A new dinoflagellate zone at the Maastrichtian/Danian boundary in Denmark

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A new dinoflagellate zone, the *Chiropteridium inornatum-Palynodinium grallator* Concurrent Range Zone, is added to a previously established biozonation. The zone is restricted to the uppermost c. 0.5 m of the Maastrichtian chalk in northwestern Denmark. The biostratigraphical events at the Maastrichtian/Danian boundary is discussed and documented with examples from the sections at Kjølby Gård, Nye Kløv, Bjerre, Eerslev and Dania.

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In 1977 a dinoflagellate stratigraphy for the Upper Maastrichtian and Danian of Danmark was proposed. This zonation includes 3 Upper Maastrichtian and 4 Danian biostratigraphical units (Hansen 1977). The possibility to establish one further zone immediately below the boundary was mentioned, since at Kjølby Gård (fig. 1) *Chiropteridium inornatum* Drugg 1970 was found to occur already below the Maastrichtian/Danian boundary whereas at other localities investigated (Stevns Klint, Copenhagen core TUBA 13) *C. inornatum* occurred only above the boundary together with other characteristical dinoflagellate species such as *Danea mutabilis* Morgenroth 1968, *Carpatella cornuta* Grigorovitch 1969, *Membranilarnacia tenella* Morgenroth 1968, and *Hafniasphaera hyalospinosa* Hansen 1977. This biostratigraphical differential development of the Maastrichtian/Danian boundary in Denmark was believed to reflect a more complete development of the boundary in northwestern Denmark compared to the type area of the Danian in eastern Denmark.

Since much interest is attributed to the biostratigraphy of the Mesozoic/Cainozoic boundary and therefore especially to the Maastrichtian/Danian boundary in Denmark, the level of first occurrence of *Chiropteridium inornatum* has been further investigated at various localities in northwestern Denmark. Thus close sampling of the Maastrichtian/Danian boundary sections at Nye Kløv, Kjølby Gård, Bjerre, Eerslev and Dania (fig. 1) has been done. All of these sections showed that *Chiropteridium inornatum* occur below the first occurrence of *Car-*

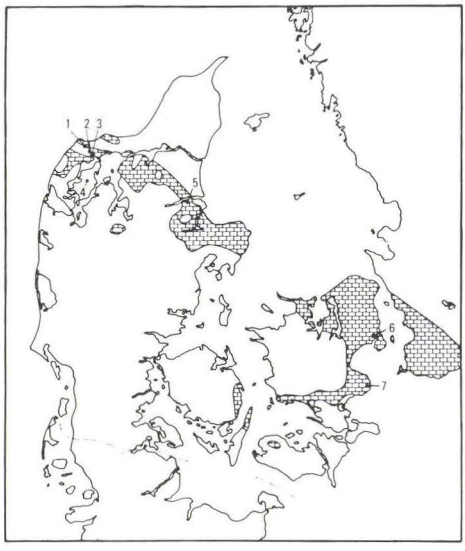

Fig. 1 Geological map of the Danian showing position of localities. 1: Bjerre. 2: Kjølby Gård. 3: Nye Kløv. 4: Eerslev. 5: Dania. 6: Copenhagen TUBA 13. 7: Stevns Klint.

patella cornuta, Danea mutabilis, and *Membranilarnacia tenella* and below the disappearance of *Palynodinium grallator* Gocht 1970 and *Spiniferites ramosus cavispinosus* Hansen 1977.

In fig. 2 the stratigraphical occurrence of biostratigraphically diagnostic dinoflagellates is presented. It is seen that some diagnostic Danian species occur at all localities, whereas *Hafniasphaera hyalospinosa* is only found at the easternmost localities. On the basis of these observations 5 biostratigraphical events may be defined to establish a basis for a discussion of the chronostratigraphical value of these events:

1). First occurrence of *Palynodinium grallator.*
2). First occurrence of *Thalassiphora pelagica.*
3). First occurrence of *Chriropteridium inornatum.*
4). First occurrence of *Membranilarnacia tenella, Carpatella cornuta, Danea mutabilis* and disappearance of *Palynodinium grallator* and *Spiniferites ramosus cavispinosus.*
5). First occurrence of *Xenicodinium rugulatum.*

At the localities Kjølby Gård, Nye Kløv, Bjerre, Dania and Eerslev these events take place in the same order whereas at Stevns Klint and in Copenhaven core TUBA 13 events 3) and 4) are confluent. This differential development of the biostratigraphy can be explained in two basically different ways: sediments con-

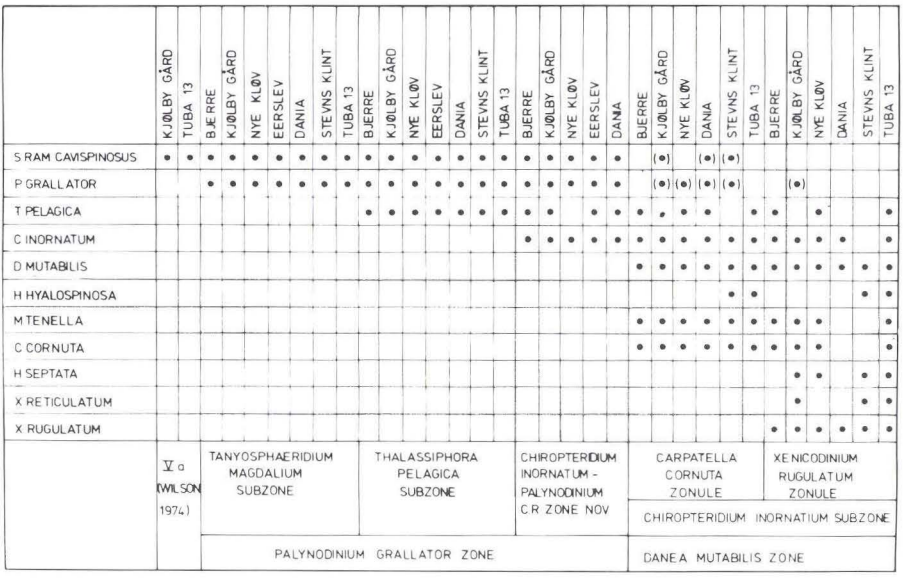

Fig. 2 Scheme showing the occurrences of some stratigraphycally significant species at different localities and at different stratigraphical levels. Brackets indicate occurrences of specimens, that are belived to be reworked.

taining event 3) may be missing at the easternmost localities, or event 4) could be palaeoenvironmentally controlled.

The fact that event 4) including not less than 3 first occurrences and 2 disappearances at most localities take place at the base of a marl layer containing clasts of Upper Maastrichtian age indicates that a part of the section is missing. However, in Stevns Klint the clasts are rounded giving the marl layer a conglomeratic appearance whereas at Kjølby Gård and Dania the clasts are angular giving the marl layer as well as the superposing sediment in Kjølby Gård a brecciated appearance. Furthermore, the clasts in Kjølby Gård are derived from both sediments older than event 4) and younger than event 5) whereas in Stevns Klint all clasts are older than event 4). The section at Kjølby Gård as well as the section at Eerslev, where the marl layer is missing, are situated above halokinetically induced structures elevating Mesozoic and Tertiary strata (cf. Rasmussen 1978). This deformation of the strata combined with the different competance of the flint-poor Maastrichtian chalk and of the flint-rich Danian chalk and bryozoan limestones could easily explain the brecciation of the Maastrichtian/Danian boundary strata at Kjølby Gård whereas at Stevns Klint the clasts more likely have been formed during the long durated (cf. Hansen 1977 for discussion) accumulation of the marl layer. Therefore, it may be concluded that the sedimentological develop-

ment of the boundary strata indicates a hiatus at Stevns Klint and Eerslev whereas incomplete preservation of the boundary strata at other localities could partly be explained by post-sedimentary deformation and solution. In addition to this point of view hardgrounds in contact with the Maastrichtian/Danian boundary are clearly developed only at Stevns Klint and Eerslev.

On the other hand, if the differential biostratigraphical development of the Maastrichtian/Danian boundary is only palaeoenvironmentally controlled, the first occurrence of all diagnostic species should be related to lithological changes. However, *Chiropteridium inornatum* occurs below the marl layer in northwestern Denmark but in the marl layer in eastern Denmark together with diagnostic Danian species. This confluence of two biostratigraphical events in eastern Denmark could easily be explained by a small hiatus below the Maastrichtian/Danian boundary. Palaeoenvironmentally controlled differences are more likely to be reflected in the relative abundance of certain species. Thus *Hafniasphaera hyalospinosa* has not been found at all in northwestern Denmark whereas it is abundant in eastern Denmark. A similar pattern is observed with respect to the species *Carpatella cornuta* and *Membranilarnacia tenella* which are most frequent in northwestern Denmark.

Systematic biostratigraphy

Chiropteridium inornatum – Palynodinium grallator Concurrent Range Zone nov.
Definition: Sediments containing both *Chiropteridium inornatum* Drugg 1970 or *Spiniferites ramousus cavispinosus* Hansen 1977 but excluding sediments containing *Carpatella cornuta* Grigorovitch 1969, *Danea mutabilis* Morgenroth 1968, or *Membranilarnacia tenella* Morgenroth 1968.

Stratigraphical range: Upper part of the Upper Maastrichtian *Thalassiphora pelagica* Subzone which constitutes the upper part of the Upper Maastrichtian *Palynodinium grallator* Zone (Hansen 1977).

Reference section: Kjølby Gård; upper c. 0.5 of the Withe Chalk until the base of marl layer (cf. fig. 3).

Correlations: This zone is equivalent with the youngest ammonite-bearing strata in Denmark, since *Baculites* sp. has been found up to the top of the zone and never above.

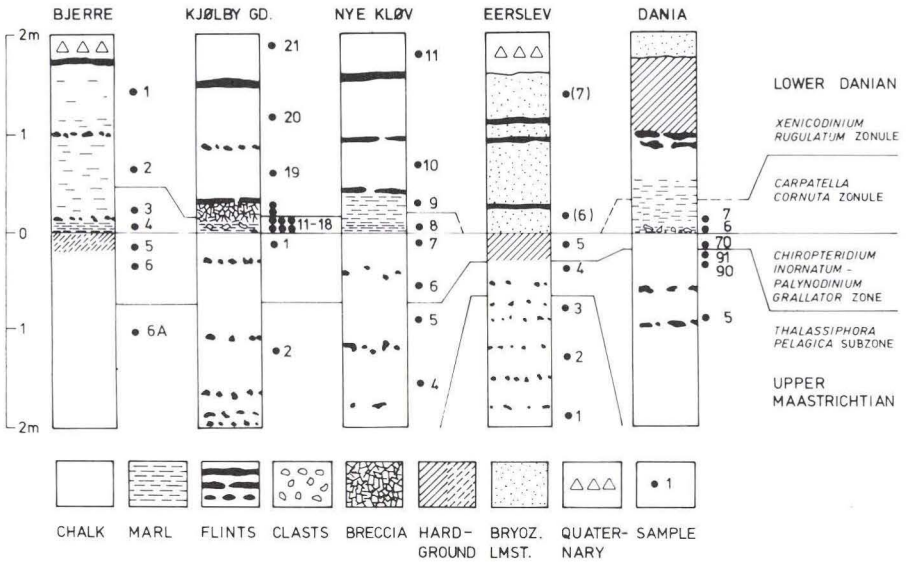

Fig. 3 Lithological sections of the upper 2 m of the Maastrichtian and the lower 2 m of the Danian in northwestern Denmark. Dinoflagellate zonation and position of samples indicated. Brackets indicate samples without dinoflagellates.

Remarks: This zone comprises c. 0.5 m at Kjølby Gård, c. 0.7 m at Nye Kløv, c. 0.28 m at Dania c. 0.7 m at Bjerre and 0.2 m at Eerslev. I tseems to be absent in Stevns Klint and Copenhagen core TUBA 13.

Conclusions

The dinoflagellate stratigraphy established across the Maastrichtian/Danian boundary in Denmark yields a very detailed biostratigraphical resolution of the boundary strata (fig. 3). Furthermore, several diagnostic dinoflagellates including *Carpatella cornuta, Danea mutabilis* and *Chiropteridiun inornatum* have been reported from especially North America (Drugg 1967 and 1970, Evitt 1973) and Europe (Grigorovitch 1969, Jan du Chêne 1977). Consequently, the stratigraphical scheme presented here may prove to be an effective tool in the paleontological dissection of the Cretaceous/Tertiary boundary.

Although it is not the objective of the present study to carry out a revision of the taxa involved, it should be mentioned that some taxonomical problems remain unsolved corcerning the species *Carpatella cornuta, Danea mutabilis* and *Chiropteridium inornatum*. In the concept of the present author *Carpatella cornuta* Grigorovitch 1969 compares well with parts of the type material of

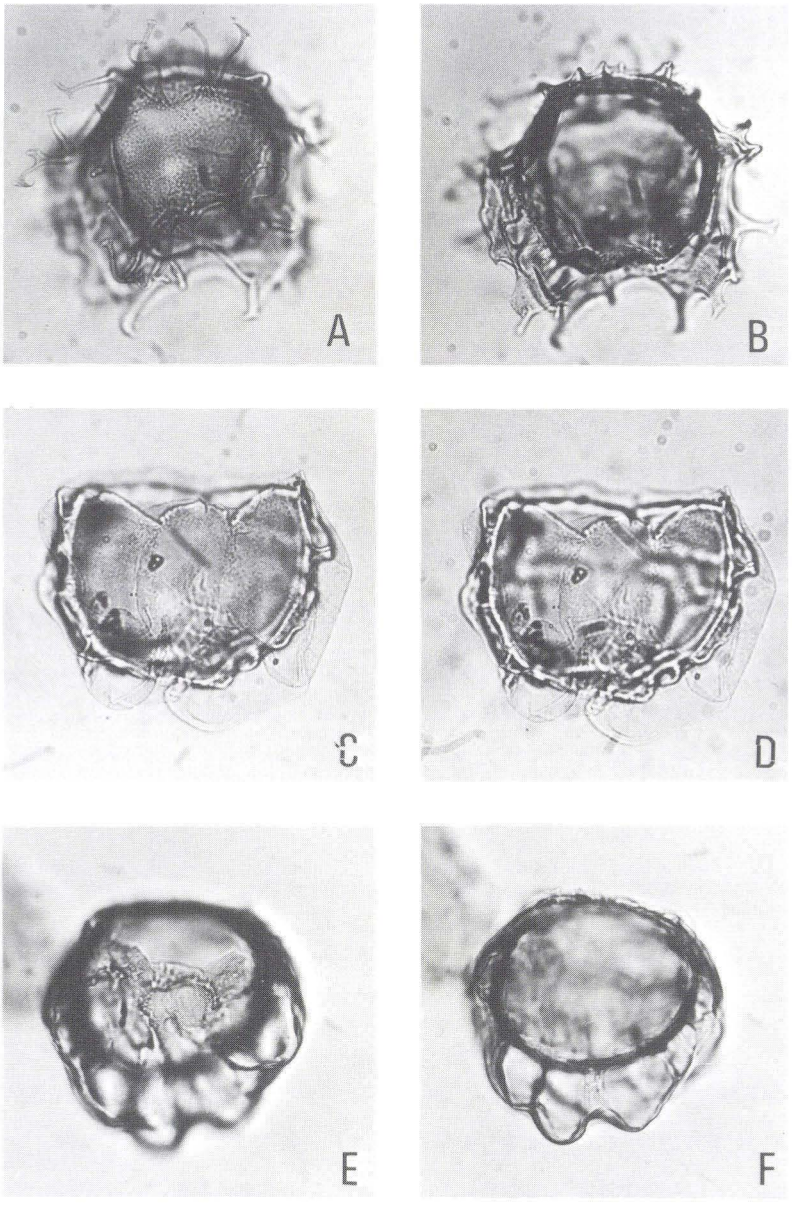

Fig. 4 All figures 500 X. A: *Palynodonium grallator*, high focus, Dania 70, 2:26.1-106.6. B: *Palynodinium grallator,* low focus, same as A. C: *Chiropteridium inornatum,* high focus, Nye Kløv 10, 1:23,0-104.4 D: *Chiropteridium inornatum,* low focus, same as C. E: *Chiropteridium inornatum,* high focus, Dania 70,2:46.2-103.9. F: *Chiropteridium inornatum,* low focus, same as E.

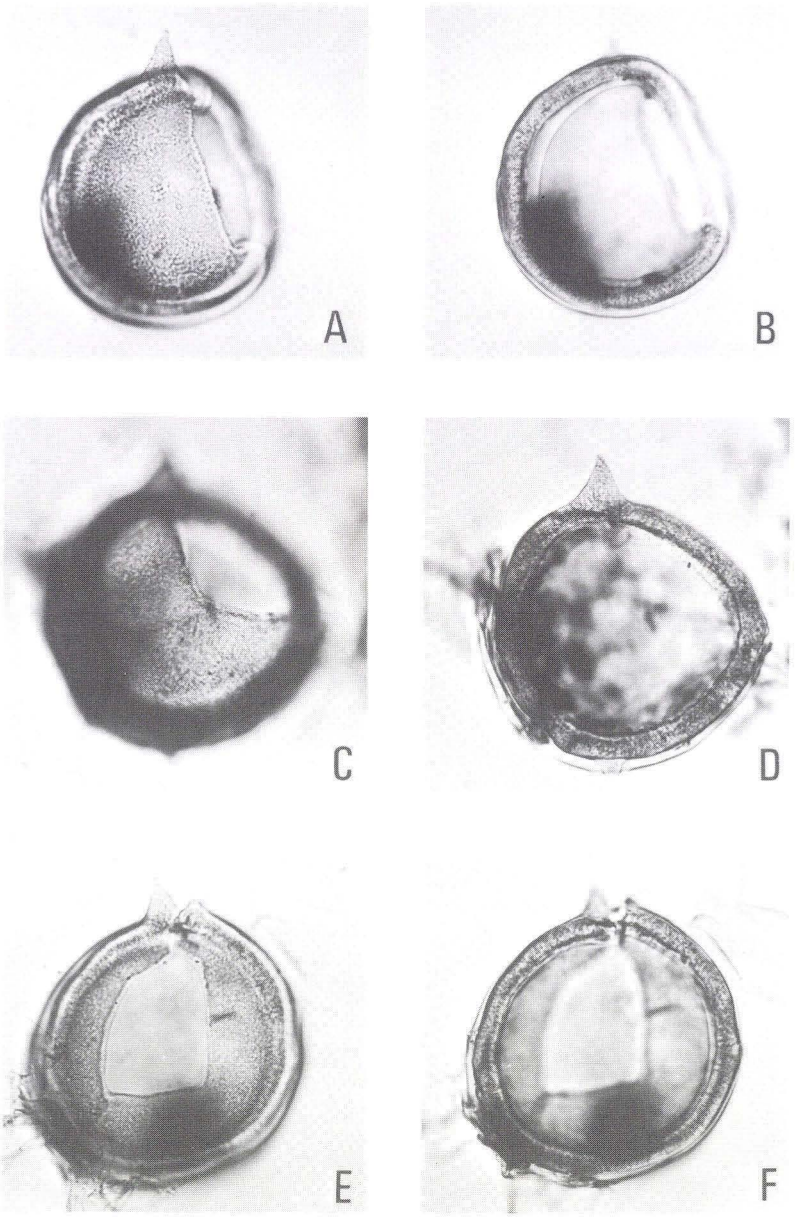

Fig. 5 All figures 500 X. A: *Carpatella cornuta*, high focus, Bjerre 2,3:22.2-101.5 B: Carpatella cornuta, low focus, same as A. C: *Carpatella cornuta,* high focus, Bjerre 2,3:51.9-107.2 D: *Carpatella cornuta,* low focus, same as C. E: *Carpatella cornuta,* high focus, Bjerre 2,2:44.5-97.2 F: *Carpatella cornuta*, low focus, same as E.

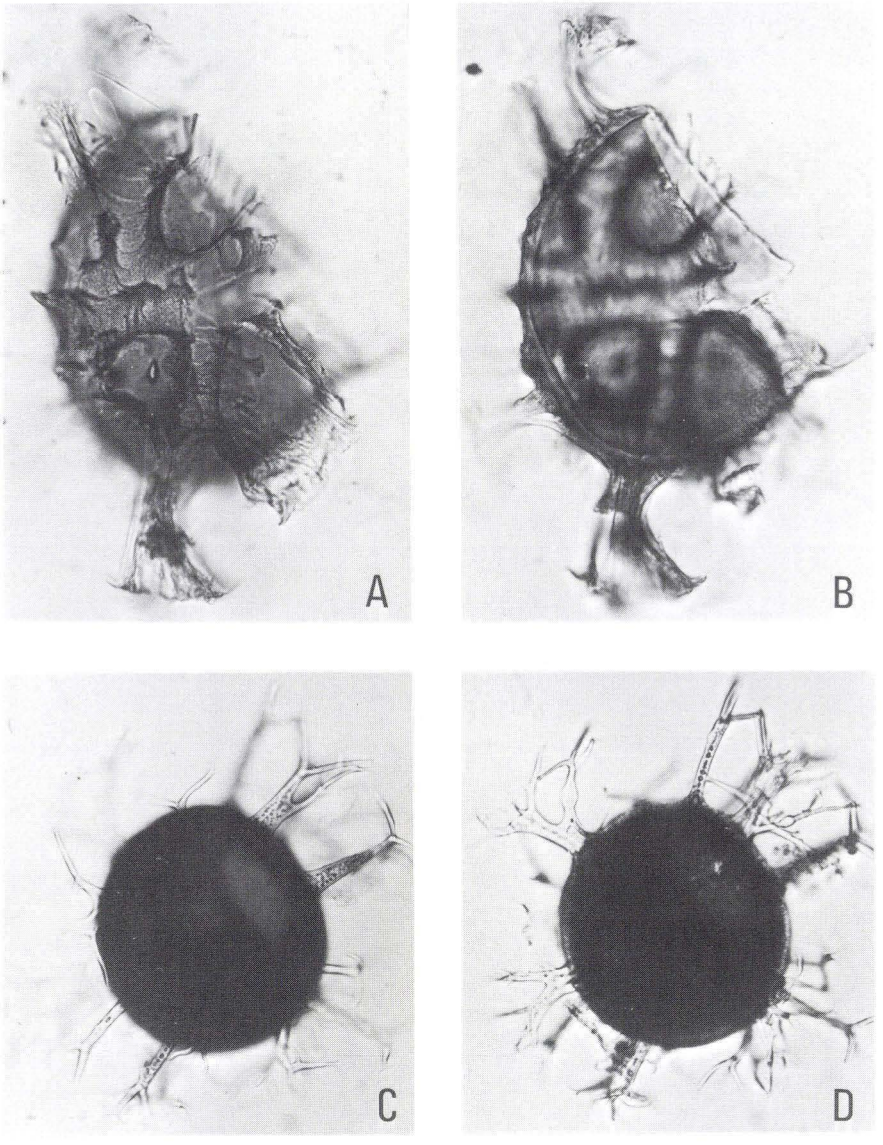

Fig. 6 All figures 500 X. A: *Danea mutabilis,* high focus, Copenhagen TUBA 13, MGUH 13966. B: *Danea mutabilis,* low focus, same as A. C: *Hafniasphaera hyalospinosa,* high focus, Copenhagen TUBA 13, A1:13093. D: *Hafniasphaera hyalospinosa,* low focus, same as C.

Danea mutabilis Morgenroth 1968 (pl. 44, fig. 1-3, *non* pl. 43, figs. 5-9). *Danea mutabilis* (Morgenroth 1968, pl. 43, figs. 5-9) on the other hand compares well with *Palmnickia californica* Drugg 1967, which thus seems to be a *senior synonym* of *Danea mutabilis*. Drugg (pers. comm. 1974) agrees with this point of view. *Chiropteridium inornatum* Drugg 1970 compares well with parts of the type material of *Rhenidinium membraniferum* Morgenroth 1968 (pl. 47, fig. 2, *non* pl. 47, fig. 1). However, to prevent stratigraphical confusion, and revision of the stratigraphical names, the well-known names are maintained provisionally.

Dinoflagellate list

The 40 most abundant dinoflagellates from the Maastrichtian/Danian boundary sections at Bjerre, Kjølby Gård, Nye Kløv and Eerslev are listed below. The letters 'M' and 'D' indicate that the species has been found in Maastrichtian and Danian sediments, respectively.

Achomosphaera ramulifera, M+D.
Achomosphaera sagena, M.
Amphidiadema rectangularis, M.
Cannosphaeropsis utinensis, D.
Carpatella cornuta, D.
Areoligera spp., M+D.
Catillopsis sp., D.
Cordosphaeridium inodes, M+D.
Chiropteridium inornatum, M+D.
Cyclonephelium spp., M+D.
Danea mutabilis, D.
Deflandrea diebeli, M.
Deflandrea galeata, M.
Eisenackia circumtabulata, D.
Fibradinium annetorpense, D.
Gonyaulacysta wetzeli, M+D.
Hafniasphaera septata, D.
Hafniasphaera sp., M.
Hexagonifera chlamydata, M.
Hystrichokolpoma bulbosa, M+D.
Hystrichokolpoma fimbriata, D.
Hystrichosphaeridium recurvatum, M+D.
Hystrichosphaeridium tubiferum, M+D.
Lanternosphaeridium axiale, M+D.
Lanternosphaeridium ovale, M+D.
Membranilarnacia tenella, D.
Palaeocystodinium sp., M.
Palaeoperidinium pyrophorum, M+D.
Palynodinium grallator, M.
Pyxidiella sp., D.
Rhenidinium membraniferum, D.
Spiniferites ramosus cavispinosus, M.
Spiniferites ramosus granosus, M+D.
Spiniferites ramosus ramosus, M+D.
Spiniferites cf. cornutus, M+D.
Spongodinium delitiense, D.
Tanyosphaeridium magdalium, M+D.
Thalassiphora pelagica, M+D.
Trithyrodinium sp., M.
Xenicodinium rugulatum, D.

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