GUIDE TO MAASTRICHTIAN AND DANIAN BOUNDARY STRATA IN JYLLAND

Eckart Håkansson &
Jens Morten Hansen

E.H.: Institute of Historical Geology and Palaeontology
Øster Voldgade 10, DK-1350 Copenhagen K

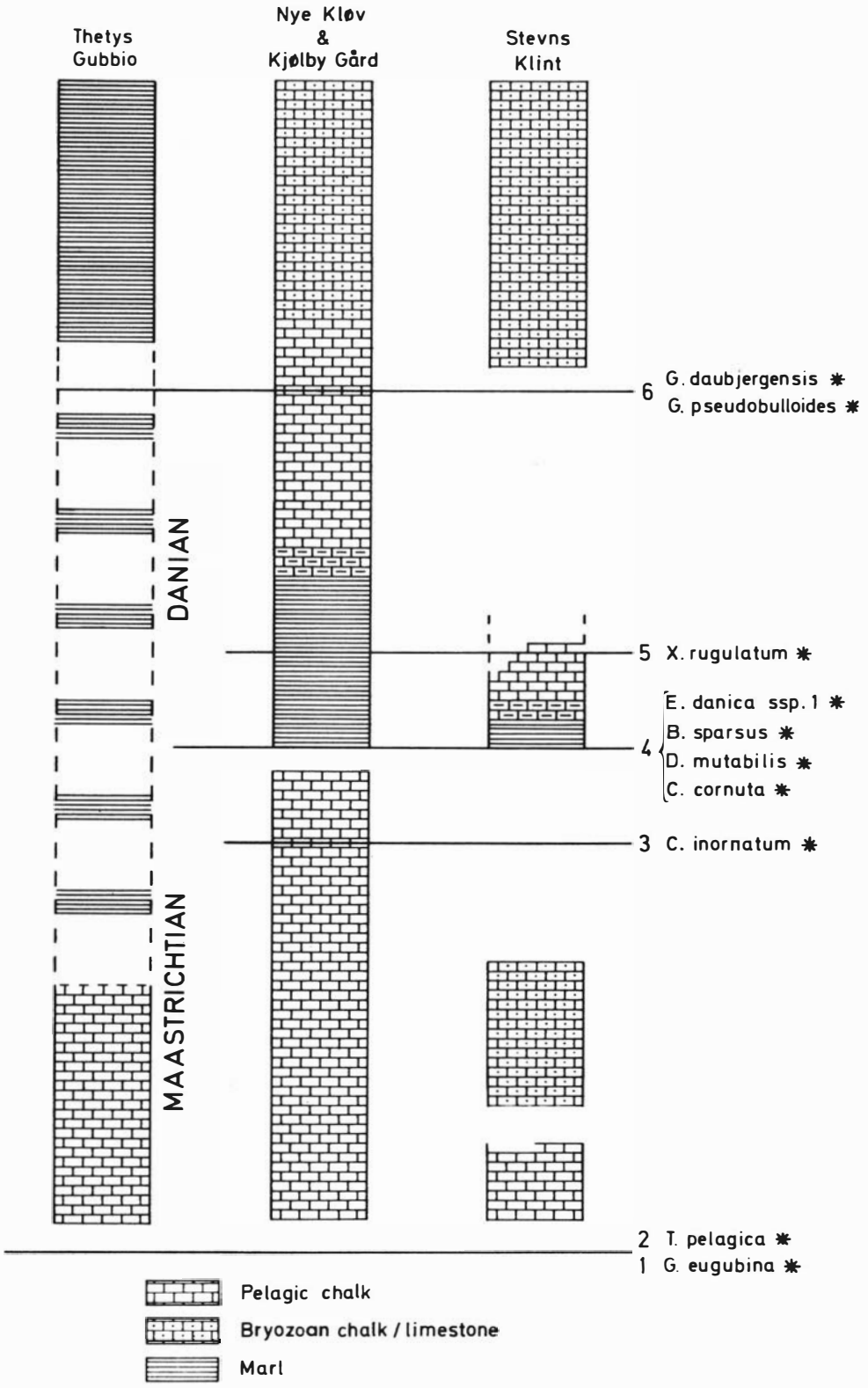
J.M.H.: Geological Survey of Denmark
Thoravej 31, DK-2400 Copenhagen NV

In northern Jylland a number of outcrops from the central part of the Danish Basin exhibits a remarkably complete sequence of strata across the Maastrichtian/Danian boundary. Within this basin, accumulation of pelagic chalk persisted above the boundary in the northwestern part, whereas the classic development seen at Stevns Klint (Surlyk, this volume) is approached towards the southeast. This trend of a gradually more complex development of the boundary strata towards Stevns Klint appears to be associated with an increase in the time represented by hiati and residual marl (Fig. 1). Apparently the time interval at the boundary also increases towards the off-shore North Sea area (Bang, this volume) where, however, the preferred drilling sites on structural units may conceal a generally more complete depositional record.

The boundary strata in Jylland were first described in detail by Jessen & Ødum (1923) and Ødum (1926) who included most known localities. The sediments are uniform, pure carbonates ranging from pelatic chalk with virtually no benthic constituents to bryozoan limestones (see Bromley, this volume, for lithological descriptions). The only important exception to this is the thin residual marl bed constituting the lowermost Danian bed in most localities (Hansen, 1977), which contains a significant amount of non-carbonate, has a distinct lower limit and, typically, grades upwards into pure carbonates.

STRATIGRAPHY

Being the type of the lower part of the Danian and - by implication - the termination of the Maastrichtian, the floral and faunal sequence at Stevns Klint should retain a central position in the development


Thetys
Gubbio
Nye Kløv
&
Kjølby Gård
Stevns
Klint
DANIAN
MAASTRICHTIAN
6 G. daubjergensis ✱
G. pseudobulloides ✱
5 X. rugulatum ✱
E. danica ssp. 1 ✱
B. sparsus ✱
4
D. mutabilis ✱
C. cornuta ✱
3 C. inornatum ✱
2 T. pelagica ✱
1 G. eugubina ✱
Pelagic chalk
Bryozoan chalk / limestone
Marl

of a coherent international biostratigraphic scheme to cover the Cretaceous/Tertiary boundary. Unfortunately the state of biostratigraphic resolution of the boundary strata in Denmark has been somewhat inadequate, but recent progress has been substantial, allowing a number of improvements in correlation. Thus, at Stevns Klint the Danian is initiated at the base of the thin marl layer (the Fish clay, see Surlyk, this volume) as is the case in most Danish boundary sequences (Hansen, 1979).

The development of the pelagic flora and fauna in particular has been investigated and, although correlation between the groups has not been fully tested, a provisional zonal scheme may be put forward to cover the Cretaceous/Tertiary boundary event in Denmark (Fig. 2). How much of this zonation has a more than basin-wide application remains to be tested, but a single, crucial question requires some comments.

In apparently continuous pelagic sequences in the Alpine region, Luterbacher & Premoli Silva (1964) and Premoli Silva (1977) defined the *'Globigerina' eugubina* Zone and claimed it to be the basal Danian zone. This dating of the *'G.' eugubina* Zone has been widely accepted, in particular in connection with the Deep Sea Drilling Project where, for instance, Premoli Silva & Bolli (1973), Boersma (1977) and Premoli Silva & Boersma (1977), and Thierstein & Berger (1978) use the first occurrence of *'G.' eugubina* as datum for the onset of the Danian.

In Denmark, Inger Bang (1979, Symposium Volume II, and personal communication) recently has found a planktic foraminiferal fauna (informally named the 'Lønnerup Assemblage') which she considers a lateral equivalent of the *'G.' eugubina* Zone. In Denmark, however, this 'Lønnerup Assemblage' has been identified also in the topmost, ammonite bearing Maastrichtian, below the marl at the boundary (*cf.* also Hofker, 1966b). Returning now to the Alpine sequences containing

Fig. 1. Bio- and lithostratigraphy in the type Danian at Stevns Klint and at Gubbio, Italy (*cf.* Arthur & Fischer, 1977) compared to the sequence in northwestern Jylland. The two Danish sequences are closely correlatable due to a high degree of biostratigraphic solution, whereas only two significant biostratigraphic events have so far been identified in the comparable part of the sequence at Gubbio. Datum levels: 1-2) First occurrence of *'Globigerina' eugubina* and *Thallasiphora pelagica*, 3) first occurrence of *Chiropteridium inornatum*, 4) first occurrence of *Carpatella cornuta*, *Biantolithus sparsus*, *Eoglobigerina danica* sp. 1, etc., 5) first occurrence of *Xenicodinium rugulatum*, 6) first occurrence of *Globoconusa daubjergensis* and *Globorotalia pseudobulloides*.

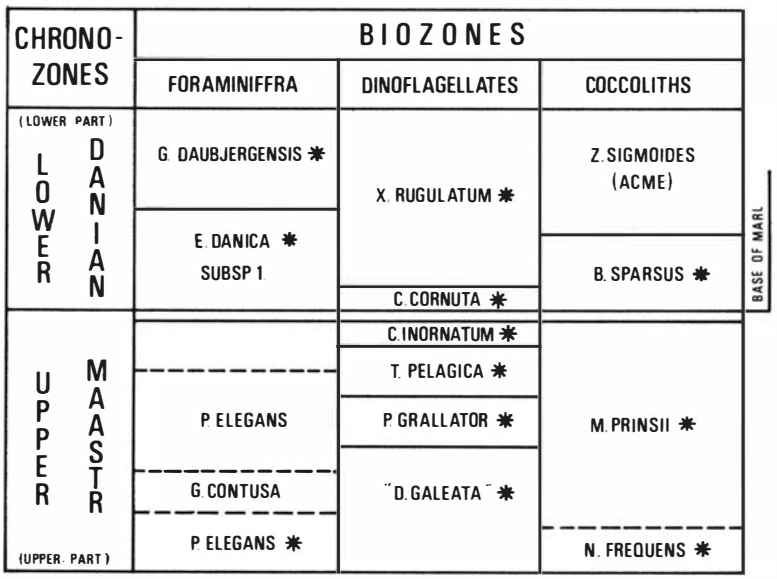


Fig. 2. Zonal scheme covering the Cretaceous/Tertiary boundary event in Denmark. The compilation is largely based on data from Troelsen (1955), Hansen (1977, 1979), Perch-Nielsen (this volume), and I. Bang (pers. comm. 1979).

the *'G.' eugubina* Zone it is striking to note that in both places the first occurrence of the fauna of the *'G.' eugubina* Zone is situated just below a marl (or shale) layer (Luterbacher & Premoli Silva, 1964, fig. 1; Arthur & Fisher, 1977, fig. 1) as is the case in Denmark. Comparable developments have apparently been recorded in at least the Atlantic Ocean where, for instance, a hiatus is present above the *'G.' eugubina* Zone at site 152 (Premoli Silva & Bolli, 1973), and a distinct marl is associated with this zone at site 356 (Perch-Nielsen, Supko *et al.*, 1977, p. 184).

Thus, based on the faunal development in the Danian type area, it seems fairly obvious to conclude that the *'G.' eugubina* fauna is at least partly of Maastrichtian age (*cf.* also Hofker, 1978). And as a direct result of this conclusion it becomes increasingly evident that the formation of a marl layer in the base of the type Danian is closely related to a single, world-wide event responsible also for the formation of the marl layers or hiati in the Alpine region and the deep oceans. This event then marks the Cretaceous/Tertiary boundary.

Tappan (1968) and Worsley (1971) proposed that fluctuations in the CCD were responsible for this world-wide interval of carbonate non-deposition

and laying down of residual marls. Much as we are in favour of this hypothesis, we feel it necessary to point out that subsequent attempts at confirming this notion through biostratigraphic dating of the event (Worsley, 1974) was less successful, in particular as regards Danish localities. Nevertheless, in view of the improved zonal scheme now available (Fig. 2), a correlation between the zonation in the Danish Basin and more fully oceanic sequences (here exemplified by Gubbio, Italy) may be attempted (Fig. 1), reassessing the biostratigraphic frame for the Worsley/Tappan notion.

BOUNDARY TYPES IN JYLLAND

Within the Danish Basin there is a great deal of variation in the detailed lithology in relation to the Maastrichtian/Danian boundary. Most notable in this respect is a seemingly regional trend from highly complex lithological developments in the type Danian at Stevns Klint to the almost continuous pelagic development in northern Jylland. In Jylland the outcrops containing the boundary strata may be arranged in three somewhat artificial groups according to their boundary development.

A number of outcrops encircling the halokinetically controlled, low Hanstholm dome (Fig. 3) exhibits the most complete, undisturbed sequence known in the basin (Håkansson & Hansen, 1977). In these outcrops the boundary is marked as a thin marl in an otherwise monotonous sequence of pelagic chalk. Local variations in the development of the marl layer are largely attributed to postdepositional movements in the dome where the marl acted as an internal smear surface. As indicated from the sedimentational monotony the dome was probably not activated until after the Cretaceous/Tertiary boundary event; and during the Holocene the elevation has been in the order of 5-10 m. Two small abandoned chalk pits from this area will be visited during the excursion: Nye Kløv and Kjølby Gaard.

The outcrop at Eerslev owes its particular development to a location on another halokinetically controlled structure, but in this case the outcrop is situated directly on top of a transpiercing diapir. The top Maastrichtian is developed as a comparatively thick hardground and no marl is found at this locality. Since the sequence is condensed and the boundary hiatus may be slightly longer than in neighbouring outcrops (Hansen, 1979) the Eerslev diapir was probably active some time close to the Cretaceous/Tertiary boundary event. Similar transpiercing structures are quite common in large parts of the North Sea Basin but, most likely, they will exhibit local deviations in their boundary development corresponding to differences in the periods of activity.

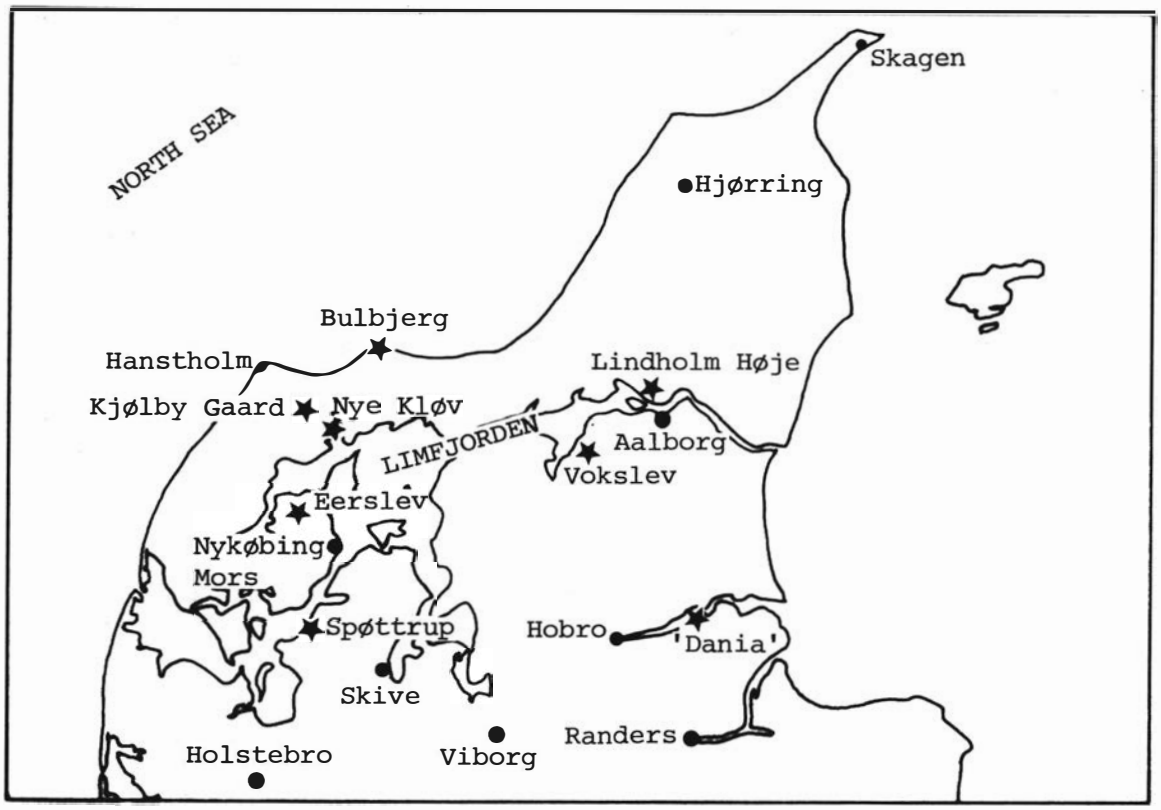


Fig. 3.

ROAD LOG - EXCURSION STOPS

1st day: Kjølby Gaard (M/D boundary)
Nye Kløv (M/D boundary)
Bulbjerg (Lower Danian bryozoan limestone with well developed bryozoan mounds)
Hanklit (Upper Paleocene-Lower Eocene diatomite with volcanic ash layers)
Eerslev (M/D boundary)

Night in Nykøbing Mors

2nd day: Spøttrup (Castle from the 14th century)
Vokslev (M/D boundary)
'Dania' (M/D boundary)
Lindholm Høje (Viking cemetery)

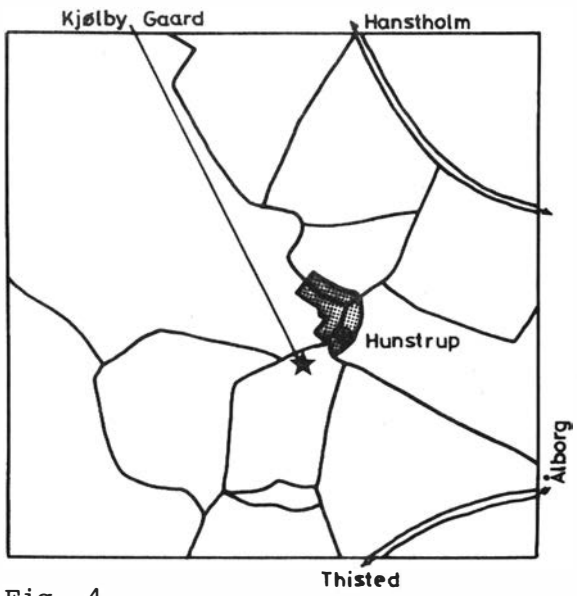


Fig. 4.

The last boundary type includes outcrops recording a depositional history intermediate between the outcrops in northwestern Jylland and the type Danian at Stevns Klint. In this type the boundary is associated with a thin marl interrupting a pelagic sequence, and the pelagic sediments are abruptly overlain by bryozoan limestone. Thus, at Vokslev the pelagic regime is terminated by a simple erosional phase in the early Danian, whereas at Dania the pelagic sedimentation was succeeded by the development of a complex hardground. Rather complicated structural patterns in the subsurface have recently been recorded in eastern Jylland, and perhaps the erosion and hardground formation affecting these areas in the early Danian may be associated with the development of highly localized inversion axes around active salt structures.

Kjølby Gaard

A small abandoned quarry in an old sea cliff c. 300 m west of the church in Hunstrup (Fig. 4).

The sequence at Kjølby Gaard is dominated by pelagic chalk with scattered flints and only at the extreme top does it approach a typical lower Danian bryozoan limestone (Fig. 5). Low in the section the Kjølby Gaard Marl (M 9; *cf.* Troelsen, 1955) exhibits a characteristic lithology with 'reverse' trace-fossils (i.e. white *Zoophycos* in the grey marl) which is found also in a number of marl layers in 'Dania'.

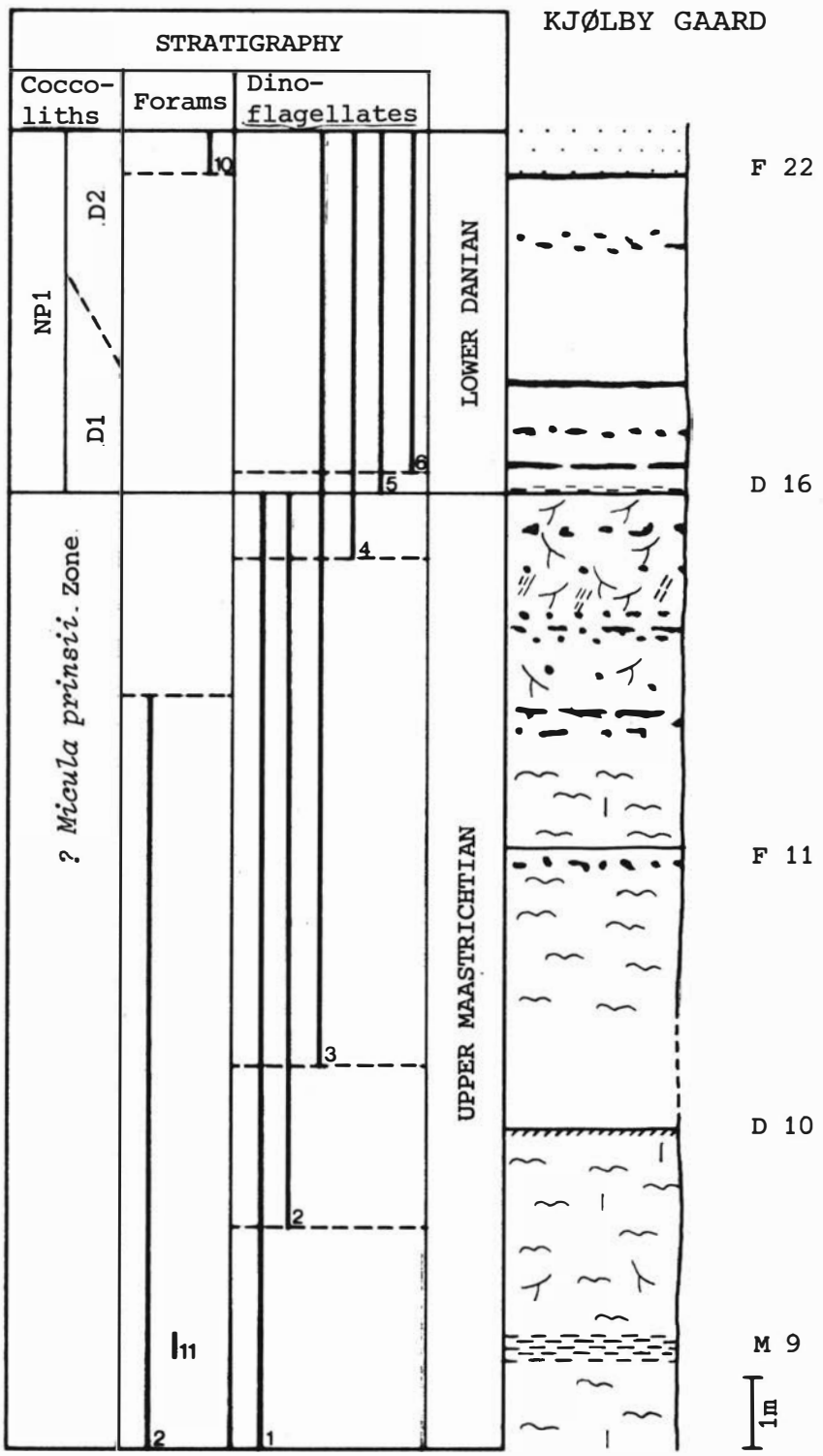
The basal Danian marl (M 17) has the appearence of a conglomerate with angular to rounded clasts of pelagic chalk. However, as the dinoflagellate flora of individual clasts prove a multiple origin from both below and above the marl itself, they have most likely been displaced at a later date as a result of halokinetic movements in the subsurface dome. In accordance with this the rocks between M 17 and F 18 appear distinctly brecciated.

Macrofossils are comparatively scarce throughout the sequence at Kjølby Gaard. In the Maastrichtian chalk ammonite moulds are fairly abundant, in particular in a level approximately 4 m below the boundary. Echinoids (including *Tylocidaris baltica*), bryozoans, and bivalves are also recorded from the Maastrichtian.

The stratigraphic columns compiled for this as well as the other localities include most of the available information about the planktic groups. The detailed coccolith zonation used here is discussed elsewhere (Perch-Nielsen, this volume). However, as in most localities, *Micula prinsii* itself has not been identified among the coccoliths from Kjølby Gaard. Through correlations it is believed, nevertheless, to have been originally a member of the pelagic flora in at least the higher parts of the Maastrichtian at Kjølby Gaard, in particular as preferential dissolution of certain species is known to be frequent in the top Maastrichtian chalk (Perch-Nielsen, 1973 and this volume). The foraminiferal zonation is still insufficiently developed and here is only indicated the distribution of a small number of species believed to be of stratigraphic significance. Noteworthy in particular in Kjølby Gaard is the occurrence of double keeled *Globotruncana* spp. (mostly *G. contusa*) in the Kjølby Gaard Marl (Troelsen, 1955). Finally the distribution of seven selected species of dinoflagellates defines the zonation developed by Hansen (1977, 1979).

Selected literature: Ødum (1926), Troelsen (1955), Perch-Nielsen (1969, 1973), Worsley (1974), Håkansson & Hansen (1977), Hansen (1977, 1979), Jørgensen (this volume).

Fig. 5. Kjølby Gaard. Lithological profile measured in 1975 by E. Håkansson and J.M. Hansen. Coccolith data provided by K. Perch-Nielsen (pers. comm. 1979); Foraminifera: 2) *Pseudotextularia elegans*, 11) *Globotruncana contusa*, 10) *Globoconusa daubjergensis* (data from Troelsen, 1955 and I. Bang, pers. comm. 1979); Dinoflagellates: 1) *Spiniferites ramosus cavispinosus*, 2) *Palynodinium grallator*, 3) *Thallasiphora pelagica*, 4) *Chiropteridium inornatum*, 5) *Danea mutabilis* and *Carpatella cornuta*, 6) *Xenicodinium rugulatum* (*cf.* Hansen 1977, 1979).


KJØLBY GAARD
STRATIGRAPHY
Cocco-liths
Forams
Dino-flagellates
NP1
D2
D1
? Micula prinsii. Zone
LOWER DANIAN
UPPER MAASTRICHTIAN
F 22
D 16
F 11
D 10
M 9
1m

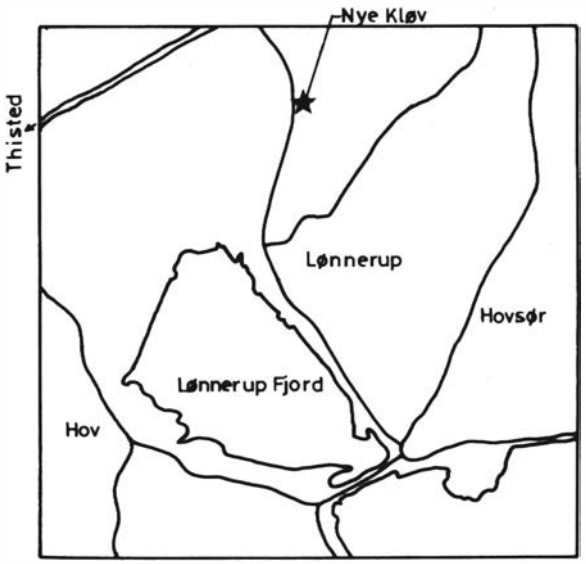


Fig. 6.

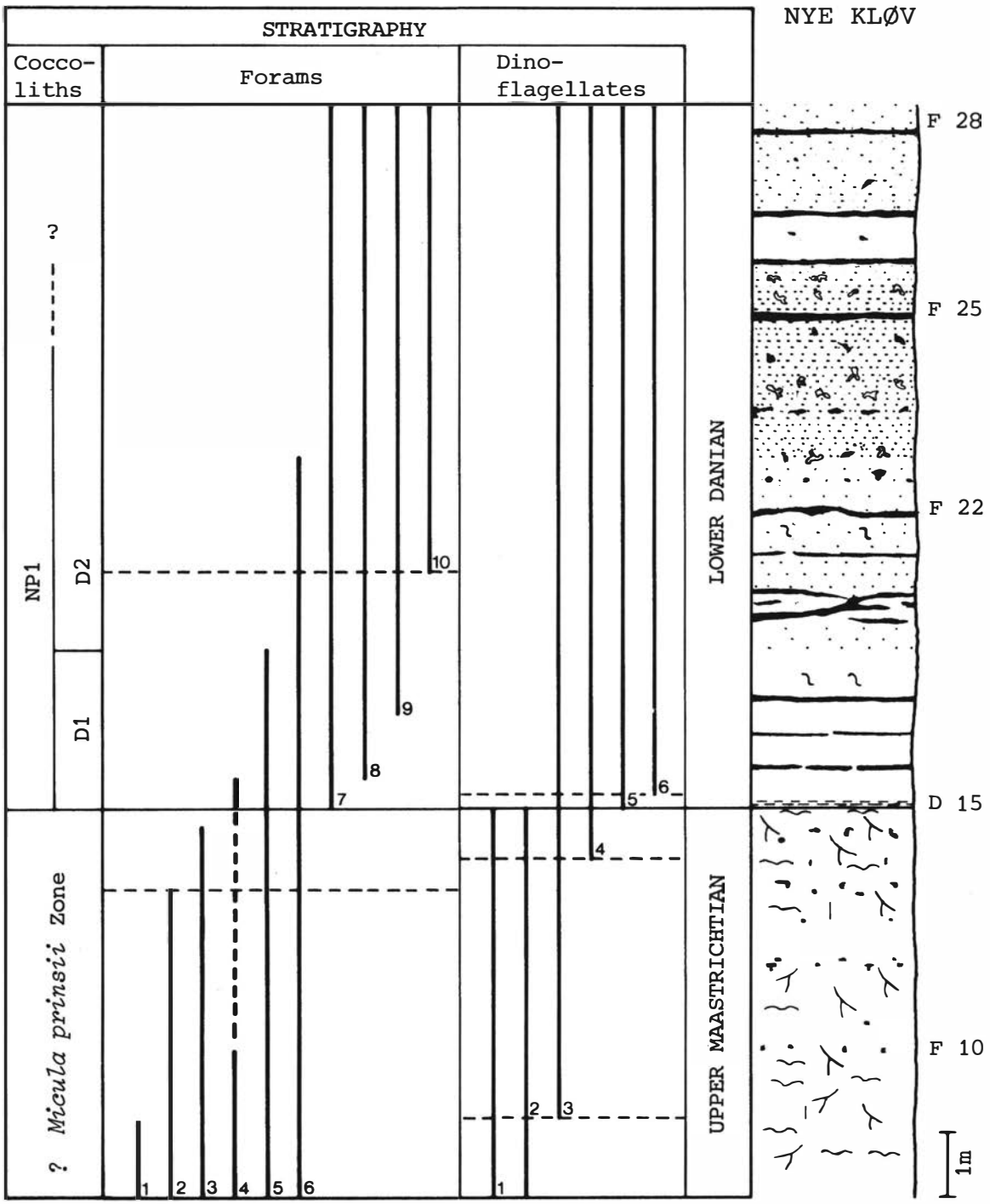
Nye Kløv

A small abandoned quarry in an old sea cliff facing the inner, drained parts of Lønnerup Fjord (Fig. 6).

The sequence at Nye Kløv compares closely with that of Kjølby Gaard, but, in addition, exhibits a more complete transition into bryozoan limestone in the lower Danian (Fig. 7). However, no bryozoan mounds are developed. In contrast to the sequence at Kjølby Gaard the basal Danian marl at Nye Kløv (M 16) appears largely undisturbed by later movements.

Apart from a significant bryozoan content in the higher parts of the Danian (*cf.* Håkansson & Thomsen, this volume) macrofossils are comparatively scarce in the rocks exposed at Nye Kløv. From the Maastrichtian chalk *Baculites* and *Inoceramus* may be emphasized, and in the Danian bryozoan limestone *Tylocidaris abildgaardi* occurs.

Fig. 7. Nye Kløv. Lithological profile measured in 1978 by E. Håkansson and J.M.Hansen. Coccolith data provided by K. Perch-Nielsen (pers. comm.) 1979); Foraminifera: 1) *Globotruncana arca*, 2) *Pseudotextularia elegans*, 3) *Globotruncanella petaloides*, 4) Elements of the 'Lønnerup Assemblage', 5) *Heterohelix* spp., *Hedbergella* spp., and *'Globigerinella' aspera*, 6) *Guembelitria* spp., 7) *Chiloguembelina* spp., 8) *Woodringina* sp., 9) *Eoglobigerina danica* s.l., 10) *Globoconusa daubjergensis* (data provided by I. Bang, pers. comm. 1979). Dinoflagellates: see Fig. 5.


STRATIGRAPHY
Cocco-liths
Forams
Dino-flagellates
NYE KLØV
NP1
D2
D1
?
LOWER DANIAN
UPPER MAASTRICHTIAN
? Micula prinsii Zone
F 28
F 25
F 22
D 15
F 10
1m
1
2
3
4
5
6
7
8
9
10

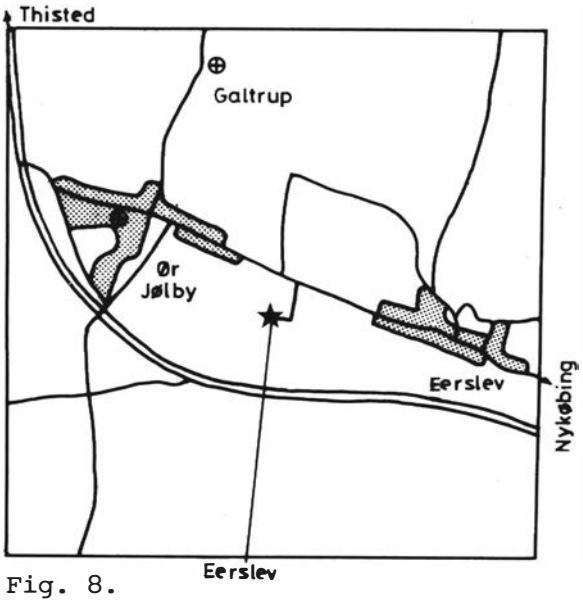


Fig. 8.

In addition to the general stratigraphic information the distribution of the planktic foraminifera in the sequence at Nye Kløv has been investigated more thoroughly than at other localities visited by the excursion. Note that a group of characteristic Maastrichtian forms (here united in column 5) have been extensively reworked into the basal Danian beds. This is true also for the coccoliths (Perch-Nielsen, this volume) and, typically, the lowermost meter or so of the Danian strata in northern Jylland is totally dominated by reworked Maastrichtian plankton. Interesting in this connection is the occurrence of species belonging to the 'Lønnerup Assemblage' (column 4) which show a similar distribution and, possibly, have also been reworked into the Danian (I. Bang, personal communication 1979).

Selected literature: Ødum (1926), Hansen (1979), Håkansson & Thomsen (this volume), Jørgensen (this volume).

Eerslev

In a group of abandoned chalk pits situated between the villages Øster Jølby and Eerslev (Fig. 8) a single section comprising the Maastrichtian/Danian boundary may still be visited. As a result of its position centrally on the Eerslev diapir this sequence deviates significantly from the remaining localities in Jylland, partly in the lack of a basal Danian marl and partly in the development of a hardground (Fig. 9). Additionally, the thin Danian sequence preserved below the Quaternary cover exhibits bryozoan limestone developed directly on top of this hardground.

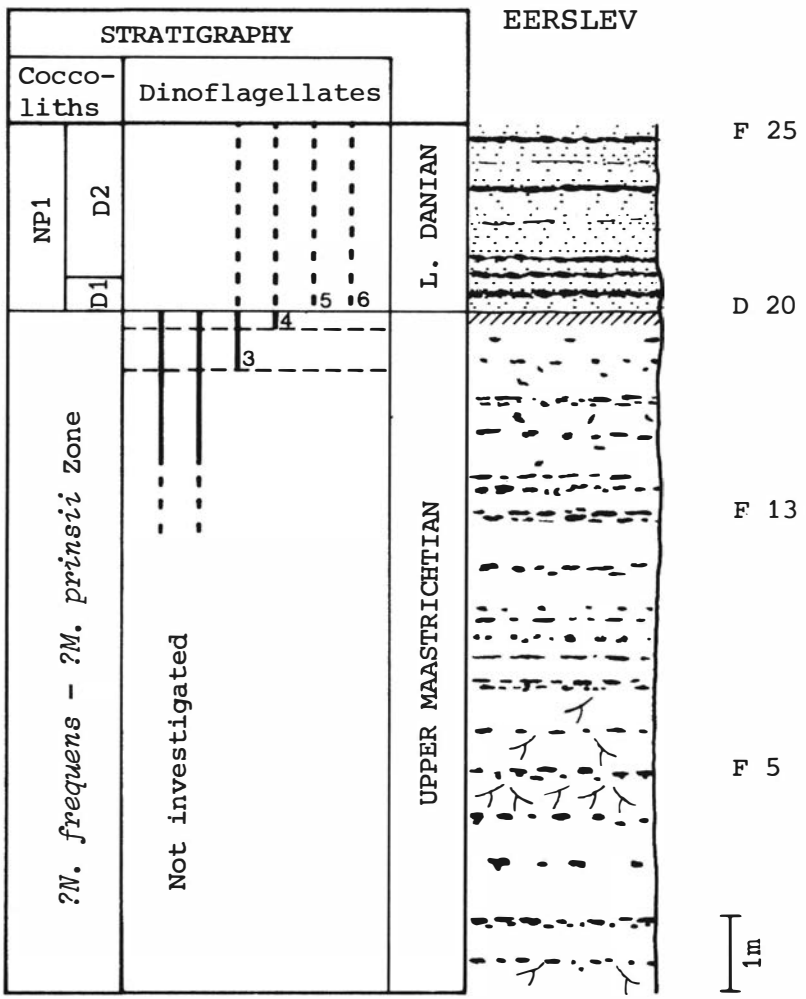


Fig. 9. Eerslev. Lithological profile measured in 1972 by F. Surlyk. Coccolith data provided by K. Perch-Nielsen (pers. comm. 1979). Dinoflagellates: see Fig. 5 (note that no dinoflagellates are preserved in the Danian part of the sequence).

The macrofauna from Eerslev is scarce, and from the Maastrichtian may be mentioned ammonites, echinoids (including *Tylocidaris baltica*) as well as bryozoans.

From the distributional data of the planktic biota it appears that the sequence at Eerslev, in spite of the lithological differences, is almost as complete as in other parts of northern Jylland. However,

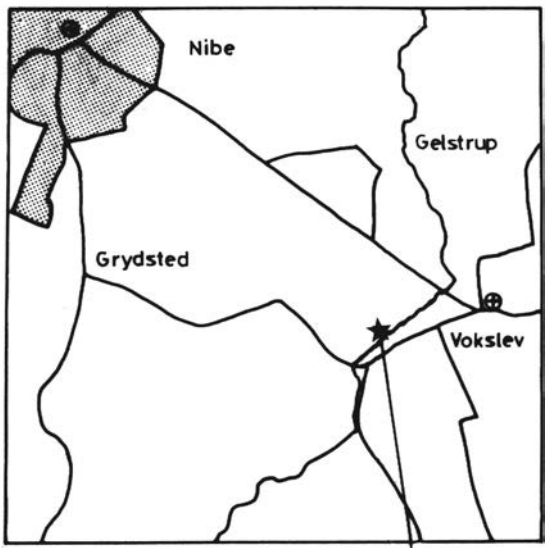


Fig. 10.

the sequence is obviously condensed, probably reflecting synsedimentary activity in the underlying Eerslev diapir.

Selected literature: Ødum (1926), Håkansson *et al.* (1974), Hansen (1977, 1979), Jørgensen (this volume).

Vokslev

The Cretaceous/Tertiary boundary at Vokslev was investigated early in the century (Jessen & Ødum, 1923) in an erosional slope made by a small stream just outside the village Vokslev (Fig. 10). Until very recently it has not been accessible.

By comparison with the boundary sequence in 'Dania' it appears reasonable to expect the sequence at Vokslev to contain an almost complete record across the boundary (Fig. 11). In contrast to 'Dania' no hardground formation seems to be associated with the termination of the pelagic chalk regime. An apparently abrupt change from pelagic chalk to bryozoan limestone is recorded across a massive flint (F 10) which possibly conceals a simple erosional surface.

The Maastrichtian macrofauna at Vokslev is somewhat richer than in northwestern Jylland, and *Baculites*, bryozoans and fairly abundant echinoids (including *Tylocidaris baltica*) may be mentioned. While the Danian pelagic chalk is poor in macrofossils the bryozoan limestone (mostly visible in a nearby quarry) contains the macrofauna typical of

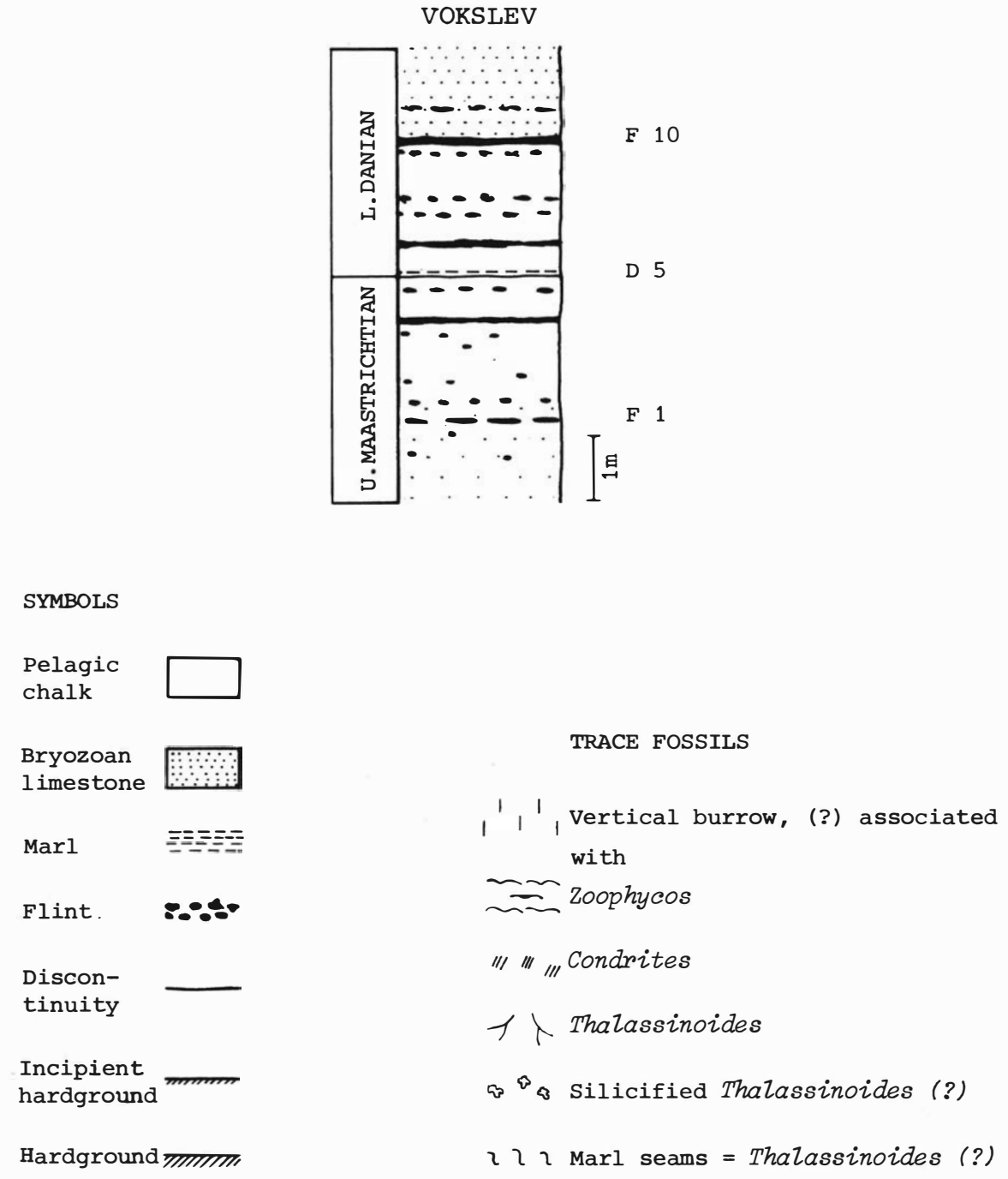


Fig. 11. Vokslev. Lithological profile measured in 1979 by E. Thomsen, C. Heinberg, and E. Håkansson.

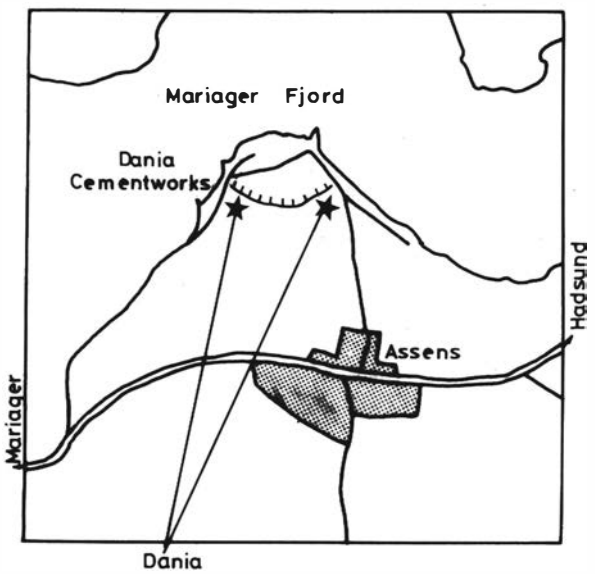


Fig. 12.

this sediment with echinoids, brachiopods and bivalves in addition to the dominating bryozoans.

Selected literature: Jessen & Ødum (1923), Ødum (1926).

'Dania'

In a very long, at present abandoned wall in the quarry of the 'Dania' cement work (Fig. 12) is exposed a series of more than 30 m of carbonate rocks spanning the Maastrichtian/Danian boundary (Fig. 13).

The Maastrichtian chalk at 'Dania' is exceptionally rich in marly horizons corresponding in lithology to the Kjølby Gaard Marl (*cf.* Troelsen, 1955). The basal Danian marl may be divided into a lower conglomeratic unit (M 29) and an upper more uniform unit gradually changing into a pure pelagic chalk. Upwards this pelagic sequence is developed into a thick hardground terminated by an erosional surface (D 31). In the hardground is found rounded, hard clasts of chalk and rolled glauconitised fossils testifying to a complex depositional history involving at least two episodes of cementation and erosion. The remaining Danian strata are developed as bryozoan limestones, but in spite of the sometimes very high bryozoan content no mounds have been developed.

Macrofossils are fairly abundant at most levels in 'Dania'. The Maastrichtian pelagic chalk in particular contains a highly diverse

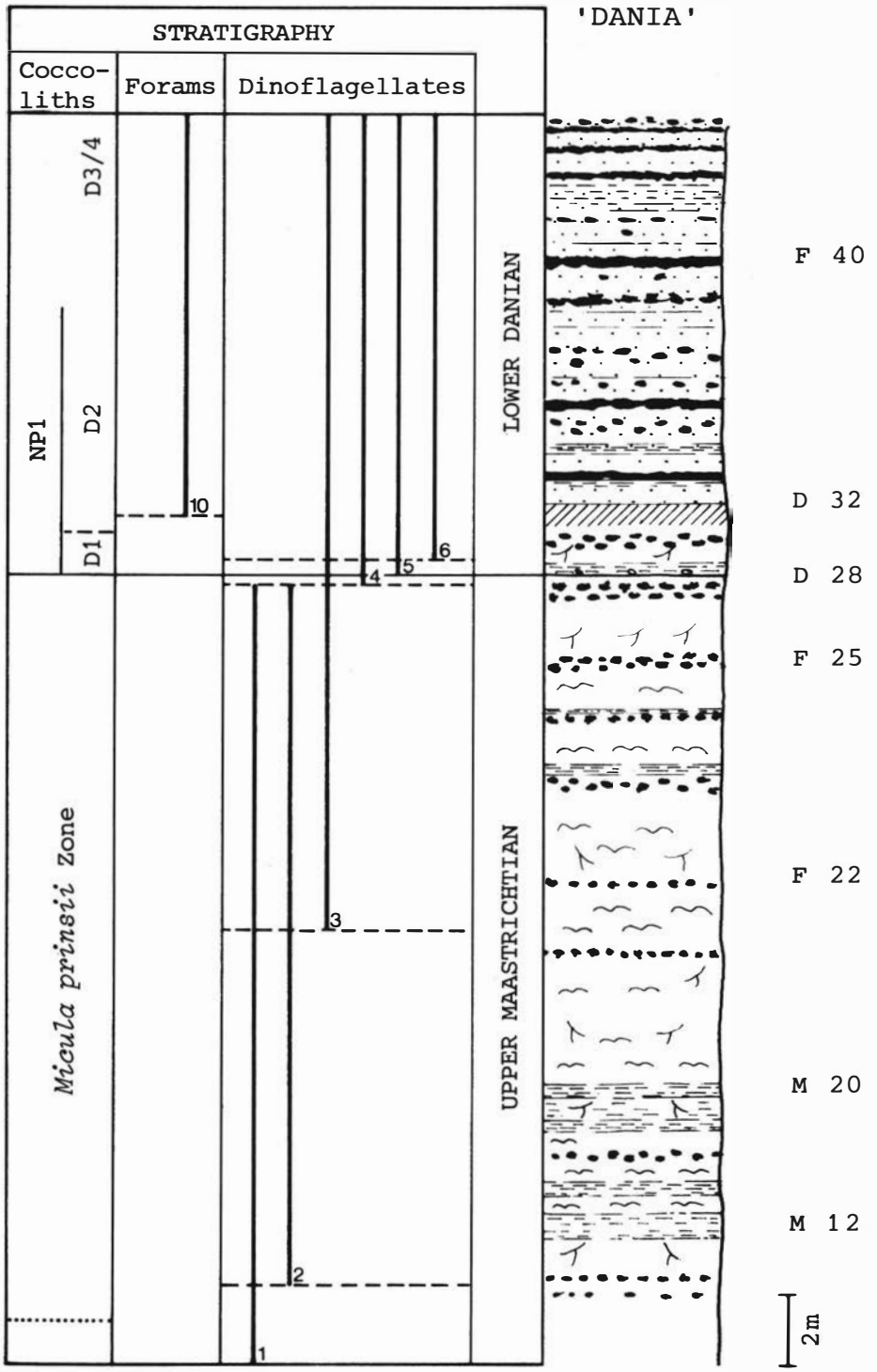


Fig. 13. 'Dania'. Lithological profile measured in 1972 by F. Surlyk and E. Håkansson. Coccolith data provided by K. Perch-Nielsen (pers. comm. 1979); Foraminifera: 10) *Globoconusa daubjergensis* (data provided by I. Bang, pers. comm. 1979); Dinoflagellates: see Fig. 5.

fauna including several ammonite species, belemnites, echinoids (including *Tylocidaris baltica*), bivalves, brachiopods, bryozoans, etc. In the Danian pelagic chalk a single echinoid species is the only abundant form, whereas in the bryozoan limestone the diversity rises again, and from here *T. abildgaardi* may be mentioned.

The sequence at 'Dania' is unique among Danish boundary sequences by containing the topmost Maastrichtian zonal species *Micula prinsii*. However, as it has only been recorded from one of the marl layers low in the sequence (Perch-Nielsen, pers. comm. 1979), *M. prinsii* has probably suffered almost as severe dissolution here as in other Danish top Maastrichtian sequences. The isolated occurrence in 'Dania' agrees well with the unusually high standard of preservation noted earlier for this locality (Perch-Nielsen, 1973).

The stratigraphic distribution of the dinoflagellates in 'Dania' suggests that accumulation of pelagic mud during the Maastrichtian has been almost twice as high here as compared to other localities. This is interpreted as a strictly local phenomenon, related to synsedimentary structural developments in the subsurface.

Selected literature: Troelsen (1955), Perch-Nielsen (1969, 1973), Håkansson *et al.* (1974), Worsley (1974) Jørgensen (1975), Hansen (1977, 1979), Jørgensen (this volume).