Correlation of Miocene North Sea sequences with the Danish land area based on foraminifera

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Abstract

In the present study comparisons are made between the Miocene North Sea sequences and the Danish onshore formations based on foraminiferal biostratigraphy. Foraminiferal faunas of four onshore borings previously analyzed by Kristoffersen have been reviewed. Biozones NSB 9 - NSB 13 of the offshore sequences were all found in the Danish Miocene formations, and the obtained results promise well for a future more detailed correlation between the North Sea and the Danish land area.

Introduction

A recent sequence stratigraphical study of the eastern North Sea region have revealed 21 sequences during the Cenozoic (Michelsen et al., in press). Seven of these sequences are located within the Miocene. The sequence boundaries and the maximum flooding surfaces in the Miocene interval are chronostratigraphically allocated primarily by means of foraminiferal biostratigraphy. The North Sea foraminiferal zonations of King (1989) has been applied for the Miocene.
In the present study we have re-examined the foraminiferal biostratigraphy of four onshore borings, in order to test the applicability of the offshore stratigraphy in the Miocene of Denmark, and to assess its reliability in future offshore stratigraphic investigations. As onshore seismic data and petrophysical logs are of varying quality we have chosen to correlate the North Sea sequences and the Danish onshore formations primarily on the basis of foraminiferal biostratigraphy. Emphasis has been placed on examining whether the revised version of King's (1983) North Sea foraminiferal zonation (King, 1989), can also be applied in onshore regions (of the North Sea basin) in the Miocene, and in particular, whether biozones NSB 9 to NSB 13 are present in the Danish Miocene formations. To reach this goal the foraminiferal faunas of four of the onshore borings previously analyzed by Kristoffersen (1972) were reviewed (for location see Fig. 1).

The borings

Selected details of the foraminiferal stratigraphy of four borings at Høruphav, Alkærsig, Gram and Sæd, Denmark (Fig.1) are shown in Figs. 2-5. In order to ease correlation with the biostratigraphical North Sea zonation (King, 1989) the data are presented as events (highest occurrence). The sample interval is approximately half a meter. The borings are described in ascending stratigraphical order.

Høruphav (Fig. 2):
Bolivina antiqua d'Orbigny and *Plectofrondicularia seminuda* (Reuss) were found in the Høruphav boring (DGU ref. No. 170.381). These are index species of North Sea Benthic Zones (NSB) 8c and 9 (King, 1989), respectively (Late Oligocene and Early Miocene). Between the highest occurrences of these two species a fossil poor interval with no stratigraphical important species was encountered. This interval is difficult to correlate to any established zonation. *Loxostomum sinuosum* (Cushman), substitute marker of NSB 10, had its highest occurrence approximately two metres above the highest occurrence of *P. seminuda*. In the same interval *Asterigerina staeschei* ten Dam & Reinhold was also present. The coexistence of *L. sinuosum* and *A. staeschei* has previously been shown from the Arnum

Formation (Kristoffersen, 1972). The presence of the planktic species *Cassigerinella chipolensis* (Cushman & Ponton) indicates correlation to the German local Hemmoorian stage of the Lower Miocene (Spiegler, 1986). The Arnum Formation was previously correlated to the Hemmoorian (Rasmussen, 1966).

Alkærsig (Fig. 3):
The Arnum Formation is well represented in the Alkærsig boring (DGU ref. No. 93.101). *Loxostomum sinuosum* (substitute marker of NSB 10) had its highest occurrence in the lower half of the boring, while *Bulimina dingdenensis* Batjes marked the top of the Arnum Formation (lithostratigraphic subdivision by Rasmussen, 1961). *Bulimina dingdenensis* is also a substitute marker of NSB 10 (King, 1989). The highest occurrence of *L. sinuosum* below the highest occurrence of *B. dingdenensis* could consequently be useful in subdividing NSB 10 in the Danish onshore area. Slightly below the top of NSB 10 the planktic *Globorotalia praescitula* Blow, index species of North Sea Planktic Zone (NSP) 11 (King, 1989), had its highest occurrence together with *C. chipolensis*. This indicates correlation to the German local Hemmoorian stage. *Asterigerina staeschei* (index species of NSB 11) dominates the fauna in the sediments of the Middle Miocene Hodde Clay (lithostratigraphic subdivision by Rasmussen, 1961). NSB 12 may be present in this boring, but according to King (1989) *Uvigerina semiornata saprophila* von Daniels & Spiegler should be present in NSB 12. In Alkærsig only *Uvigerina semiornata semiornata* d'Orbigny is present, and NSB 12 is, therefore, marked by a question mark.

Gram (Fig. 4):
The lithostratigraphical allocation of the lowermost part of the Gram boring (DGU ref. No. 141.277) is uncertain. It may belong to the Arnum Formation or the lower part of the Hodde Formation. However, a quartz gravel zone is present in the interval from 36.5-37.4 m below surface (Rasmussen, 1966). This feature has previously been described in the lowermost part of the Hodde Formation (Rasmussen, 1961, 1966). None of the characteristic species normally seen in the Arnum Formation are present in the interval below the Hodde Clay. Slightly below the top of the Hodde Clay *A. staeschei*, index species of NSB 11, has its highest occurrence. *Bolboforma reticulata* von Daniels & Spiegler and *Bolboforma badenensis* Szczechura have also their highest occurrences in this interval. In deep sea sediments these species occur in nannoplankton Zones NN 5-6 (Müller & Spiegler, 1993). This harmonizes with the fact that NSB 11 was previously correlated with NN 5 (King, 1989).
The Gram Clay is separated from the Hodde Clay by a Glauconite Clay, which is barren of foraminifera. The Gram Clay is, however, relatively rich in foraminifera. In the lower part of this formation the occurrence of *Elphidium antoninum* (d'Orbigny) indicates the presence of NSB 12b. Slightly above this event, *Bolboforma clodiusi* von Daniels & Spiegler (index species of NSP 13) has its highest occurrence. None of the index species of NSB 12c and NSP 14a are present in the boring, but the occurrence of *Uvigerina pygmaea langenfeldensis* von Daniels & Spiegler could indicate the possible presence of NSB 12c. In the range chart of King (1989, p. 439) *U. p. langenfeldensis* has a range across the boundary between NSB 12c and NSB 13a. This is the reason for the question mark and the inclined dashed line at the top of NSB 12c in Fig. 4. In the topmost sample *Bolboforma metzmacheri* (Clodius) and *Uvigerina pygmaea langeri* von Daniels & Spiegler are present. These are index species of NSP 14b and NSB 13a, respectively.

Sæd (Fig. 5):
Bolboforma metzmacheri and *U. p. langeri* were also found in the "typical" Gram Clay in the boring at Sæd (DGU ref. No. 167.445). However, a rather scattered occurrence of *U. p. langenfeldensis* in the same interval could indicated the possible presence of NSB 12c.
A clay occurs above the typical Gram Clay which "must undoubtedly be termed Gram Clay" (Rasmussen, 1966, p. 320). Previously this clay was mentioned as Sæd Clay. There are no index species present in this interval, but a substitute marker of NSB 13b, *Valvulineria mexicana grammensis* Langer, is found, and the planktic foraminifera *Neogloboquadrina acostaensis* (Blow), index species of NSP 15a, is also present. According to King (1989) the top of NSP 15a should correlate with the top of NSB 13a. This is not the case in the Sæd boring.

Correlation

Correlation of the Danish formations with the NSB/NSP zonation has changed through time (Fig. 6). The first attempt by King (1983) to correlate the Danish Upper Oligocene and Miocene formations was based on Larsen & Dinesen's (1959) and Kristoffersen's (1972) data. In 1989 King published another correlation of the Danish formations with the NSB zones. The revised version was based on additional, unpublished data and is, therefore, unfortunately lacking an explanation for the major changes: The Vejlefjord and Klintinghoved Formations are not separated and they include NSB 8c and part of NSB 9. The boundary between the Klintinghoved Formation and the Arnum Formation is rather variable but it occurs within NSB 9. The base of the Hodde Formation was moved down to within NSB 10 and the hiatus between the Gram and Hodde Formations disappeared. The boundary between these two formations coincides with the boundary between NSB 11 and 12 (Fig. 6) in King's 1989 stratigraphy.
The present review of borings previously analyzed by Kristoffersen (1972) suggests the following correlation: The Vejlefjord Formation (represented by the Brejning Clay in the boring at Høruphav) is correlated with NSB 8c on the basis of the presence of *B. antiqua*. The Klintinghoved Clay corresponds to NSB 9 because of the presence of *P. seminuda*. The gradual transition from NSB 9 to the faunas of the Arnum Formation (NSB 10) in the Høruphav boring places the upper boundary of the Klintinghoved Clay at the upper boundary of NSB 9. The presence of the substitute markers *L. sinuosum* and *B. dingdenensis* in the Arnum Formation in the Alkærsig boring indicates correlation with NSB 10. In the Borg-1 oil well the index species of NSB 10, *Uvigerina tenuipustulata* van Voorthuysen is present together with these substitute markers. The Hodde Clay contains *A. staeschei* and correlates with NSB 11. It was not possible to judge whether the Glauconite Clay at the basis of the Gram Clay can be correlated to NSB 12a because it was barren. The presence of *E. antoninum*, *U. p. langenfeldensis*, *U. p. langeri*, and *V. m. grammensis* in the Gram Clay indicates correlation with NSB 12b, 12c, 13a and 13b, respectively.

Conclusion

The comparison of the foraminifera in four Danish onshore borings with the established North Sea foraminiferal zonation by King (1983, 1989) shows that it is possible to use this zonation in the onshore region. Biozones NSB 9 - NSB 13 were all found in Danish onshore borings. In the light of this it should be possible to identify the North Sea sequences in the outcrops and borings in onshore Denmark. These results promise well for future more detailed correlations between the North Sea and the Danish land area. Analysis of land

profiles should yield more information with a higher resolution than obtainable in offshore oil drillings due to closer sampling interval. This might perhaps successively result in a more detailed North Sea stratigraphy.

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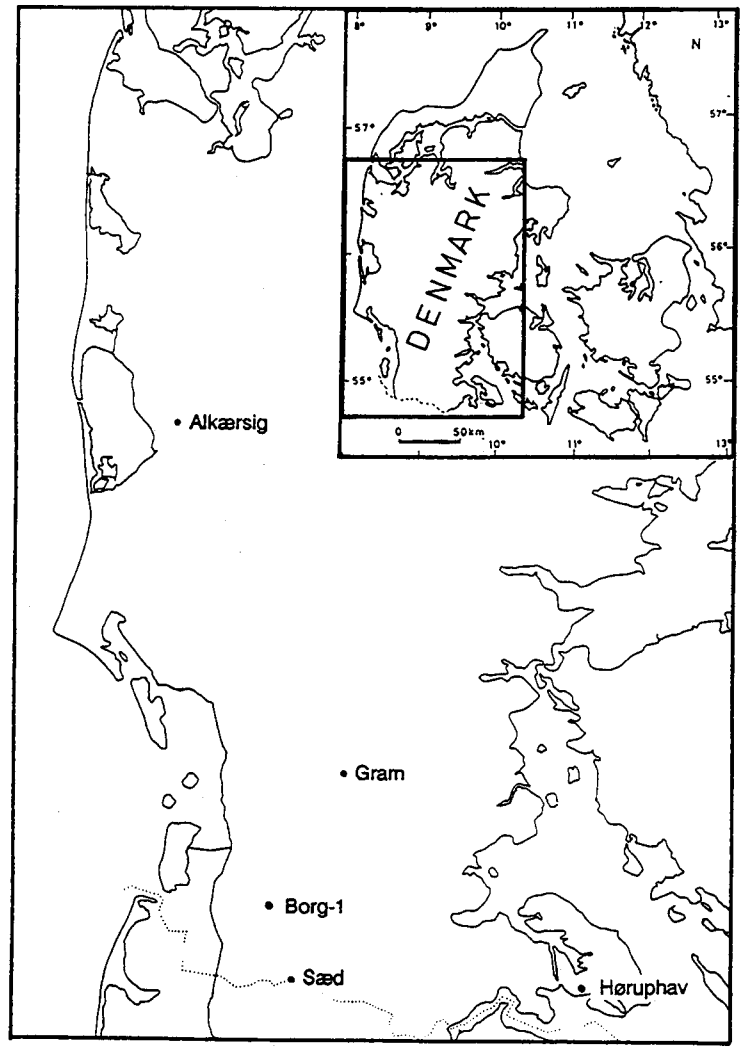

Fig. 1 The location of the borings mentioned in the text. After Rasmussen, 1966.

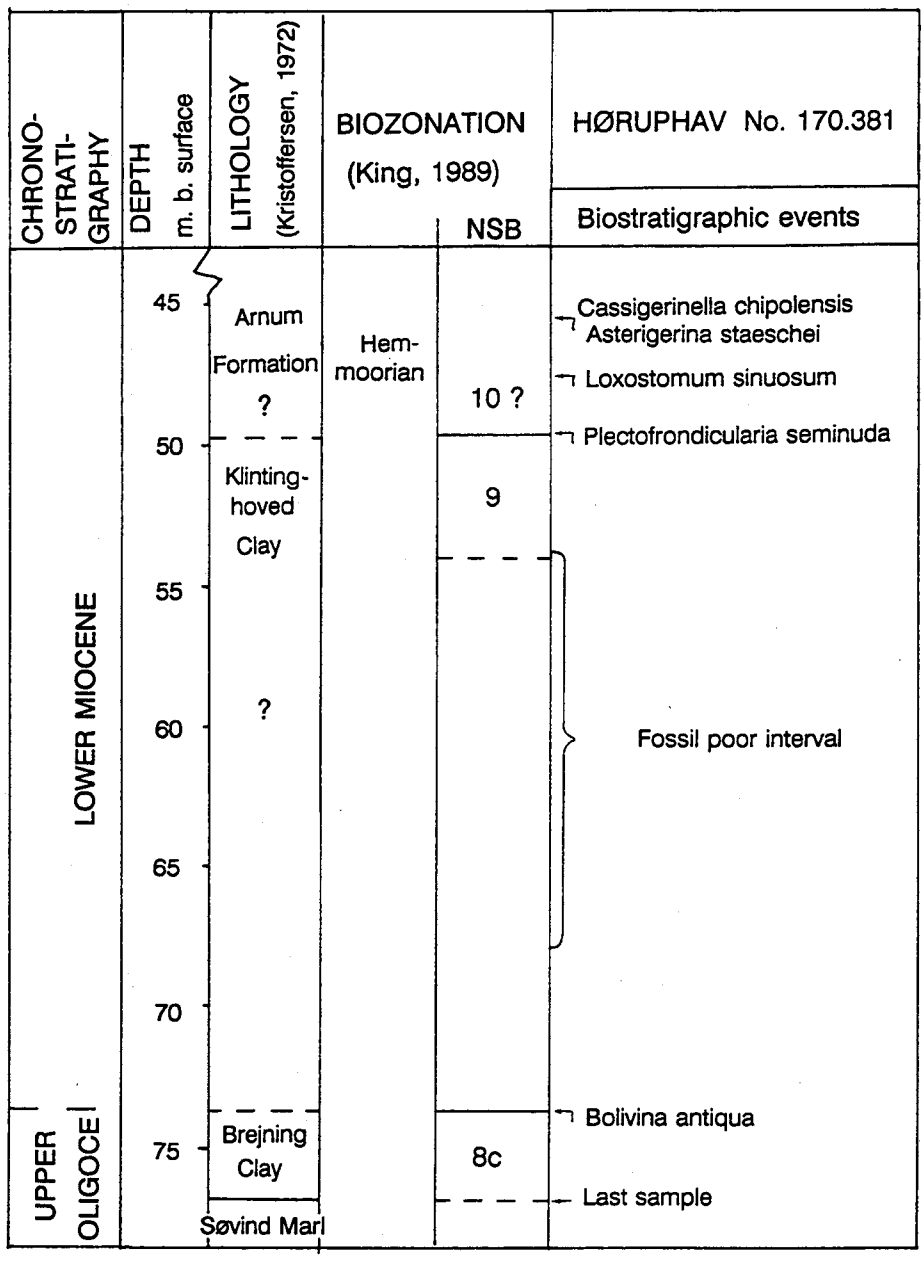

Fig. 2 Biostratigraphic events, lithological units and biozonation in the Upper Oligocene to Lower Miocene sediments of the Høruphav boring (data from Kristoffersen, 1972) (for location see Fig. 1). Arrows indicate highest occurrences.

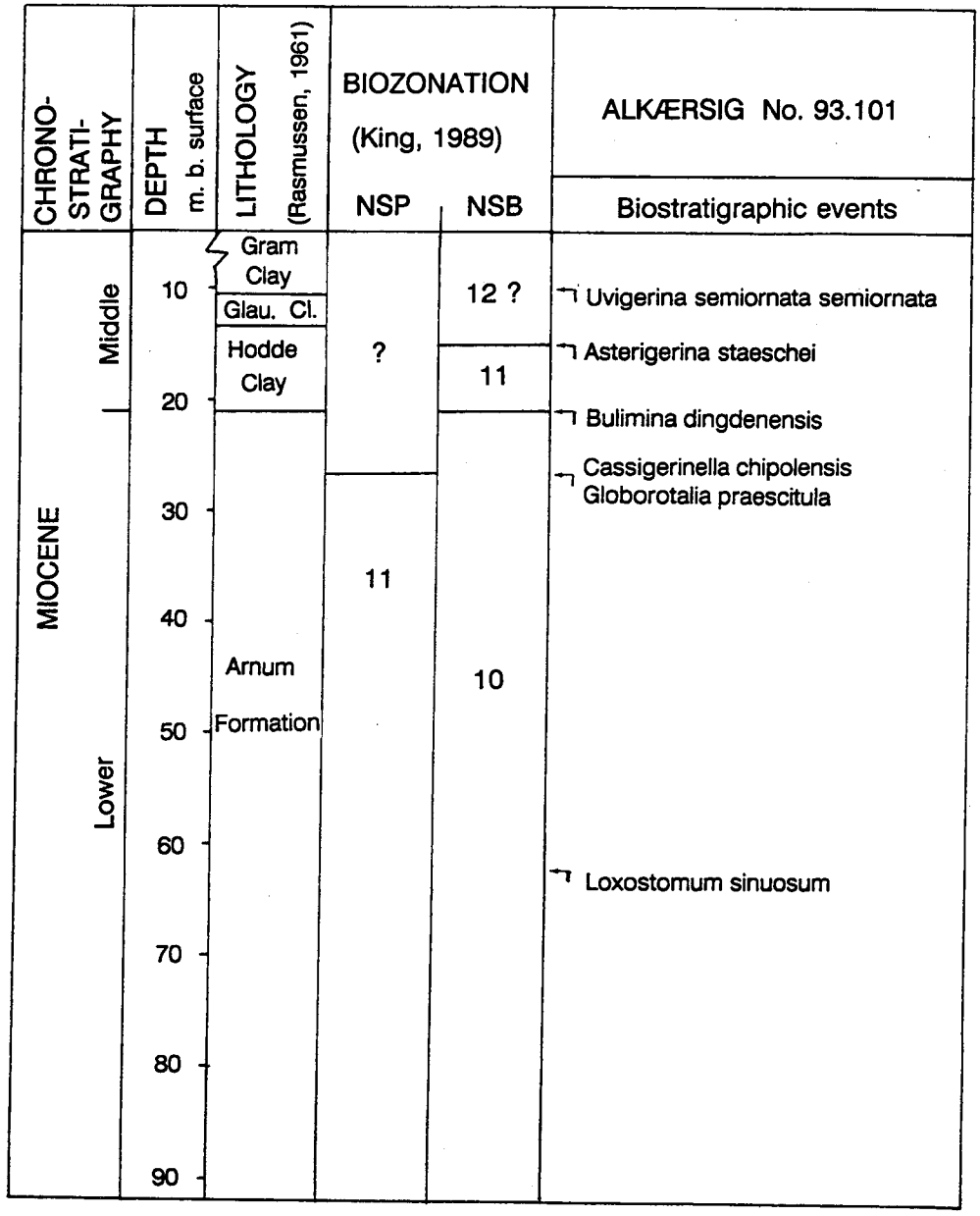

Fig. 3 Biostratigraphic events, lithological units and biozonations in the Lower to Middle Miocene sediments of the Alkærsig boring (data from Kristoffersen, 1972) (for location see Fig. 1). Arrows indicate highest occurrences.

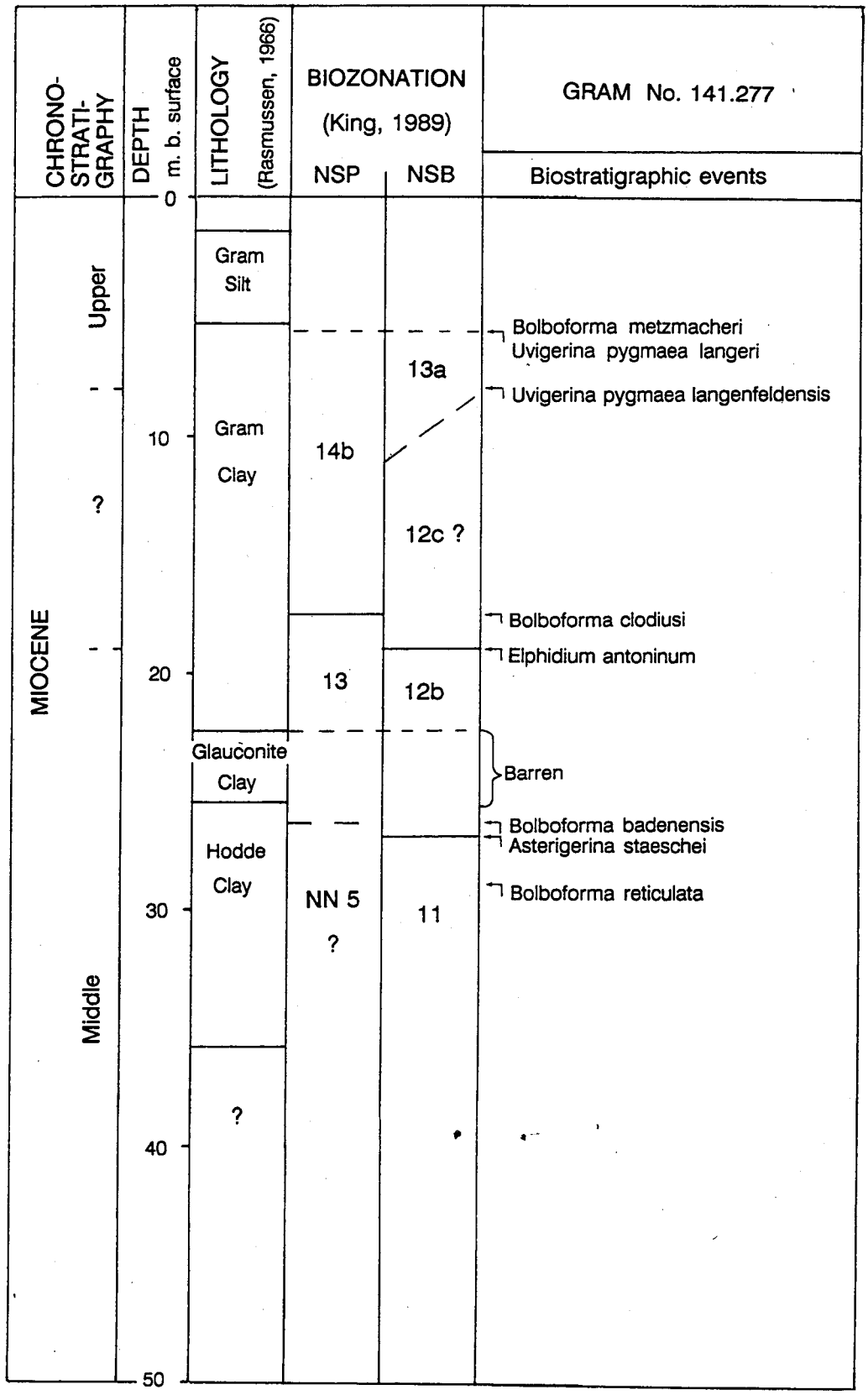

Fig. 4 Biostratigraphic events, lithological units and biozonations in the Middle to Upper Miocene sediments of the Gram boring (data from Kristoffersen, 1972) (for location see Fig. 1). Arrows indicate highest occurrences.

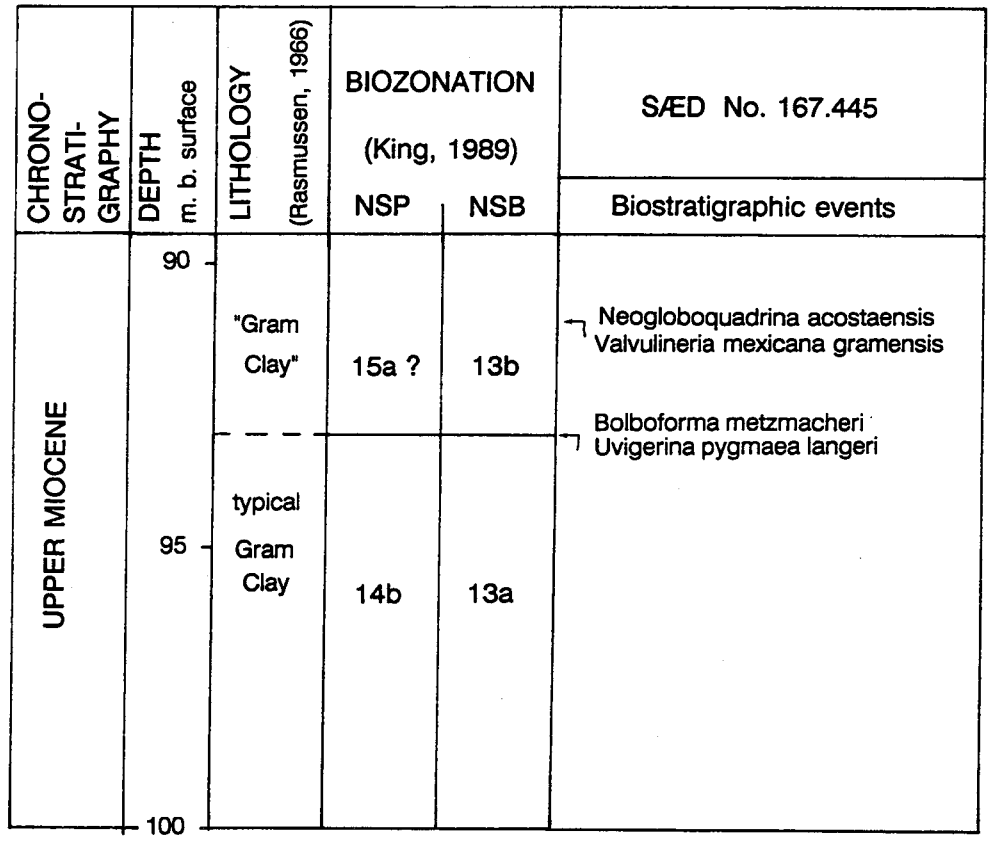

Fig. 5 Biostratigraphic events, lithological units and biozonations in the Upper Miocene sediments of the Sæd boring (data from Kristoffersen, 1972) (for location see Fig. 1). Arrows indicate highest occurrences.

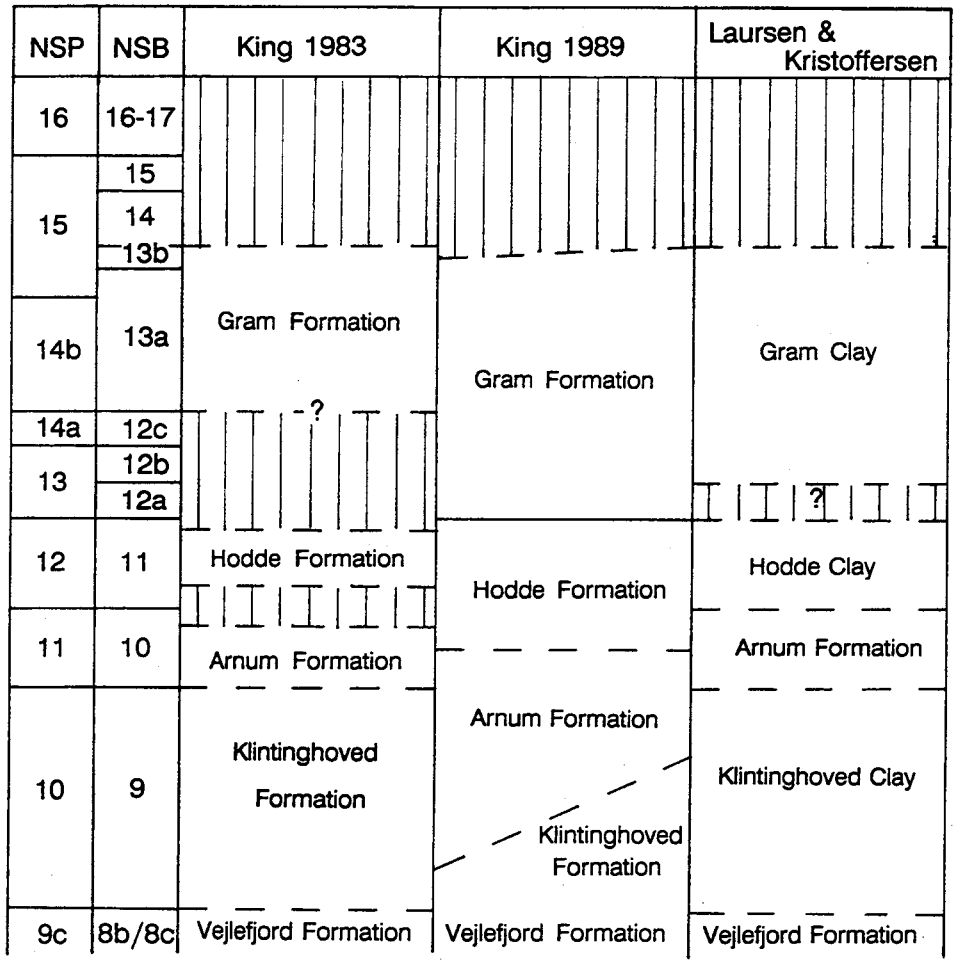

Fig. 6 Correlation between Danish onshore lithostratigraphical formations and North Sea offshore planktic (NSP) and benthic (NSB) foraminiferal zones.