GUIDE TO STEVNS KLINT

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Map sheets: 1512 I NØ & 1512 I SØ, 1:25.000.

Position: East coast of the Stevns peninsula 40 km due south of Copenhagen.

Type of exposure: 12 km long and 20-41 m high beautifully exposed cliff with easy access at many places. Several quarries along the cliff margin.

Stratigraphy: Uppermost Maastrichtian-middle Danian. The Maastrichtian-Danian boundary is extremely well exposed. Stevns Klint and Faxe Quarry constitute together the classical type area of the Danian Stage (Desor, 1847).

Earlier work: The section has been studied by many Danish geologists since the first description by Abildgaard (1759). A review is given by Milthers (1908) and the complicated stratigraphical nature of the Maastrichtian/Danian boundary was unravelled by Rosenkrantz (1924). The stratigraphic position of the Maastrichtian section was studied by Troelsen (1937), Birkelund (1957) and Surlyk (1970b), whilst Berggren (1962a, 1964) and Hofker (1962a) discussed both the Maastrichtian and Danian stages and the boundary between them. Aspects of the lithology have been described by Rosenkrantz & Rasmussen (1960), Surlyk (1969, 1972), Bromley (1967, 1968, 1975b), Håkansson (1971), Håkansson *et al.* (1974) and Svendsen (1975).

The basal Danian marl layer - the Fish clay has been described in detail by Christensen *et al.* (1973), whilst the impressive Danian bioherms have received little more than general study. Svendsen (1975) has, however, examined a section in some detail.

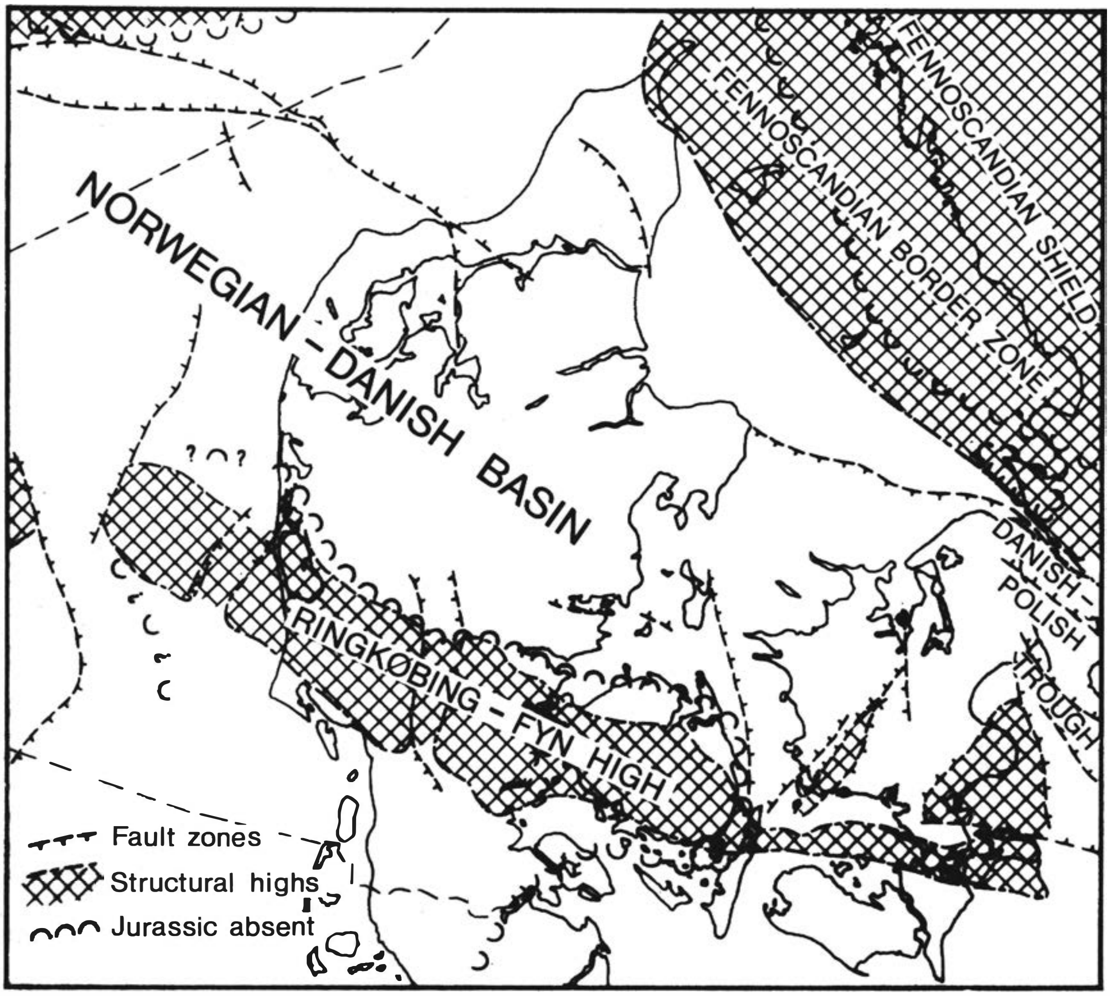

Fig. 1. Schematic structural map of Denmark (from Rasmussen, 1978).

GEOLOGIC SETTING

Stevns Klint is situated over a fault limited structural high between the eastern end of the Ringkøbing-Fyn High and the Fennoscandian Border Zone (Fig. 1). The Maastrichtian facies types are of more shallow water types than in the majority of exposures in Denmark.

THE MAASTRICHTIAN SEQUENCE

The Maastrichtian is represented by different subfacies of chalk and a total thickness of c. 35 m is exposed along the cliff (Fig. 2). The

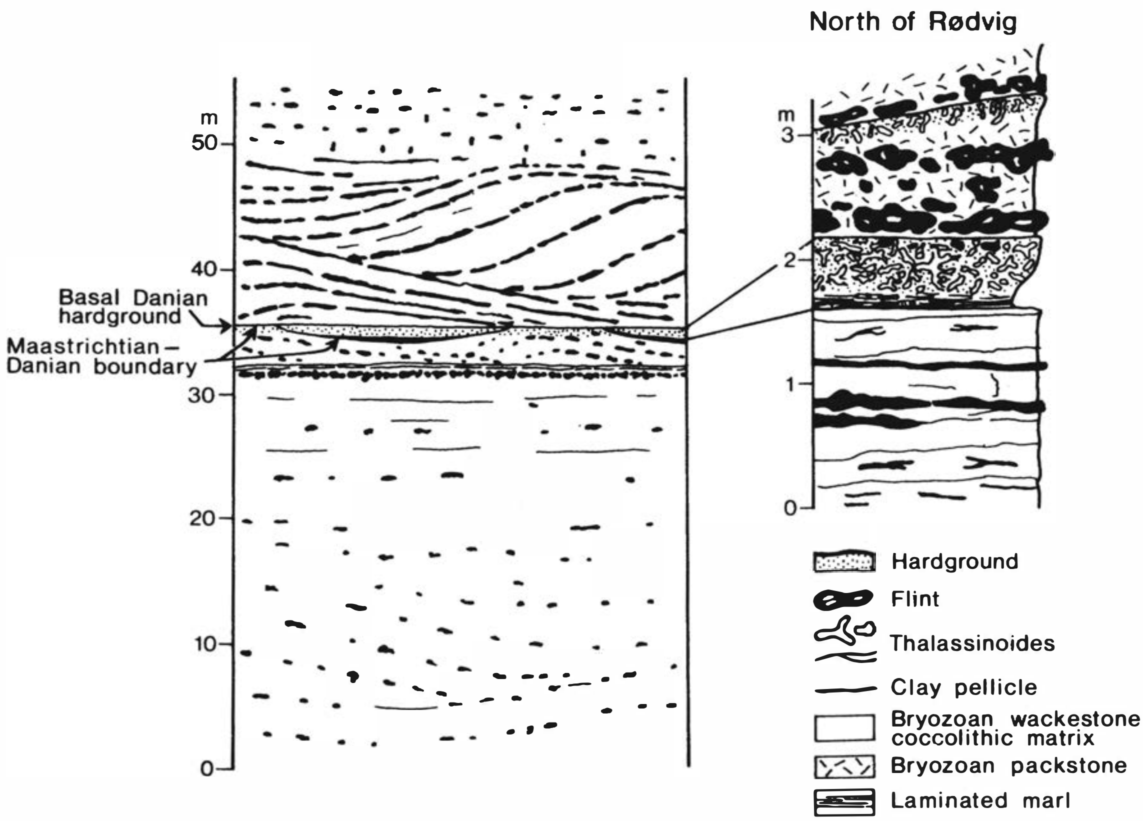

Fig. 2. Simplified composite section of the sequence exposed at Stevns Klint.

lowest 5-10 m of the exposed sequence comprise white chalk with a large content of bryozoans. The chalk was deposited as low mounds revealed most notably by the undulating course of the flint bands. Some of the mounds show a slight overlap. The level with mounds is followed upwards by about 20 m of horizontally bedded chalk with scattered flint nodules and a lower fossil content. This unit is characterized by a high density of *Zoophycos* burrows. A prominent nodular flint layer occurs about 3-4 m below the Maastrichtian-Danian boundary. This layer can be traced almost along the whole length of the cliff. Along the main part of the cliff the flint layer is followed by two omission surfaces topping weakly lithified chalk. These surfaces are outlined by a yellowish rusty colour and form the top of the normal soft white chalk. Both surfaces are extremely irregular, probably as a result of erosion after a stage of early nodular lithification. The highest of these incipient hardgrounds underwent small-scale overthrusting reminiscent of teepee structures.

The upper surface forms the base for a sequence of grey chalk 2.5 - 3.5 m thick showing a very high content (up to 20%) of small benthic fossils, notably bryozoans. The grey chalk was deposited as low asymmetric, biohermal ridges or mounds each of which overlap the next ridge to the south. The southern flank is steepest and shortest and strong flint bands are only found within the less steep northern flank. The bioherms are characterized by *Thalassinoides*, the fill of which is sometimes burrowed by *Chondrites*. The highest density of recognizable *Thalassinoides* occur in 50 cm thick bands which dip to the north parallel to the surface of the bioherms. Synsedimentary slumping and slurry flows were characteristic processes on the flanks. The flows were normally of a rather small size incorporating masses of chalk at maximum a few tens of centimetres thick and 1-2 metres long. The growth of the bioherms can probably be explained by the same model as proposed by Thomsen (1976, 1977b) for other Danian bryozoan bioherms. According to Thomsen the mounds grew under influence of unidirectional currents which promoted growth in an upcurrent direction. The Maastrichtian bioherms are altogether richer in matrix than their Danian analogues and the sediment can be classified as a bryozoan wackestone all through the mound structures (Svendsen, 1975). They can probably be considered a slightly deeper water, early stage of the more impressive and more benthos rich Danian mounds.

THE DANIAN SEQUENCE

Maastrichtian carbonates are abruptly overlain by a dark-grey marl band, the so-called Fish clay constituting the basal Danian bed. It occurs in the low basins between the summits of the Maastrichtian bryozoan bioherms and reaches a thickness of 20-35 cm in the deepest parts of the basins. It wedges out completely towards the margins of the basins. The Fish clay has been studied in some detail by Christensen *et al.* (1973) who distinguished 4 beds, beginning with 1) a grey laminated marl, followed by 2) black marl with pyrite concretions, which again is overlain by 3) black laminated marl. This gives way to 4) light-grey marl with flattened lenses of white chalk, which gradually passes into the indurated Cerithium limestone (Fig. 3). The fine, undisturbed lamination of especially bed 3) and the abundant occurrence of pyrite concretions suggest euxinic conditions during deposition of the lower part of the Fish clay. The provenance of the bed seems to be in part terrigenous (quartz and feldspar) in part authigene (mixed-layer clay minerals).

The Fish clay contains relatively few fossils such as fish scales and teeth, which have given name to the unit. Reworked late Maastrichtian fossils are quite abundant and the coccolith assemblage consists of reworked Upper Maastrichtian forms (99%) and only very few indigenous

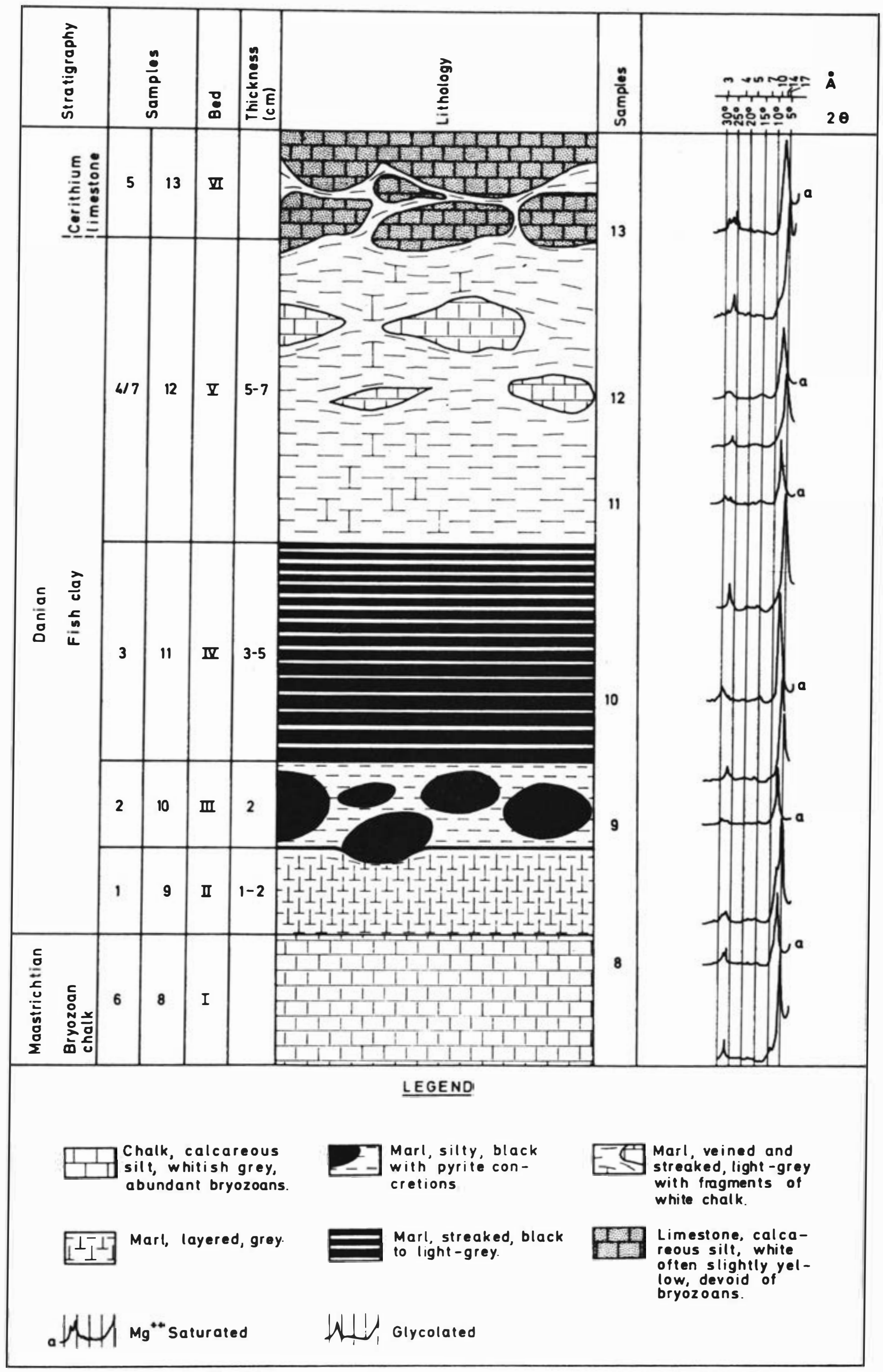

Fig. 3. Detailed section of the Maastrichtian/Danian boundary at Stevns Klint (from Christensen *et al.*, 1973).

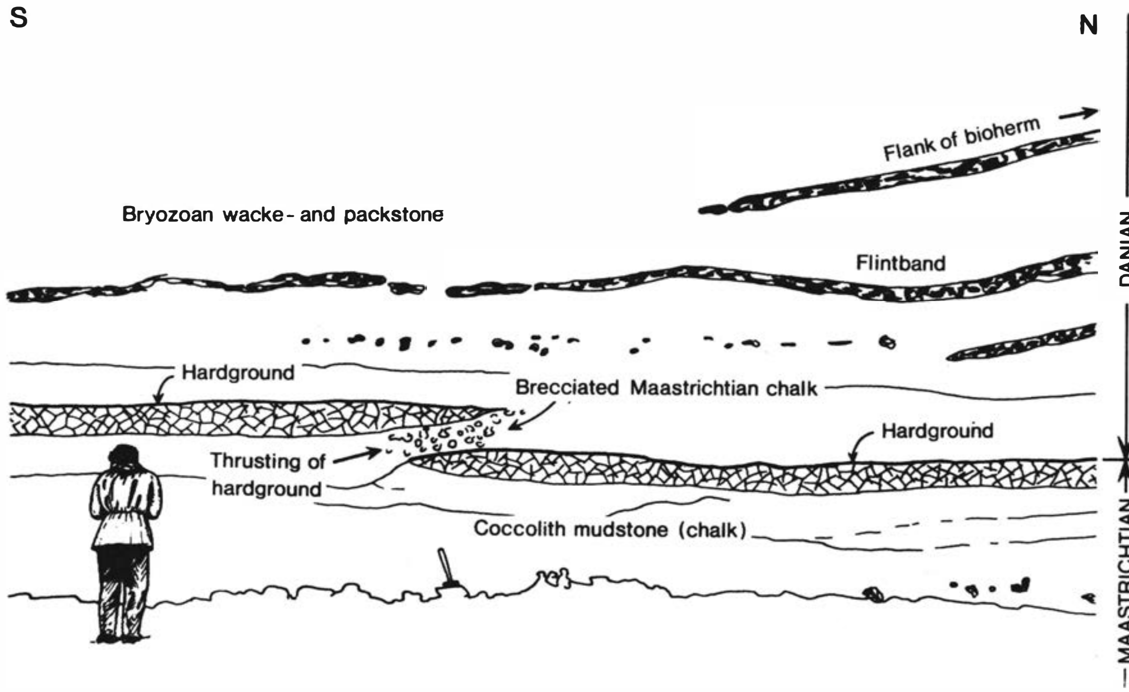

Fig. 4. Early diagenetic thrusting of basal Danian hardground. The thrusted sequence is underlain by undisturbed Maastrichtian coccolithic chalk and overlain by Danian bryozoan wacke- and packstones. Stevns Klint, north of Kulsti Rende (from Surlyk, 1969).

species characteristic for the lowest Tertiary nannoplankton zone (NP1) (K. Perch-Nielsen, pers. comm., 1979).

The Fish clay gives way with a gradual transition to the hard yellow Cerithium limestone. The latter is penetrated by innumerable *Thalassinoides* burrows and micro-faults with slickensides. The next stage was characterized by erosion of the top part of the Cerithium limestone and the intervening crests of the Maastrichtian bioherms. In this way a horizontal erosion surface was developed which cuts alternately through the highest Maastrichtian bryozoan chalk and the lower Danian Cerithium limestone. This process was probably submarine and was followed by early diagenetic submarine cementation down to a depth of about 30 cm. The *Thalassinoides* burrows comprise both pre-omission and omission suites. The latter are deformed by concurrent activity of the burrowing infauna and the lithification processes (Bromley, 1967, 1975b).

The planar erosion surface cuts through the remains of horizontal burrow networks destroying the upper half. Some of these burrows reach a diameter of 12 cm (Bromley, 1968). The fill of the burrows mainly comprises the delicate skeletons of Danian bryozoans and often shows some degree of silicification. To the south are seen all stages from grey, porous chalcedonic flint to solid, black flint. These variations can occur even within one burrow (Surlyk, 1969). The burrow wall is the preferential site of silicification and in more advanced stages the fill and the surrounding limestone is also silicified. At several localities along the cliff early diagenetic thrusting of the hardground has taken place (Fig. 4, Surlyk, 1969). This is interpreted as being due to a diagenetically caused volume increase and expansion analogous to the thrusts and folds described by Shinn (1969) from hardgrounds in the Persian Gulf.

The hardground itself contains a diverse fauna comprising among others originally aragonite shelled gastropods and bivalves. Tests of the lower Danian echinoid *Brissopneustes danicus* are commonly found in the burrow fill.

The erosion surface of the basal Danian hardground formed the foundation for the upbuilding of the very impressive lower Danian bryozoan bioherms (Fig. 2).

The Danian bioherms show the same type of asymmetry as those in the top Maastrichtian, but they are larger, contain more flint arranged in thick, often continuous, layers and have a much higher grain/matrix ratio. The dominant grains are stems of delicate bryozoans, but whole and fragmented echinoid skeletons are also conspicuous constituents. The biohermal sequence reaches thicknesses of about 20 m at the southern end of the cliff decreasing to 8-10 m to the north. This thickness trend together with the overlapping nature of the bioherms (the northern bioherms overgrow their southern neighbours) suggest a considerable northwards younging of the whole Danian sequence. The bioherms were probably formed by upcurrent growth of bryozoan mounds as described for contemporaneous mounds in eastern Jylland by Thomsen (1976).

Some southern flanks of bioherms are encased by thin hardgrounds which may reach from the summit of the bioherm and right down to the basin between two bioherms. In this way a flank hardground can come into direct contact with the ubiquitous basal Danian hardground which comprises both the Cerithium limestone and the top of the Maastrichtian bioherms. Care in collection of fossils and samples is essential in such cases to avoid mixed faunas (of three different ages).

Apart from hardgrounds the flanks are characterized by abundant evidence of mass-flows such as slurry and debris flows. Thin beds composed solely of skeletal debris without the usual coccolithic matrix may suggest periods of current winnowing.