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Age and depositional environment of the Kuhfeld Beds (Lower Cretaceous) in the Alstätte Embayment (W Germany, E Netherlands)

G.F.W. Herngreen[1], C. Hartkopf-Fröder[2] & G.H.J. Ruegg[1]
[1] *Geological Survey of the Netherlands, P.O. Box 157, 2000 AD Haarlem, the Netherlands;* [2] *Geological Survey of North Rhine-Westphalia, P.O. Box 1080, 4150 Krefeld, Germany*

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Abstract

Major parts of the Lower Cretaceous Kuhfeld Beds as present in the Alstätte Embayment, Dutch-German border area, have a marine origin and were not exclusively deposited in a limnic-terrestrial setting as previously thought. For the first time, direct fossil evidence is available. This dates the base of the formation as transitional Ryazanian-Valanginian and indicates a late Early-Late Hauterivian age higher in the formation.

Introduction

Since the Kuhfeld Beds were introduced in 1930, the precise nature of these strata has remained uncertain and has been the subject of a long-lasting debate. Poor exposures and a lack of carefully sampled wells prevented a thorough biostratigraphical and sedimentological investigation. An extensive drilling programme, carried out since the late eighties, and frequently changing situations in sandpits renewed interest in the age and depositional environment of the Kuhfeld Beds because this formation is of utmost importance for ground-water catchment in the Dutch-German border area (e.g. Bolsenkötter & Koch 1974). A combined palynological and sedimentological investigation provided information on the palaeoenvironment and enabled a more precise dating.

Historical perspective

Regional setting

The Kuhfeld Beds (referred to in German literature as Kuhfeld Schichten) are restricted to the area southeast of Alstätte (Fig. 1). Deposition took place in the Alstätte Embayment, a southwestern extension of the Lower Saxony Basin. The embayment is bounded to the east by the Rhenish Massif, which is regionally known as Münsterländer Festland, and to the west by the East Netherlands Triassic High.

The source area of particularly the coarser clastics is, according to Wolburg (1954), the Rhenish Massif. In his view the East Netherlands Triassic High was of minor importance. Thicknesses of the Kuhfeld Beds vary from 10 to 40 m in the area southwest of Alstätte (Kemper 1976). Wolburg (1954) estimated in this area a thickness of approximately 50 m. Locally, a thickness of about 200 m is found in the wells Ammeloe–1 and 2 and Ottenstein–1 (Bolsenkötter & Koch 1974; Schott 1950; Wolburg 1954) and also in well Alstätte–1 (Fig. 2).

The concept of Bentz

The concept of the Kuhfeld Beds (Kuhfeld Schichten) was first established by Bentz (1930 and 1930–1933). According to Bentz they are a sequence of limnic strata, thought to be of Valanginian age. They consist mainly of white sandy clay or clayey fine-grained sand deposits which pass into white fine-grained quartzitic sands in the northern part of the Alstätte Embayment (Bentz 1930–1933, Alstätte, Ottenstein, Vreden and Wennewick geological map sheets). Many layers are

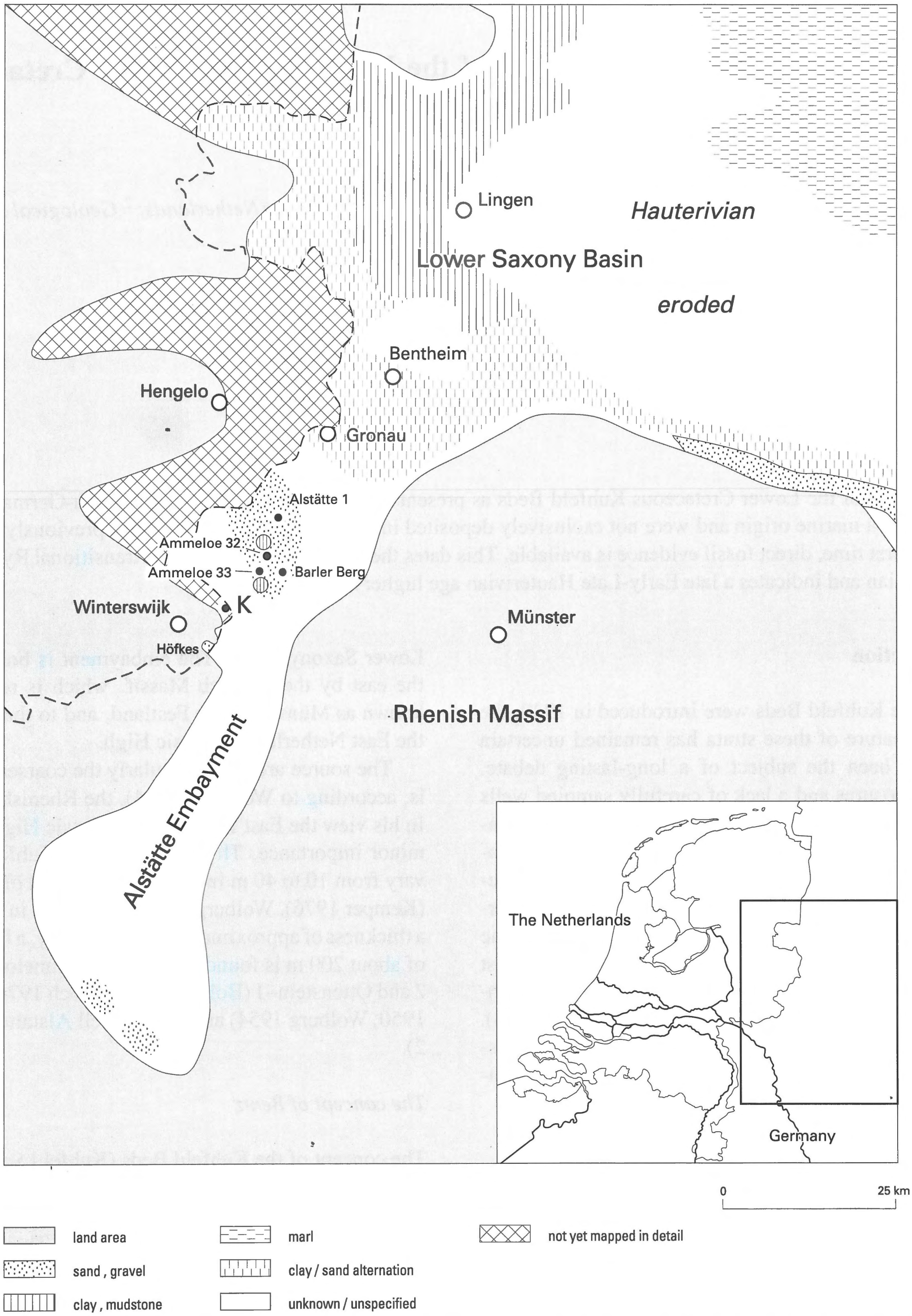

Fig. 1. Location map of quarries and wells in the Dutch-German border area. Palaeogeography shown is that of the Hauterivian (after Bundesanstalt für Bodenforschung 1967). K = well K.

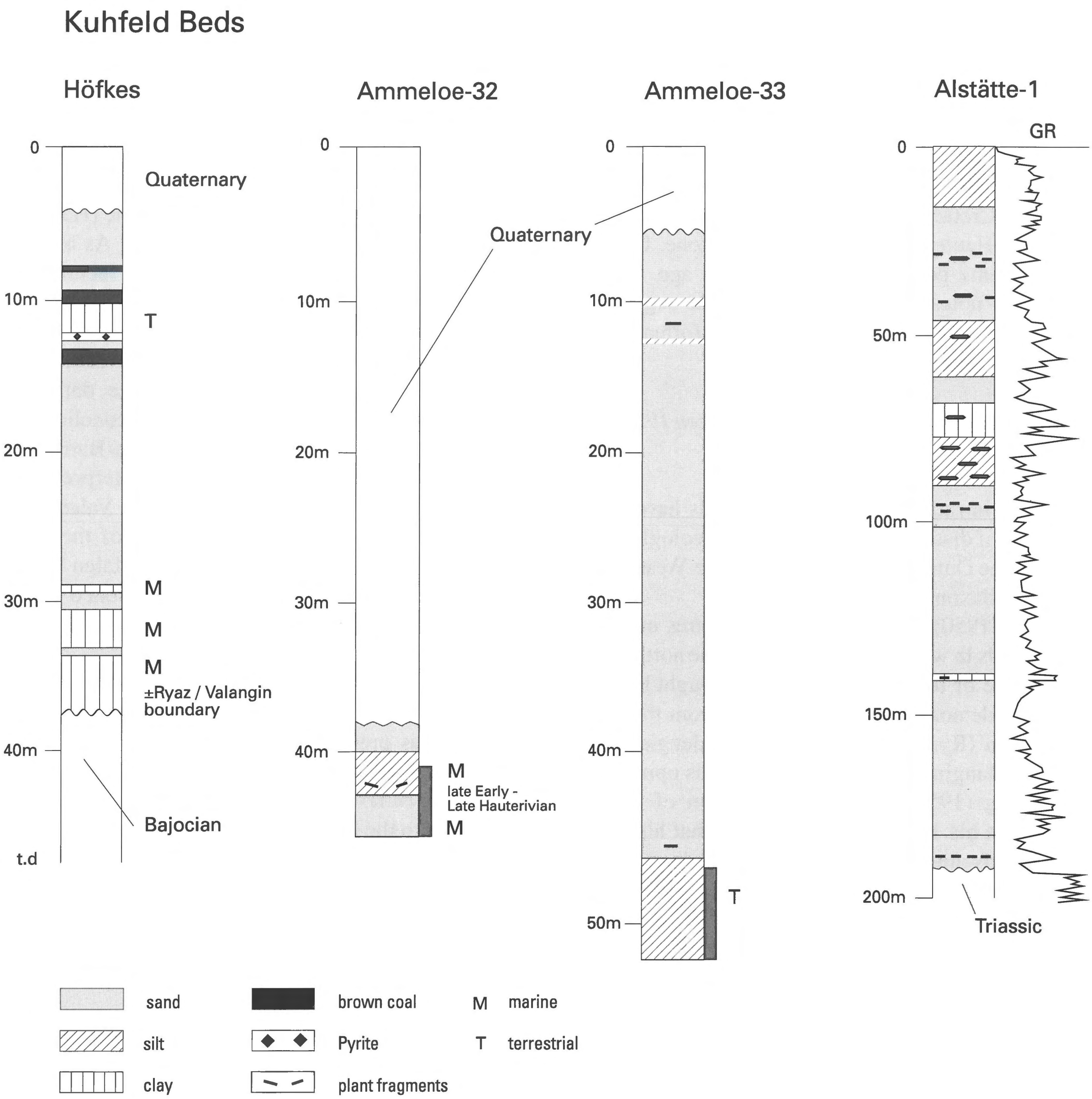

Fig. 2. Lithological columns of the Kuhfeld Beds in wells Alstätte–1, Ammeloe–32 and –33 (Germany), and Höfkes (the Netherlands). Locations in Fig. 1. Bars along columns in Ammeloe–32 and –33 indicate investigated cored intervals.

contain large quantities of pyrite, and wood fragments are common. In the southern part of the subbasin (Oeding and Stadtlohn sheets), white to yellow sands predominate, with occasionally quartz-rich gravel lenses and indurated gravel layers. Throughout the entire succession, lignite layers occur regularly.

At least two types of coalified material are present in the Barler Berg area according to M. & R. Teichmüller (1952) and Kettelhack (1989). Coal particles reworked from the Carboniferous should be distinguished from Wealden coal fragments. This last type most likely corresponds to brown-coal layers like those found in well Höfkes (this paper), and like those reported from elsewhere as lignite. Megafauna and microfossils (foraminifers and ostracods) are unknown.

Bentz did not define a stratotype section, but indicated a region of indefinite extension as shown in Fig. 1. He referred to the Kuhfeld plain southwest of Alstätte and near Lünten, to exposures near Vreden, 12 km SSW of Alstätte (the 'Vredener Sand' of Hosius 1887 and 1889), and to the Barler Berg area where sandpits exist in the gravelly sands near the top of the Kuhfeld Beds. The Kuhfeld Beds are underlain by Wealden strata (in Germany Wealden has a chronostratigraphic connotation, i.e. freshwater deposits of the lowermost Cretaceous = Ryazanian) and overlain by the marine Hauterivian Gildehaus Sandstone. Consequently, Bentz postulated a Valanginian age. In his explanatory notes to the Alstätte sheet, he suggested that the Gildehaus Sandstone rests unconformably on older Valanginian Kuhfeld Beds.

The Kuhfeld Beds in German studies between 1950 and 1978

Since their introduction the Kuhfeld Beds have been the subject of discussions in the regional geological literature of the Dutch-German (North Rhine-Westphalia and Lower Saxony) borderland.

1. Schott (1950) described over 214 metres of Kuhfeld Beds in well Ottenstein–1 (near the northwestern edge of the Barler Berg). He thought he was able to demonstrate a span of time from the later Wealden (Ryazanian) to the older Valanginian; a Late Valanginian age is uncertain in his opinion.
2. Wolburg (1952) doubted the opinion of Schott 1950. In his 1954 paper he stressed that his Kuhfeld Beds are superposed on lower *Polyptychites*-Beds (late Early Valanginian) in the area of the Alstätte sheet and on about middle *Polyptychites*-Beds to lowermost *Dichotomites*-Beds (transitional Early-Late Valanginian) in the northwest part of the Ottenstein sheet. In his view the Kuhfeld Beds are not a time equivalent of the Wealden Beds (Ryazanian), but of the *Polyptychites*-Beds (Early Valanginian). He concluded that deposition of the Kuhfeld Beds started during the Valanginian and continued to transitional Valanginian-Hauterivian. He suggested that the Kuhfeld Beds are a lateral equivalent of the marine Bentheim Sandstone. Wolburg was not very very specific in his environmental interpretation. On one hand he thought of a limnic-terrestrial, on the other of an estuarine and deltaic depositional environment.
3. Thiermann & Arnold (1964, their Table 1) indicated the Kuhfeld Beds as time-stratigraphical equivalent of the upper part of the Wealden and the Bentheim Sandstone. As such their age is latest Ryazanian to earliest Late Valanginian.
4. On the basis of sporomorph analyses of samples from well Ammeloe–2 by G. von der Brelie, Bolsenkötter & Koch (1974) stated that the limnic-clastic development of the Kuhfeld Beds southwest of Ottenstein terminated in the Barremian. They restrict the Kuhfeld Beds to unconsolidated deposits, whereas the Bentheim Sandstone (Valanginian) and Gildehaus Sandstone (Hauterivian) consist of consolidated material. As outlined by the first author (GFWH) in his lecture during the 4th International Cretaceous Symposium (Hamburg, September 1992), neither the knowledge around 1970 nor the resolution level of sporomorphs did permit such an accurate dating. It was suggested that von der Brelie concluded to an age within the interval Valanginian-Barremian, a communication which was misinterpreted by Bolsenkötter & Koch (1974: 103) as Valanginian to Barremian. In an internal report of the Geologisches Landesamt Nordrhein-Westfalen by von der Brelie dated 10–12–1968 it was stated clearly that, indeed, unspecified Valanginian-Barremian was meant.
5. Braun & Thiermann (1975) agreed with Wolburg (1954) that the deposition of the limnic Kuhfeld Beds, as present in the northwestern part of the Recklinghausen sheet, started at the time of the *Polyptychites* Beds (Early Valanginian) and continued to the beginning of the Hauterivian. In their opinion the dating of the top of the formation is uncertain.
6. Kemper (1976) mentioned limnic-terrestrial sands of Early Valanginian age. Referring to Wolburg (1954) he suggested that the Kuhfeld Beds may have an estuarine to deltaic origin.
7. Kemper & Ernst (1978) mentioned sands of limnic origin (Kuhfeld Schichten). Part of these strongly bioturbated sands contain siderite and/or glauconite which caused iron concretions. This facies is indicated as Wellar Sand in the Ottenstein-Barler Berg area (their Fig. 29A).

Summary

Without exception, between 1930 and 1978 all authors agreed on the limnic-terrestrial facies of the Kuhfeld Beds. Only Wolburg (1954), who was cited by Kemper (1976), suggested a deltaic-estuarine depositional environment.

On the basis of superposition of strata, a possibly Late Ryazanian, Valanginian and Early Hauteriv-

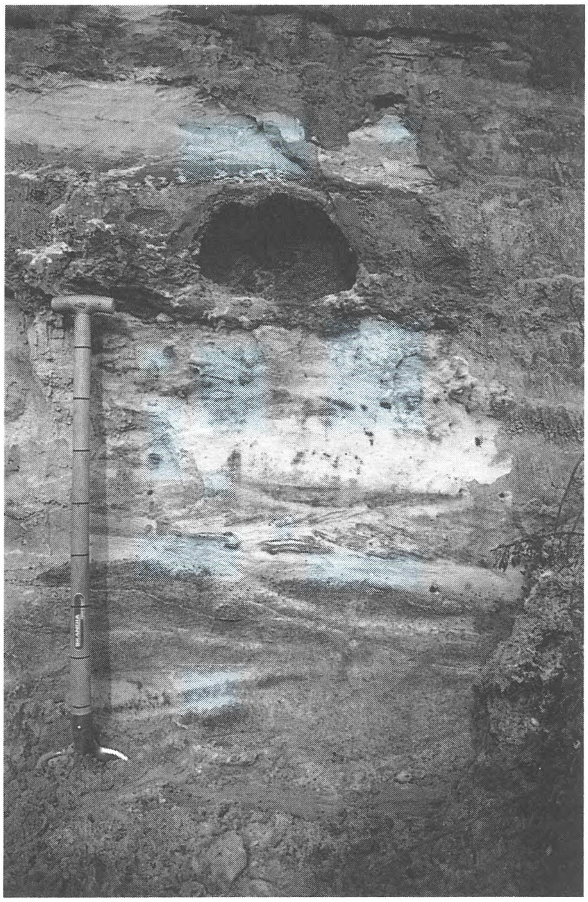

Fig. 3. Bidirectional cross bedding in the lowermost exposed interval of the Kuhfeld Beds in the Lukassen sandpit. Just above the shovel handle a cavity of a gravel ball enveloped by clay is visible. Shaft with decimetre-scale.

ian age was proposed for the Kuhfeld Beds by various authors. The Barremian age as mentioned by Bolsenkötter & Koch (1974) is definitely a misinterpretation of data presented by von der Brelie.

The Kuhfeld Beds in the Netherlands

Kuhfeld Beds have been described from two regions in the eastern Netherlands: from Twente, in the province of Overijssel, and from the Achterhoek, in the province of Gelderland. For an extensive review, reference is made to Herngreen (1973); the following remarks are based on that paper.

Twente area

A. Bentz visited the Geological Survey of the Netherlands in January-February 1929 and studied the Twente wells I–XI which are located southeast of Hengelo. On the basis of this examination he assigned the limnic clay deposits in wells Twente I, II, III, VI, VIII and IX without any doubt to the Kuhfeld Beds, and as such to the Valanginian (Bentz 1930: 296; Bentz 1930, explanatory notes Ottenstein: 22; Bentz 1933, explanatory notes Alstätte: 21). Herngreen (1973), based on palynological analyses, was able to prove that these strata are of marine origin and of (partly Early) Eocene age.

Achterhoek area

Two test-wells, viz. C and K of the 'Dienst Rijksopsporing van Delfstoffen', the predecessor of the Geological Survey of the Netherlands (Van Waterschoot van der Gracht 1918) were reinterpreted by the district geologist H.D. Burck in an unpublished internal RGD (= Rijks Geologische Dienst, the Geological Survey of the Netherlands) memorandum of 1929. He attributed particular sections of these wells to the Kuhfeld Beds. Only samples from well K were available for micropalaeontological and palynological analyses. These yielded a possibly Valanginian age for the sediments, which were deposited in a brackish-water environment (Herngreen 1973). Taking into account the definition of the Kuhfeld Beds as limnic deposits, Herngreen rejected the inclusion of the interval between 21–42 m depth in well K in that formation. Some other well sections, which were assigned to the Kuhfeld Beds, yielded late Early Cretaceous or Quaternary ages, and Herngreen (1973) concluded that they were misinterpreted lithologically. For further details reference is made to section 'New results from the Achterhoek, the Netherlands'.

New results from the Barler Berg area

Since the late eighties, new information has become available from one of the type areas, the Barler Berg area (Fig. 1) near Ottenstein, where exploitation started of the Lukassen sandpit, and the nearby smaller Erning sandpit, to supply local sand requirements.

Fig. 4. Gravel balls overlying a thin gravel layer (below jointer) in the Lukassen sandpit. Gravel particles in the layer are larger than those in the balls. Length of jointer 32 cm.

Lukassen sandpit

The Lukassen sandpit is located 3 km S of Ottenstein (topographical map 1:25 000, Ottenstein sheet 3907, coordinates R 25.63380, H 57.68640).

An approximately 150 m-long W-E corridor (N100°E) is present, the northern wall of which is exposed. In the eastern part of the narrow corridor a deep niche was excavated to the north in November 1989. In June 1992 this part of the sandpit was extended westward, and a smaller excavation, also in a northerly direction, was dug at the entrance. The strata dip uniformly 5–10°ENE.

Erning sandpit

This excavation is situated about 400 m north of the Lukassen sandpit (coordinates R 25.63440, H 57.68960). It shows a 70 m-long SW-NE active exploitation face, as well as an inactive face from the NE corner towards the NW of about the same length. The succession comprises the same beds and exhibits a very similar development as in the Lukassen sandpit. The uppermost 4 m of the Lukassen succession were not exposed in the Erning sandpit during the present investigation.

Sedimentology

In stratigraphical order the following succession of strata is present.

- Some 3 m of fine-grained sand (grain-size mean less than 250 μm); cross bedding occurs, as well as homogeneous parts. Locally, bidirectional cross bedding (Fig. 3), burrows and small clay clasts are present. Brown and violet-brown discolorations suggest a palaeosol. In the uppermost part, an up to 20 cm-thick clayey interval, a thin gravel layer and gravel balls occur locally. When clay and gravel balls are found together, the clay covers, and locally envelopes, the balls (Fig. 3). When the gravel layer and balls exist together, the balls overlie the gravel layer, which suggests deposition as gravelly clasts (Fig. 4).

Fig. 5. Second gravel layer (about 3 m above the gravel-ball level of photograph in Fig. 4) behind the upper shovel handle; Lukassen sandpit. Distance between top second gravel layer and base of Fe-enrichment in upper part of exposure is 2.3 m.

- About 3 m of fine-grained sands follow with ghost structures of shells and burrows. This is terminated by a 5–20 cm-thick continuous sandy gravel layer (Figs 5, 6).
- This gravel layer is overlain by an about 12.95 m (Lukassen) to 12.25 m (Erning) thick deposit of predominantly whitish and clean fine-grained sands, which is cut off by a thin gravel layer, the basal part of the next interval. This slightly lithified unit shows a coarse layering, a phenomenon which is enhanced by several parallel, decimetre-thick, dark-brown horizons cemented by iron-oxide and containing ghost structures of marine molluscs (pers. comm. T. Meijer, RGD, Haarlem). The first (discontinuous) Fe-enrichment level occurs approximately 2.3 m above the base (Fig. 5).

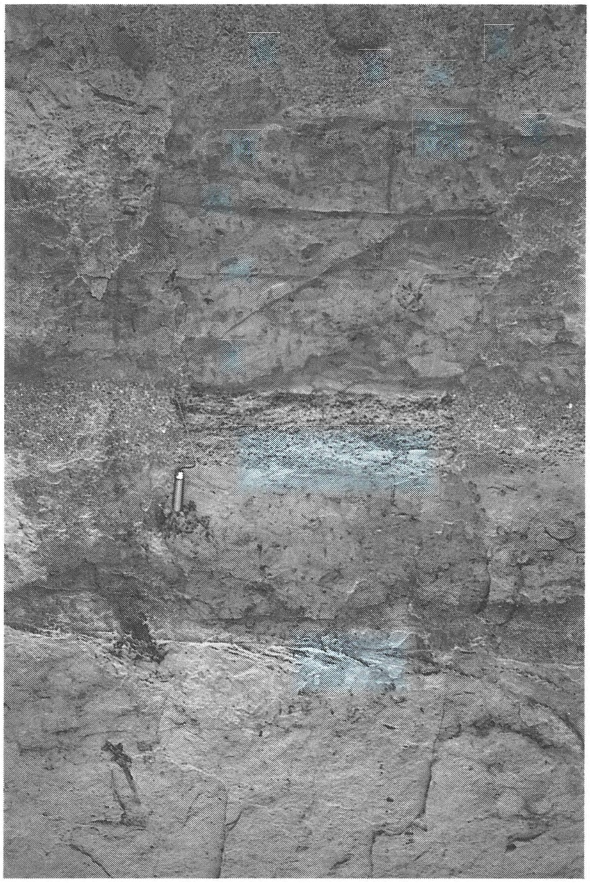

Fig. 6. Detail of the layering around the second gravel layer (below jointer handle) in the Lukassen sandpit.

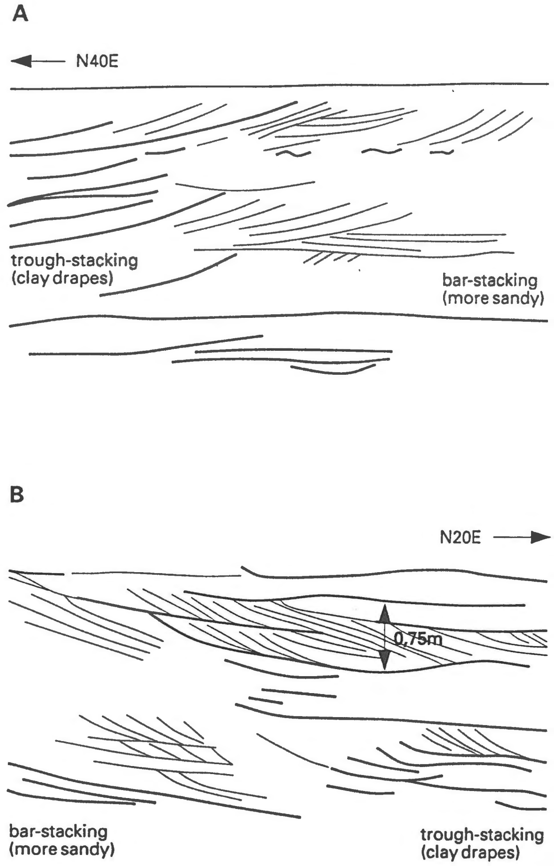

Fig. 7. Stacking of sedimentary units in the 12–13 m thick interval of the Kuhfeld Beds. A: Erning sandpit; B: Lukassen sandpit. Scale in B applies also to A.

The relations between cross-bedding, bioturbation and homogenization, and between sand, clay and Fe-enrichment, have been investigated in some detail. Most frequently, fine-grained cross-bedded sand layers up to some decimetres thick occur. They are generally stacked in complexes up to some metres thick (Figs 7, 9, 10). The cross-bedded intervals locally contain small clay clasts, as well as laminae and concentrations of charred wood fragments; these concentrations are related to burrowing. The cross-bedded intervals also exhibit disturbances caused by bioturbation as shown in Fig. 11 where such disturbances are underlain by circular burrows. In one case an echinoid cast was found in connection with one of these burrows. Set boundaries are undulating and locally accentuated by an up to several millimetres thick clay layer; clay-sand boundaries are very abrupt (Fig. 9). The surface of these cross-bedded units is undulating as well. By far the majority of the cross-bedded sets indicates megaripple migration towards the northeast. Shallow depressions in the upper surfaces, often situated in a lateral connection between two successive bar-like structures, were filled by a depression-concordant sand-clay layering (Figs 12, 13) which forms a minor part of the section. These infillings also have sharp clay-sand boundaries, and show upwards increasing bioturbation which may lead to complete homogenization. In some levels the highest parts of the cross-bedded units are covered by the extensions of depression fills as well. The vertical stacking of these two elements (Fig. 7), viz. cross-bedded sand layers and depression

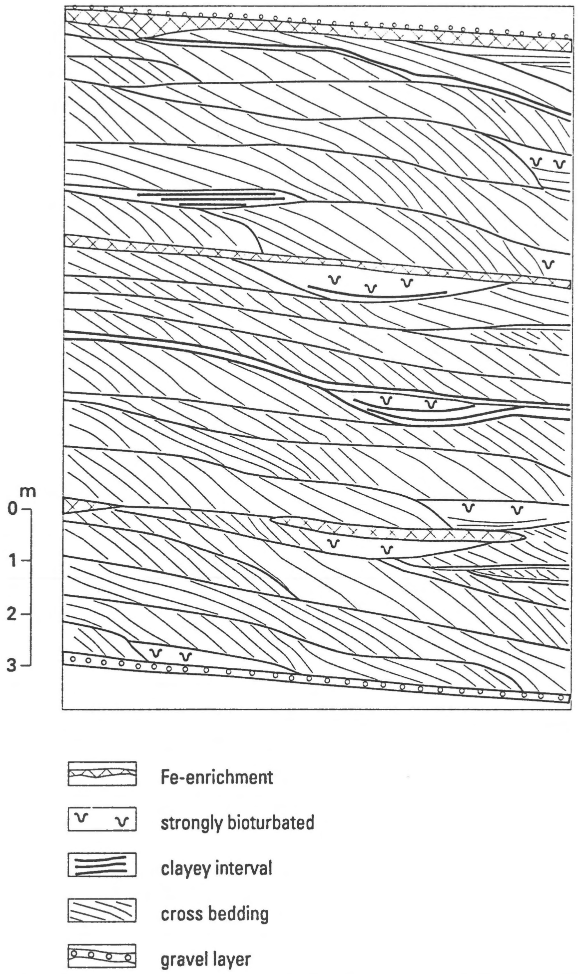

Fig. 8. Schematic sketch of the layering between the gravel bearing intervals in the Kuhfeld Beds of the Lukassen sandpit; for clarity, not all cross-bedded sets have been drawn.

fills, suggests episodic sedimentation of a bar-like feature bordering a depression without much lateral movement of the bar. A higher-order regularity is accentuated by three or four thick Fe-enrichment layers or lense levels (including the one just above the base of the overlying interval). It concerns laterally more or less continuous zones, which are entirely homogenized by bioturbation, and which reflect rather prolonged periods of non-deposition and bioturbation. Figure 8 shows the described setting schematically.

– Another 6 m of fine-grained sands with some thin scattered layers of gravel, are exposed in the Lukassen sandpit. In the Erning sandpit, only the lowermost two metres of this deposit are exposed. In the Lukassen sandpit, an important Fe-enrichment zone is situated in and just above the gravel layer at the base of the 6 m-thick deposit. In the Erning sandpit, 20 cm of non-enriched sand separate a comparable iron-rich zone from the underlying gravel layer. Investigation of this highest exposed interval is difficult because of its partial destruction as a result of its position near the surface.

The genesis and age of the Fe-enrichments have not been studied. The feature is mentioned here only because of its preferential occurrence in, and accentuation of, strongly bioturbated zones. Similar concretions of 'clay-ironstone' are common in the Lower Cretaceous Hils Clay Formation of the Bentheim Embayment north of Gronau (Kemper 1976) and are considered to be synsedimentary.

The sedimentary structures, the bioturbation, the mollusc ghosts and the sea-urchin indicate a marine depositional environment. The most conspicuous feature is the overall unidirectionality towards the northeast, as demonstrated by the individual megasets and by the low-angle onlapping of the strata. The bidirectional cross bedding in the lowermost interval, the sharp clay-sand contacts and the intraset clay clasts suggest some tidal influence. The episodicity of the sedimentary process is demonstrated by the thicker depression fills and the more continuous bioturbated and slightly more fine-grained intercalations. During the deposition of these fills and intercalations, the migration of sand bodies was interrupted for long periods (long compared to slack-water stages within neap-spring cycles). In contrast to what is to be expected in a tidal setting, the bars do not move laterally over large distances but stay in place during longer periods as can be deduced from their stacked nature (stacking of lee-side clay drapes and stacking of mega cross bedding). Figure 7 comprises two field sketches made by Th. B. Roep; Fig. 8 represents a schematical sketch of the 12 to 13 m-thick interval. Indications of major channeling are absent. These properties point to deposition in a shallow marine environment with northeastward-moving small sand waves, driven by episodic wind-induced currents (cf. Allen 1980, Nio 1976). Other possible marine settings, such as ebb-tidal deltas or estuaries, are less probable, because of the virtual absence of tidal features in the two Barler Berg exposures (e.g. Sha 1990, for ebb-tidal deltas, and Boothroyd 1985, for estuaries). However, indications of wave action on a more detailed scale, e.g. hummocky cross stratification or wave-ripple deposits, could not be demonstrated with certainty.

Fig. 9. Erning sandpit: the 12.25 m interval showing cross-bedded sets separated by thin clay layers in middle part of photograph.

The gravel intercalations reflect high-energy events, presumably heavy storms or massive discharges connected with a nearby river mouth.

An intriguing feature is the presence of dark bands in a number of the cross-bedded units (Fig. 10). These bands are grouped in the way of tidal bundles, including double layers. However, the bands do not consist of mud, but owe their colour to an enrichment of angular ore grains. These grains have about the same size as the embedding quartz grains.

Micropalaeontology and palynology

A mixed sample of silty and clayey sand, taken near the base of the iron concretions in the 6 m-thick deposit of the Lukassen sandpit, did not yield foraminifera or ostracods (pers. comm. Th. Lissenberg, RGD).

Kettelhack (1989), however, mentioned marine influence in the Kuhfeld Beds from this quarry. She reported a limited number of foraminiferal species of which *Triplasia* cf. *emslandensis* and *Ammovertella cellensis* indicate a Valanginian-Hauterivian age.

The clay layers near the base of the succession in the Lukassen sandpit were processed palynologically. Only acritarchs, which are qualitatively as well as quantitatively well represented, and a few other aqueous algae were encountered. The following taxa could be identified: *Botryococcus*, *Cymatiosphaera*, *Leiosphaeridia*, several species of *Micrhystridium*, two species of *Pterospermopsis* and *Schizosporis reticulatus*. This association has no stratigraphical significance as all types are long-ranging. However, their presence indicates a marginal marine environment, possibly marine to brackish in a lagoonal setting.

Barler Berg area, summary of observations and discussion

Bentz (1930: 22, 24) correlated the top part of the sequence, upwards from the sandstone with (clay-) ironstone concretions, with the Gildehaus Sandstone. This is apparently the same unit as the Wellar Sand of Kemper & Ernst (1978). The lower part of the sequence was assigned by Bentz (1930: 20) and by Kettelhack

Fig. 10. Erning sandpit: part of the 12.25 m interval showing cross-bedded set with laminae containing abundant dark ore grains.

(1989) to the upper part of the Kuhfeld Beds. It should be noted that from a sedimentological point of view there is no distinct break in the succession of strata, neither in the Lukassen, nor in the Erning sandpit.

The absence of sporomorphs in the clayey samples is striking. As an explanation we can only offer some speculations: 1) run-off from rivers was absent in this particular part of the Alstätter Embayment, 2) standing water intervals in lakes etc. may have caused step-wise deposition of clastics from rivers, so that there was very little or no deposition of land-derived material in the distal extremities. Or, more likely, 3) strong subaerial corrosion of the land plant material took place before it reached the basin.

The gravel levels, the concentrations of charred plant fragments, the burrows, the scarce fossil content consisting of mollusc ghosts and a sea urchin cast, combined with the limited marine microflora of acritarchs as well as sedimentological evidence, point to a near-shore marine depositional environment for the strata of the Kuhfeld Beds in the Erning and Lukassen sandpits.

Wells Ammeloe–32, –33 and –1

Well Ammeloe–32

Corehole Ammeloe–32 was drilled near Doemern, ENE of Vreden (topographical map 1:25 000, Ottenstein sheet 3907, coordinates R 25.60900, H 57.69300; Fig. 1).

A total of 17 slides from between 41.00 and 45.50 m depth were analyzed palynologically (Fig. 2). The organic residue was sieved using a 10 μm mesh sieve for a superficial sporomorph and more detailed dinoflagellate analysis. A second set of nine dinoflagellate-containing samples from the same interval was sieved with a mesh size of 20 μm in order to obtain a better concentration of marine microplankton. The corresponding distribution charts may be obtained on request from the first author.

In almost all samples marine elements such as acritarchs and dinoflagellates were found. A distinct concentration of dinos, as recorded by the number of specimens and by species diversity, is present between

Fig. 11. Lukassen sandpit: the 12.95 m interval showing cross-bedded sand with collapse structures which are underlain by circular burrows. The collapse structures are excellently visible due to laminae containing abundant dark ore grains.

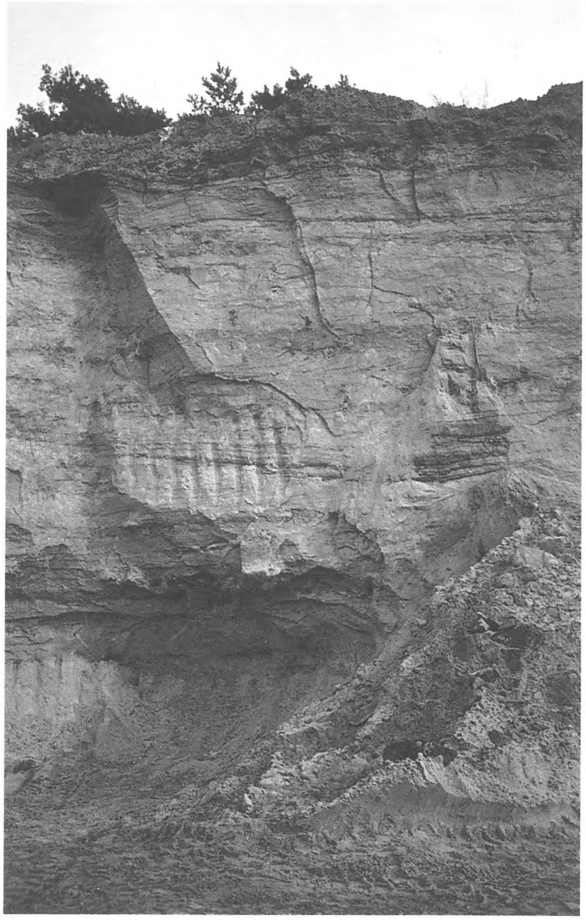

Fig. 12. Lukassen sandpit: depression situated near the middle part of the section and filled with alternating thin sand and clay beds. Shovel for scale. Details in Fig. 13.

41.00–41.75 and 45.00–45.30 m. In the samples from a depth of 41.95 to 44.33 m, dinoflagellates are scarce or absent. This corresponds with quantitatively rich sporomorph assemblages of low species diversity. In general, the number of dino-species is low compared with entirely marine assemblages found in an open shelf area. Combined with the sporomorph characteristics and the palynofacies macerals, a distinct environmental succession is reflected from low-energy near-coastal marine, via probably delta-plain lagoonal with some marine influence, back to near-shore marine.

The age of the dino-assemblages is, broadly speaking, typically Early Cretaceous. The use of a larger mesh sieve greatly increased the number of dinoflagellates and species diversity. Various time-stratigraphically significant species were found, specifically *Callaiosphaeridium asymmetricum*, *Canningia duxburyi*, *Chlamydophorella trabeculosa*, *Coronifera oceanica*, *Nelchinopsis kostromiensis* and *Subtilisphaera terrula*. *Pterodinium cingulatum* subsp. *reticulatum* could possibly be added to this group of marker species. Top and/or base occurrences of these selected species have been listed in Fig. 14. It is evident from the ranges that the samples from Ammeloe–32, interval 41.00–45.50 m, should be assigned a late Early-Late Hauterivian age. If the range of *Pseudoceratium 'eopelliferum'*, a less well-known species, is reliable, then the age is around the transition *regale-inversus* Zones, i.e. late Early Hauterivian.

The sporomorph assemblages found between 41.95 and 42.10 m depth, which are dominated by *Cyathidites-Concavisporites* and *Gleicheniidites*, are very similar to those found in Ammeloe–33.

Fig. 13. Detail of depression fill of photograph in Fig. 12.

Discussion

The closely spaced sample intervals between 41.00–45.50 m depth enabled a tripartite palynological subdivision. The cyclicity (marine dinoflagellates – dominant terrestrial sporomorphs – common marine palynomorphs) indicates regressive-transgressive events. The boundaries between the palynomorph events are not precisely recorded in the lithologically fairly uniform section. The succession of Fig. 2 might be interpreted as two parasequence maximum flooding surfaces present in a condensed transgressive system tract. The coarser sand (42.3–42.4 m) may be related to the boundary between the two parasequences. The high numbers of *Subtilisphaera* in sample 41.00 m are probably related to reduced salinity levels (cf. Harding 1986).

Well Ammeloe–33

Corehole Ammeloe–33, is located in the Vredener Field, E of Vreden (topographical map 1:25 000, Ottenstein sheet 3907, coordinates R 25.60710, H 57.67670; Fig. 1).

The eight samples examined between 47.60 and 51.60 m (Fig. 2) show almost identical sporomorph assemblages. Marine elements as acritarchs and dinoflagellates were not found. Especially the coaly layers are rich in well-preserved trilete spores particularly *Cyathidites-Concavisporites* and very rich in *Gleicheniidites* (samples 49.70 and 51.60 m). The first plexus is characteristic of a delta-plain environment, while the second group of species, produced by the plant *Gleichenia*, reflects a pioneer vegetation. A very similar assemblage was described by Herngreen (1971) from the Upper Barremian-Lower Aptian of the Boulonnais, NW France, and by Van Amerom *et al.* (1976) from the Valanginian-Hauterivian of the West Netherlands Basin.

More diverse assemblages with strongly ornamented spores such as *Cicatricosisporites*, *Plicatella*, *Impardecispora apiverrucata* regularly occur together with *Classopollis* and bisaccate pollen grains. Though *Classopollis* grains were always observed in low percentages, they imply a marine influence or at least deposition not far from the sea. *Classopollis* was produced by *Hirmeriella* and belongs to the Cheirolepidiaceae, which were an important component of the forests bordering the Jurassic and Cretaceous coasts.

The palynomaceral composition with predominance of P2 and P4 types and some P1 (Van der Zwan 1990; Whitaker 1984), in combination with the palynomorph characteristics, indicates more or less in-situ deposition in a low-energy, fluvial or lacustrine environment.

From the miospore assemblages an Early Cretaceous age may be deduced. Low frequencies of *Parvisaccites radiatus* and *Clavifera triplex* suggest a Valanginian-Hauterivian age.

Well Ammeloe–1

Well Ammeloe–1 (see Bolsenkötter & Koch 1974) is one of the classical deep wells in which Kuhfeld Beds occur. Raw sample material of this hole was recently located, together with that from Alstätte–1 (Figs 1, 2) and Ammeloe–2. A preliminary investigation of a slide from 210 m again yielded marine dinoflagellate assemblages which will be dealt with in a future contribution.

New results from the Achterhoek, the Netherlands

Test-well K

Interval 39.00–63.50 of test-well K (see Herngreen 1973) was re-investigated micropalaeontologically as well as palynologically. The results are summarized below:

39.00–39.60 m	Marine Valanginian
39.60–41.90	Iron oolites
41.90	Unconformity
41.90–63.50	Portlandian
c. 64	Unconformity
65.00–214	Lias

For two reasons this sequence is exceptional: this is the only occurrence of Portlandian and of iron oolites in the Achterhoek area. The two features are common to the north in the Twente area and we wonder whether about 90 years ago samples from well K and a more or less simultaneously drilled well in Twente, were inadvertedly exchanged. Because of this uncertainty test-well K was not taken into consideration; it was recently decided to drill a new hole at that location in the near future.

Well Höfkes

Well Höfkes (topographical map 1:25000, sheet 41F, No. 131, coordinates x 440,000 and y 251,025) is located just west of the Dutch-German boundary, SE of Winterswijk near Kotten (Fig. 1). Between 3.95 and 37.50 m, sands and locally fine gravel, clay which often displays a violet shine, and brown-coal layers occur. This succession corresponds in detail with that described from the type area of the Kuhfeld Beds (Fig. 2). A number of clay samples yielded the following palynological results (the distribution chart may be obtained on request from the first author):

10.25–12.25 m
Exclusively terrestrial sporomorph assemblages of unspecific Valanginian-Hauterivian age occur in two samples.

29.00–29.40 m
The marine dinocyst association reveals a Valanginian-Early Hauterivian age based on *Batioladinium* (cf.) *varigranosum* and *Pseudoceratium 'eopelliferum'*.

30.65–33.10 m
The dino-assemblage contains a limited number of stratigraphically significant species such as *Batioladinium* (cf.) *varigranosum* and *Meiourogonyaulax pertusa*. The approximate age is latest Ryazanian-Hauterivian.

33.60–37.50 m
Rich dinoflagellate associations with, for example, *Ctenidodinium elegantulum*, *Kleithriasphaeridium corrugatum*, *K. porosispinum*, *Meiourogonyaulax pertusa*, *Muderongia extensiva*, *Pseudoceratium pelliferum* and *Tubotuberella apatela* indicate marine deposition around the Ryazanian-Valanginian boundary (*albidum-Paratollia* Zones).

It may be concluded that a major part of the clay layers was deposited in a marine environment. The base of the Kuhfeld Beds can be dated as close to the Ryazanian-Valanginian boundary.

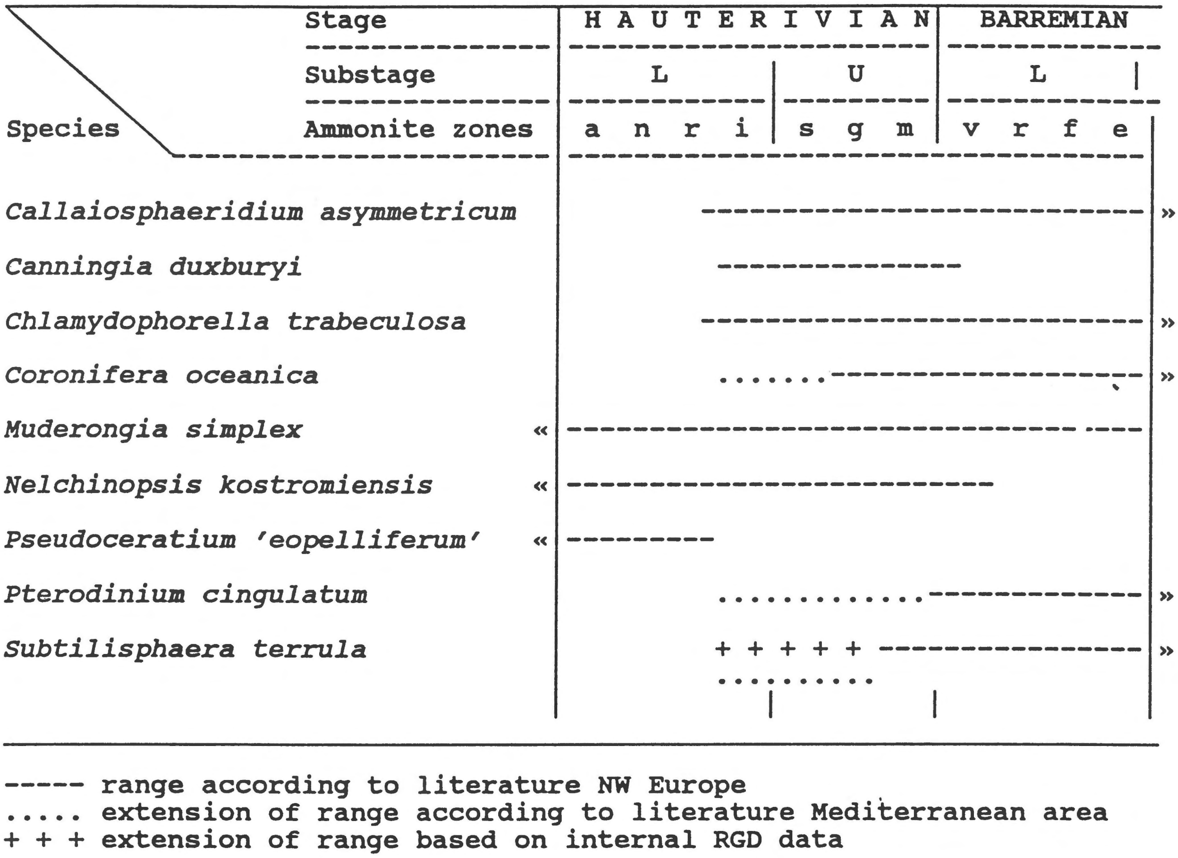

Fig. 14. Ranges of selected dinoflagellates. Chevron marks indicate extensions beyond interval shown. Abbreviations of names according to Lower Cretaceous standard ammonite zones.

Summary of results and discussion

Fieldwork in the Lukassen and Erning sandpits in the Barler Berg area, south of Ottenstein, and a palynological investigation of core samples of wells Ammeloe–32 and –33, south of Alstätte, renewed interest in the stratigrapical position and depositional environment of the Lower Cretaceous Kuhfeld Beds (Fig. 15).

Near the top of the formation, as exposed in the Lukassen sandpit, and cored in well Ammeloe–32, marine deposits can be clearly demonstrated. This result rectifies the original concept of Bentz (1930) and the views expressed by various authors between 1950–1978, that the Kuhfeld Beds are a limnic-terrestrial sequence.

A second conclusion concerns the age (near the top) of the formation. The publications dealing with the Kuhfeld Beds mention ?Ryazanian, Valanginian-Hauterivian, and ?Barremian ages. This is exclusively based on superposition of strata as the deposits were thought to be unfossiliferous except for woody material. The present investigation, resulted in a late Early-Late Hauterivian dating based on dinoflagellates found in Ammeloe–32.

The statement in Bolsenkötter & Koch (1974) that the Kuhfeld Beds terminate in the Barremian is clearly based on a misinterpretation of an internal report by von der Brelie.

In well Höfkes in the Netherlands, near the base of a characteristic Kuhfeld Bed succession, marine clays can be dated as latest Ryazanian-earliest Valanginian. This is the first palaeontological dating for the base of the Kuhfeld Beds.

An intriguing question is why Bentz interpreted the Kuhfeld Beds as limnic. In the present authors' opinion the answer may be found in a sixty years old note of the Dutch district-geologist Burck: "deposits barren of fossils of pre-Bartonian age, which are rather prematurely considered by Bentz as limnic" (internal memorandum RGD). In other words, simply because

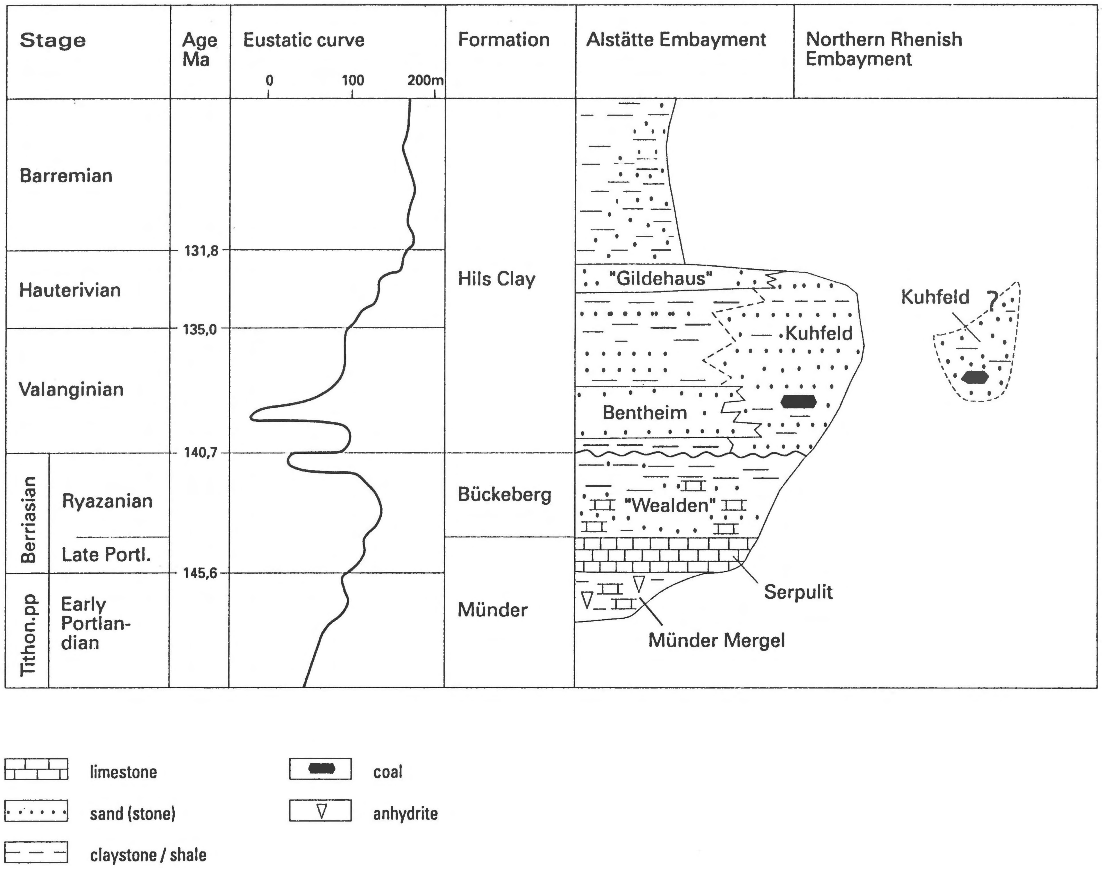

Fig. 15. Stratigraphical diagram of the Portlandian-Hauterivian in the Alstätte Embayment area (after Hiss, 1992).

there was no palaeontological evidence of a marine setting, these beds were considered to be deposited in a limnic environment.

These results raise the question regarding the status of the Kuhfeld Beds and their relation with the Valanginian and Hauterivian strata described from the Bentheim region, viz. the Bentheim, *Dichotomites*, Grenz, *Noricum* and Gildehaus Sandstones, the *Platylenticeras* Beds and other claystones separating the sandstone bodies. All these members of the Hils Clay Formation are marine units, which justified, at that time, a separate limnic-terrestrial Kuhfeld Formation. We have demonstrated, however, that at least the late Early-Late Hauterivian top of the Kuhfeld Beds was deposited in a marine environment. This means that the top of the Kuhfeld Beds is a time-stratigraphical equivalent of the Gildehaus Sandstone (Fig. 15). However, in the Lukassen sandpit, the distinction between Kuhfeld Beds and Gildehaus Sandstone, as differentiated by Bentz (1930: 22), is extremely difficult to make. Bolsenkötter & Koch (1974) considered the Kuhfeld Beds to consist of unconsolidated sediments, whereas the Gildehaus Sandstone is consolidated. This criterion seems unreliable since both units consist of almost unconsolidated material in the Lukassen and Erning sandpits. The only difference seems to be the presence of (clay-)ironstone concretions in the Gildehaus or Wellar Sandstone. Unfortunately, this feature was not mentioned for the type section(s) of the Gildehaus Member which are characterized by sponge spicules and a considerable carbonate content. Taking into consideration that many details of the lithological development are still uncertain, the present authors propose to interpret for the time being the Kuhfeld Beds as a predominantly marginal marine sequence of strata, consisting mainly of sands with subordinate clay- and siltstones, and restricted to the Alstätter Embayment. Parts of the sequence, e.g. the siltstone in well Ammeloe–33 and the topmost clay in well Höfkes, are interpreted as terrestrial.

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