Notes – *Notiser*

Planktonic foraminifers under the Norwegian Coastal Current: surface sediment assemblages

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A preliminary survey of planktonic foraminiferal shells in surface sediments along the Norwegian continental margin has shown that the following species are common: *Globoquadrina pachyderma* (dextral and sinistral phenotypes), *Globigerina bulloides*, *G. quinqueloba*, *Globorotalia inflata*, *Globigerinita glutinata*. The distributions of these shells in modern sediments follow major water masses of the Norwegian Coastal Current and North Atlantic Drift regimes whose course is clearly controlled by the Norwegian continental margin. Though planktonic foraminifers are relatively rare under the coastal water masses, they even reach Skagerrak and the outer fjord basins in numbers sufficient for a comprehensive faunal analysis.

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Planktonic foraminifers have been successfully used for paleo-oceanographic reconstructions because their biogeography is directly controlled by the hydrographic properties of the oceanic surface water masses (Bé 1977). The distributional pattern of their biocoenoses can be reconstructed using taphocoenoses from the modern pelagic sediment cover (Kipp 1976), and they are henceforth a very useful tool to describe the circulation pattern of the modern and ancient oceanic surface water masses. As part of the Project 'Den norske Kyststrøm' we are therefore presently trying to determine which planktonic foraminiferal species are common in the eastern Norwegian Sea and how distinct the faunal assemblages of the coastal water masses off Norway are from those of the open pelagic environment. In this preliminary report we will try to outline the distributional pattern of the important species of planktonic foraminifers in Skagerrak, northern North Sea and in the eastern Norwegian Sea, and we will try to define qualitatively the relationship to the overlying water masses (Fig. 1). We have studied the planktonic foraminiferal shell assemblages from more than 35 samples in the size fraction $> 150\ \mu$m because we wanted to be able to compare our data to those of Kellogg (1973, 1976). Many of these samples have been obtained from graduate students who have studied small regions of this area in great detail (Kihle 1971, Lind-Hansen 1978, Miljeteig 1975, Ofstad 1977, Nagy & Ofstad 1980). Data of the planktonic/benthonic foraminifer ratio of the northernmost areas have been taken from Vorren et al. (1978).

Planktonic foraminiferal shell assemblages

The distribution of planktonic foraminiferal shells in the eastern Norwegian Sea, northern North Sea, and Skagerrak reveals quantitatively as well as qualitatively a zonation with steep gradients essentially perpendicular to the Norwegian continental margin (Fig. 2a and b). Abundances of less than 100 specimens per 1 g of dry bulk surface sediment (Fig. 2a) are typical for the coastal water masses of Skagerrak and of the northern North Sea (cf. Jarke 1961). A transitional belt of 100–1000 specimens per 1 g of dry bulk surface sediment can be traced along the continental margin off Norway, whereas abundances climb to $> 10{,}000$ specimens under the water masses of the North Atlantic Drift (cf. Fig. 1). It is also characteristic that the proportion of planktonic in total foraminiferal shell assemblages (Fig. 2b) reveals a zonation parallel to the continental margin because of the increase of planktonic foraminifers and the decrease of benthic foraminifers with increasing water depth and distance from the coast.

The modern planktonic foraminiferal sediment assemblages along the Norwegian continental

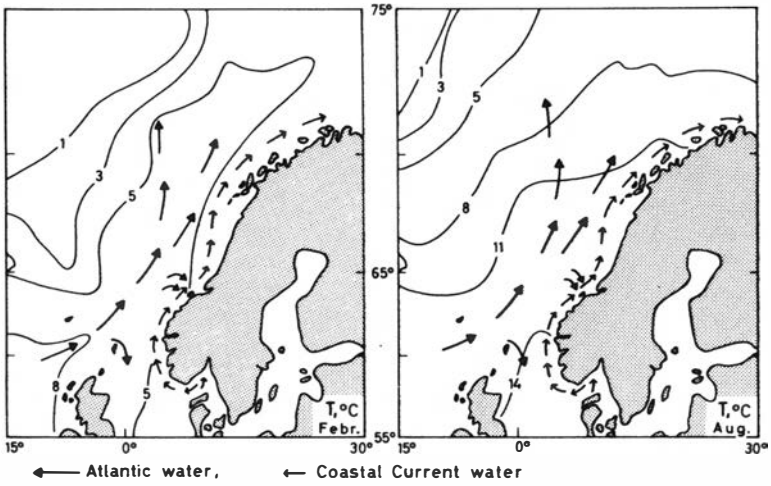

Fig. 1. Winter (February) and summer (August) Norwegian Sea surface temperatures. Isotherms in degrees Celsius simplified after U. S. Naval Oceanographic Office 1965, 1967 and U. S. Navy Hydrographic Office 1958. The arrows indicate the direction of the Norwegian Coastal Current (small arrows) and of the North Atlantic Drift (large arrows).

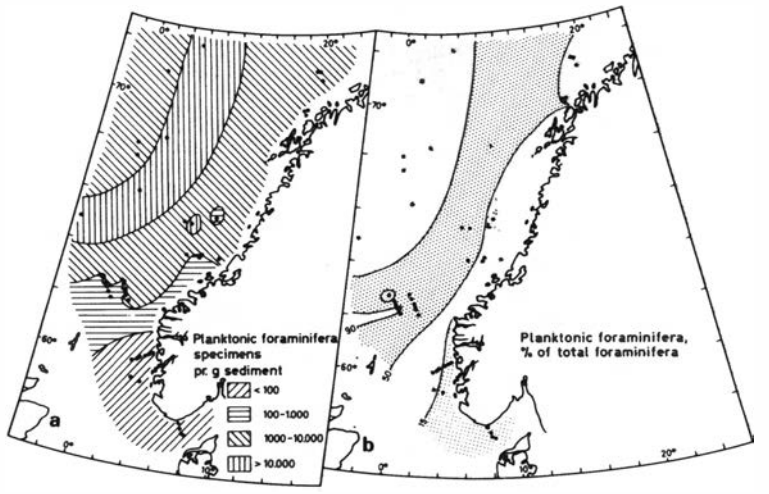

Fig. 2. a. Abundance of planktonic foraminiferal shells (> 150 μm) in surface sediments along the Norwegian continental margin (in nos. of shells/1 g of dry bulk sediment). b. Concentrations (%) of planktonic foraminifers in total foraminiferal faunas (> 150 μm).

margin are composed of 13 species. The most important ones are *Globoquadrina pachyderma* (Ehrenberg), *Globigerina quinqueloba* Natland, and *Globigerina bulloides* d'Orbigny, but also common are *Globorotalia inflata* (d'Orbigny) and *Globigerinita glutinata* (Egger). *Globoquadrina dutertrei* (d'Orbigny), *Globigerina falconensis* Blow and *Orbulina universa* d'Orbigny have been found relatively seldomly, whereas only a few specimens of *Globigerina digitata* Brady, *Globigerinella aequilateralis* (Brady), *Globorotalia scitula* (Brady), and *Globorotalia crassaformis* (Galloway & Wissler) have been observed. *Globigerinita uvula* (Ehrenberg) is a common but very small species so that its occurrence is suppressed because of the size fraction > 150 μm used.

Planktonic foraminiferal species distribution

The most abundant planktonic foraminiferal species in the sediments of the Norwegian Sea and along the Norwegian continental margin is *G. pachyderma* (Fig. 3), which is elsewhere characteristic of subpolar surface water masses (Bé & Tolderlund 1971, Bé 1977). In this region it is most abundant along the northernmost part of the Norwegian continental margin where most of the other species are absent and where the relatively warm surface water masses of the North Atlantic Drift (Fig. 1) fade away. The dextral (= right coiling) modification of *G. pachyderma* (Fig. 3), which is known to prefer warmer surface water masses than the sinistral

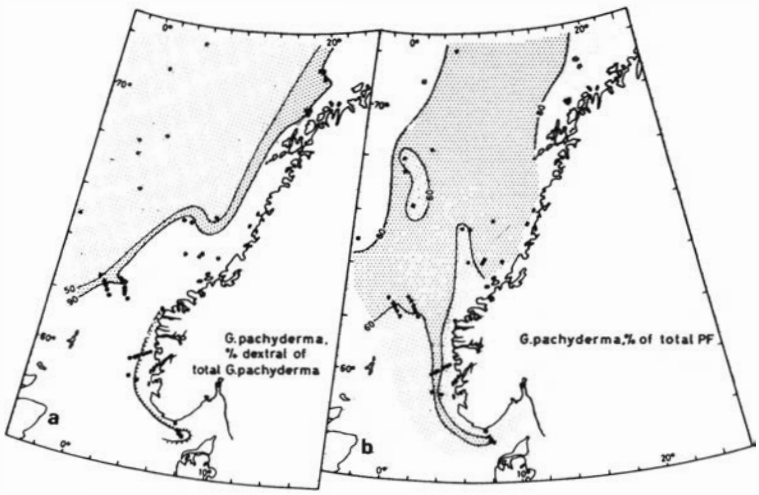

Fig. 3. a. Distribution of dextral *G. pachyderma,* in percent of total *G. pachyderma*. b. Distribution of *G. pachyderma* in percent of total planktonic foraminiferal faunas.

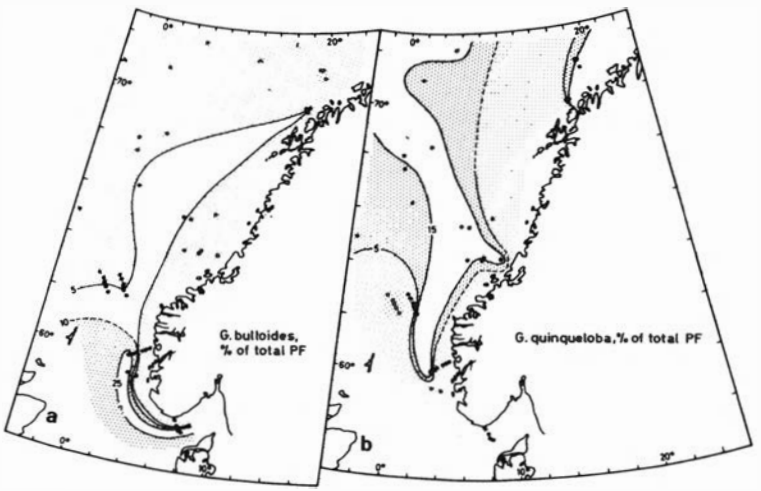

Fig. 4. a. Distribution of *G. bulloides* in percent of total planktonic foraminifers. b. Distribution of *G. quinqueloba* in percent of total planktonic foraminifers.

modification (Ericson 1959, Bandy 1960), can be traced far into Skagerrak. It is notable, however, how narrow the belt of dominantly right coiling *G. pachyderma* is along the Norwegian continental margin, whereas the sinistral modification supersedes it in the entire open Norwegian Sea.

The other species typical of the subpolar surface water masses (Bé 1977) is *G. quinqueloba,* which is registered in most samples (Fig. 4) although in considerably smaller percentages than *G. pachyderma*. At present we are not able to explain the distribution pattern of *G. quinqueloba* (Fig. 4). When more data will become available from the shelf off Nordland this problem may be solved. *G. bulloides,* which characterises today transitional surface water (Bé & Tolderlund 1971), is confined to the relatively warm water masses of the North Atlantic Drift (Fig. 4). *G. inflata* and a few other transitional species are also restricted to the south of the area studied, where the warmer surface waters of the North Atlantic Drift enter the Norwegian Sea.

Discussion and conclusion

From the comparison of the Norwegian Sea surface temperatures (Fig. 1) and the distributional patterns of the single planktonic foraminiferal species, it is obvious that they are confined to specific water masses. They allow separation of the polar water masses of the open Norwegian Sea, the transitional water masses of the North Atlantic Drift which are cooling considerably on

their passage along the Norwegian continental margin, and the water masses of the Norwegian Coastal Current regime. It is particular noteworthy that the planktonic foraminiferal faunas found under the coastal water masses are smaller and distinct in their composition from those of an open Norwegian Sea. Faunas observed in the outermost western Norwegian fjord basin are similar to those of these coastal water masses (Aarseth et al. 1975).

Comparison of the summer and winter sea surface temperatures with a number of foraminiferal parameters also suggests an influence of seasonal hydrographic changes on the plantonic foraminiferal shell assemblages. Dextral *G. pachyderma* (Fig. 3a) seems to correspond well to the summer surface temperatures (Fig. 1); it is found to be most abundant under the coastal waters, but decreases towards the open ocean. Kellogg (1973), however, suggested that the distribution of right coiling *G. pachyderma* corresponded to the winter temperatures, but we think Kellogg's interpretations may be due to lack of data from the eastern and northern areas. The distribution pattern of *G. bulloides*, however, seems to be correlated rather to the winter than to summer isotherms.

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