MG AND SR DISTRIBUTION IN CARBONATE ROCKS IN THE BOUNDARY SEQUENCE IN THE DANISH BASIN AND THE NORTH SEA CENTRAL GRABEN

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The usefulness of minor elements, i.e. Mg and Sr, as tools in facies analyses in sedimentary carbonate rocks has been intensively discussed by several authors (see Bathurst, 1976, for references). Consideration of possible regional and facies changes in Mg and Sr distribution are closely related to carbonate chemistry, mineralogy of skeletal carbonates and the effects of diagenetic processes. So many different factors have been taken into account as possible controls of these elements that interpretations are difficult and generalizations impossible.

Nevertheless, a characteristic negative correlation between the concentrations of Mg and Sr in the topmost Maastrichtian chalk has previously been recorded at two localities in the Danish Basin (Honjo & Tabuchi, 1970; Jørgensen, 1975). This observation has led the present author to initiate a comprehensive study of the Mg and Sr distribution in the Maastrichtian/Danian boundary sequence in the Danish Basin and the North Sea Central Graben.

The boundary sequence is characterized by a more variable lithology than generally observed in the Maastrichtian strata in the Danish Basin (see Rosenkrantz, 1966; Håkansson *et al.*, 1974; Jørgensen, 1975; Childs & Reed, 1975; Nielsen, 1976; Stenestad, 1976). However, in the present study only two major sediment types are considered: (1) Maastrichtian and Danian chalk, including subordinate marl layers and hardgrounds and (2) Danian bryozoan limestone.

Mg AND Sr DISTRIBUTION

The material studied includes a large number of samples from 13 outcrops or boreholes encompassing the Maastrichtian/Danian boundary

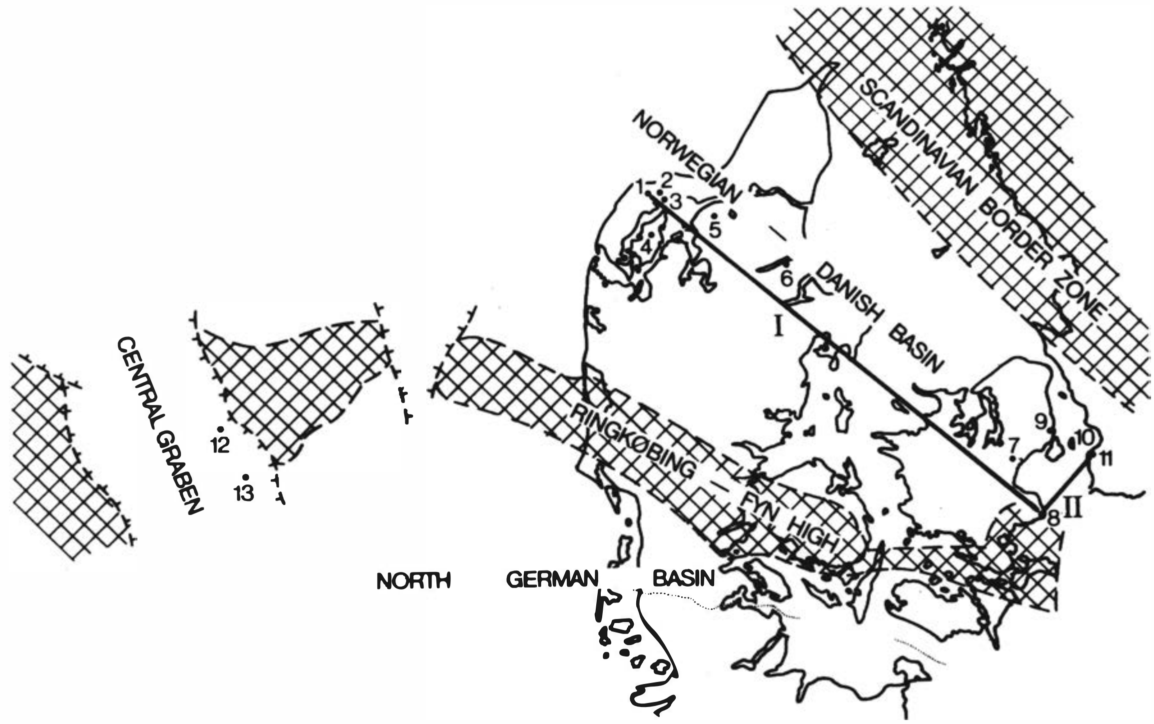


Fig. 1. Map of Denmark and the North Sea showing the 3 geographical areas and the localities studied in the present paper. (1) The North Sea Central Graben: 12: E-1, 13: M-1x. (2) The axial part of the Danish Basin (Section I): 1: Bjerre, 2: Kjølby Gaard, 3: Nye Kløv, 4: Eerslev, 5: Vokslev, 6: Dania, 7: Karlstrup, 8: Stevns. (3) The transitional marginal zone (Section II): 9: Copenhagen TUBA 13, 10: Saltholm, 11: Limhamn.

in the Danish Basin and the North Sea Central Graben (Fig. 1). The localities are divided into three groups on the basis of geographical location, lithology and elemental distribution. These are (1) the North Sea Central Graben, (2) the axial part of the Danish Basin (section I) and (3) a transitional marginal zone in the Danish Basin (section II) approaching the Fennoscandian Border Zone.

The Mg and Sr concentrations were determined by atomic absorption photospectrometry. The results are treated from two points of view: (1) stratigraphic distribution within the individual localities and (2) geographical pattern.

Stratigraphic distribution

The general distribution of the elements within the individual sequences is rather similar for all localities studied. The most conspicuous feature is the negative correlation between the two elements in the uppermost Maastrichtian chalk, i.e. increasing Mg and decreasing Sr concentrations towards the Maastrichtian/Danian boundary (Figs 2-4).

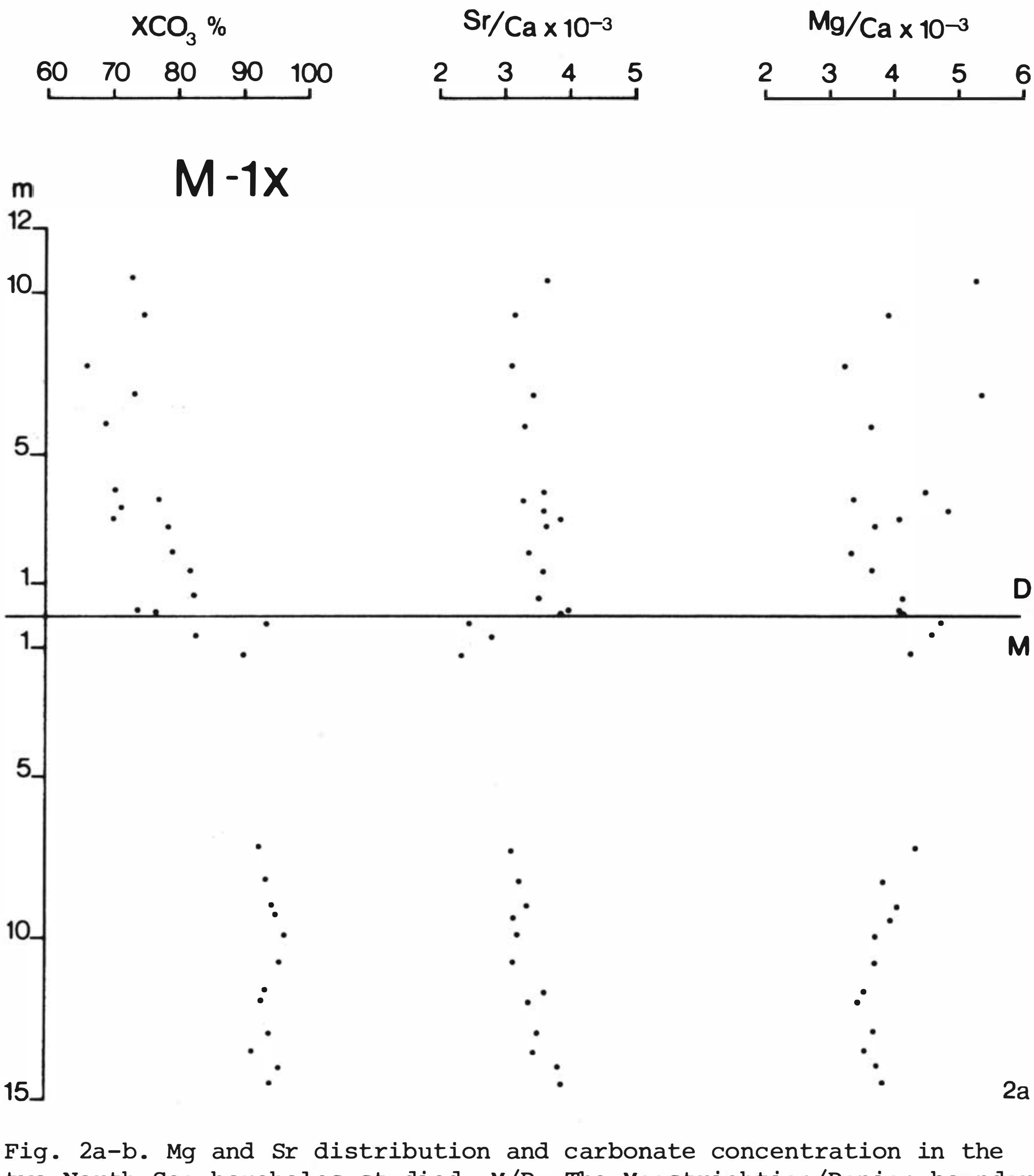
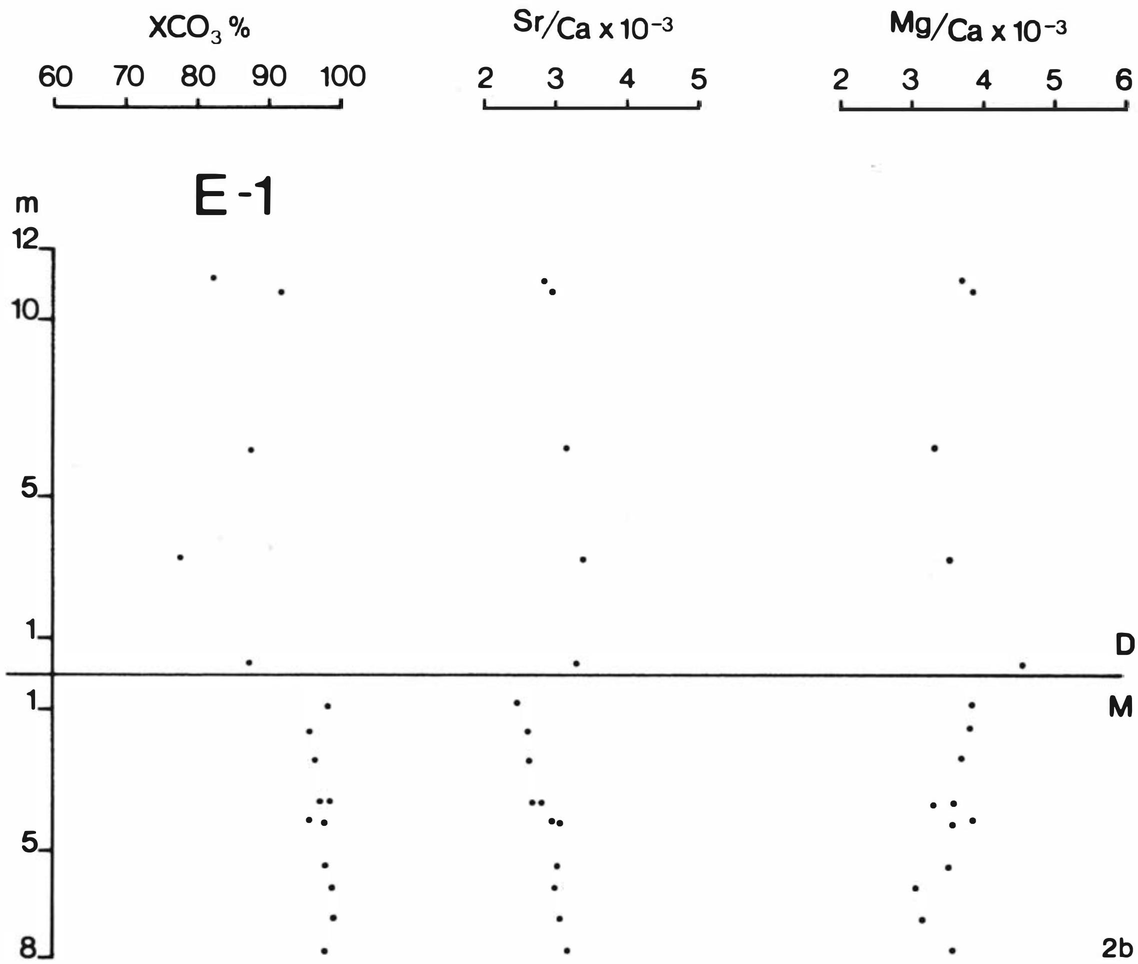


Fig. 2a-b. Mg and Sr distribution and carbonate concentration in the two North Sea boreholes studied. M/D: The Maastrichtian/Danian boundary.



The trend of the decreasing in Sr concentration is very constant, varying from 0.1 Sr/Ca × 10^{-3} per metre sediment in the North Sea Central Graben to 0.2 Sr/Ca × 10^{-3} per metre sediment in the Danish Basin. The only significant variability in Sr concentration in the Danish Basin is found in section II (Fig. 4). Variations in Mg concentration are much more pronounced. However, on the basis of the present data the trend of the increase in Mg concentration is estimated to be approximately 0.1 Mg/Ca × 10^{-3} per metre sediment.

The variable lithology of the Danish sequence to some degree blurrs the general pattern of the elemental distribution, but the negative elemental correlation obtained in the Maastrichtian strata is replaced here by a relatively constant proportion between the Mg and Sr correlations. Furthermore, there are significantly higher concentrations of Mg in the bryozoan limestone in comparison to the value found in the chalk.

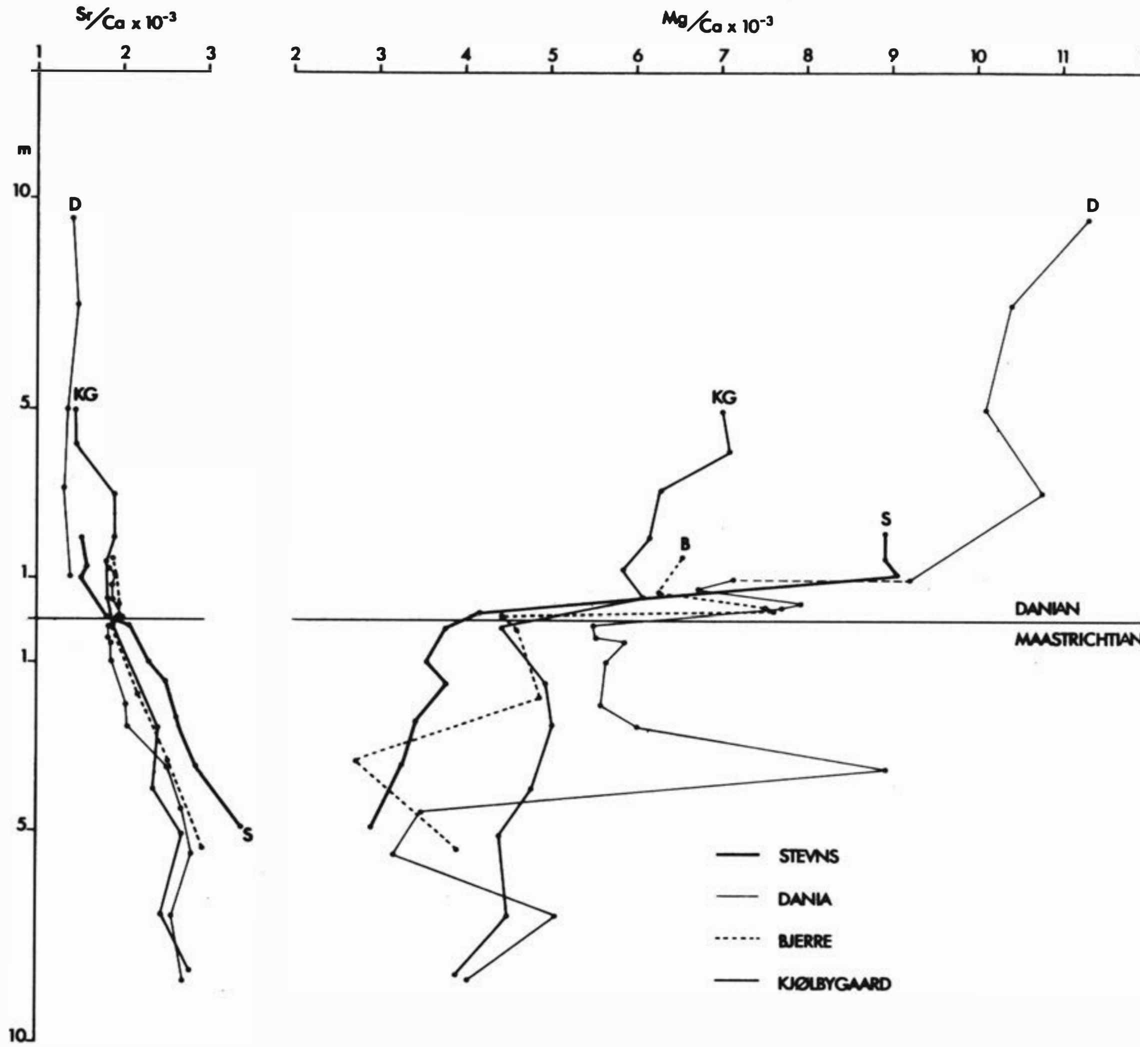


Fig. 3. Mg and Sr distribution at selected localities from the axial part of the Danish Basin (Section I).

Geographical distribution

The geographical distribution reveals a clear variation between the three areas studied. The differences are accompanied by textural modifications, particularly with respect to the carbonate mud. The term carbonate mud is here used for particles < 63 µm. These are of indeterminate origin and constitute the overwhelming majority of particles in both chalk and bryozoan limestone (Jørgensen, 1975; Nielsen, 1976; Bromley, this volume).

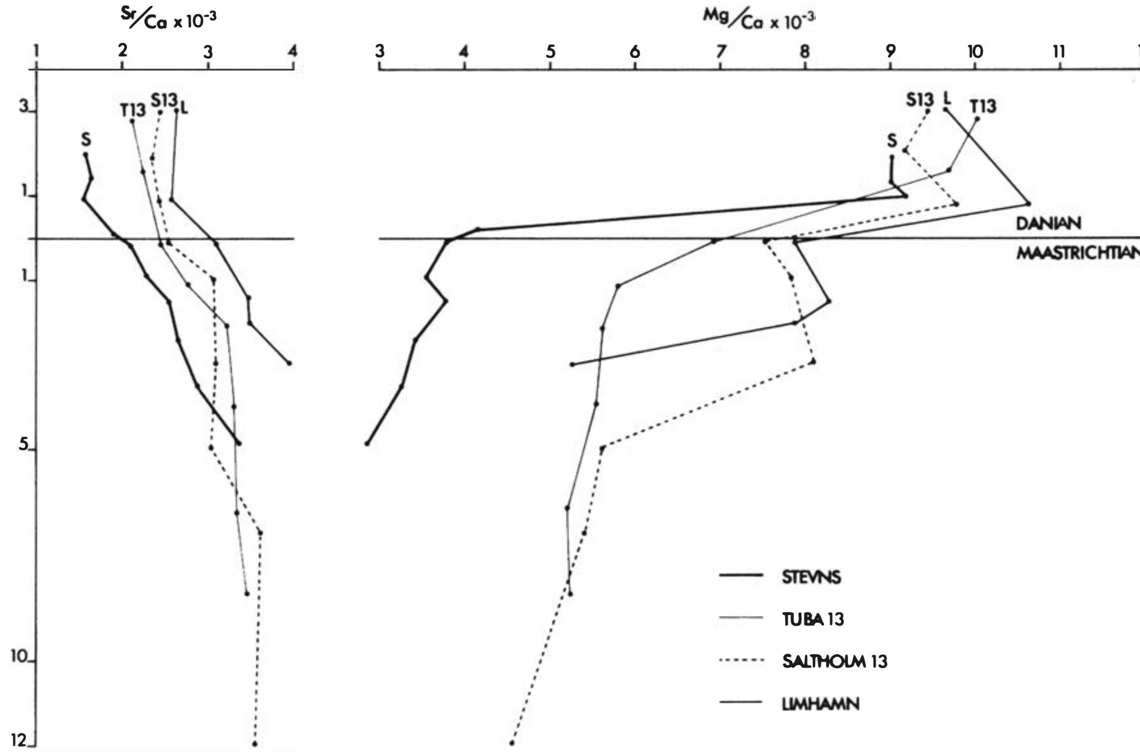
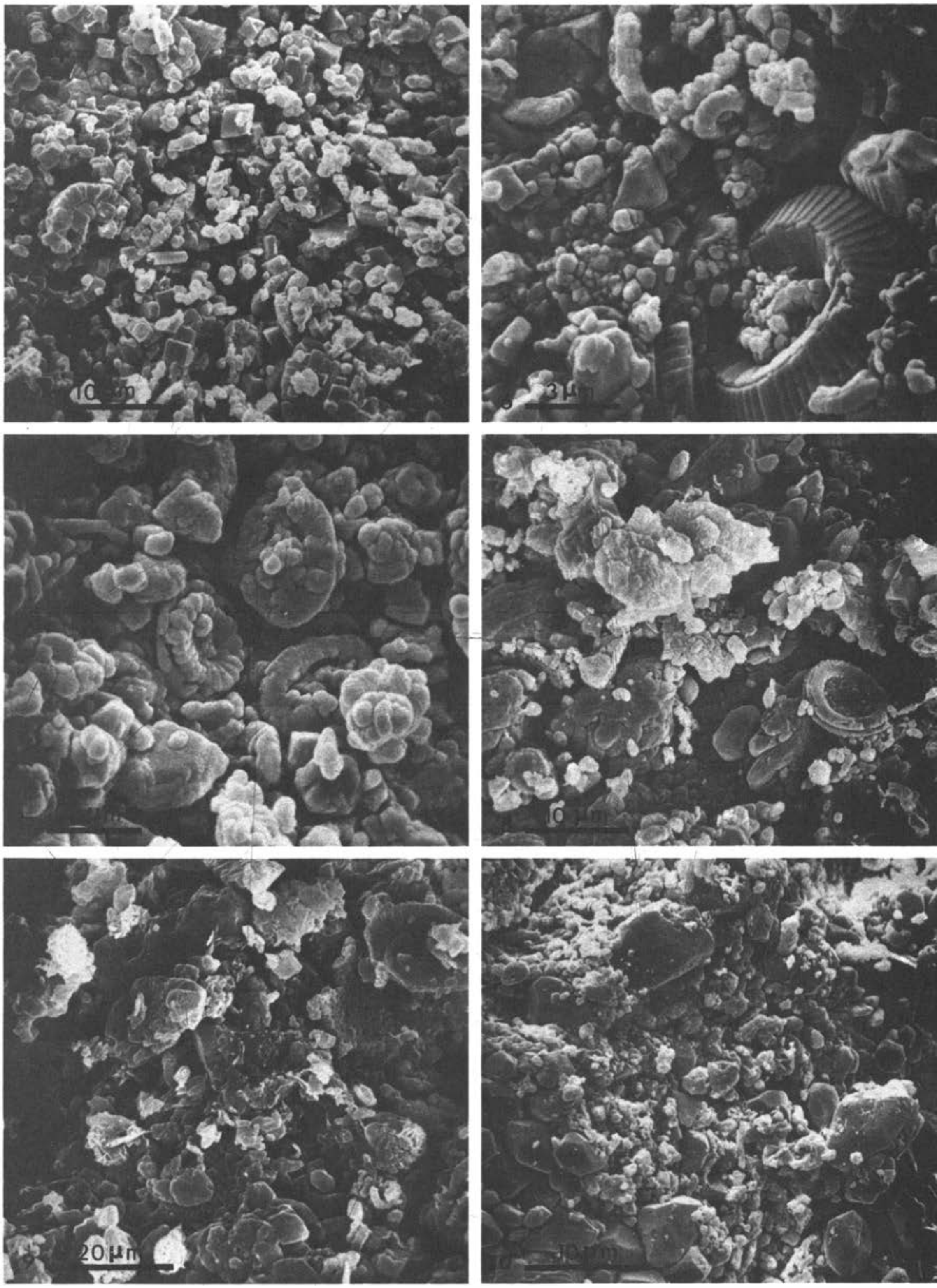


Fig. 4. Mg and Sr distribution at localities from the transitional marginal zone (Section II).

The carbonate mud of the North Sea chalk has a remarkably uniform textural appearance, i.e. regular grain shape and almost entirely micritic in size (Figs 5,6). Skeletons generally observed originate from pelagic micro- and nannofossils, whereas larger skeletal fragments are virtually absent. The elemental distribution is practically identical in the two boreholes studied.

The texture of the chalk in the axial part of the Danish Basin is quite similar to that of the North Sea chalk (Fig. 7), but the number of

Figs 5-10. SEM pictures of fracture surfaces. Fig. 5: Maastrichtian chalk from M-1x, the North Sea Central Graben. Fig. 6: Danian chalk from M-1x, the North Sea Central Graben. Fig. 7: Maastrichtian chalk from Vokslev, the axial part of the Danish Basin. Fig. 8: Danian bryozoan limestone from Stevns. Fig. 9: Maastrichtian chalk from Limhamn, the transitional marginal zone. Fig. 10: Cemented Maastrichtian chalk from Saltholm 13, the transitional marginal zone.


10 µm
3 µm
10 µm
20 µm

larger skeletal fragments and the amount of insoluble residue are significantly greater and much more variable (Jørgensen, 1975). The elemental distribution recorded is almost identical to that found in the North Sea chalk, but is characterized by more variable concentrations.

The elemental distribution in the transitional marginal zone shows a clear trend of increasing Mg and Sr concentrations in a north-eastern direction. The texture of the carbonate mud is characterized by irregular and angular grain shape and a considerable number of the particles is within medium silt size fraction (Figs 8,9). A partial cementation of the rocks of the studied area may have an early date (Fig. 10).

CONCLUSION

The negative correlation between the elements is restricted to a particular part of the stratigraphic sequence studied. The data derives from three different geographical areas with slightly different lithology and diagenetic impact. The elemental distribution is revealed not only by examination of bulk samples, but recent investigations of individual skeletons of different taxa have demonstrated a similar pattern (Jørgensen, 1975). The remarkably regular and organized stratigraphic and geographical distribution of Mg and Sr cannot be due to incidental diagenetic effects alone, but suggest a significant dependence on the original formation of the sediments. The almost totally biogenic origin of the carbonate constituents indicates that the phenomenon most likely is caused by the biochemical uptake of these elements. It is therefore believed that the elemental distribution to a certain degree reflects physicochemical alterations in the late Maastrichtian sea, e.g. temperature and salinity. Consequently, the general variations in the elemental distributions may be time correlative and thereby significant for stratigraphic and environmental interpretations.

The geographical distribution of the elements reveals the existence of two biogeochemical facies within the area studied: (1) an axial basinal facies including the North Sea Central Graben and the axial part of the Danish Basin and (2) a transitional marginal facies.

The basinal facies is characterized by a comparatively stable elemental composition, probably caused by the dominance of pelagic organisms among the identifiable skeletons and most likely also among the constituents of the carbonate mud.

The transitional marginal facies reveals metastable geochemical conditions as reflected by increasing Mg and Sr concentrations and the impact of diagenesis. The feature applies to both chalk and bryozoan limestone. The texture of the carbonate mud clearly indicates a different origin from the basinal carbonate mud. The geographical distribution of the elements suggests a northeastward increase in amount of metastable carbonate matter i.e. towards the margin of the Maastrichtian sea. Although there is no obvious authigenic source of metastable carbonate matter in the studied sequences, the existence of such a source cannot be excluded. However, a supply of metastable carbonate mud transported from near-shore environments to the transitional marginal zone should also be considered. The Maastrichtian littoral communities could certainly have supplied a considerable amount of magnesian calcite and aragonite in the form of metastable carbonate detritus.

The metastable carbonate mud in turn would have been influenced by the physicochemical changes in the late Maastrichtian sea. Thus the irregular distribution of the elements in the transitional marginal zone most likely is governed by two independent factors: (1) a dominant factor consisting of the physicochemical properties of the sea water and (2) the supply of metastable carbonate detritus.