# GUIDE TO
# LIMHAMN QUARRY

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The quarry at Limhamn, south Sweden (located immediately south of Malmö) is today the principle exposure of the Danian Stage in Scandinavia. (Figs 1-2). More than 60 m of uppermost Maastrichtian chalk and Danian limestones are exposed in the quarry. Prior to 1965 nearly 20 m of uppermost Maastrichtian chalk were exposed in the deepest part of the quarry. Today, however, that section is under water and only 3 m of chalk at the Maastrichtian/Danian boundary are accessible (although with great difficulty). A detailed profile of the section comprising the Maastrichtian/Danian boundary at Limhamn is presented in Fig. 4, while a more generalized profile of the Danian exposed in the quarry is shown in Fig. 3.

These sediments are only exposed together at this outcrop. However, Maastrichtian and Danian limestones otherwise occur throughout the southwesternmost part of southern Sweden, and, except for extremely restricted and small occurrences of Middle Paleocene sediments (Brotzen, 1948; Gustafsson & Norling, 1973), are the youngest pre-Quaternary rocks in Sweden. The depositional basin that these and underlying Mesozoic sediments were deposited in is considered part of the Danish Basin. In Sweden this basin is bordered along the northeast by the Fennoscandian Border Zone of the Baltic Shield, the border being distinctly recognized as the Tornquist Line (see discussion in Bergström *et al.*, 1973; Baartman & Christensen, 1975).

Whereas the Maastrichtian chalk appears to have a fairly uniform distribution throughout the basin, the facies and thickness of the Danian is not uniform over the entire area. During Danian times sediment deposition appears to have been affected by the existence of basement controlled swells and depressions running approximately parallel to the Fennoscandian Border Zone and reflecting the prevalent tectonic pattern of the Danish Basin adjacent to the zone.

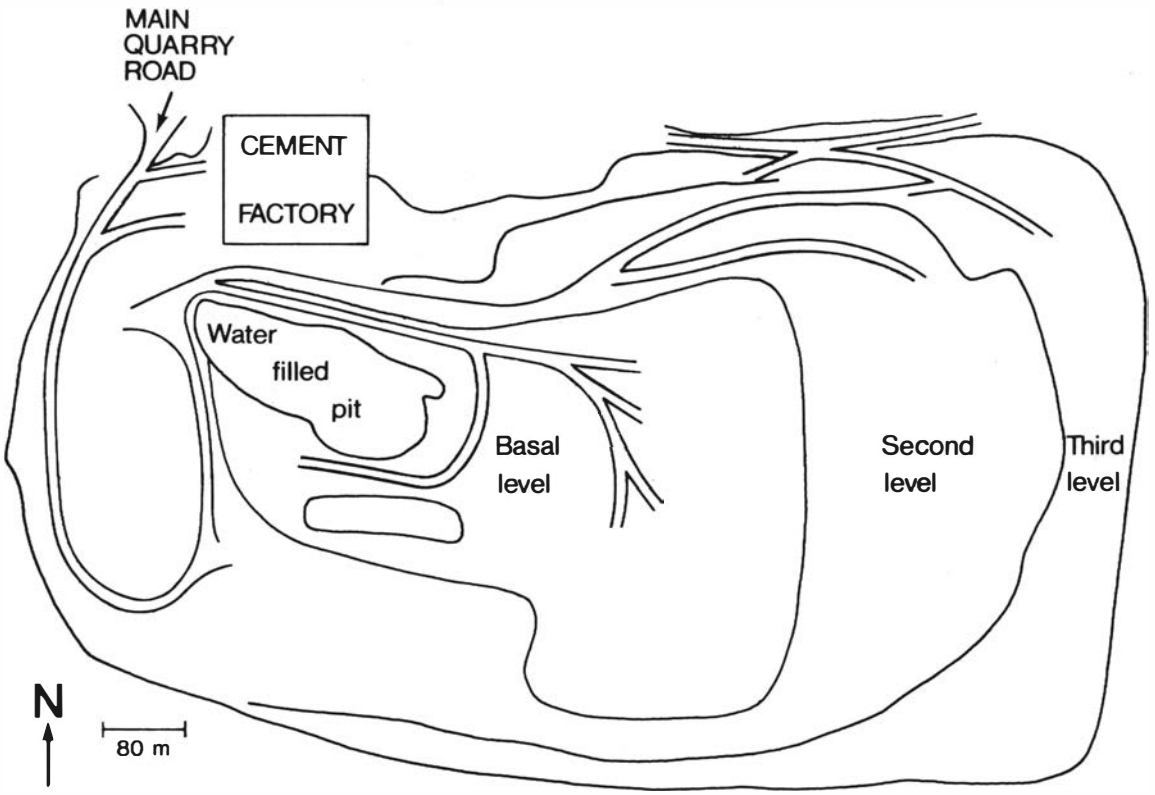



Fig. 1. Map of Limhamn Quarry, south Sweden. The various levels of the quarry mentioned in the text are indicated.

The Alnarp Graben, adjacent to the Tornquist Line, possesses thick Danian sequences, the Danian bryozoan limestones at Landskrona reaching 180 m in thickness. Two distinct areas occurring away from the border zone which may represent swell-like structures have thinner Danian sequences, one of which shows evidence of condensation. They extend from the Limhamn area across the Öresund towards the Copenhagen region and along the south coast of Sweden from the Falsterbo peninsula eastwards to the border zone. At Limhamn the Danian, approximately 60 m thick, is represented by a nearly complete sequence of the stage, although several horizons in the quarry show evidence of condensation. On the Falsterbo peninsula 48 m and 46 m of Danian limestones were penetrated in two drillings (Brotzen, 1944). Comparable thicknesses, approximately 40 m, of Danian limestones are met with along the south coast to Ystad. At Ystad the Danian carbonates are replaced by a more

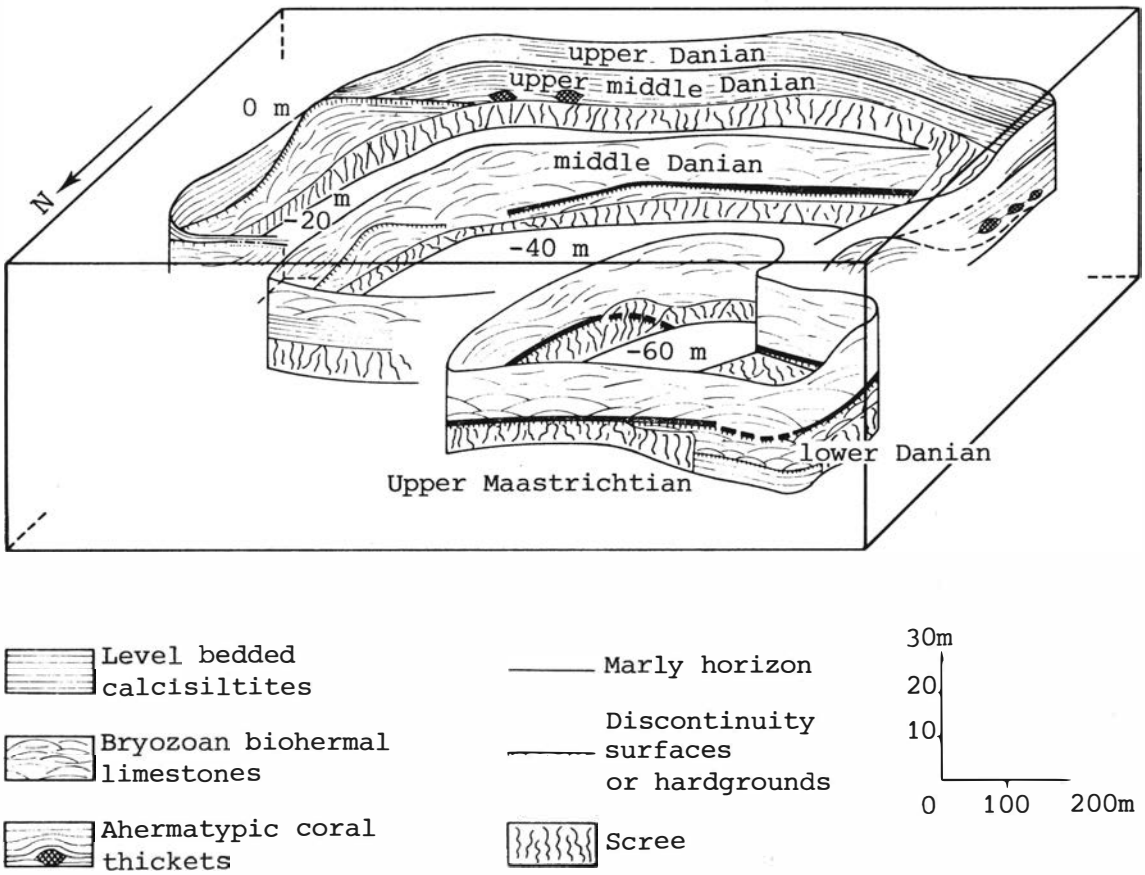



Fig. 2. Schematic view of Limhamn Quarry. After unpubl. drawing by Finn Jacobsen.

arenaceous facies (Brotzen, 1948). These two areas of thinner Danian sequences are separated by a shallow trough with somewhat thicker Danian deposits. The total thickness of the Danian in this trough is not known exactly, but at Klagshamn, 5 km south of Limhamn, more than 60 m of limestones were penetrated in a drilling without reaching the base of the Danian (Brotzen, 1940).

The occurrence and stratigraphy of the Maastrichtian and Danian in Sweden are chiefly known through the publications by Brotzen (1940, 1944, 1948, 1959). Other studies on the Danian at Limhamn include those by Hennig (1899) and Hadding (1933, 1941) (see also the exhaustive bibliography in Brotzen, 1959).

The systematics and stratigraphic distribution of planktic foraminifera from the Maastrichtian and Danian strata of southern Sweden have been studied by Troelsen (1957), Berggren (1960, 1962a, b,) and Malmgren (1974, 1976). Berggren erected a 3-fold zonation of the Danian: the Danian Stage is equated with the *Globoconusa daubjergensis* zone P1, while the three subzones are, from the base of the Danian, *Subbotina pseudobulloides* Subzone P1a, *S. triloculinoides* P1b, and *Planorotalites compressa* P1c.

Malmgren (1974, p. 78) found it possible to recognize a further subdivision of the P1c Subzone, applicable to the Danian of southern Scandinavia. This zonule, the *S. pseudobulloides* Right Coiling Zonule, is characterized by (1) the presence of *P. compressa* and (2) statistically significant right coiling of *S. pseudobulloides*. Berggren's and Malmgren's zonations are summarized and correlated with the Limhamn section in Fig. 3.

Ødum (1971) summarized the data collected from a number of boreholes penetrating Danian and Maastrichtian strata on the Falsterbo peninsula, 20 km south of Limhamn. Kjellström (1973) described Maastrichtian dinoflagellates from the Höllviken 1 borehole located here. Cheetham (1971) examined the distribution and palaeoecology of cheilostome bryozoans in the Danian bryozoan mounds exposed in the Limhamn Quarry, while Brood (1973) treated the cyclostome bryozoan fauna from the Maastrichtian and Danian at Limhamn.

## THE LIMHAMN QUARRY

Brotzen (1959) described in detail the section at Limhamn and recognized the Maastrichtian/Danian boundary. The Danian sequence was divided by him into four zones based on the spines of the regular echinoid *Tylocidaris*. A *Tylocidaris* zonation had earlier been applied at Danian localities in Denmark, including the type localities Stevns Klint and Fakse (Ødum, 1926; Wind, 1954; see Asgaard, this volume). Brotzen correlated the Limhamn section with the type Danian sections and the Limhamn area was considered by him as part of a type region of the Danian.

Recent work by Hansen (1977) on the dinoflagellate distribution in the Danian of Denmark has demonstrated that the *Tylocidaris* zonation is diachronous relative to the dinoflagellate zonation. The various *Tylocidaris* species are apparently each restricted to particular facies. Thus, the *Tylocidaris* zones of the Danian at Limhamn, each well defined lithologically, should be perhaps regarded as informally denoting lithostratigraphic units. It is in this form that they are retained in this guide.

## The uppermost Maastrichtian

Approximately 3 m of uppermost Maastrichtian chalk are exposed in a very small section at the base of the quarry along the west wall just above the water filled pit. The lithology and the planktic foraminiferal fauna of five samples taken from the chalk are schematically shown in Fig. 4. The planktic foraminiferal fauna includes the following species: *Pseudotextularia elegans*, *Heterohelix striata*, *Planoglobulina brazoensis*, *Guembelitria cretacea*, *Globigerinelloides multispina*, and *Hedbergella monmouthensis*.

The Maastrichtian exposed here is composed of rather hard white chalk intercalated with two marly layers and five beds with flint-filled burrows (*Thalassinoides*). The Maastrichtian sequence is topped by a hardground. Although no encrusting or boring organisms are present on the hardground surface, the presence of angular fragments of the hardground together with hiatus sediments in burrows in the hardground indicate that this bed underwent synsedimentary lithification prior to the deposition of the overlying sediments of Danian age. The planar upper surface of the hardground and the occurrence of different sediments in the burrows show that there has been a period of alternating sedimentation and erosion and scour before uninterrupted sedimentation resumed. Thus, a hiatus of unknown duration marks the boundary between the Maastrichtian and the Danian here. The section at Limhamn differs considerably from the boundary section at Stevns Klint (*cf.* Rosenkrantz & Rasmussen, 1960; Håkansson, 1971; Surlyk, this volume). No Fish clay or bed comparable to the Cerithium limestone as found above the Maastrichtian at Stevns Klint is present above the hardground at Limhamn.

## The lower Danian

The lower Danian, the *Tylocidaris oedumi* Zone, is exposed around the entire basal level (- 60 m BSL) of the quarry. Above the Maastrichtian hardground the first 3 m of the Danian are developed as alternating hard and soft, level-bedded bryozoan biomicrites (bryozoan limestone facies). Beds with black flint occur at various intervals, these appear mainly as replacements of burrow fills (*Thalassinoides*) and occur throughout the whole Danian sequence here. The succeeding 8 m of the

Fig. 3. Schematic and composite section of the Maastrichtian and Danian sequence at Limhamn. The *Tylocidaris* zones, the standard planktic foraminiferal zones (P1a-c) and the occurrence and range of the planktic foraminifera of the Danian sequence are shown.

UPPER DANIAN
TYLOCIDARIS VEXILLIFERA ZONE
MIDDLE DANIAN
TYLOCIDARIS BRUENNICHI ZONE
TYLOCIDARIS ROSENKRANTZI ZONE
LOWER DANIAN
TYLOCIDARIS OEDUMI ZONE
UPPER MAASTRICHTIAN
MOUND SEDIMENTS
MOUND SEDIMENTS
MOUND S
Globoconusa daubjergensis
Subbotina pseudobulloides
P1a subzone
S. trinidadensis
Chiloguembelina spp.
S. triloculinoides
P1b subzone
Planorotalites compressa
P1c subzone
S. pseudobulloides Right coiling zonule
Bryozoan biomicrites
Calcisiltites
Hardgrounds and discontinuity surfaces
Hiatus concretions
Ahermatypic corals & coral thickets
Slumping

lower Danian are developed as bryozoan biomicrite mounds. The mounds that occur throughout the lower and middle Danian at Limhamn are in lateral contact with one another for the most part and appear to have grown upwards overlapping older mounds. Thus, an intermound facies is difficult to distinguish. The uppermost 4 m of the lower Danian shows a return to essentially level-bedded biomicrites. This zone is topped by a massive limestone bed approximately 1 m thick which can be followed around the entire basal floor of the quarry. The upper surface of this bed is paved with hiatus concretions. These synsedimentarily lithified concretions indicate a pause in deposition and some degree of submarine erosion. No indication of subaerial exposure of this bed has been observed. The hiatus concretions are slightly phosphatized and have been colonized chiefly by boring sponges.

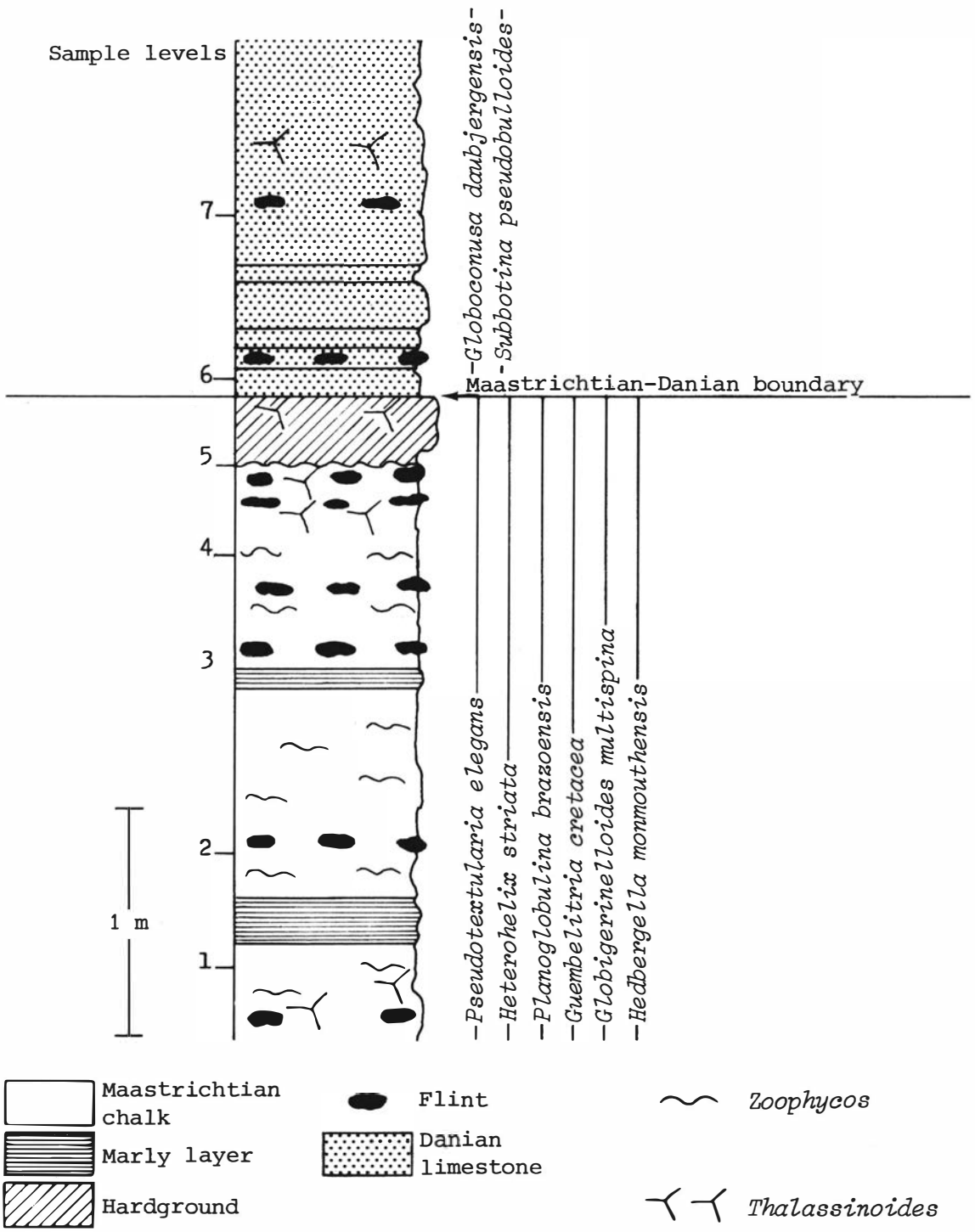
Already in the lowermost bed of this zone *Globoconusa daubjergensis* and *Subbotina pseudobulloides* occur. *S. trinidadensis* and *Chiloguembelina* spp. appear approximately 4 m below the uppermost bed of this zone.

The middle Danian

The middle Danian is comprised of a lower and upper bryozoan biomicrite mound complex. These are referred to the *Tylocidaris rosenkrantzi* Zone and the *T. bruennichi* Zone respectively. The middle Danian sequence begins with 0.5 - 1 m alternating hard and soft biomicrite beds. These beds are replaced upwards by the lower bryozoan mound complex. This complex is approximately 12 m thick. 6 - 7 m above the base of the middle Danian thin lenses (50 cm thick and 3 - 4 m long) of ahermatypic corals are intercalated with the bryozoan biomicrites. The upper parts of these mounds in this complex throughout the quarry frequently show evidence of slumping, with up to 6 - 10 m lateral and downward displacement of mound sediments. Both simple displacement and mushroom-like anticlinal folds, accentuated by late flint diagenesis within burrows, can be seen in the north wall of the basal level of the quarry.

A minor discontinuity surface has been observed approximately 20 m above the base of the middle Danian and can perhaps be regarded as marking the boundary between the two *Tylocidaris* zones of the middle Danian. It is, however, difficult to discern in the exposure. The next level of the quarry exhibits the upper middle Danian bryozoan bioherms or mounds.

Fig. 4. Detailed section of the Maastrichtian/Danian boundary at Limhamn, south Sweden, indicating the occurrence of planktic foraminifera.


Sample levels
7
6
5
4
3
2
1
1 m
-Globoconusa daubjergensis-
-Subbotina pseudobulloides-
Maastrichtian-Danian boundary
-Pseudotextularia elegans
-Heterohelix striata
-Planoglobulina brazoensis
-Guembelitria cretacea
-Globigerinelloides multispina
-Hedbergella monmouthensis
Maastrichtian chalk
Marly layer
Hardground
Flint
Danian limestone
Zoophycos
Thalassinoides

A major change in the depositional environment is indicated in the uppermost middle Danian, exposed in the third level of the quarry. Here, an extensive level of ahermatypic coral thickets is developed on the crests and flanks of the large middle Danian mounds. These lenticular shaped thickets range in size from 3 - 15 m long and 2 - 4 m high. These thickets are highly fossiliferous and suppert a diverse invertebrate fauna (Brotzen, 1959, p. 23; Hadding, 1933). The sporadic occurrence of the light dependant coral *Heliopora incrustans* indicates growth of these thickets at least within the lower limits of the photic zone. The bryozoan mounds are believed to have been deposited in perhaps somewhat deeper water, around 100 - 200 m (see discussion in Cheetham, 1971, with review of earlier literature). The ahermatypic coral thickets are covered by 1 - 4 m level bedded biomicrites. The uppermost bed of the middle Danian is a discontinuity surface which shows great lateral variation and development. Along the northern half of the quarry the discontinuity surface is represented by a complex well-developed hardground and hiatus concretions. Southwards in the quarry these synsedimentarily lithified sediments are replaced by an unlithified discontinuity surface.

Brotzen (1959) regarded the ahermatypic coral thickets and the overlying discontinuity surface as evidence of a period of shallowing and emergence. However, the thickets are essentially composed of a deeper water coral fauna (Floris, 1972) and the hardground and hiatus concretions show no evidence or indication of subaerial exposure.

Approximately 7 m above the base of the middle Danian *Subbotina triloculinoides* appears, while *Planorotalites compressa* makes its first appearance 3 m below the discontinuity surface marking the top of the middle Danian.

The upper Danian

The upper Danian, *Tylocidaris vexillifera* Zone, is best exposed along the south wall of the upper level of the quarry. Here 8 - 10 m of alternating hard and soft calcisiltites occur above the discontinuity surface that tops the middle Danian. Grey to black flint-filled *Thalassinoides* are prominent throughout the sequence. The uppermost beds of the Danian have been glacially eroded and the sequence is covered by Quaternary deposits.

While Brotzen (1940, 1959) suggests that the lower part of the upper Danian is represented at Limhamn and the uppermost beds of the Danian exposed at Klagshamn 5 km south, it should be borne in mind that the hardground-discontinuity surface at the base of the upper Danian at Limhamn represents a hiatus of unknown duration.

DISTRIBUTION OF CALCAREOUS NANNOFOSSILS, RESUMÉ SUPPLIED BY KATHARINA PERCH-NIELSEN

Samples from the quarry as well as from cores provided by Euroc Corp. have been studied. In the Maastrichtian, at the bottom of the quarry and in the cores, the *Nephrolithus frequens* Zone is represented with its usual assemblage. Above the Cretaceous-Tertiary boundary, assemblages of the lower and the upper part of NP1 were found. They include varying amounts of reworked Maastrichtian forms, but are dominated by the genera already known in the Maastrichtian and surviving into the Danian: *Biscutum*, *Crepidolithus* and *Cyclagelosphaera*, and in the upper part of the zone: *Zygodiscus* and *Markelius*. NP1 is about 7 m thick and the overlying NP2 seems to reach a similar thickness. As at Stevns Klint, the 2 subzones could be distinguished in NP 2, the upper one characterized by the presence of *Prinsius dimorphus*. The coccoliths of the overlying NP3 are usually poorly preserved and rare. *Neochiastozygus* was, however, found in a few samples in the cores. Thus it can be assumed that besides the basal part of NP3, the next subzone is also represented at Limhamn. No well developed, typical *Prinsius martinii* and no *Neochiastozygus saepes* were found in the quarry or in the cores, indicating that the uppermost Danian is probably missing here.

At Klagshamn quarry, 5 km south of Limhamn, the uppermost Danian preserved here also belongs to the *Neochiastozygus modestus* assemblage and no *N. saepes* was found. In the overlying Selandian (Middle Paleocene) the coccolith assemblage contains *Prinsius martinii* and *Neochiastozygus perfectus*, thus the uppermost Danian with *N. saepes* seems to be missing in this area.