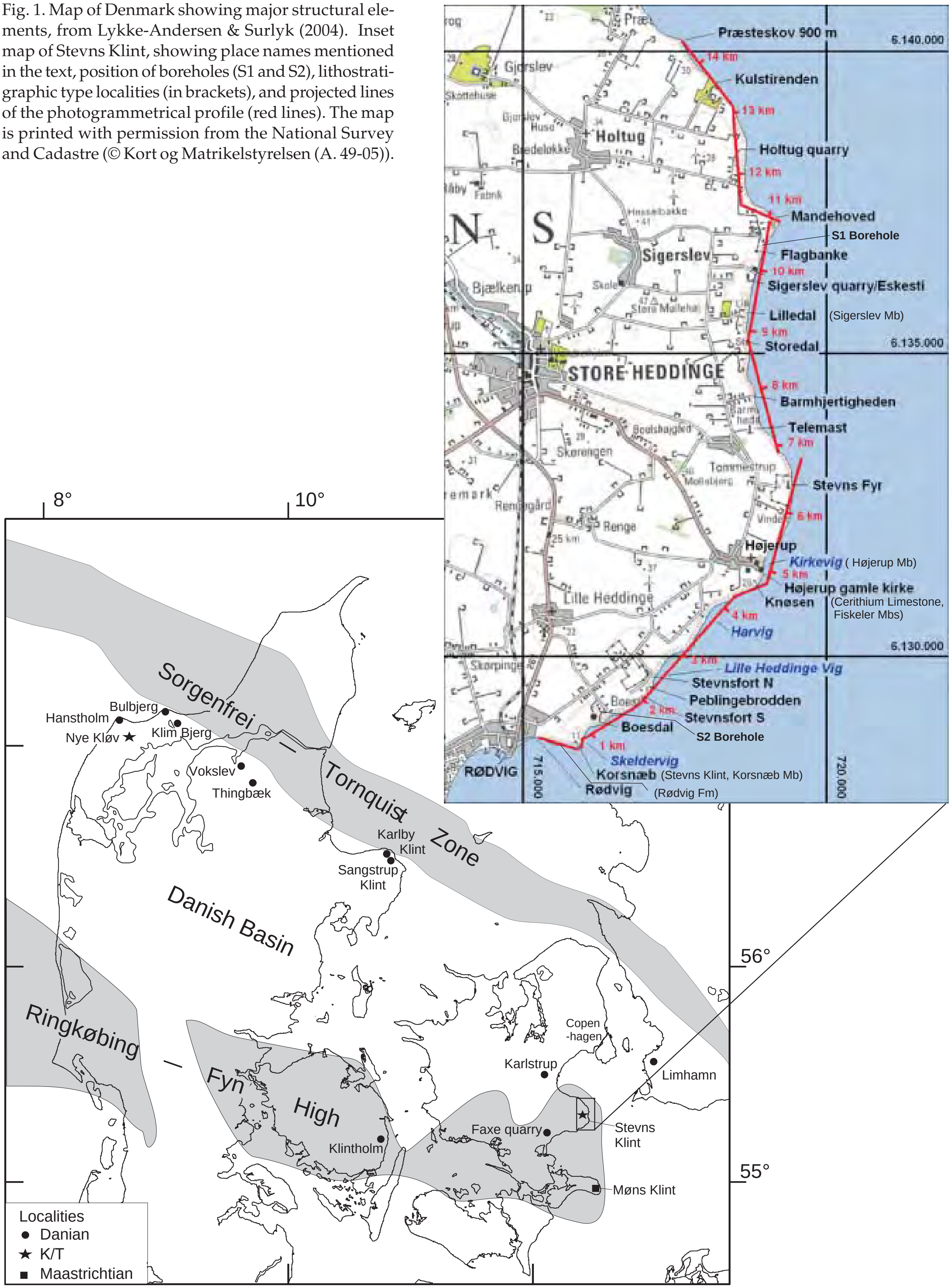


Fig. 2. The classical Cretaceous–Tertiary boundary locality below the old Højerup church ('Højerup gamle Kirke') and type section of the Højerup Member. The new stratigraphic units indicated. View from northeast.

gene Subsystems and we accordingly use the expression Cretaceous–Tertiary rather than Cretaceous–Paleogene boundary. In 1989 the Working Group on the Cretaceous–Tertiary boundary under the International Commission of Stratigraphy by vote decided the Cretaceous–Tertiary boundary to be defined at the base of a clay bed at the Maastrichtian–Danian boundary in the El Kef section in Tunisia coinciding with the famous iridium anomaly of Alvarez *et al.* (1980). This locality shows the most complete and thickest known succession across the boundary. Microfossils occur in abundance but macrofossils are virtually absent and the sediments are developed in fine-grained siliciclastic facies so it is of limited use as a reference for study of the boundary in the carbonate-dominated Boreal Upper Cretaceous – Danian of northern Europe.

The succession exposed along the length of Stevns Klint is of latest Maastrichtian – early Danian age and the Cretaceous–Tertiary boundary strata are very well exposed (Håkansson & Surlyk 1997). Until the late 1970s the main attention was paid to the fossil content of the section. Following the seminal paper of Alvarez *et al.* (1980) the interest in the boundary strata exploded, and numerous studies of nanno- and micropalaeontology, geochemistry and clay mineralogy of the succession have been published over the last 20 years (e.g. Elliot *et al.* 1989; Surlyk & Håkansson 1999; Schmitz *et al.* 1992; Bauluz *et al*. 2000; Frei & Frei 2002; Hart *et al.* 2004, 2005; Rasmussen *et al*. 2005). The under- and overlying upper Maastrichtian and lower Danian strata have received much less attention, mainly in the form of palaeoecological and sedimentological studies (e.g. Surlyk 1972, 1997; Ekdale & Bromley, 1984; Heinberg 1999; Larsen & Håkansson 2000; Bjerager & Surlyk submitted a, b).

A new lithostratigraphic scheme is erected here for the Maastrichtian and Danian succession exposed in eastern Denmark (Fig. 4; Appendix). It forms the basis for the following description of the geological evolution of the succession exposed in Stevns Klint and of the individual cliff sections portrayed in Plates 1–12.

Stratigraphic evolution of the succession exposed in Stevns Klint

Mound-bedded Maastrichtian chalk (Sigerslev Member, Tor Formation)

The stratigraphically lowest strata exposed in the cliff occur between Storedal and Sigerslev quarry which at the time of writing is called Stevns Kridtbrud, and comprise soft, white chalk showing irregular, wavy or mound-like bedding outlined by thin bands of nodular flint (Figs 5–7) (Rosenkrantz 1937, 1966; Surlyk 1969, 1972; Anderskouv *et al*. submitted). The term "mound" is used here in a geometrically descriptive sense and does not necessarily have any biological implications. The unit is of mid late Maastrichtian age and may reach down into the early late Maastrichtian (Surlyk 1984; Christensen 1997). A minimum of 32 m is exposed at the Sigerslev quarry and data from the boreholes S1 and S2 (Fig. 1) indicate that uniform moderately bryozoan-rich chalk extends downwards to a depth of more than 70 m below terrain surface, where it passes into a cyclic chalk–marl succession (Susanne L. Rasmussen, personal communication 2006). The convex-upward mound-like structures generally do not show any systematic stacking pattern or geometry but N–S and E–W oriented walls in the Sigerslev quarry suggest that the mounds may be ridge-like more or less ENE–WSW trending features. Recent work by Anderskouv *et al*. (submitted) shows, however, that regular, asymmetric bryozoan-rich mounds occur at one level in the quarry. The largest mound-like structures are 200–500 m long and about 10 m high and can be seen in the coastal cliff and smaller structures are 75–100 m long from basin to basin and about 5 m high (Fig. 5). Similar irregular bedding is seen on a much larger scale on seismic profiles onshore and immediately offshore Stevns Klint (Fig. 3). The Base Chalk reflector is planar over at least 50 km in a N–S direction, dips only 0.6° towards the north, and the mounded bedding is thus not due to folding but represents a primary sea-floor topographic relief (Lykke-Andersen & Surlyk 2004). The exposed mound structures can be directly compared to the smallest wave-like structures seen on the seismic data (Anderskouv *et al*. submitted).

The mound-bedded chalk passes gradually upwards into gently wavy to almost horizontally bedded benthos-poor chalk characterized by the trace fossil *Zoophycos* and interpreted as representing the deepest water deposit exposed in the cliff.

The member is topped by two closely spaced incipient hardgrounds characterized by nodular hardening and an irregular, small-scale erosional relief of a few centimetres and common small-scale thrusts (Surlyk 1969, 1972, 1997). The distance between the two incipient hardgrounds is generally 10–25 cm but they may merge into a single hardground. A prominent layer of nodular flint occurs 30–50 cm below the upper hardground and forms a marker bed, which can be traced along most of the cliff (Figs 7–8). This flint band was recognized already by Forchhammer (1825, 1847, 1852) who noted that it could not be found in the northernmost part of the cliff. The lower incipient hardground records a complete stop in sedimentation, onset of nodular hardening a few tens of centimetres below the sea floor, followed by erosion and sea-floor exposure of the partially cemented layer. Sedimentation was resumed for a short time but stopped again and a second episode of nodular hardening and erosion resulted in the formation of the upper incipient hardground. During the periods of non-sedimentation, a gallery of *Thalassinoides* burrows was formed 30–50 cm below the omission surfaces and the fill of the burrows later formed the nucleation sites for precipitation of silica leading to the formation of the nodular marker flint band.

The oldest exposed chalk up to and including the upper incipient hardground is placed in the new Sigerslev Member. This member is here included in the Tor Formation erected for the Maastrichtian chalk in the North Sea. It is possible that future work will lead to the definition of a new formation for the more shallow marine, partly benthos-rich Maastrichtian chalk of eastern Denmark.

Upper Maastrichtian mounded bryozoan chalk wackestone (Højerup Member, Tor Formation)

The incipient hardground at the top of the Sigerslev Member is overlain by bryozoan chalk wackestone of the new Højerup Member which has previously been referred to as 'Gråkridt' or 'Grey Chalk' (Rosenkrantz 1924; Surlyk 1972, 1997; Svendsen 1975; Larsen & Håkansson 2000; Hart *et al.* 2004). The member belongs to the uppermost Maastrichtian and is like the Sigerslev Member included in the Tor Formation. The member is up to 4–5 m thick but thins gradually towards the north and has almost wedged out in the northern part of the cliff, probably due to a combination of post-depositional erosion and reduced sedimentation. The wackestone is rich in benthos, notably bryozoans and other small suspension feeders. Deposition took place in small, asymmetrical mounds, showing migration direction towards the

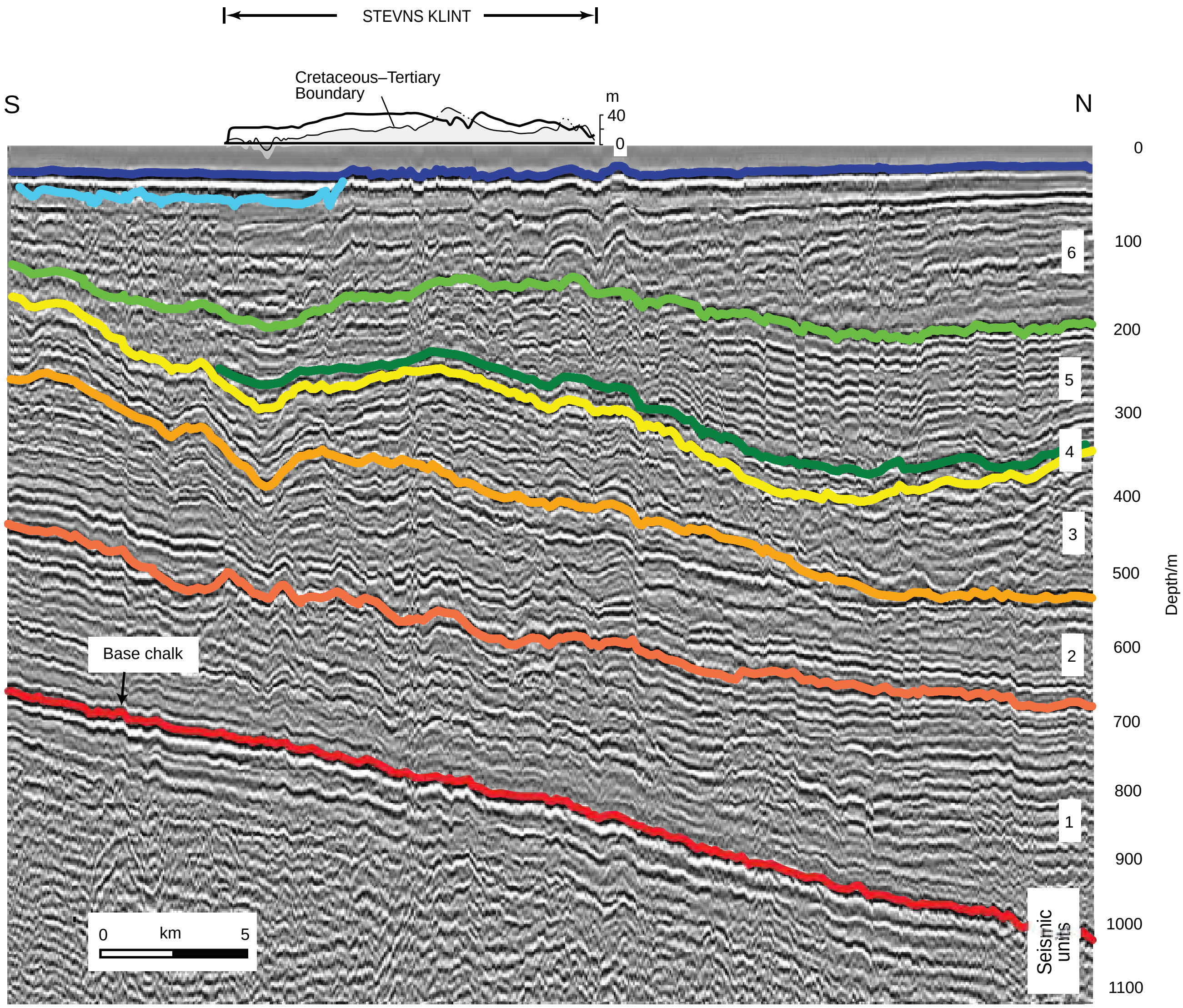
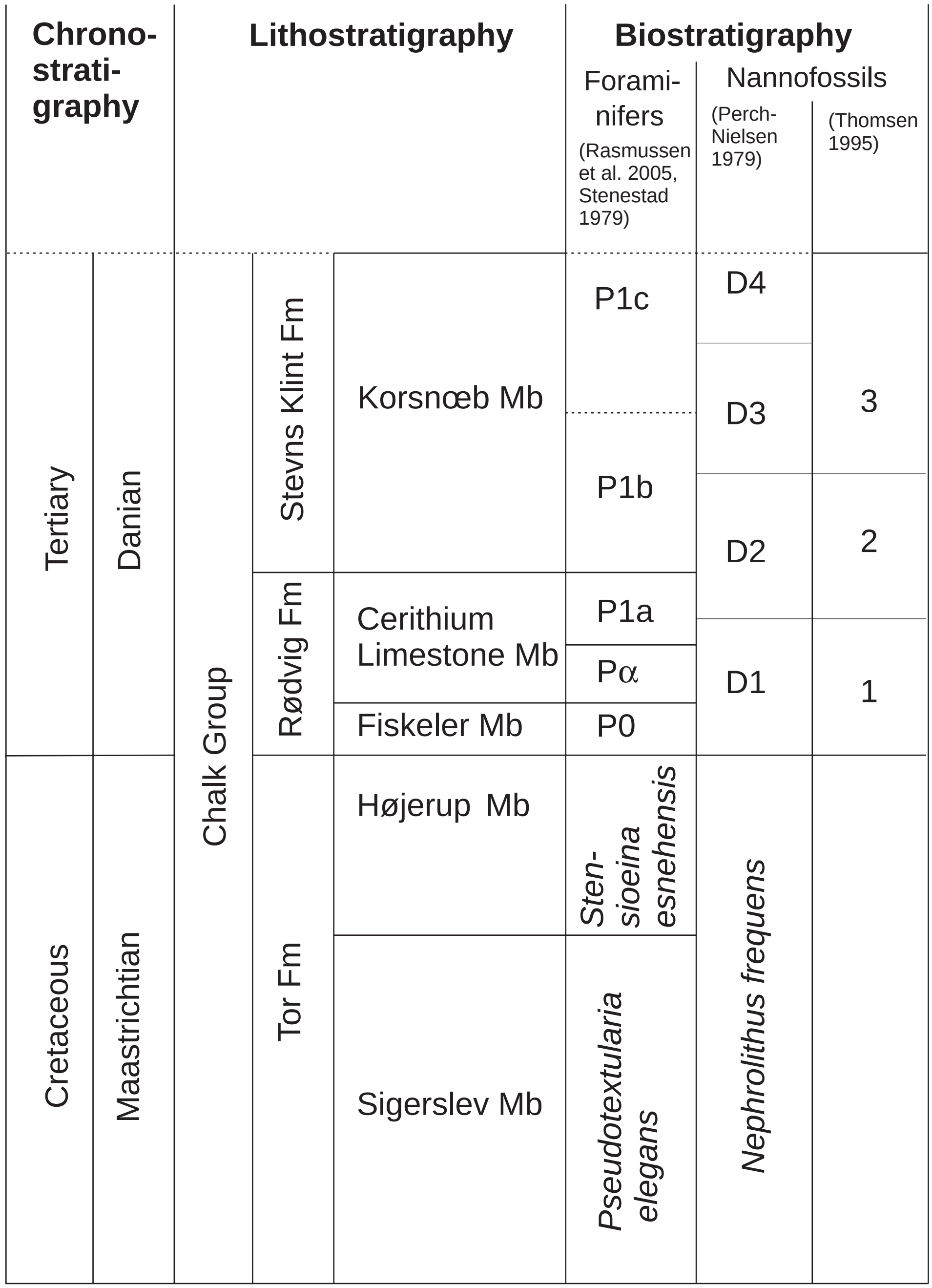


Fig. 3. N–S oriented seismic profile immediately offshore the coastal cliff, Stevns Klint, showing the irregular mounded reflection pattern of the Upper Cretaceous succession. The Stevns Klint profile is projected onto the line in the same scale. Note that the relief of the Cretaceous–Tertiary boundary follows the subsurface relief with a valley beneath the southern end of the cliff and a wide ridge beneath the central part. From Lykke-Andersen & Surlyk (2004).

south (Figs 2, 7). Mound growth was by combined lateral migration and upwards aggradation and the position of the mound crest gradually shifted towards the south during growth. Accumulation on the northern flanks was slow and the beds are thin. They are outlined by prominent inclined bands of nodular flint representing *Thalassinoides* burrow galleries formed during periods of low sedimentation rates (Fig. 8). The individual mounds are roughly contemporaneous but show some southward overlap of each other and it is crucial for any type of stratigraphic sampling that the depositional architecture is correctly identified (Alvarez et al. 1984; Surlyk 1997; Hart et al. 2004).

The bryozoan wackestone is characterized by *Thalassinoides* boxworks and the burrow fills become light grey in the top 30 cm, in places down to 80 cm, approaching the base of the overlying Fiskeler Member. This part of the chalk wackestone is smeared and has been subject to pervasive early post-burial soft-sediment deformation. The mounded unit is particularly well exposed in the classical section below the old Højerup church where the studies of Surlyk (1972, 1997), Svendsen (1975) and Larsen & Håkansson (2000) were undertaken and where most geochemical and micropalaeontological sampling has been carried out.

Fig. 4. New stratigraphical scheme for the Maastrichtian – Danian succession exposed at Stevns Klint.



The Cretaceous–Tertiary boundary strata (Fiskeler and Cerithium Limestone Members, Rødvig Formation)

The mounded bryozoan chalk wackestone of the Højerup Member is overlain by the basal Danian Fiskeler Member, which is up to about 10 cm thick in most of the cliff, but show thicknesses up to about 30 cm to the north at Kulstirenden (Figs 9–12) and 45 cm according to Hart *et al.* (2004, 2005). The old term Fiskeler is kept as part of the new formal member name although it does not follow standard lithostratigraphic practice. There are abundant references to the name in the literature and it is neutral and does not give any indications concerning age or environment. The boundary between the Højerup Member and the Fiskeler Member coincides with the Cretaceous–Tertiary boundary. The clay is restricted to the basins between the crests of the Højerup Member wackestone mounds and thins towards the basin margins where it commonly passes into a bedding plane which appears as a gently inclined joint juxta-

Fig. 5. Type locality of mound-bedded Maastrichtian chalk of the Sigerslev Member at Lilledal (Figs 1, 11; Plate 8, 9300 m). The cliff is 27 m high.

posing hardened Maastrichtian chalk wackestone and lower Danian Cerithium Limestone (Fig. 9). The top few centimetres of the light bryozoan chalk wackestone is developed as grey marl, showing abundant evidence of post-depositional dissolution such as flaser structures and clay-rich solutions seams (Garrison & Kennedy 1977). It is overlain by the Fiskeler. The first detailed study of the Fiskeler was by Christensen *et al.* (1973) who labeled the top Maastrichtian bryozoan wackestone chalk as Bed I, the thin grey transitional marl as Bed II, the overlying subunits of the Fiskeler as Beds III–V, and the Cerithium Limestone as Bed VI (Fig.12). This number system is somewhat confusing because it starts with the bed beneath the Fiskeler, which forms the top of the Maastrichtian bryozoan chalk wackestone. The grey marl (Bed II) should not be included in the Fiskeler Member since all the lowest geochemical anomalies, which are used to define the Cretaceous–Tertiary boundary, are found at the base of Bed III. Other number systems or subdivisions have been proposed but the units of Christensen *et al.* (1973) have been recognized by all subsequent workers and form the basis for microstratigraphical analyses of the Fiskeler. It is remarkable, that metal enrichments with anomalously high Ni-values, were found already by Christensen *et al.* (1973), heralding the discovery of the famous iridium-anomaly by Alvarez *et al.* (1980).

The Fiskeler Member becomes more carbonate-rich upwards and passes gradually into the Cerithium Limestone Member. Schmitz *et al.* (1992) argued that there was an important hiatus between the Fiskeler and the Cerithium Limestone. Recent work by Rasmussen et al. (2005) shows that the Cerithium Limestone is diachronous being younger from south to north along the cliff. There is a hiatus including all of the *P. eugubina* Zone in the northern part, whereas such a hiatus cannot be demonstrated in the southern part. The traditional name of this new formal member has also been kept because of its long use. The gastropod *Cerithium* is a long-ranging genus which still lives and has no age connotations. The member consists of micrite and is strongly burrowed by *Thalassinoides*. The burrows are cylindrical and the burrow fills are mainly derived from the overlying lower Danian bryozoan limestone and post-date deposition of the Cerithium Limestone necessitating great care in all types of sampling. The base of the Cerithium Limestone contains abundant rounded, subangular or lense shaped clasts of chalk, possibly derived from erosion of the intervening crests of the Maastrichtian bryozoan mounds. M. Hart (pers. comm. 2006) however, informs us that he has not found abundant (or even many) Cretaceous foraminifers in the clasks, as would be expected if they were really reworked Maastrichtian chalk.

Lower Danian erosion surface

A prominent erosional hardground surface truncates the top of the Cerithium Limestone Member and the intervening crests of the uppermost Maastrichtian bryozoan mounds of the Højerup Member. At Kulstirenden it is developed as a double hardground like

Fig. 6. Detail of mound-bedded chalk of the Sigerslev Member shown in Fig. 5. In the background is the pier at the Sigerslev quarry.

the one at the base of the Højerup Member (Hart *et al*. 2004). A dense *Thalassinoides* boxwork was formed beneath the surface. The upper 35 cm of sediment beneath the hardground surface is strongly cemented. The complex stratigraphic nature of this hardened interval was not realized by early workers who did not discriminate between the lower Danian Cerithium Limestone within the Fiskeler basins and the lithified top Maastrichtian chalk between the basins as both units show similar hardening and open burrows with loose lower Danian fill (e.g. Ravn 1903; Milthers 1908, 1923; Nielsen 1917). They thus collected fossils from both types of cemented layers beneath the erosion surface, consisting of alternating topmost Maastrichtian bryozoan chalk wackestone and lowermost Danian Cerithium Limestone (Fig. 9). This mixing of fossils collected in strata of different ages led to the notion of a transitional nature of the fauna across the Cretaceous–Tertiary boundary (e.g. Ravn 1903; Nielsen 1917). The true stratigraphic nature of the boundary strata was first unraveled by Rosenkrantz (1924) who clearly distinguished between the two cemented layers during fossil collection.

The position of the erosion surface varies from about 5 m below present-day sea level to about 30 m above and forms a series of highs and lows reminiscent of anticlines and synclines (Fig. 13). The boundary reaches its highest elevation in the central and northern part of the cliff around Storedal and goes below modern sea level in the southern part of the cliff in the Peblingebrodden area. Seismic data show that the wavy relief represents the original sea floor relief (Lykke-Andersen & Surlyk 2004) and is not a result of folding as suggested by Rosenkrantz (1937). The largest topographic features comprise a wide WNW–ESE trending valley to the south bordered to the north by a ridge (Lykke-Andersen & Surlyk 2004).

Lower Danian bryozoan mounds (Korsnæb Member, Stevns Klint Formation)

The erosional hardground truncating the Cerithium Limestone formed the basis for the growth of the impressive, asymmetrical lower Danian bryozoan mounds, which formed when accommodation space increased in the early Danian. The mounds show migration direction towards the SSW like their uppermost Maastrichtian predecessors (Figs 14–15). The mounds are typically 50–100 m long and had a sea-floor relief of about 5–9 m. The mounds are elongate oval in plan view and their axes strike WNE–ESE parallel to the axis of the Danish Basin and to the palaeo-bathymetric contours (Bjerager 2004; Bjerager & Surlyk submitted a). The internal architecture is clearly displayed by thick dark bands of flint formed by precipitation of silica in the fill of *Thalassinoides* burrows formed 30–50 cm below the sea floor. The southern flanks are somewhat steeper than the northern flanks and the bed thicknesses increase strongly from the northern to the southern flanks (Fig. 7). The

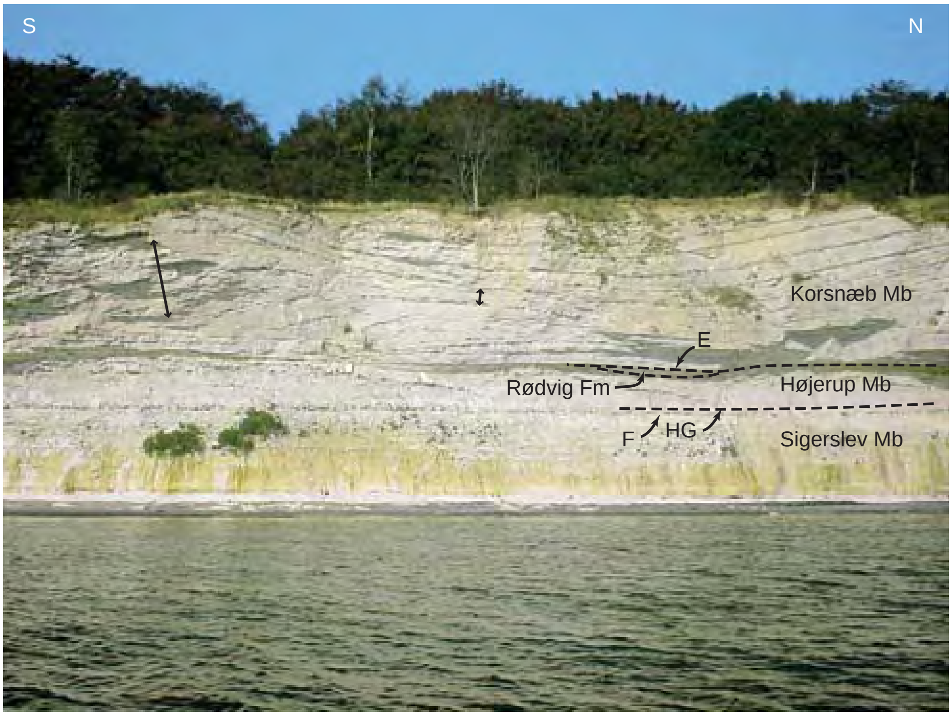


Fig. 7. Cliff section at Kirkevig (Figs 1, 2). Stratigraphic boundaries indicated with dashed lines in the northern part of the figure. At the base horizontally to gently wavy bedded chalk of the Sigerslev Member. The prominent layer of nodular flint (F) and the two incipient hardgrounds (upper indicated with a dashed line) are seen in the middle part of the section, overlain by bryozoan wackestone of the Højerup Member (type locality). Basins filled with the Fiskeler and Cerithium Limestone Members of the Rødvig Formation are truncated at the top by the lower Danian erosion surface (E). The interval marked with double arrows in the Korsnæb Member shows an example of pronounced increase in bed thickness across a bryozoan mound from the northern to the southern flank.

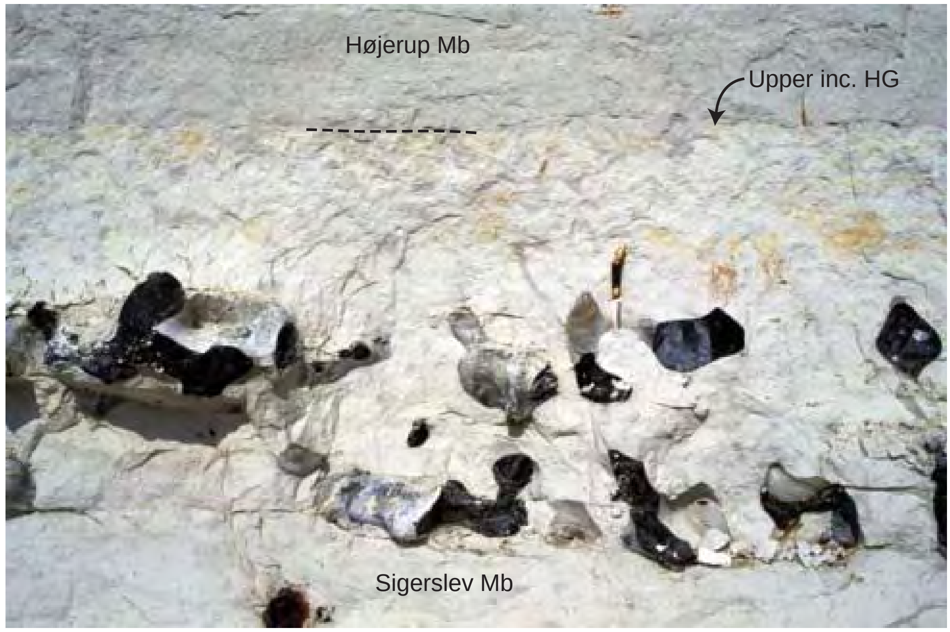
southern flank beds are typically developed as rudstones and floatstones, whereas the northern flanks are mainly packstones (Bjerager & Surlyk submitted a). The thin northern flank beds are commonly topped by shingled hardgrounds, termed 'crab-layers' in the older literature due to the presence of unusual faunal elements (Fig. 15). The mounds become lower in the northern parts of the cliff and the bedding changes to almost flat and horizontal in several areas associated with a lateral change from bryozoan rudstone into a muddier chalk-like facies. The steep southern mound flanks are commonly truncated by concave-up northward dipping erosion surfaces (Fig. 16) (Surlyk 1997). The morphology and architecture of the mounds are key elements in the photogrammetric profile of the cliff illustrated in Plates 1–12. The mound-bedded bryozoan limestone exposed in Stevns Klint is placed in the new Korsnæb Member which forms the lower part of the new Stevns Klint Formation.

The mounded bryozoan limestone is characterized by extremely poor sorting, dominance of large biogenic clasts, and lack of worn and rounded clasts. The lithology thus comprises three size classes: lime mud matrix, millimetre-sized skeletal fragments, notably bryozoans, and large centimetre-sized fossils, such as echinoids. The fossils are typically fragmented but unworn. The mounds are thus mainly of biogenic origin and are not current produced bedforms but bottom currents played an important role in their formation (Bjerager & Surlyk submitted a). The mounds have been interpreted as biogenic structures formed by upcurrent migration towards the south due to preferred growth of bryozoans on the upper part of the steeper southern flanks where nutrient carrying currents had the strongest flow velocity (Thomsen 1976, 1977a, b, 1983). However, the northward-dipping erosion surfaces, and the common presence of hardgrounds on the northern flanks are clear indications of periodical powerful current action resulting in non-sedimentation, winnowing, erosion and cementation of the sea floor (Figs 15–16). The hardgrounds are commonly shingled so that several densely spaced hardgrounds occupy successively higher positions in the cliff section (Fig. 15).

Methods

Multi-model photogrammetry allows production of high quality lateral profiles from series of photographs taken with small-frame hand held cameras (Dueholm 1992). Construction of undistorted profiles in any scale and projection can be made in a fast and easy way. A detailed description of the method and a series of papers illustrating its applications can be found in an instructive volume edited by Dueholm & Pedersen (1992). The long series of photographs

Fig. 8. Close-up of the incipient hardgrounds at the top of the Sigerslev Member. The lower hardground is difficult to trace in detail due to the highly nodular character of the hardening. The upper hardground forms the top of the Sigerslev Member. The knife is 15 cm long.



which form the base for the present work are colour slides and were taken in 1992. Today digital cameras would be used but the actual digitizing of the geological structures and layering is essentially done in the same way.

Multi-model photogrammetry makes it possible to move quickly between up to 39 stereo pairs or models combined into one multi-model. Photographs used in the models can be of different scales and taken with different cameras. Data are automatically stored digitally in a chosen coordinate system (usually UTM) and can later or simultaneously be plotted in a chosen scale and plane of projection.

Cameras used to obtain photographs can be ordinary small-frame hand held cameras (35 mm or 70 mm). The highest accuracy is obtained by use of wide-angle lenses. Pictures should overlap between 60 and 80%, and directions should be kept parallel within 10°. Further details are presented in Dueholm (1992) and Dueholm *et al.* (1993). Pictures taken through the open window of a small airplane can be combined with pictures taken from the ground or the sea because the method allows combination of pictures taken from different angles and with different cameras. This makes the method excellent for profiling steep inaccessible cliffs.

Initial orientation of the photographs is rather time consuming, whereas reorientation of a block only takes a few minutes. Models can be oriented with reference to e.g. UTM coordinates read from a topographical map or to a local coordinate system. Data collection is made through three-dimensional focusing with the help of a floating point. Any visible data can be recorded and the possibility of moving from one model to another keeping the same point in focus makes it easy to trace one object in different models. Digital storing of data allows for later plots in different scales and projection planes. Data can also be transferred to standard computerized drawing programs.

In the present study the method combines stereo-models of small-frame colour photographs taken with a hand-held camera from a small aircraft. Nine multi-model blocks were created with a total of 151 stereo-models to cover the main part of the coastal cliff Stevns Klint. Photographs were taken through the open window of an airplane with a Hasselblad and an Olympus OM2 camera. Photograph scale is about 1:5,000 giving an accuracy of about 25 cm (Stig Schack Pedersen, pers. comm. 2005). The photogrammetrically mapped part of the cliff was subsequently projected onto chosen planes (Figs 1, 17; Plates 1–12). The geology of the northernmost part of the cliff was later added based on photo-mosaics made from photographs taken from a small boat.

The cliff shows a marked topographic overhang, because the Danian bryozoan limestones are harder and more resistant to weathering than the underlying Maastrichtian chalk (Fig. 2). The airplane photographs were taken obliquely downwards and the Cretaceous–Tertiary boundary strata are commonly invisible on the photographs as they are situated immediately beneath the overhang. It is not possible to map the position of the Fiskeler basins by inspection from the beach because the overhanging nature of the Danian limestone prevents precise localization.

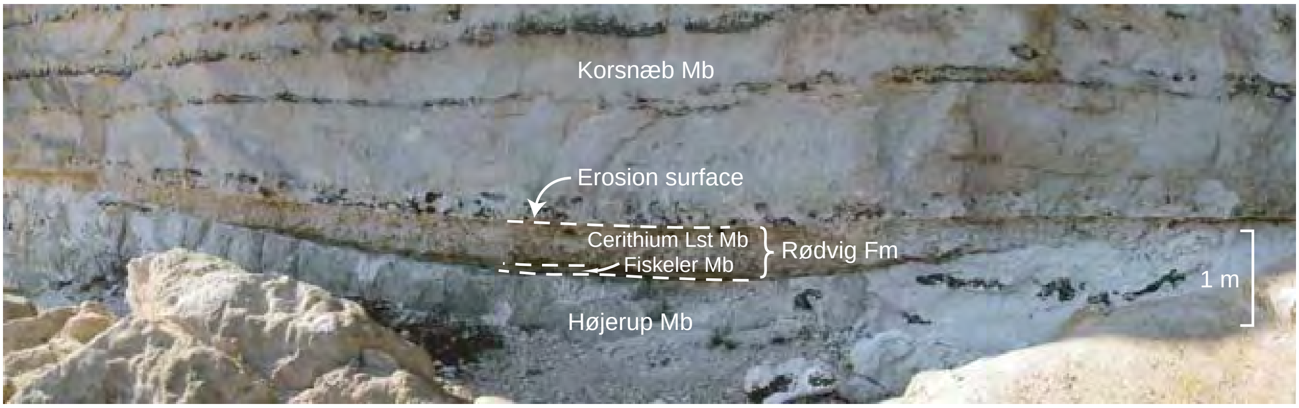


Fig. 9. Fiskeler basin south of the old Højerup church (Fig. 1). Note that the Fiskeler wedges out towards the margin of the basin, where it passes into a bedding plane. The next basin to the north is the type locality of the Fiskeler and Cerithium Limestone Members.

The whole mapped profile was therefore checked from a boat and the positions of Fiskeler basins were marked on the profile aided by binoculars and photographs taken with a telephoto lens.

Results

The results of the photogrammetric interpretation of Stevns Klint are presented in Plates 1–9 (south of Mandehoved), whereas Plates 9–12 (north of Mandehoved) are based on photographs taken from a boat. The accompanying text serves to highlight the main features seen on each plate. The 12 segments of the cliff profile are described consistently from left to right (mainly south-to-north). The terms 'strike' and 'dip' sections are throughout used for sections that are respectively perpendicular and parallel to migration direction of the lower Danian mounds of the Korsnæb Member (Stevns Klint Formation). Strike and dip sections are thus oriented roughly E–W and N–S, respectively. A key to the ornamentation to the plates is shown in Figure 18.

Plate 1

Rødvig – Boesdal, 0–1200 m

In this cliff section the Cretaceous–Tertiary boundary falls gradually from about 4 m above sea level in the south down to sea level in the north. The cliff profile from Rødvig to Korsnæb is oriented E–W and shows a strike section of the bryozoan mounds of the Korsnæb Member. Two very long Fiskeler basins are exposed in the south-westernmost 300 m of the section. A relatively long ridge-shaped mound is exposed from 150–300 m as revealed by the parallel nature of the flint bands. Further to the east the mounds change shape and become symmetrical with several examples of bidirectional downlap of the flint bands. At Korsnæb the orientation of the cliff changes from E–W to N–S, and the profile north of Korsnæb (type locality of the Stevns Klint Formation and Korsnæb Member) exposes an excellent and easily accessible dip section of bryozoan mounds. At Korsnæb (660 m) there is a prominent NNW-inclined erosion surface in the lower part of the cliff, which truncates the underlying S-dipping flank of a mound (see fig. 11 in Surlyk, 1997). It probably cuts through up to 2 m of bryozoan limestone, but its lower termination is covered by scree. It is developed as a nodular N-dipping hardground, which truncates S-dipping beds of the underlying succession marked by flint bands. A similar N-dipping erosion surface is well exposed in the top part of the cliff at the northern end of the Skeldervig bay at 875–900 m. It continues downward behind the triangular scree at 900 m (see fig. 9 in Surlyk 1997). The hardground can be traced towards the west into the southern wall of the Boesdal quarry, indicating a roughly E–W strike of the hardground. The small limestone outcrop forming the southern wall of the coastal entrance to the Boesdal quarry also shows a N-dipping erosional hardground at 1215 m (Plate 2). Its relation to the previous hardground is unknown. The bryozoan limestone of the Korsnæb Member between Rødvig and Boesdal thus consists of three mound groups separated by three N- to NNW-dipping erosion surfaces.

Fig. 10. Fiskeler basin SE of Kulstirenden, showing the unusually thick Rødvig Formation, comprising the Fiskeler and Cerithium Limestone Members.

Plate 2

Boesdal – Peblingebrodden, 1200–2400 m

The Cretaceous–Tertiary boundary is situated some metres below sea level in this section, which only exposes bryozoan mounds of the Korsnæb Member. The cliff is not accessible as there are no or only narrow, isolated beaches. The northern part of the profile from 1850–2400 m shows some of the finest examples of the asymmetrical bryozoan mounds along Stevns Klint (Fig. 14B). The length of the mounds varies between 70–150 m and their original sea-floor relief was 4–11 m as shown by tracing individual flint bands. The exposed mound successions are up to 15 m thick. The mound complex in the northern part of the profile can be studied in the military tunnel system at Stevnsfort, allowing three-dimensional reconstructions of some of the mounds (Bjerager & Surlyk submitted a). A prominent erosion surface truncates the crest and steep flank at 1935 m (Fig. 16), and a hardground is developed on a N-dipping flank at 2330 m.

Plate 3

Lille Heddinge Vig, 2400–3600 m

The Cretaceous–Tertiary boundary rises above sea level at 2950 m and reaches an altitude of about 7 m in the northern end of the profile. A total of about 14 asymmetric bryozoan mounds of the Korsnæb Member are exposed in the upper part of the cliff. North-dipping flank hardgrounds (‘crab layers’) (Fig. 15) occur at 2525 m, 2640 m and 3390 m, and a prominent truncation surface and hardground is seen at 2720 m. A number of small Fiskeler basins are well exposed between 3240–3380 m. Some of the basins are double with Fiskeler and Cerithium Limestone covering two basins and the intervening crest of a low Maastrichtian mound, for example between 3330–3360 m. The incipient hardground at the top of the Sigerslev Member has its southernmost exposure at 3500 m.

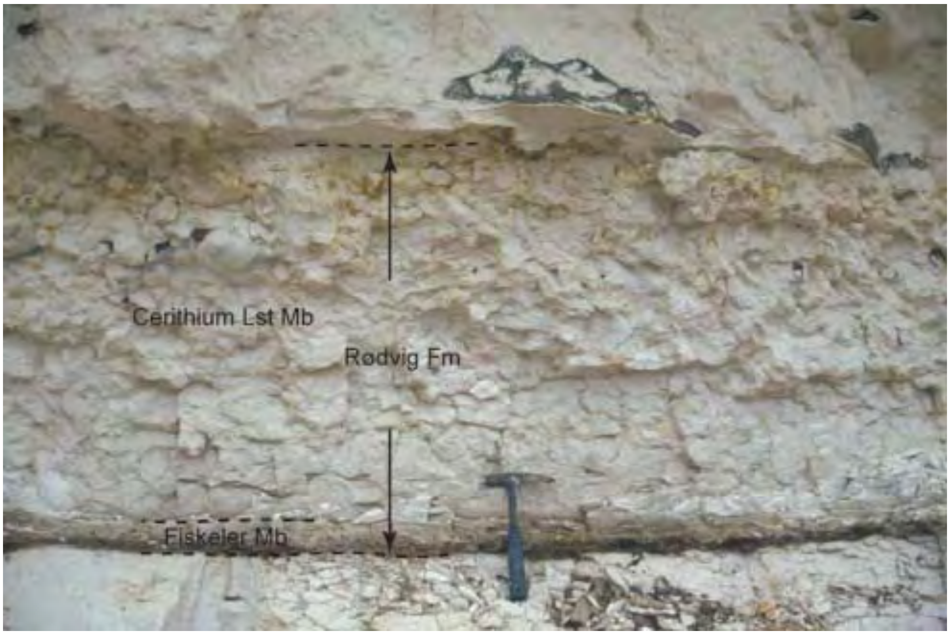


Fig. 11. Type locality of the Rødvig Formation between Rødvig and Korsnæb (Figs 1, 17), showing the Fiskeler and Cerithium Limestone Members. The hammer is 33 cm long.

Plate 4

Harvig – Knøsen, 3600–4800 m

The Cretaceous–Tertiary boundary continues to rise towards the north, culminating with an altitude of 11 m at 4350–4400 m; further north it is slightly wavy and its altitude varies between 6 and 10 m. The nodular flint band immediately below the base of the Højerup Member is a prominent marker in this part of the cliff (Fig. 8). It is overlain by bryozoan wackestone of the Højerup Member, up to 5.4 m thick, showing small asymmetrical mounds. A large number of relatively short Fiskeler basins occur along most of the profile, corresponding to the short wavelength of the chalk mounds of the Højerup Member in this dip section. The very long, slightly asymmetrical Danian bryozoan mounds of the Korsnæb Member are oblique sections. They are less regular than in other parts of the cliff and some are rather flat. Prominent hardgrounds are seen on the northern flanks at 3710–3740 m and 4510–4560 m, and a minor one occurs at 3630 m.

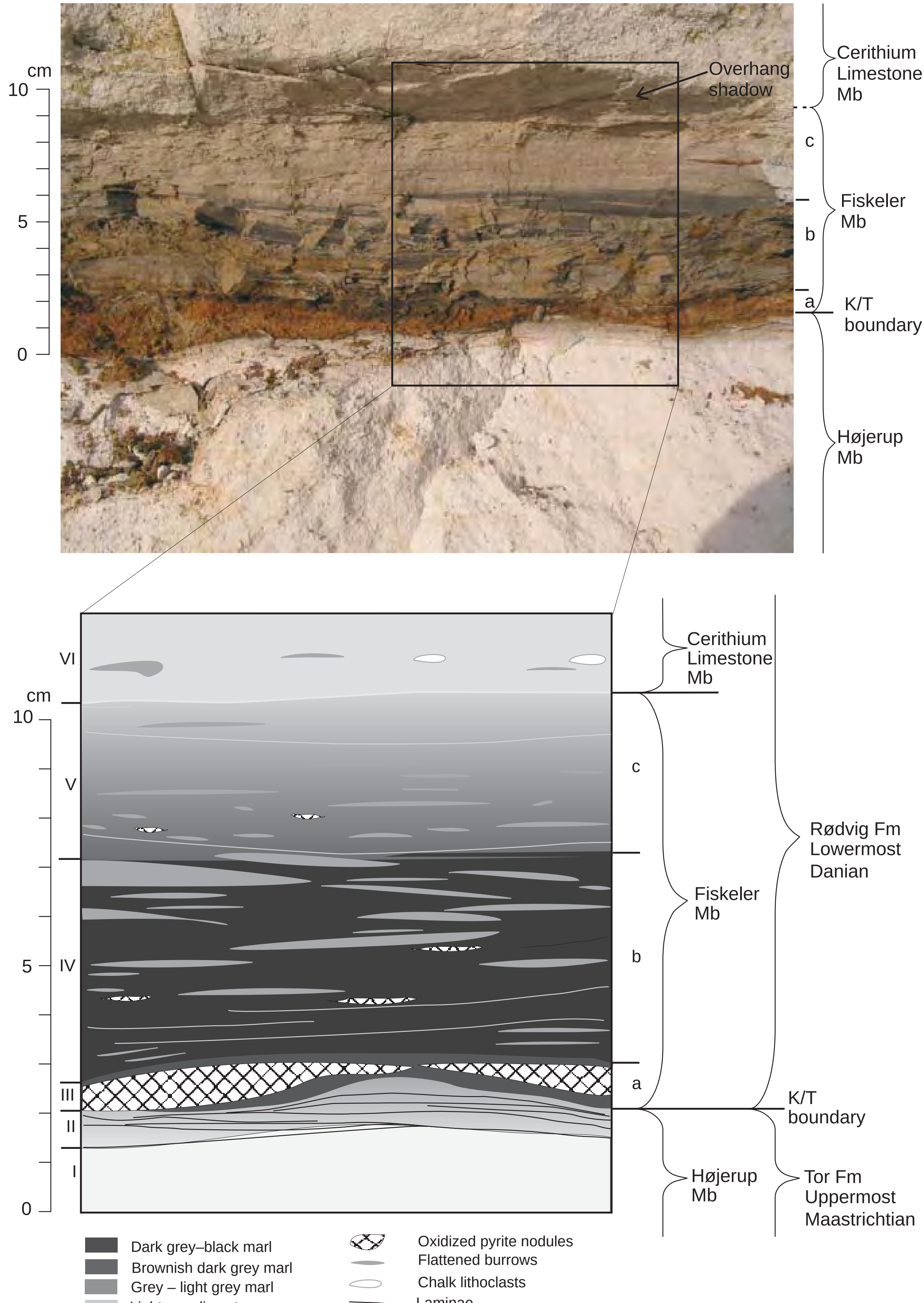
Plate 5

Højerup, 4800–6000 m

This is the best-known and most commonly visited part of the cliff, situated beneath the old Højerup church ('Højerup gamle Kirke') where solid stairs lead down to the beach (Fig. 2). This is also the place where most sampling for geochemistry and micropalaeontology has been undertaken and the site (at 4905–4925 m) of the original iridium anomaly samples of Alvarez *et al.* (1980). The top Cerithium Limestone hardground is subhorizontal and its altitude varies between 7 and 15 m with two gentle culminations north of the flagpole at 5170 m and at 6210 m in Plate 6.

The lowest 4–10 m of the section consist of benthos-poor, horizontal to gently wavy bedded chalk of the Sigerslev Member with scattered flint nodules. It is topped by the two closely spaced incipient hardgrounds underlain by the nodular marker flint bed. Then follows the asymmetrical bryozoan chalk mounds of the Højerup Member, which is up to 5 m thick in this part of the cliff. The section beneath the flagpole is the best exposure of the member along Stevns Klint and is also the type section (see photograph on the front cover). A particularly fine view of the asymmetry and great regularity of the mounds can be obtained from the beach by looking south along the cliff from the scree at 5300 m. Eleven Fiskeler basins are well exposed between the stairs at the church and the scree; they are commonly attached to the overhangs formed by the hard

Facing page:
Fig. 12. Detailed section of the Cretaceous–Tertiary boundary strata at Stevns Klint, showing our subdivision of the Fiskeler Member (a–c) compared to the numbering (I–IV) of Christensen *et al.* (1973) which includes the uppermost Maastrichtian.


cm
10
5
0
Overhang shadow
Cerithium Limestone Mb
c
b
a
Fiskeler Mb
K/T boundary
Højerup Mb
VI
V
IV
III
II
I
Rødvig Fm Lowermost Danian
Tor Fm Uppermost Maastrichtian
Dark grey–black marl
Brownish dark grey marl
Grey – light grey marl
Light grey limestone
White chalk
Oxidized pyrite nodules
Flattened burrows
Chalk lithoclasts
Laminae

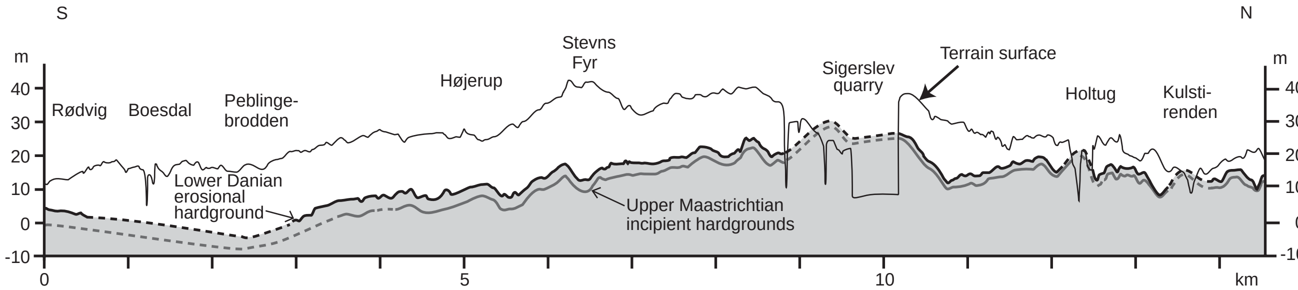


Fig. 13. Elevation of the lower Danien erosional hardground (E in Fig. 7) and the upper Maastrichtian incipient hardgrounds (HG in Fig. 7) at Stevns Klint cliff based on the photogrammetrical profile (Plates 1–12). Vertical exaggeration ×40.

Danian bryozoan limestone of the Korsnæb Member. The Cerithium Limestone is intensely burrowed and nodular hardened, and unusually thick horizontal *Thalassinoides* burrows penetrating down from the top Cerithium Limestone hardground are seen attached to the flat, overhanging base of the Danian bryozoan limestone of the Korsnæb Member. The bryozoan limestone mounds are well exposed but their geometry is not easy to see from the beach because the cliff wall is extremely irregular due to extensive quarrying. A prominent N-dipping erosional hardground occurs below the church and a hardground drapes the northern flank of a mound at 5510–5540 m, and at 5960 m.

Plate 6

Stevns Fyr (lighthouse), 6000–7200 m

The Cretaceous–Tertiary boundary is situated 12–19 m above sea level and the boundary strata and the overlying bryozoan limestone of the Korsnæb Member are not easily accessible. Up to 14.5 m of the benthos-poor, horizontally to gently wavy bedded chalk of the upper Sigerslev Member is exposed in the lower part of the cliff. It is topped by the two incipient hardgrounds underlain by the nodular flint marker bed. The overlying uppermost Maastrichtian mounded bryozoan chalk of the Højerup Member is 2.2–3.9 m thick. Numerous, fairly short Fiskeler basins occur along the profile. The cliff north of the lighthouse shows a fine succession of regular, asymmetrical lower Danian bryozoan limestone mounds of the Korsnæb Member with an average length of 70–90 m in dip section. The northern mound flanks are draped by hardgrounds at 6600–6620 m, 6660 m and 6340 m.

Plate 7

Barmhjertigheden, 7200–8400 m

The altitude of the Cretaceous–Tertiary boundary rises gently towards the north and reaches 25 m at the northern end of the profile. The base of the cliff exposes up to 22 m of the benthos-poor, gently wavy bedded chalk of the upper Sigerslev Member, overlain by 0.4–0.6 m of mounded bryozoan chalk of the Højerup Member. The flint marker bed and the overlying incipient hardgrounds, which separate the two members, are well exposed. The Cretaceous–Tertiary boundary beds and the overlying bryozoan limestones of the Korsnæb Member are situated too high in the cliff to allow detailed study. The mounds are, however, low, irregular and rather flat. This phenomenon is seen along several parts of the cliff where the Cretaceous–Tertiary boundary is situated relatively high above sea level. The orientation of the profile has changed to NNW–SSE compared to the NNE–SSW orientation of the profiles on Plates 5 and 6.

Plate 8

Storedal – Lilledal, 8400–9600 m

The Cretaceous–Tertiary boundary climbs above the top of the cliff north of Storedal and the northern part of the cliff only exposes Maastrichtian chalk. The original position of the boundary can be roughly estimated by interpolation to have reached an altitude of at least 30 m. The lower 17 m of the chalk succession shows pronounced mounded bedding and belongs to the Sigerslev Member. The mounds are 75–100 m long and up to about 5 m high and represent the internal architecture of a larger mound, at least 400 m long and about 10 m high at 9150–9600 m. This unit passes gradually upwards into about 15 m of the benthos-poor, gently wavy to horizontally

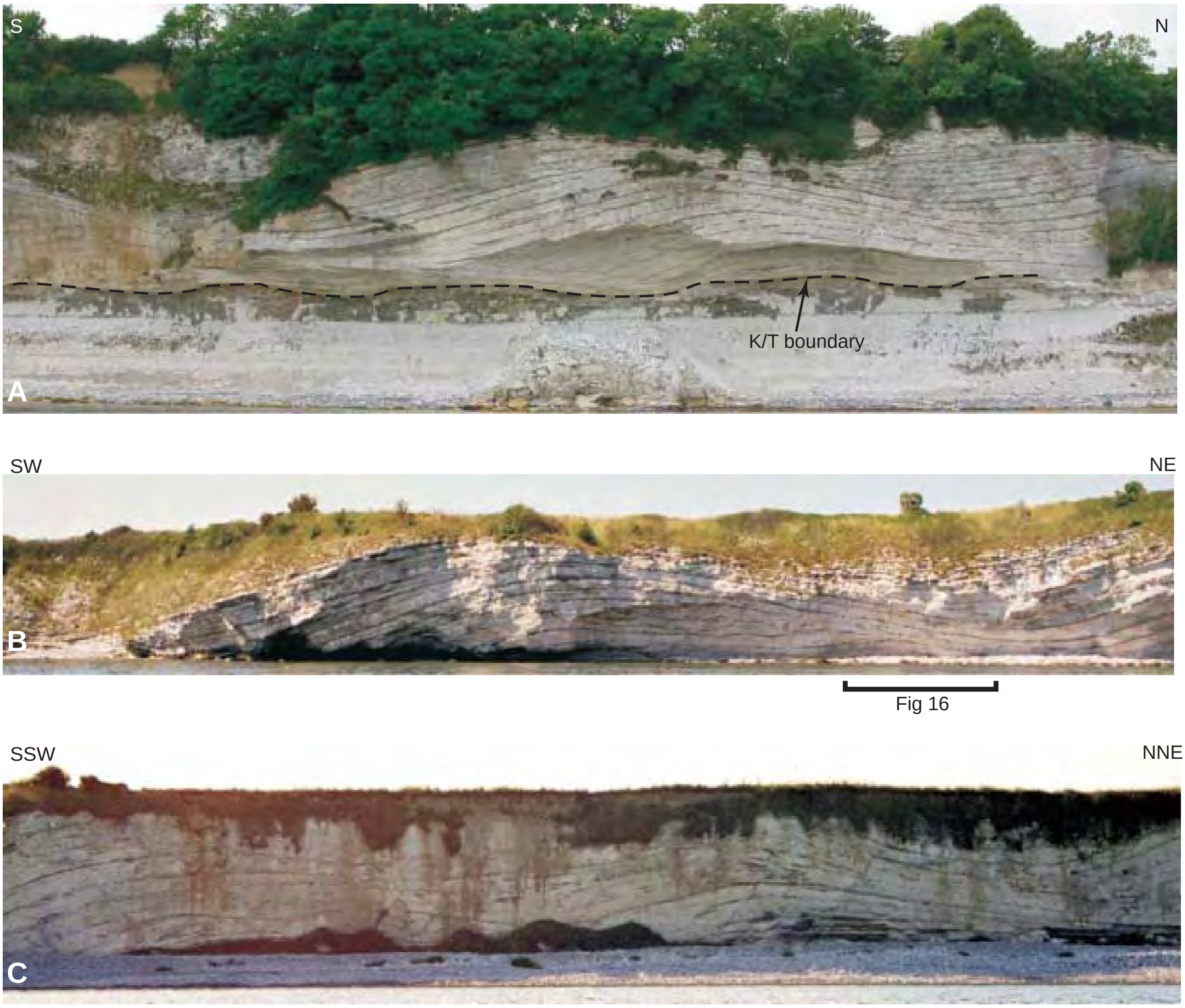


Fig. 14. Well-exposed Danian bryozoan mounds with steep southern flanks and gently dipping northern flanks. A) Mound north of Stevns Fyr about 80 m long and 9 m high (Fig. 1; Plate 6, 6500 m). B) Mound about 100 m long and 11 m high south of Peblingebrodden, slightly oblique section (Fig. 1; Plate 2, 1900 m). C) Type locality of the Korsnæb Member in the Skeldervig bay between Korsnæb and Boesdal. The northern mound is about 60 m long and 6 m high (Fig. 1; Plate 1, 750 m).

bedded chalk characterizing the upper part of the member, which is topped by the marker flint bed and the two incipient hardgrounds. It is overlain by the mounded bryozoan chalk of the Højerup Member which thins northwards from 3.6 m to 1.7 m immediately to the south of Storedal. The Cretaceous–Tertiary boundary strata, which are inaccessible, are overlain by up to 13 m of mounded bryozoan limestone of the Korsnæb Member south of Storedal, with an erosional hardground at 8775 m.

Plate 9

Sigerslev – Mandehoved, 9600–11250 m

The southernmost part of this profile is intersected by the large, working Sigerslev quarry, which is connected to a pier used to load chalk onto large vessels. A path known as Eskesti in the literature (e.g. Heinberg 1976, 1979) has recently been quarried away. The cliff profile starts again at 10175 m. From 10950 m and further north (Plates 10–12) the mapping is not based on stereo-photogrammetry but on photographs taken from a boat. The Cretaceous–Ter-

Fig. 15. Shingled hardgrounds ("Krabbelag") on gently dipping northern mound flanks at Lille Heddinge Vig (Fig. 1; Plate 3, 2525 m). The cliff is 17 m high.

tiary boundary falls to the north from its previous high position between Lilledal and the quarry to an altitude of 26 m, immediately north of the quarry and further down to 13.5 m at Mandehoved at 10940 m. The mound-bedded chalk of the lower Sigerslev Member is exposed in the lowest 5 m of the cliff but is at present covered by scree. E–W oriented walls in the quarry show well developed mounded bedding, whereas bedding in N–S walls shows gentler, longer wavelength mounded and subhorizontal bedding, suggesting that the mound-like bedding seen in the cliff profile represents a ridge and valley sea-floor relief. The higher parts of the member are horizontally to gently wavy bedded and are well exposed in the cliff north of the quarry. The mounded bryozoan chalk of the Højerup Member is only 1.1 m thick due north of the quarry but increases gradually in thickness further north to 2.5 m at 10450 m; it decreases to 1.5 m south of Mandehoved and increases further north to 3.3 m. Only a few Fiskeler basins occur from the quarry and northward to about 10630 m, whereas they become more densely spaced further north towards Mandehoved. The mounded succession of the Korsnæb Member is up to 17 m thick in this part of the cliff. The mounds are rather small but regular and asymmetrical north of the quarry to about 10460 m and a minor one occurs at 10490 m. A prominent northern flank hardground occurs at 10420–10450 m. Further north the mounds are poorly developed and the bedding is unusually flat at 10460–10700 m and at 10980–11250 m. The cliff profile changes to an ESE–WSW orientation at 10915 m and shows strike sections through the Danian mounds. The upper part of the Korsnæb Member between 10700–10900 m shows thick beds in the lower part which can easily be followed across several mounds, and much thinner less distinct beds in the upper part. The mounds are about 45 m long and up to 4 m high.

Fig. 16. Erosion surface (E) truncating the crest and upper part of the southern flanks of the mound to the left (Fig. 14B; Plate 2, 1935 m).

Plate 10

Holtug quarry, 11250–12450 m

There is a marked change in orientation of the profile from WNW–ESE to almost due N–S at 11520 m. The Maastrichtian part of the section is generally poorly exposed except for a stretch between 11700–11800 m where gently wavy to subhorizontally bedded chalk of the Sigerslev Member forms the lower part of the cliff overlain by the relatively thinly developed bryozoan chalk of the Højerup Member. Eight closely spaced Fiskeler basins are seen between 11400 and 11580 m, whereas they occur more scattered further north. The Cretaceous–Tertiary boundary is situated about 17–19 m above sea level in this part of the cliff and only a few metres of the lower Danian bryozoan limestone of the Korsnæb Member are exposed, showing low relief mound bedding.

Plate 11

Holtug – Kulstirenden, 12450–13650 m

The level of the Cretaceous–Tertiary boundary is rather wavy in this part of the cliff and decreases to about 10 m above sea level at 13300 m. It rises again towards the north and ascends above the cliff at 13450 m. The upper Maastrichtian Sigerslev Member comprising chalk with little flint is well exposed along much of the cliff and is overlain by a few metres of the bryozoan-rich chalk of the Højerup Member which decreases gradually in thickness towards the north. The marker flint bed at the junction between the two members can be followed to 13380 m. An apparent Fiskeler basin immediately north of the Holtug quarry at 12530 m is actually an erosional scour in the top Maastrichtian filled with lower Danian bryozoan limestone of the Korsnæb Member (see fig. 3 in Rasmussen 1971). Fiskeler basins are common northwards to 12800 m, but are rare to absent further north. An unusually long (ca. 200 m) and about 1.5 m deep Fiskeler basin with thickly developed Fiskeler (up to 30 cm) and Cerithium Limestone Members occurs between 13150–13300 m (Fig. 10). The thick Fiskeler is described by Hart *et al.* (2004, 2005) who indicated a thickness of 45 cm. Micropalaeontological data show that the lower parts of the Cerithium Limestone are missing in this part of the cliff (Heinberg 2005; Rasmussen *et al.* 2005). The western wall in the abandoned Holtug quarry shows a northwards change in depositional architecture of the lower Danian Korsnæb Member from mound-bedding to horizontal bedding accompanied by a change from bryozoan limestone to much finer grained chalky limestone. Well developed bryozoan mounds are again seen north of the quarry from about 12500 to 12700 m, but further north the mounds are rather low and in some places the bedding is gently wavy to subhorizontal. The quarry is now a preservation site due to the presence of carbonate-loving steppe-type flora.

Plate 12

Kulstirenden – south of Præsteskov, 13650–14550 m

This is the northernmost part of Stevns Klint. Only Maastrichtian chalk is exposed in the sides of the creek Kulstirenden and the Cretaceous–Tertiary boundary is either covered by scree and vegetation or situated above the cliff top. It descends, however, towards the north and is again exposed in the cliff from 13900 m and to the northern end of the cliff. The lowest part of the section consists of upper Maastrichtian chalk of the Sigerslev Member, showing gentle mound-like bedding. The overlying subhorizontally bedded upper part of the member is only about 10 m thick and the bryozoan-rich Højerup Member has almost wedged out. There are thus several lines of evidence for condensation or even winnowing and erosion in the northernmost part of Stevns Klint compared to the rest of the cliff section. The top Cerithium Limestone hardground is unusually wavy on both sides of 14450 m. The hardground north of Kulstirenden at 14435 m shows a beautiful example of synsedimentary thrusting interpreted as caused by expansion due to sea-floor cementation (Surlyk 1969, 1979, 1980; Bromley & Ekdale 1987). The thrust is covered by scree at the time of writing.

Late Cretaceous – Danian palaeoenvironments

Seismic data from offshore Stevns Klint show that powerful long-lived current systems sculpted the sea floor into large-scale WNW–ESE trending valleys and ridges throughout the Late Cretaceous (Lykke-Andersen & Surlyk 2004). The currents flowed parallel to the inverted Sorgenfrei–Tornquist Zone and to the axis of the Danish Basin and appear to have been amplified in the gateway where the seaway narrowed and shallowed in the area between the Sorgenfrei–Tornquist Zone and the eastern end of the Ringkøbing–Fyn High (Fig. 1). The current system persisted into the Danian where the waters were shallower and the constriction of the seaway in the study area even more pronounced than in the Late Cretaceous. A revised model for the formation of the lower Danian bryozoan mounds which acknowledge the sedimentological observations without contradicting the biological data is presented by Bjerager & Surlyk submitted a,b). It is suggested that the mounds represent a combined biological and physical response to a long-living, roughly WNW–ESE flowing current system. Reflection seismic data from the Kattegat sea indicate that the currents flowed towards the WNW at least during the Maastrichtian (cf. Fig. 1; Surlyk & Lykke-Andersen in press). The main sea-floor valley in the Stevns Klint area had its axis beneath the southern end of the cliff at Peblingebrodden and the SSW-dipping northern flank of the valley extended from this area to the Sigerslev quarry over a distance of 7.5 km. The WNW-flowing current would be deflected towards the right by the Coriolis force and would supply nutrition for bryozoan mound growth towards the SSW. The bryozoan thickets in addition acted as traps for mud-sized carbonate particles and in this way the mounds grew towards the current i.e. towards the SSW and obtained their characteristic asymmetry. The current velocity probably oscillated on a seasonal and longer term basis, following climatic fluctuations and the mound topography exerted a strong influence on local deviation of currents paths. Periodical, possibly wind-generated strong currents from the east caused winnowing, hardground formation and erosion of the NNE-dipping mound flanks increasing the pronounced asymmetry (Bjerager & Surlyk submitted a).

The most well developed mounds are located over the wide palaeo-sea-floor valley around Peblingebrodden and northwards up the southern slope of the ridge around Stevns Fyr, whereas they give way to almost horizontally bedded limestone and smaller mounds to the north over the ridge. The succession in addition shows condensation farther north where the Højerup Member has almost wedged out and the lower part of the Cerithium Limestone Member is missing (Heinberg 2005; Rasmussen *et al.* 2005). This indicates that the main mound formation took place downslope away from the ridge, which received reduced sedimentation.

The Late Cretaceous – Danian epeiric sea of the Danish area was thus a highly dynamic depositional system governed by powerful bottom currents. The sea floor was sculpted into a wide range of mounded topographic features. The bryozoan mounds described here from the lower Danian of Stevns Klint illustrate the complex interplay of biogenic growth, fluctuating current velocities and directions superimposed on a large-scale sea-floor relief which persisted through much of the Late Cretaceous and Danien and formed by a probably thermohaline bottom current system.

Conclusions

The 14.5 km long Stevns Klint sea cliff is a classical locality for the study of the succession across the Cretaceous–Tertiary boundary. In addition it shows excellent exposures of one of the finest examples in the world of a laterally extensive relatively cool water, sub-photic carbonate mound complex. We have constructed a profile of the complete coastal cliff of Stevns Klint based on multi-model photogrammetry supplemented by mapping and photography from boat. This is the first profile of the cliff since the classic pen-drawing by Puggaard (1853). Our mapping and field studies form the basis for the definition of a new lithostratigraphic scheme to cover the succession exposed in the cliff. The lowermost part of the succession belongs to the upper part of the new Sigerslev Member which is characterized by benthos-rich mound-bedded chalk (lower part) over gently wavy-bedded to horizontally bedded benthos-poor chalk in the upper part. The member is overlain by bryozoan-rich chalk deposited in asymmetrical mounds of the new uppermost Maastrichtian Højerup Member. The top of this member coincides with the Cretaceous–Tertiary boundary marked by the base of the overlying lowermost Danian Fiskeler Member which is here defined as a new formal member. The Fiskeler passes gradually upwards into the Cerithium Limestone Member which is also defined as a new formal member. The two members are grouped into the new Rødvig Formation which was deposited in shallow basins between the crests of the underlying mounds of the Højerup Member. The Cerithium Limestone and the mound crests of the intervening Højerup Member are truncated by an erosional hardground, which forms the basis for the overlying impressive bryozoan limestone mounds of the new lower Danian Korsnæb Member. The relief of the erosion surface has an amplitude of about 40 m along the length of the cliff with several culminations and depressions, representing the original sea-floor topography. The stratigraphic development is rather uniform along the cliff but two of the lithostratigraphical units, the uppermost Maastrichtian Højerup Member and the lowermost Danian Cerithium Limestone Member show thinning, condensation or even erosion in the northern part of the cliff.

Fig. 17a–f. Vertically exaggerated (×4) profile of Stevns Klint based on the photogrammetric profiles shown in Plates 1–12

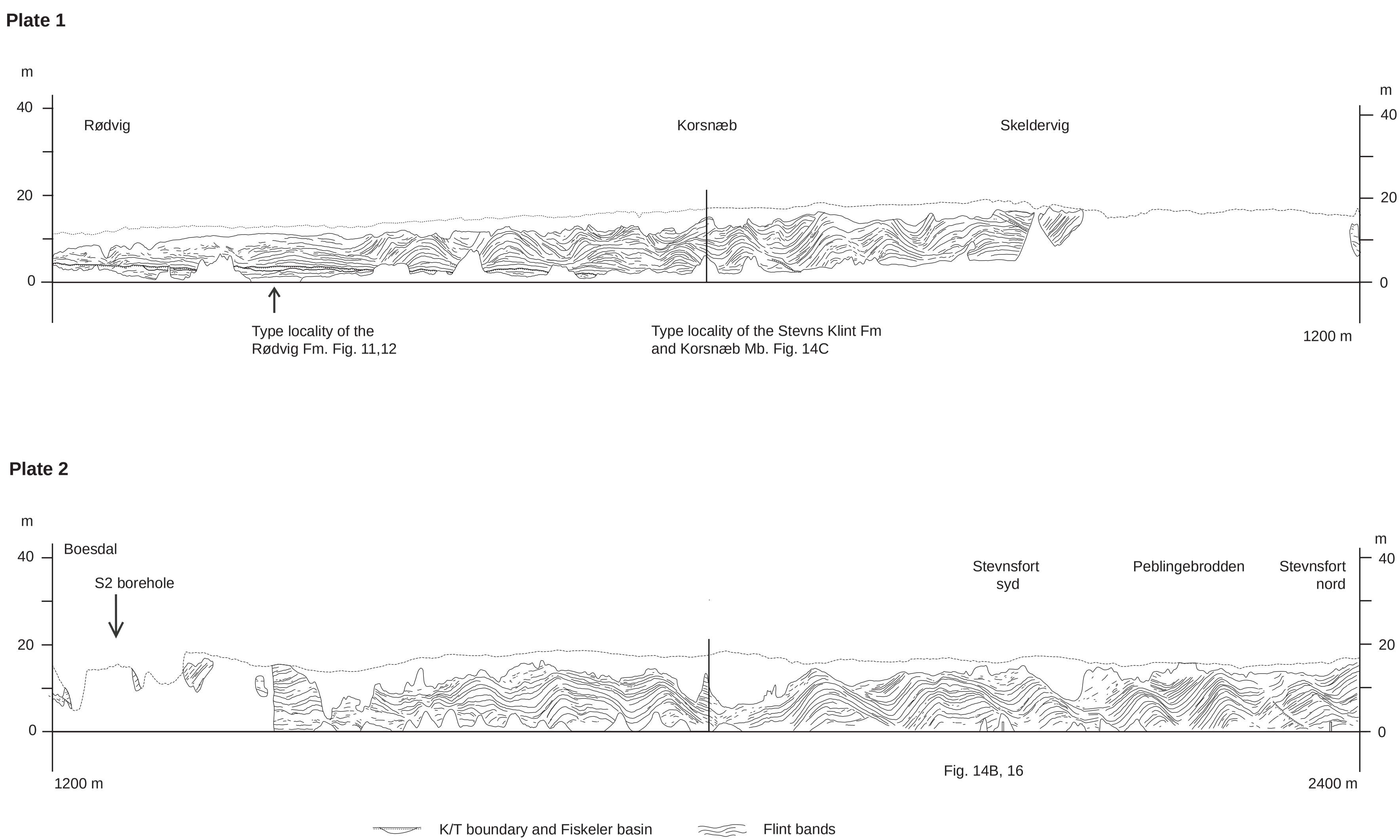


Fig. 17a. Plates 1–2: Rødvig (0 m) – Peblingebrodden (2400 m)

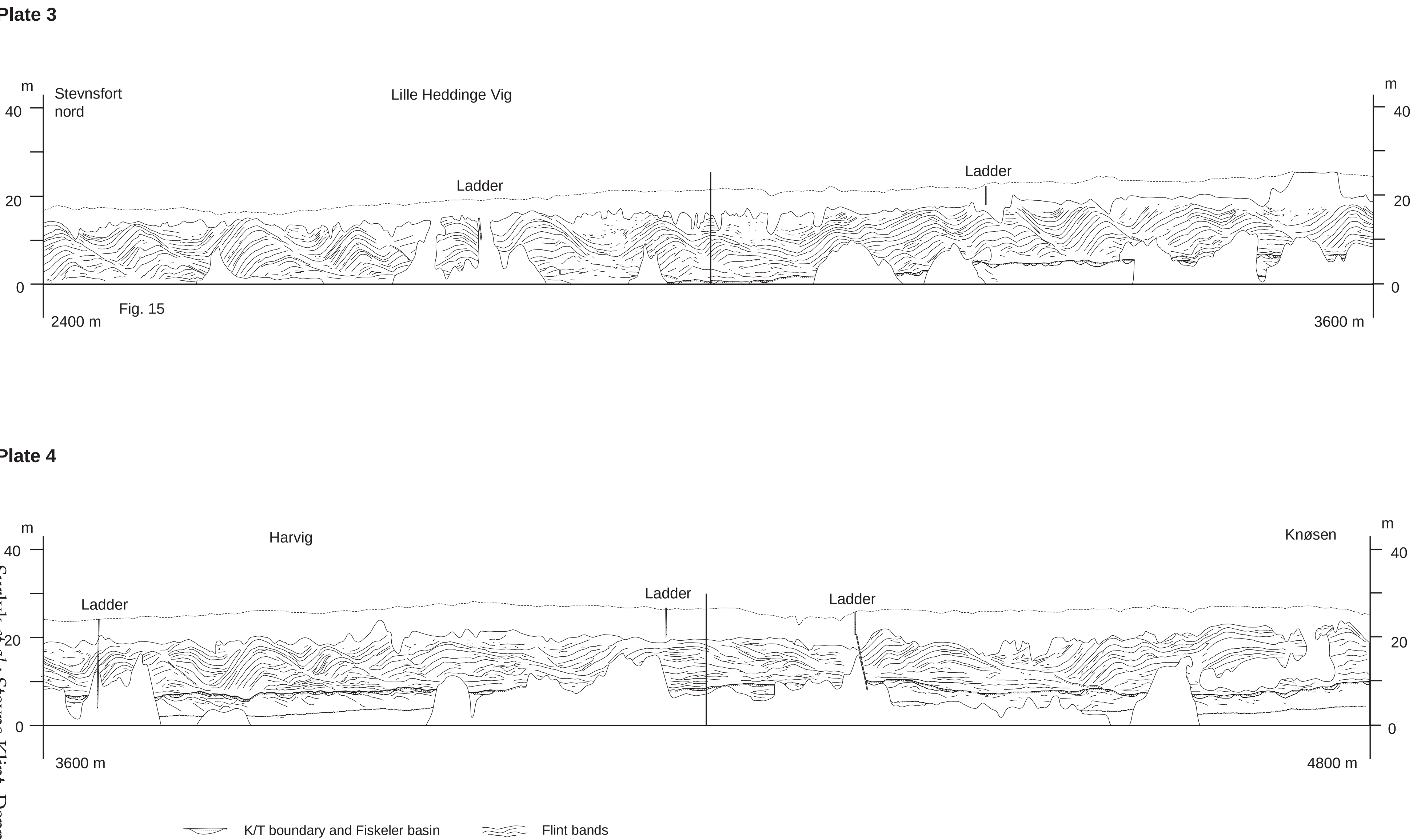


Fig. 17b. Plates 3–4: Lille Heddinge Vig (2400 m) – Knøsen (4800 m)

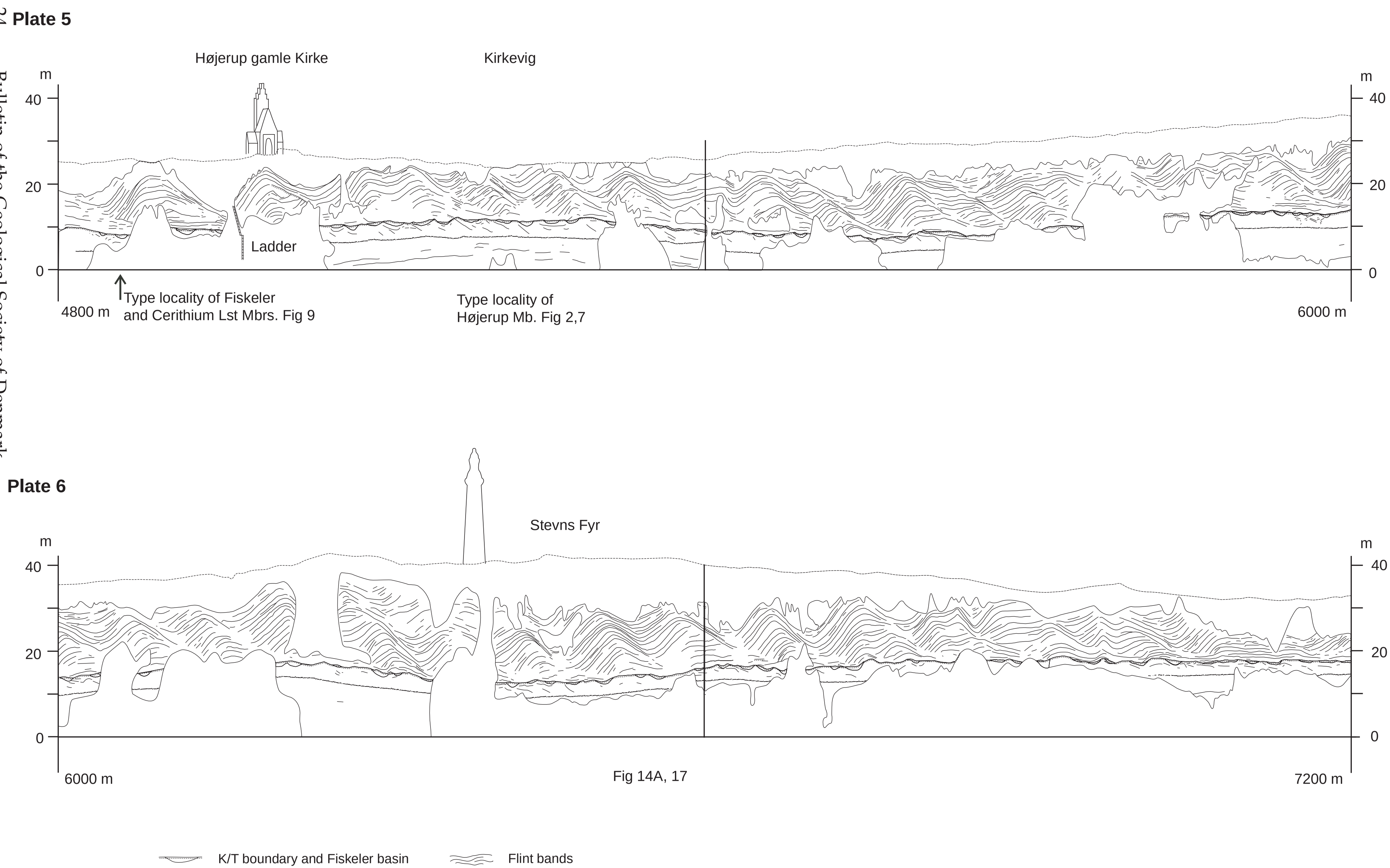


Fig. 17c. Plates 5–6: Højerup (4800 m) – Stevns Fyr (lighthouse) (7200 m)

Plate 7

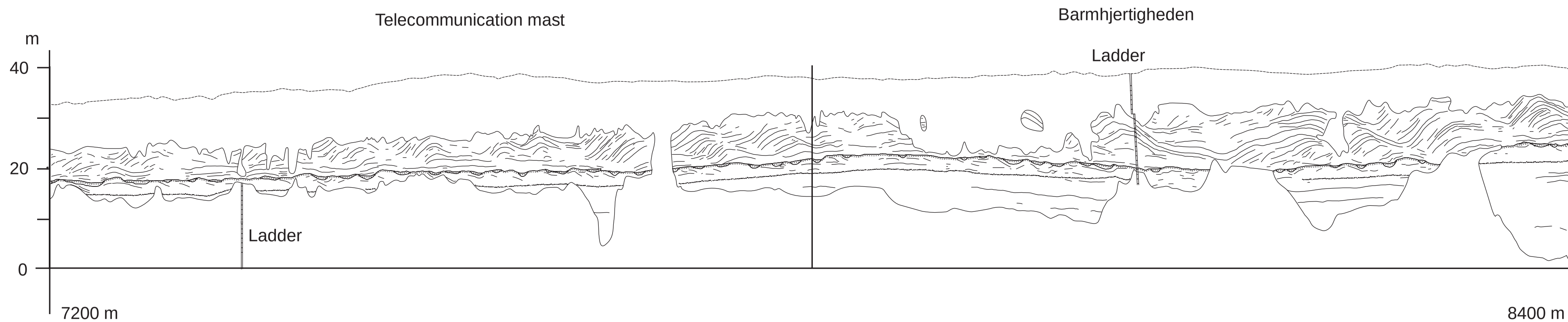


Plate 8

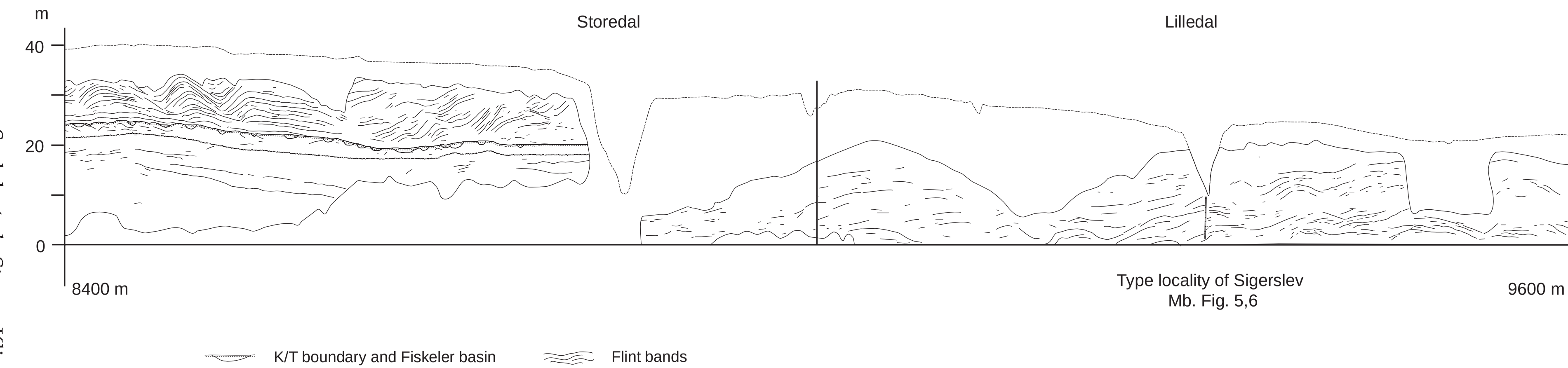


Fig. 17d. Plates 7–8: Barmhjertigheden (7200 m) – Lilledal (9600 m)

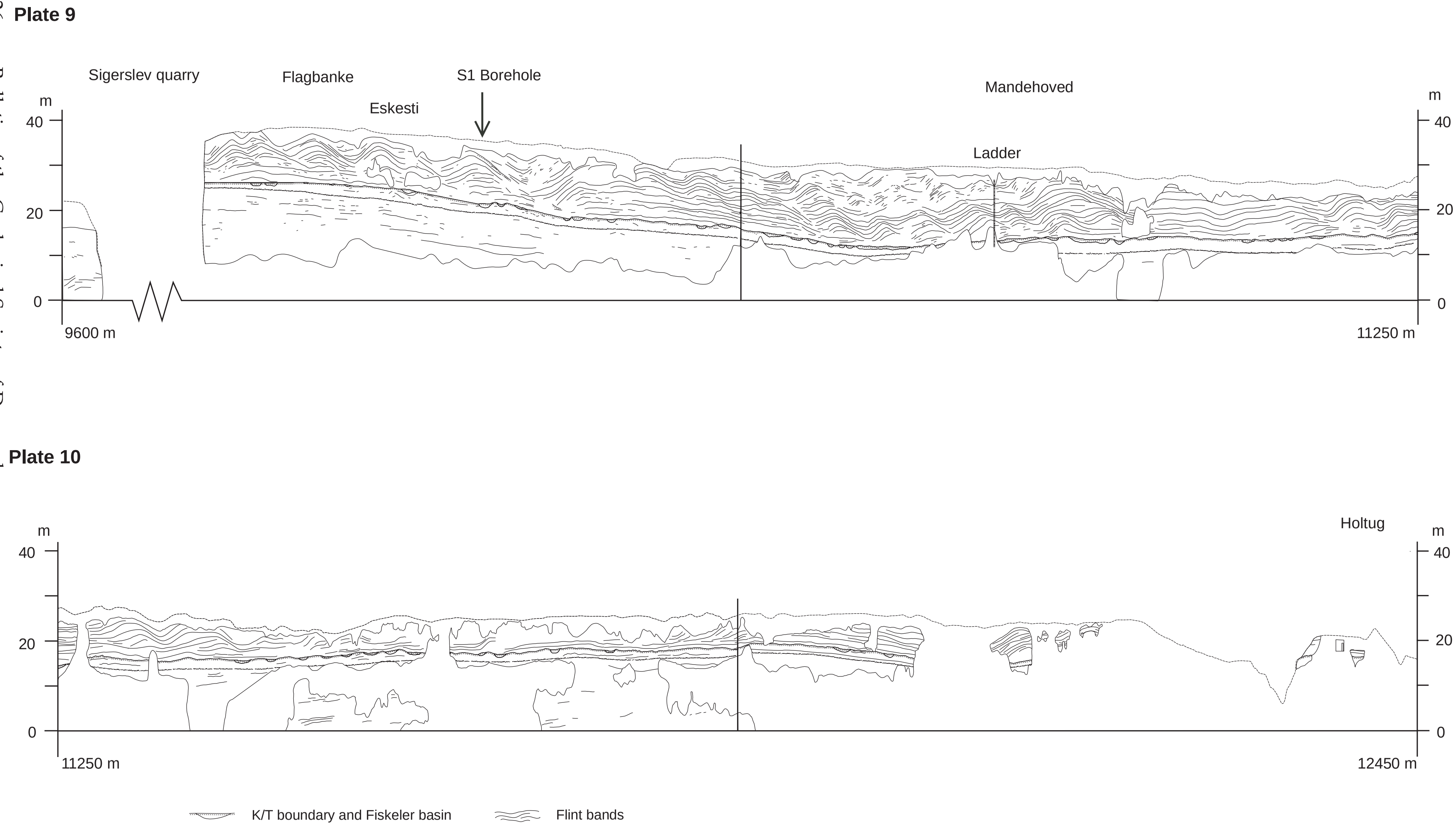


Fig. 17e. Plates 9–10: Sigerslev (9600 m) – Holtug (12450 m)

Plate 11

Plate 12

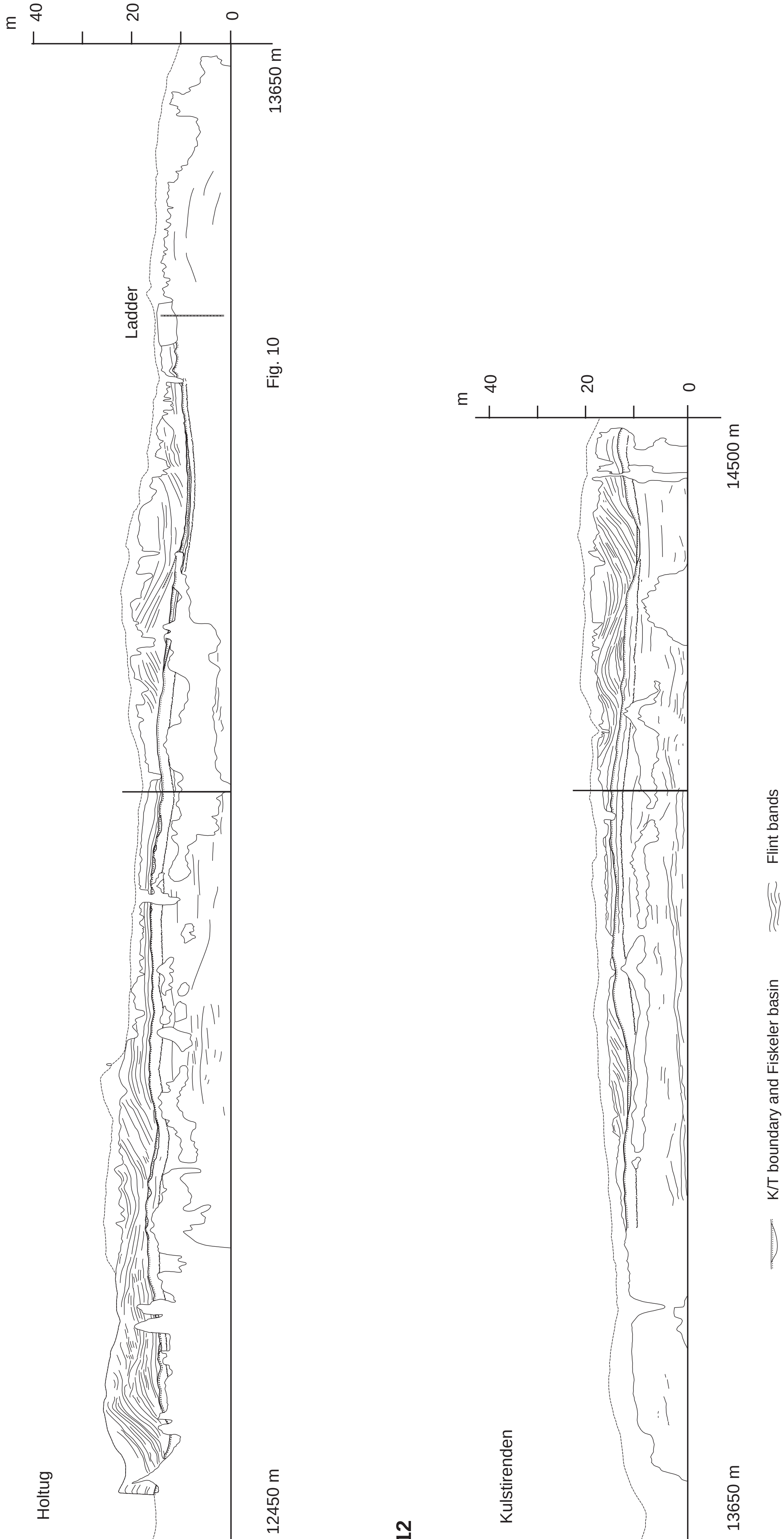


Fig. 17f. Plates 11–12: Holtug (12450 m) – south of Præsteskov (14550 m)

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Appendix

Maastrichtian – Danian lithostratigraphy of eastern Denmark

The Upper Cretaceous chalk of onshore Denmark is rather monotonous and has not been lithostratigraphically subdivided. In much of the North Sea the Maastrichtian chalk has been placed in the Tor Formation, and the Danian chalk in the Ekofisk Formation (Deegan & Scull, 1977; see review in Surlyk *et al.* 2003). The new lithostratigraphic units defined below are based on outcrops as only very few cored borings have been made in eastern Denmark. The main exposures Møns Klint and Stevns Klint are, however, extensive and give an excellent picture of the main units. The carbonates in this area were deposited over the eastern end of the Ringkøbing–Fyn High and are generally much more fossiliferous and of more shallow water nature than the deeper water chalks of the North Sea and Danish Basins. This is particularly the case with the Danian succession. Two fully cored boreholes, S1 and S2 were drilled in 2005 to depths of 456.1 m and 350 m, respectively (Stemmerik *et al.* in press). S1 was drilled immediately north of the Sigerslev quarry and S2 in the Boesdal quarry, corresponding to positions close to the main palaeo-sea-floor ridge and valley, respectively as seen on offshore seismic data (Lykke-Andersen & Surlyk 2004). The well logs, sedimentology and stratigraphic palaeontology of the two cores will give useful information on the Maastrichtian succession below the cliff exposure. According to the International Stratigraphic Guide it is considered proper to translate the lithological term which is part of some lithostratigraphic names whereas the geographic component should not be translated (Salvador 1994). Traditional and well-established names should not be abandoned merely because they lack geographic names. Following these recommendations we have retained the well-established names Fiskeler and Cerithium Kalk as new formal member names. They have always been used to describe lithostratigraphic units and should be written Fiskeler Member (not Fish Clay Member) and Cerithium Limestone Member in English and Fiskeler Led and Cerithium Kalk Led in Danish.

Chalk Group

The group was erected by Deegan & Scull (1977) to cover the chalk-dominated Upper Cretaceous succession in the North Sea (see e.g. Isaksen & Tonstad 1989; Surlyk *et al.*, 2003). The name of the unit is poorly chosen. It does not include a place name, and if translated to languages of other NW-European countries with Upper Cretaceous chalk-like deposits the name would change to (Schreib)Kreide Gruppe (German), (Skrive)Kridt Gruppe (Danish), Groupe de la Craie Blanche (French) etc. This is quite confusing. A more appropriate name would for example be Dover Group, conforming to lithostratigraphic convention and referring the famous White Cliffs of Dover at the south coast of England.

Tor Formation

This formation was erected to cover the uppermost formation of the Chalk Group in the North Sea (Deegan & Scull, 1977; Surlyk *et al.*, 2003). It is of Maastrichtian age but may locally reach down into the upper Campanian. It consists typically of homogeneous, white or pale grey chalk and is generally less than 150 m thick but reaches more than 250 m in the Central Graben. In spite of its apparently uniform nature it comprises a wide spectrum of facies. The lower part consists of bioturbated pelagic chalk which passes upwards into laminated–bioturbated cycles (e.g. Scholle *et al.* 1998; Damholt & Surlyk 2004). Resedimented chalk is common in the uppermost part, especially in the Norwegian sector. The upper Maastrichtian chalk exposed in the costal cliff Stevns Klint falls well within this rather wide range of facies characterizing the formation in the North Sea and is accordingly included in the Tor Formation.

Sigerslev Member

New member

Name. – From the village Sigerslev situated a short distance inland from the northern part of the coastal cliff of Stevns Klint; the village has previously given its name to the large quarry where the member is well exposed (Fig. 5), but the quarry name changes occasionally with changing ownership.

Type locality. – Coastal cliff, immediately south of the Sigerslev quarry at the former location of the creek Eskesti (now almost quarried away), Stevns Klint (Plates 8–9, Figs 5, 6).

Thickness. – The member is the lowest unit exposed in the Stevns Klint section and a minimum thickness of about 30 m is exposed at the type locality and in the adjacent Sigerslev quarry (Surlyk, 1980). Data from the new boreholes S1 and S2 suggest that the member exceeds 70 m in thickness.

Lithology. – White chalk matrix with a moderate content of minute benthic fossils, mainly bryozoans. The lower part comprises mound-bedded bryozoan-rich chalk with bedding outlined by undulating layers of flint nodules (Anderskouv *et al.* submitted). This passes upwards into gently wavy to horizontally bedded benthos-poor chalk with *Zoophycos*. Some of the mounds show a slight overlap. The term "mound" is used here in a purely geometrically descriptive sense and does not have any biological implications. Offshore seismic profiles taken a few kilometres east of the cliff show the presence of similar mound-like features in the upper part of the Maastrichtian succession, seismic unit 6 of Lykke-Andersen & Surlyk (2004).

Boundaries. – The lower boundary is not exposed but preliminary data from two new boreholes, S1 and S2 indicate that the bryozoan-rich chalk characteristic of the thick lower part of the member passes into a cyclic chalk–marl succession at depths of more than 70 m. The upper boundary is placed at the upper incipient nodular hardground above a prominent flint layer, 2–5 m below the Maastrichtian–Danian boundary along the southern and central part of the cliff, and 0–2.5 m in the northern part.

Distribution. – The member is mainly known from the northern part of Stevns Klint.

Chronostratigraphy. – The exposed part belongs to the upper upper Maastrichtian and possibly reaching down in the top lower upper Maastrichtian; *Belemnella kazimiroviensis* belemnite Zone, possibly reaching down into the *Belemnitella junior* belemnite Zone (Christensen 1979, 1997); *stevensis–chitoniformis* brachiopod Zone, possibly reaching down into the *humboldtii–stevensis* brachiopod Zone (Surlyk, 1984); *Nephrolithus frequens* coccolith Zone and *Abathomphalus mayaroensis* foraminifer Zone.

Højerup Member

New member

History. – The member is in the literature commonly referred to as 'Gråkridt' (meaning Grey Chalk) owing to the light grey colour compared to the white colour of the underlying chalk of the Sigerslev Member (Rosenkrantz, 1937).

Name. – After the village Højerup, southern Stevns Klint where the member is extremely well exposed. The partly downfallen old church of the Højerup village is situated above the type locality.

Type locality. – Stevns Klint, immediately north of the old Højerup church ('Højerup gamle Kirke') (Plate 5).

Reference localities. - (Plates 3, 4, 6–8).

Thickness. – The member is mainly 2.5–6 m thick beneath mound crests but thins gradually towards the north and has almost disappeared at Kulstirenden.

Lithology. – Bryozoan wackestone deposited in small asymmetrical, bryozoan-rich biogenic mounds (Surlyk 1997; Larsen & Håkansson 2000). Layers of flint nodules associated with *Thalassinoides* burrow horizons characterize the gently dipping northern flank of the mounds, and small-scale slump, slide and debris flow deposits are occasionally seen on the southern flanks (Surlyk 1972). The upper c. 30 cm are lithified and topped by a hardground where it is directly overlain by the bryozoan limestone of the Korsnæb Member.

Boundaries. – The lower boundary is placed at the top of the upper incipient nodular hardground, which occurs about 50 cm above a thick black marker bed of nodular flint (Figs 7, 8). In the northern part of the cliff the flint layer is poorly developed and the boundary to the underlying Sigerslev Member is more gradational. The upper boundary is placed where bryozoan wackestones are overlain by the basal Danian Fiskeler Member of the Højerup Formation, or where the Fiskeler has wedged out, by the slightly overstepping Cerithium Limestone Member or directly by lower Danian bryozoan limestone of the Korsnæb Member (Stevns Klint Formation).

Distribution. – The member is exposed along most of Stevns Klint.

Chronostratigraphy. – Uppermost Maastrichtian. Top part of the *Belemnella kazimiroviensis* belemnite Zone (Christensen 1979, 1997); *stevensis–chitoniformis* brachiopod Zone (Surlyk 1984); *Nephrolithus frequens* coccolith Zone (Perch-Nielsen 1979); *Pseudotextularia elegans* foraminifer Zone (Schmitz *et al.* 1992).

Rødvig Formation

New formation
General. – The formation is a highly distinct unit at the base of the Danian in the type area. It comprises two different lithologies, the lower Fiskeler Member and the upper Cerithium Limestone Member. The complicated stratigraphic relations of the formation were first unraveled by Rosenkrantz (1924). The formation essentially comprises the fills of a series of small basins between the crests of the underlying bryozoan mounds of the Højerup Member.

Name. – From the small town Rødvig at the southern end of the cliff.

Type locality. – Longest Fiskeler basin in the coastal cliff between Rødvig and Korsnæb (Plate 1, Figs 1, 11).

Reference localities. – Same as the Fiskeler and Cerithium Limestone Members.

Thickness. – The formation is mainly 30–70 cm thick, but reaches a maximum thickness of about 90 cm in a basin at Rødvig and 150 cm at Kulstirenden (Hart *et al.* 2004, 2005).

Lithology. – The lower part of the thin formation consists of the marly Fiskeler Member, which passes gradationally into the pure carbonates of the Cerithium Limestone Member.

Boundaries. – The lower boundary coincides with the base of the Fiskeler Member and the upper boundary with the top of the Cerithium Limestone Member.

Chronostratigraphy. – Lowermost Danian. P0–P1a planktonic foraminifer Zones (Rasmussen *et al.* 2005). Schmitz et al. (1992) indicate Zones P0–lower P1b but the zonal assignment of Rasmussen et al. (2005) is followed here. Nannofossil Zone D1, *B. sparsus* of Perch-Nielsen (1979) and zone 1 of Thomsen (1995); *C. cornuta* dinoflagellate Zone (Hansen 1977).

Fiskeler Member

New member
General. – The Fiskeler Member is mainly 5–10 cm thick, and is only known from the Stevns peninsula. It is given member status in spite of its small thickness because of the lithology, which is markedly different from the encasing carbonates. It is a classical sedimentary unit and is probably the most famous example worldwide of the Cretaceous–Tertiary boundary clay

Name. – Forchhammer (1825) named it Fiskeleer (meaning fish clay), on the basis of the content of small fish teeth and scales in the otherwise poorly fossiliferous unit. The name does not conform to standard lithostratigraphic practice but is so engrained in the literature that it is proposed preserved as a formal term. In addition the name is neutral and cannot lead to any confusion with other types of stratigraphical nomenclature.

Type locality. – Stevns Klint, small Fiskeler basin immediately south of the old Højerup church. This is the main sample locality for numerous geochemical and micropalaeontological studies (e.g. Christensen *et al.* 1973; Alvarez *et al.* 1980).

Reference localities. – The member occurs discontinuously in numerous small basins along much of the length of the cliff of Stevns Klint (Plates 1, 3–12) and long exposures are within reach from the beach in the low part of the cliff east of Rødvig (Plate 1).

Thickness. – The member is 5–10 cm thick in the central parts of the small basins and wedges out towards the margins of the basins. In the northern part of the cliff at Kulstirenden thicknesses of about 30 cm have been observed (Hart *et al.* 2004, 2005 indicate a thickness of 45 cm).

Lithology. – The detailed lithological succession of the thin member is described by Christensen *et al.* (1973) and Ekdale & Bromley (1984). Christensen *et al.* (1973) subdivided the Fiskeler into five beds (Beds I–V). This numbering is somewhat unfortunate because Bed I belongs to the white chalk wackestone of the uppermost Maastrichtian Højerup Member and the thin Bed II represents the topmost part of this member which is grey and has undergone some dissolution at the contact with the Fiskeler. Beds I–II of Christensen *et al.* (1973) are thus not included in the Fiskeler Member as here defined and we subdivide the Fiskeler into beds a–c in ascending order (Fig. 12). At the base of the member there is a black, brown-weathering clay bed, 1–2 cm thick with pyrite concretions – bed a. It is overlain by a 3–4 cm thick black to light grey streaky marl which are restricted to the deepest parts of the basins – bed b, which again is overlain by a light-grey streaked marl, up to 7 cm thick – bed c. These thicknesses are characteristic for the member in most of the cliff except for the very thick bed at Kulstirenden. Bed c can be followed to the margins of the basins. Its lower boundary is relatively sharp, whereas it passes gradationally upwards into the Cerithium Limestone via a zone with abundant reworked and flattened chalk clasts. This level may have a conglomeratic nature.

Boundaries. – The lower boundary of the member is placed where the black clay overlies the 1-2 cm thick marly top of the Maastrichtian Højerup Member (bed II of Christensen *et al.* 1973). The marly nature reflects slight dissolution of the chalk below the Fiskeler as is commonly seen at chalk-marl boundaries in chalk successions. The gradational upper boundary is placed where the marl of bed c is overlain by pure carbonate of the Cerithium Limestone Member (Fig. 12).

Distribution. – The member is only developed in its typical form along the Stevns Klint section where it occurs discontinuously in the small basins between the crests of the Maastrichtian bryozoan chalk mounds of the Højerup Member. A correlative clay bed overlies the flat surface of the Maastrichtian chalk in the more central parts of the Danish Basin. This bed is not included in the Fiskeler Member.

Chronostratigraphy. – Lowermost Danian. The member contains the famous iridium anomaly at its base (Alvarez *et al.*, 1980, 1984). P0 planktonic foraminifer Zone (Rasmussen *et al.* 2005); *C. cornuta* dinoflagellate Zone (Hansen 1977).

Cerithium Limestone Member

New member

History. – The unit was described and named Ceritkalksteen (Cerithium limestone) by Forchhammer (1825). The name was changed to Brissopneusteslaget (Brissopneustes layer) by Rosenkrantz (1924) because of the abundant presence of the irregular echinoid *Brissopneustes danicus.* It was subsequently recognized that the echinoids should be placed in the genus *Cyclaster* and the name was changed back to Cerithiumkalk by Rosenkrantz (1937), a procedure clearly illustrating the unfortunate method of naming lithostratigraphical units after fossils.

Name. – After the gastropod *Cerithium*, casts of which are common in the formation (Forchhammer, 1825). The name does not conform to standard practice for lithostratigraphic names, but it is so engrained in the literature that it is proposed preserved as a formal term. In addition *Cerithium* is not a biostratigraphically important fossil and the genus still lives, so there is little risk of confusion with zonal names. Note that Cerithium should not be italicized in the member name as it does not have any biological connotation in this connection.

Type locality. – Same as the Fiskeler Member.

Reference localities. – The member occurs discontinuously in numerous small basins along much of the length of the cliff of Stevns Klint (Plates 1, 3–12).

Thickness. – Mainly about 30–60 cm thick in the deepest parts of the basins but reaches 80 cm at some basins north of Rødvig at Korsnæb and 120 cm at Kulstirenden. Wedges out towards the margins of the basins.

Lithology. – Micrite, strongly burrowed by *Thalassinoides.* Flint nodules and pyrite concretions are common. Flint is commonly nucleated around burrows and shows all transitions between grey silicified burrow walls and large black flint nodules extending out into the surrounding limestone. Many burrows remained open after hardening of the limestone and erosion of the top of the member and were subsequently filled with lower Danian bryozoan-rich sediment.

Boundaries. – Overlies the upper marly part of the Fiskeler Member with a gradational boundary. The upper boundary is formed by a prominent erosion surface which truncates the Cerithium Limestone and the intervening mound crests of the Maastrichtian Højerup Member.

Distribution. – Occurs in small basins along the length of Stevns Klint.

Chronostratigraphy. – Lowermost Danian. Pα and lower P1a foraminifer Zone (Rasmussen *et al.* 2005; Heinberg 1999, 2005). Schmitz *et al.* (1992) indicate Zone P1b and lowermost P1c, but we follow Rasmussen *et al.* (2005). Nannofossil zone D1, *B. sparsus* and possibly lowermost D2, *P. sigmoides* of Perch-Nielsen (1979) and zone 1 and lowermost 2 of Thomsen (1995).

Stevns Klint Formation

New formation
History. – The limestones of the Danish Danian have not been lithostratigraphically subdivided except for the upper Danian København Kalk Formation (Stenestad 1976). The rather unfortunate name 'Danskekalk or 'Danske Kalk', meaning something like "the limestone of the Danes" or "the Danish limestone" has been used a few times in the literature (Andersen 1944; Hofker 1962), but we have not been able to trace the origin and use of the name should be discontinued. The formation was termed 'coralitkalksteen' (meaning coralline limestone) by Forchhammer (1825) who thought that the bryozoans were small corals. Subsequently the formation has mainly been referred to as 'bryozoan limestone', a term which has been used in both a lithostratigraphical sense and as a facies term.

Name. – From the coastal cliff Stevns Klint where the lower part of the formation is beautifully exposed.

Type locality. – Stevns Klint at Korsnæb where the asymmetrical bryozoan mounds are particularly well exposed and easily accessible.

Reference localities. – The formation is exposed almost along the length of Stevns Klint, except for a part north of Storedal where only Maastrichtian chalk is exposed; numerous cliff sections and quarries give an excellent picture of the formation. The best exposure of the mounds is at Peblingebrodden (Plate 2) but this part is inaccessible except by boat.

Thickness. – The maximum thickness of the Danian bryozoan limestone in the Danish Basin is about 175 m (Thomsen 1995); the formation wedges out towards the deeper parts of the basin where it gives way to lime mudstones.

Lithology. – Bryozoan wackestone and packstone deposited in asymmetrical mounds outlined by thick layers and nodules of flint. The southern mound flanks are steeper than the northern flanks. Hardgrounds occur commonly on northern flanks and northward dipping erosion surfaces truncate the mound bedding many places. The limestones are rich in fossils, particularly bryozoans, echinoderms and bivalves.

Boundaries. – The formation overlies the prominent erosional hardground, which truncates the top of the Cerithium Limestone Member and the intervening bryozoan chalk mound crests of the Højerup Member at Stevns Klint (Figs 2, 7, 9, 14A). Elsewhere it overlies horizontally bedded lowermost Danian limestones, which are correlatives of the Cerithium Limestone Member. The upper boundary is placed where the bryozoan limestones are overlain by lime mudstones and calcarenites of the København Limestone Formation, or directly by the Selandian Lellinge Greensand Formation and its correlatives or Quaternary deposits.

Distribution. – The formation is well exposed in numerous outcrops including Stevns Klint and Faxe on Sjælland, Limhamn in Skåne, Klintholm on Fyn, and Sangstrup Klint, Karlby Klint, Bulbjerg, Klim Bjerg, and Hanstholm in northern and eastern Jylland. In the subsurface it is widely distributed in eastern and northern Denmark (Thomsen 1995).

Chronostratigraphy. – Lower–upper Danian. Nannoplankton zones D2–D10 (Perch-Nielsen 1979) and zones 2–8 Thomsen (1995); *Tylocidaris oedumi*, *T. abildgaardi*, *T. bruennichi* and *T. vexillifera* echinoid Zones (Rosenkrantz 1924; Ødum 1926; Nielsen 1938; Brotzen 1959); foraminifer Zone P1b–P2 (Bang 1982; Rasmussen *et al*. 2005) and possibly also including the lower part of P3 (Clemmensen & Thomsen 2005).

Korsnæb Member

New member
Name. – From the Korsnæb point in the southern part of the cliff Stevns Klint, where the member is very well exposed.

Type locality. – The Korsnæb point and the adjacent Skeldervig Bay, southern part of Stevns Klint (Fig. 14C, Plate 1).

Reference localities. – Good sections through the member occur along the length of Stevns Klint except between Storedal and the Sigerslev quarry where only Maastrichtian chalk is exposed (Plate 7).

Thickness. – The member is up to at least 20 m thick at Stevns Klint but its top is not exposed. In the Limhamn quarry, southwest Scania the member is represented by 'Bioherm Group 1' which is 8–15 m thick (Brotzen 1959). In the subsurface the thickness reaches 50 m according to Thomsen (1995).

Lithology. – Mainly bryozoan rudstone and packstone deposited in asymmetrical mounds outlined by thick layers and nodules of flint. Octocoral and echinoid rudstone, bryozoan wackestone and floatstone occur locally and bioclastic and bryozoan grainstone, foraminifer packstone and marly laminae are rare. Hardgrounds are common on northern mound flanks, and northward dipping erosion surfaces truncate the mound bedding many places. In the northern part of Stevns Klint at Mandehoved and Holtug the upper part of the member shows transitions into evenly or low-amplitude mound-bedded lime mudstones and packstones, as first noted by Andersen (1944). The member is rich in fossils, particularly delicate branching bryozoans, but encrusting and nodular/arborescent bryozoan growth forms also occur. Echinoderms, bivalves, serpulids, octocorals and planktonic foraminifers can be locally concentrated.

Boundaries. – The lower boundary coincides with the lower boundary of the Stevns Klint Formation. The upper boundary is not exposed at Stevns Klint. In the Limhamn quarry this boundary is placed at a hardground capping 'Bioherm Group 1' of Brotzen (1959).

Distribution. – The member is exposed at Stevns Klint and in the Karlstrup quarry on Sjælland, in the Limhamn quarry in Skåne and at Karlby, Sangstrup, Vokslev, Nye Kløv, Bulbjerg, Tingbæk and Klim Bjerg in eastern and northern Jylland.

Chronostratigraphy. – Lower Danian. Nannoplankton Zones D2–D3 of Perch-Nielsen (1979) and zones 2–3 of Thomsen (1995); *Tylocidaris oedumi* and *T. abildgaardi* echinoid Zones (Rosenkrantz 1924; Ødum 1926; Nielsen 1938, Brotzen 1959); foraminifer Zones P1b–P1c (Schmitz *et al.* 1992; Rasmussen *et al.* 2005).

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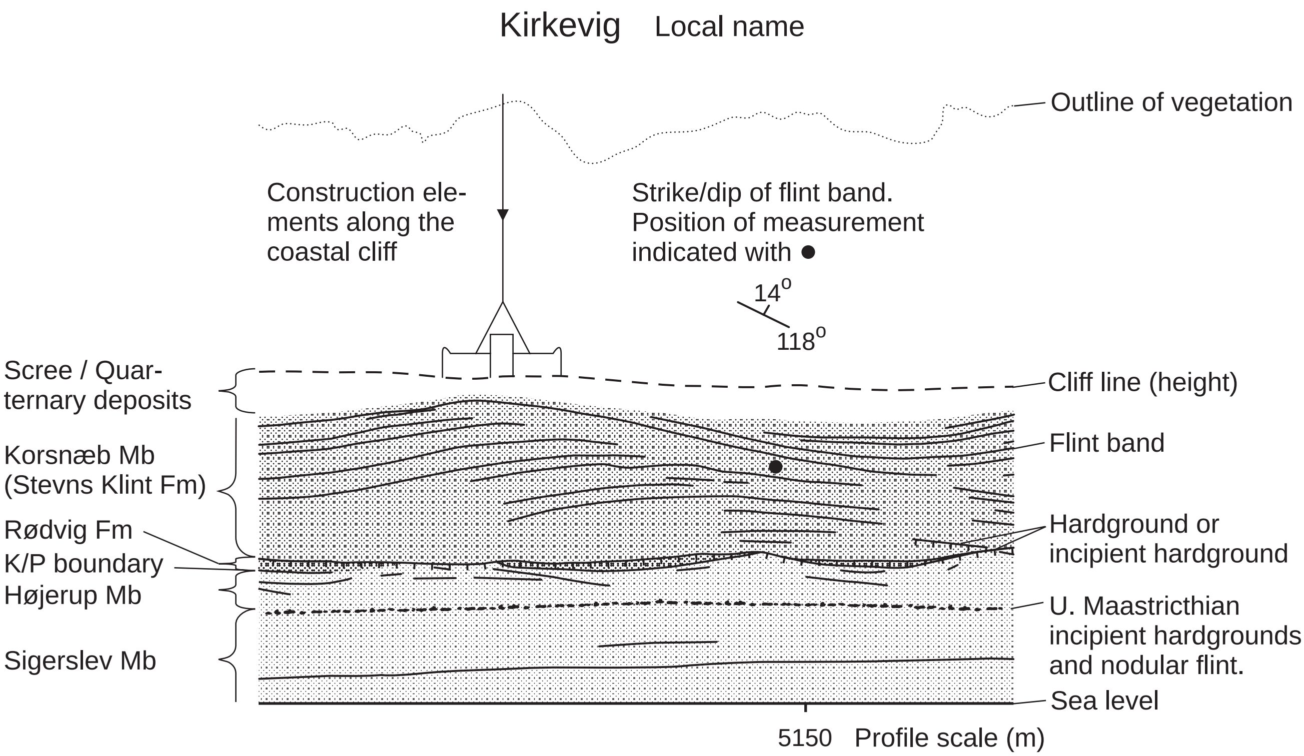


Fig. 18. Legend to plates.

Index Plates 1–12

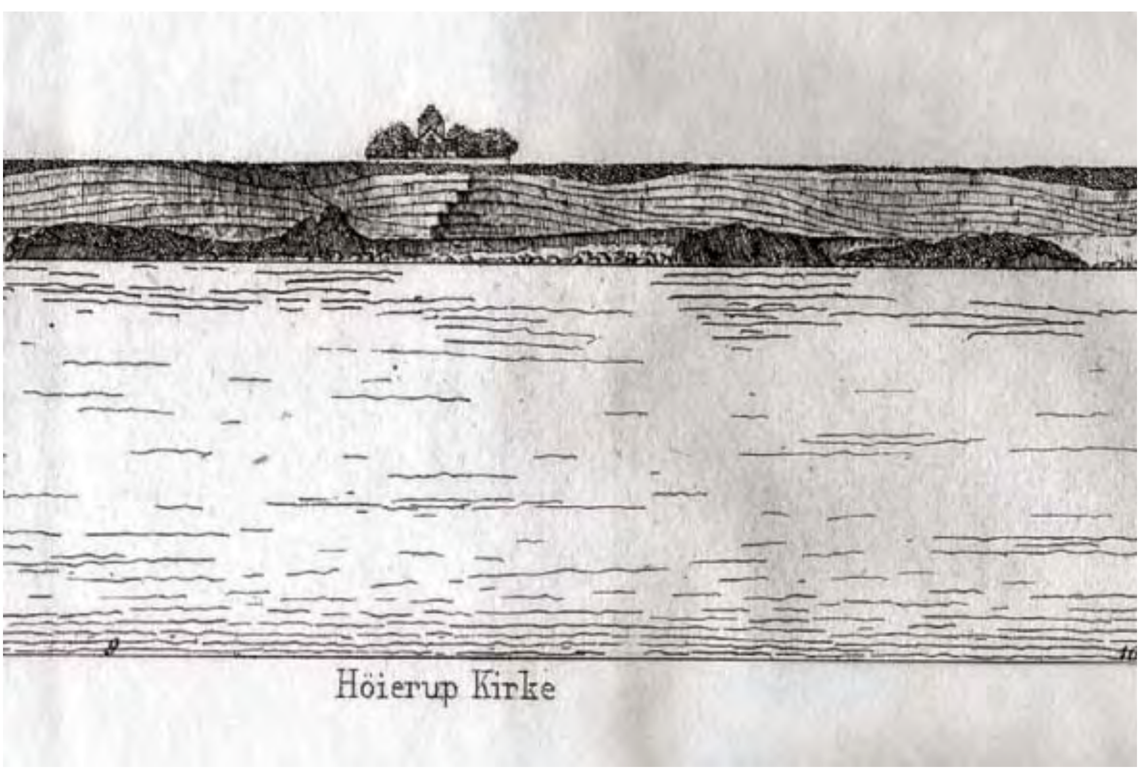
Plate 1: Rødvig – Boesdal, 0–1200 m
Plate 2: Boesdal – Peblingebrodden, 1200–2400 m
Plate 3: Lille Heddinge Vig, 2400–3600 m
Plate 4: Harvig – Knøsen, 3600–4800 m
Plate 5: Højerup, 4800–6000 m
Plate 6: Stevns Fyr (lighthouse), 6000–7200 m
Plate 7: Barmhjertigheden, 7200–8400 m
Plate 8: Storedal – Lilledal, 8400–9600 m
Plate 9: Sigerslev – Mandehoved, 9600–11250 m
Plate 10: Holtug, 11250–12450 m
Plate 11: Holtug – Kulstirenden, 12450–13650 m
Plate 12: Kulstirenden – south of Præsteskov, 13650–14550 m

Location of profile segments in plates is seen in Fig. 1.

Photographs and images of Stevns Klint (1)

Top: Photograph of the old Højerup church area taken from a small airplane looking towards the SW. Copyright P-E Fotolab Store-Heddinge, Danmark.
Bottom: Photograph of the Peblingebrodden area in the southern part of Stevns Klint taken from a small airplane looking towards the N. Note the irregular cliff line.

Photographs and images of Stevns Klint (2)



Top: Picture of the cliff section at the old Højerup church (Abildgaard 1759).
Bottom: Part of cliff section at Højerup drawn by Puggaard (1853).

Top: The old Højerup church area anno 1866. Note the talus in the lower part of the cliff beneath the church from the ongoing quarrying of bryozoan limestone (A. Rosenkrantz, unpublished). Bottom: Same section anno 2006. Note that the cliff line has moved markedly in a landward direction compared to the upper picture.

Photographs and images of Stevns Klint (4)

Top: The old Højerup church area from before the rock fall in 1928 where the cliff section and choir of the church fell into the sea. The church can be seen between the trees in the middle. Bottom: Same section anno 2002.

Top: Numerous vertical sawing marks from brick production in bryozoan limestone of the Korsnæb Member of the Stevns Klint Formation at Harvig.
Bottom: The northern entrance of the cold war fort Stevnsfort. Note the continuous thick flint bands in the upper part.

Top: E–W striking section at Korsnæb showing a strike section through a symmetrical mound. Bottom: E–W striking section at Holtug quarry showing non-mounded muddy bryozoan limestone.

Top: Bryozoan mound onlapped by unusual top mound to the left at Korsnæb.
Bottom: Bryozoan mound with downlaps towards the south onto successive slightly younger surfaces south of the old Højerup church.

Top: Bryozoan mounds at Skeldervig to Korsnæb (Type locality of the Korsnæb Member, Stevns Klint Formation).
Bottom: Low bryozoan mounds at Mandehoved.