

Palynological evidence for a diachronous low-salinity event in the C–T boundary clay at Stevns Klint, Denmark

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ABSTRACT—The frequency distribution of dinoflagellate cysts, miospores, and freshwater algae has been studied in 70 samples from the Fish Clay at Stevns Klint, eastern Denmark. The palynological assemblages change both vertically and laterally. The vertical change is from a strictly marine assemblage in the Cretaceous chalk to a freshwater or brackish assemblage in the Fish Clay. The lateral change indicates that the Fish Clay was deposited diachronously, even within the limited geographical area covered by the Stevns Klint section.

INTRODUCTION

The Fish Clay was labelled as Danian by Rosenkrantz (1966). It is a marl layer, stratigraphically located (by definition) at the boundary between the Cretaceous and the Tertiary. The Fish Clay at Stevns Klint can be subdivided into four thin subunits (Christensen *et al.*, 1973).

The Fish Clay at Stevns Klint has been the subject of many investigations, especially in recent years. Alvarez *et al.* (1980, 1982, 1984a, 1984b) used the Fish Clay at Stevns Klint as one example in a set of iridium concentration peaks in Cretaceous–Tertiary boundary layers. They suggested that this peak in iridium concentration may have been caused by the impact of an extraterrestrial body. This extraterrestrial impact hypothesis has gained much publicity as the explanation for the presumed rapid extinctions of various plant and animal taxa at the C–T boundary.

The hypothesis of an extraterrestrial impact at the C–T boundary is dependent on the assumption of world-wide time-synchronicity between the different localities, containing iridium concentration peaks. This assumption, however, has been seriously questioned by, amongst others, Officer and Drake, (1983, 1985). The use of the Danish Fish Clay as evidence for an extraterrestrial impact has been questioned by Hultberg (1985). He suggested, on the basis of dinoflagellate biostratigraphy, that the deposition of the Fish Clay at Stevns Klint took place several hundred thousand years earlier than the deposition of the C–T boundary clay at Nye Kløv and Kjølbj Gaard, western Denmark. This diachroneity raised the question of whether or not the Fish Clay was actually time-synchronous at different localities along the Stevns Klint.

The purpose of the present study was to investigate, by means of dinoflagellate analysis, the time-relationships of the Fish Clay within the Stevns Klint section, and to study, in detail, the changes in depositional environment during the formation of this layer at Stevns Klint.

MATERIAL AND METHODS

Seventy samples of the Fish Clay were collected from ten different localities in a traverse along Stevns Klint. The average distance between the sample localities was 1 km. The four different layers of the Fish Clay were collected separately at each locality. Great care was taken to avoid sampling the abundant chondrites that penetrate the Fish Clay. These chondrites contain an assemblage that differs significantly from the matrix of the clay (Hansen, pers. comm.).

All samples were weighed and submitted to standard palynological preparation techniques, but were not oxidised, in order to preserve, as much as possible, the flora of freshwater algae that is present in these samples. The residue was split into two parts. One part was sieved at a mesh size of 20 μm , and mounted on slides, using glycerole jelly as a mounting medium. The other part was mounted on slides without any further treatment, in order to preserve all organic residue for paleoenvironmental analysis.

A count of 300 dinoflagellate specimens was made for each sample, and relative abundances (percentages) were computed for each taxon.

The abundance of pollen and spores was computed in relation to the dinocysts, to give a dinocyst/spore-pollen ratio.

The absolute abundance of fresh-water algae was computed in all samples. This was done by adding a known amount of *Lycopodium* spores before preparation; the abundances were then computed through the relation between recovered *Lycopodium* spores and freshwater algae.

The gonyaulacacean ratio, defined as the ratio between gonyaulacacean and peridiniacean dinocysts (Harland, 1973) was computed in all samples containing dinocysts.

RESULTS

The lowermost layer of the Fish Clay is characterised by a typical topmost Maastrichtian dinocyst flora, dominated by abundant *Palynodinium grallator* and *Spiniferites ramosus*.

The base of the second layer was found to be totally barren of dinoflagellates at all localities. This may indicate that the flora in the overlying deposits represents primary deposited rather than reworked specimens. If the flora of layer three was severely affected by reworking, this reworking would be represented also in layer two. Pollen and spores are encountered in this layer. The top of layer two was marked by a strictly duospecific occurrence of *Manumiella druggii* and *Trithyrodinium suspectum*.

The dinocyst flora in the third layer is characterised in the northern parts of Stevns Klint by a mass occurrence of *M. druggii* and *Trithyrodinium suspectum*, together with *P. grallator*. In a southward direction, *P. grallator* is replaced by *Danea californica* and occasional *Senoniasphaera inornata* (Fig. 1).

The spore/pollen flora in layers two and three is dominated by trilete spores, with a botanical affinity to temperate ferns, such as the Gleicheniaceae, Osmun-

daceae, and the Selaginellaceae. Also abundant are spores attributable to the Lycopodiaceae. Gymnosperm pollen are rarely encountered, but occasional *Pinus* pollen do occur (Kedves, 1980). The uppermost layer is totally barren of palynomorphs.

The ratio between gonyaulacacean and peridiniacean dinocysts (the gonyaulacacean ratio) changes drastically from a high value in the lowermost layer (domination of gonyaulacacean cysts), indicating a marine environment, to a low value in layers two and three (domination of peridiniacean cysts), indicating a distinct freshwater influence (Harland, 1973) (Fig. 2). Also, the dinocyst diversity changes from a high diversity in the lowermost layer to an extremely low diversity in layers two and three, suggesting an ecologically narrow environment in layers two and three.

The dinocyst versus spore/pollen ratio exhibits an average value of 5000 in the Maastrichtian white chalk of Scandinavia. This ratio changes in the third layer of the Fish Clay to an average value of 10 (Fig. 3).

Freshwater algae are extremely rare in the Maastrichtian and Danian sediments of Scandinavia. Hultberg (1985) examined over 350 samples from the area, and only encountered three specimens of *Pediastrum* sp. in the white chalk. In the second and third layer of the Fish Clay at Stevns Klint a distinct increase in the abundance of freshwater algae is noted by the frequent occurrence of *Pediastrum* sp. (Fig. 4).

Palynodebris, such as wood particles, plant tissue etc. is rare in the Scandinavian chalk, which consistently contains over 95% CaCO₃. Layers two and three of the Fish Clay, however, exhibit vast abundances of plant cuticle and some elongate wood fragments. This is consistent with results obtained by Ekdale and Bromley (1984), showing distinctly increased values for

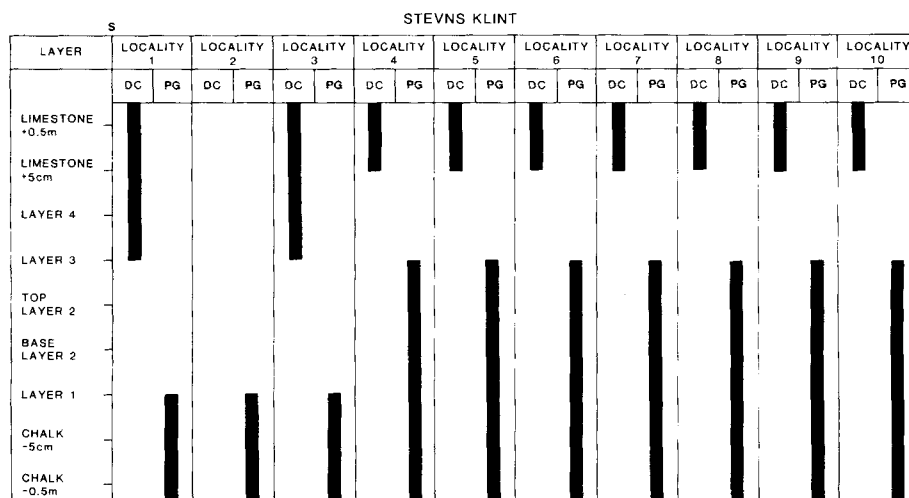


Fig. 1. Range of *Palynodinium grallator* and *Danea californica* across the C-T boundary at localities 1-10.

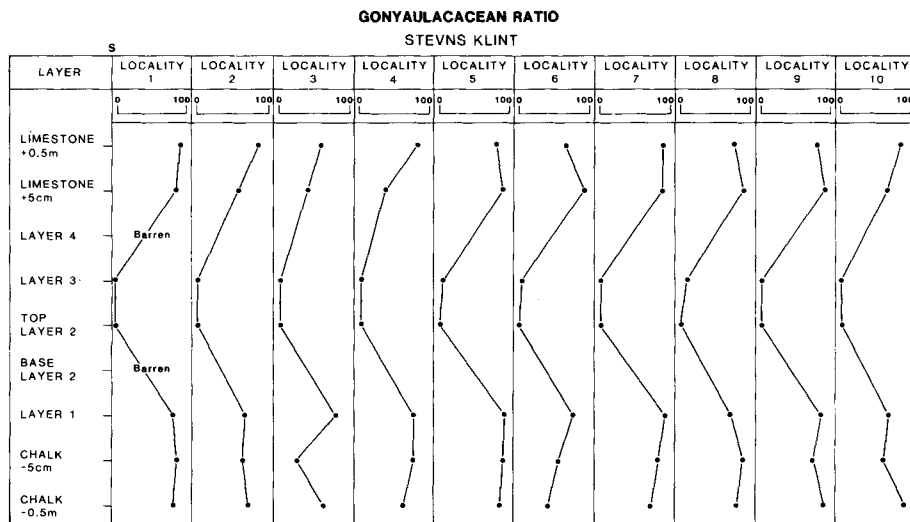


Fig. 2. Changes in the ratio between gonyaulacacean and peridiniacean dinoflagellate cysts across the C-T boundary at localities 1-10.

the percentage of organic carbon in the Fish Clay at Stevns Klint.

DISCUSSION

The gonyaulacacean ratio was suggested by Harland (1973) to represent a measure of relative salinity. A high value was suggested to represent a high salinity environment, and a low value was taken to represent a low salinity environment, the reason for this being the higher tolerance of peridiniacean cysts to low salinity.

The ratio between dinoflagellates on the one hand, and pollen and spores on the other hand is widely accepted as an indicator of marine versus terrestrial influence.

The dramatic changes in the dinocyst flora, the changes in the gonyaulacacean ratio and the dinocyst/spore-pollen ratio, as well as the increase in abundance of freshwater algae and land-derived organic debris in the Fish Clay compared to the surrounding sediments points to a distinct change in depositional environment.

The lowermost layer of the Fish Clay, characterised by a typical marine dinocyst assemblage was probably deposited during normal, stable marine, neritic conditions.

The base of the second layer of the Fish Clay was probably deposited in an environment strongly influenced by freshwater. The only palynomorphs encountered in the bottom half of this layer was freshwater algae and spores/pollen. No marine fossils are encountered. The presence of *M. druggii* and *T. suspectum* in the top half of this layer indicates a slight marine influence.

The third layer shows strong indications of being influenced by freshwater. However, the dominance of dinocysts suggests a predominantly marine influence.

This layer may have been deposited in a brackish water environment following the non marine environment in layer two.

The succession from marine to freshwater-brackish-marine may be explained in many ways. However, the abundance of land-derived matter in layers shown to be formed in a low salinity environment points to a fluvial or lacustrine cause. A possible explanation is a suddenly increased outflow from a river located close to the area, resulting in the formation of the base part of layer two, and a subsequent decrease in outflow, resulting in the formation of the top part of layer two and layer three. Another possible explanation is the formation of an estuarine/tidal flat for a short period of time following the latest Cretaceous regression (Hultberg & Malmgren, 1986). Layer two may represent a proximal tidal flat or shallow lagoonal deposit, dominated by terrestrially derived material. The top part of layer two and layer three may represent a more distal estuarine or deeper lagoonal deposit with more marine influence.

Time-relationships

P. grallator has been convincingly shown to become extinct in the topmost Maastrichtian in Germany (Gocht, 1970), USA (Koch & Olsson, 1977), and Scandinavia (Wilson, 1971, 1974; Hansen, 1977, 1979). *D. californica* has been shown to appear in the lowermost Danian in USA (Drugg, 1967), Canada (Williams & Bujak, 1977), and northwest Europe (Morgenroth, 1968; Hansen, 1977, 1979).

The gradual change from a *P. grallator* dominated dinocyst assemblage (Maastrichtian) in the northern parts of Stevns Klint, to a *D. californica* assemblage

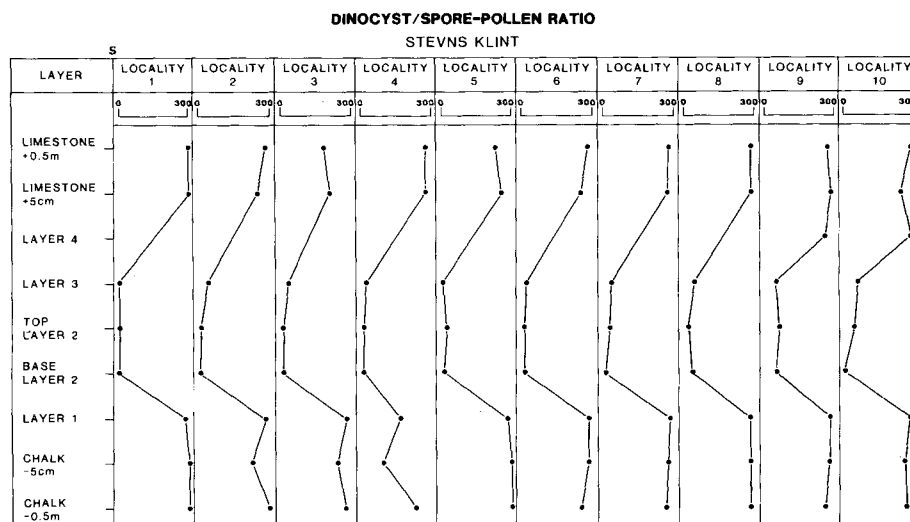


Fig. 3. Changes in the dinocyst/spore-pollen ratio across the C-T boundary at localities 1-10.

(Danian) in the south of the same section points to a time-diachronous deposition of the Fish Clay within the Stevns Klint section (Fig. 1).

CONCLUSIONS

There have been tendencies to use, in separate studies, clay and lignite layers from all over the world for interpretations of supposedly globally synchronous events, such as the C-T transition. However, it must be remembered that these types of deposits normally form in local depositional environments, such as swamps, deltas, estuaries, lagoons, etc. The C-T event in itself may, of course, have produced global effects that has had an overriding influence on these local sedimentological systems. This, however, remains to be proved. The assumption of time-synchronicity between a vast number of deep water marine, shallow marine, transitional, and terrestrial C-T boundary sections is, at present, unrealistic.

Hultberg (1985, 1986) suggested that the Fish Clay at Stevns Klint was deposited 200000y - 1.5 m.y. earlier than the corresponding clay at Dania and Kjøby Gaard in western Denmark. Hultberg also suggested that the Fish Clay at Stevns Klint was influenced by freshwater, whereas the clay in western Denmark was deposited during normal marine conditions. This study strengthens the interpretation of a local Maastrichtian freshwater agent as the source for deposition of the Fish Clay at Stevns Klint.

A speculative sedimentation model suggests that the clay deposits in western Denmark represent erosion and subsequent marine redeposition of eastern Danish Fish Clay in the central, deeper parts of the Danish embayment, where, in contrast to the clay in eastern Denmark, it is strongly bioturbated, brecciated, and

almost devoid of pollen, spores, and freshwater algae. Also, it contains a typically Danian dinoflagellate flora, strongly dominated by gonyaulacacean cysts, indicating a normal marine, neritic environment of deposition.

It could be argued that the iridium, making up the iridium concentration peak in the Fish Clay at Stevns Klint, was eroded with the Fish Clay from eastern Denmark, and redeposited in western Denmark. This would explain the lower concentrations of iridium in the western Danish sections, compared to Stevns Klint. However, too little is known about the geochemistry of the noble metals of the platinum group to determine whether that is a realistic possibility.

The diachroneity of the Fish Clay within the Stevns Klint section itself raises the question of where the actual C-T boundary is located in that section. This study suggests that the C-T boundary may be represented as a transition in a lateral direction from north to south in the Fish Clay at Stevns Klint, rather than a horizontal boundary between the chalk and the Fish Clay. If this is correct, it means that conclusions based on studies of iridium concentrations at Stevns Klint, and in a wider sense, in the C-T boundary clays of Denmark, are difficult to use for wider interpretations of the C-T transition. It is suggested that further studies of the C-T boundary are carried out jointly by geochemists, sedimentologists, and stratigraphers. This is essential for achieving reliable interpretations of the global events at the C-T transition.

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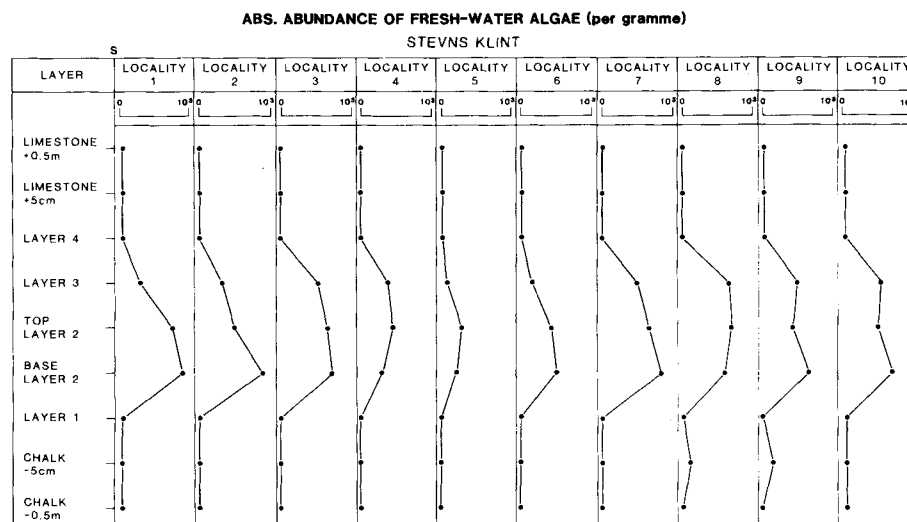


Fig. 4. Changes in the dinocyst/freshwater algae ratio across the C-T boundary at localities 1-10.

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