ENVIRONMENTAL ANALYSIS OF DEEP-SEA AGGLUTINATED FORAMINIFERA: CAN WE DISTINGUISH TRANQUIL FROM DISTURBED ENVIRONMENTS ?

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INTRODUCTION

Paleoenvironmental analysis usually requires the application of Huttonian principles to interpret the paleoecological significance of fossil assemblages. Calcareous benthic foraminifera are well suited for paleoenvironmental analysis and are now routinely used to reconstruct the subsidence and water mass history of sedimentary basins. Many of the Tertiary basins in the North Atlantic, however, contain flysch-type faunas which consist mainly of agglutinated species (Brouwer, 1964; Gradstein and Berggren, 1981; Kaminski *et al.*, 1987a). The amount of paleoenvironmental information that can be extracted from these assemblages is a function of how well we understand the ecology of modern deep-sea agglutinated faunas. Therefore, studies of modern agglutinated foraminifera play an essential role in establishing a baseline for paleoenvironmental analyses using flysch-type assemblages.

Many modern species of agglutinated foraminifera have wide geographic and bathymetric ranges, and may be less affected by water mass properties than calcareous foraminifera. Their agglutinating behavior, which enables this group to incorporate particles of the local sediment into their tests with a varying degree of selectivity, makes agglutinated species respond to changes in the substrate (Schroder, 1986). Both substrate and stability of the benthic environment are influenced by the local hydrographic regime, such as the presence of a nepheloid layer or strong bottom currents which scour or otherwise disturb the sea floor. Therefore, we might ask whether agglutinated assemblages reflect the dynamic properties of their environment.

In areas where disturbance by bottom currents results in population reduction, epifaunal species may be at risk and the rigorous environment may favor infaunal or opportunistic species. This information, if preserved in the fossil record, may be useful for determining whether vigorous deep currents were present in a given area. In this study, we test this assumption by examining the agglutinated component in modern deep-sea settings and using the resultant ecological information to interpret the paleoenvironment of Neogene agglutinated assemblages recovered on ODP Leg 105.

STUDY AREAS

Our data base for the modern distribution of agglutinated assemblages consists of 10 boxcore stations from the continental rise off Nova Scotia, 8 from the Nares Abyssal Plain, and 2 from the Panama Basin (Kaminski, 1985; Schroder, 1986; Kaminski *et al.*, 1987b). These regions represent different environments in terms of the frequency and intensity of physical disturbance. The Nares Abyssal Plain and Panama Basin are tranquil sites, whereas the lower continental rise off Nova Scotia experiences the highest bottom water turbidity and current velocities yet recorded in the deep ocean (McCave and Tucholke, 1986).

RESULTS AND DISCUSSION

To study the effect of the sedimentary environment on the structure of agglutinated foraminiferal faunas, we examined whether particular "morphogroups" (in the sense of Jones and Chernock, 1985) exhibit preference for tranquil or disturbed environments. We also simulated physical disturbance in a tranquil environment by conducting a recolonization experiment in which trays of abiotic sediment were placed on the sea floor, and benthic foraminifera allowed to colonize (Kaminski *et al.*, 1987b). A description of disturbed and tranquil sites follows:

Tranquil Environments

The Nares Abyssal Plain is covered by fine-grained

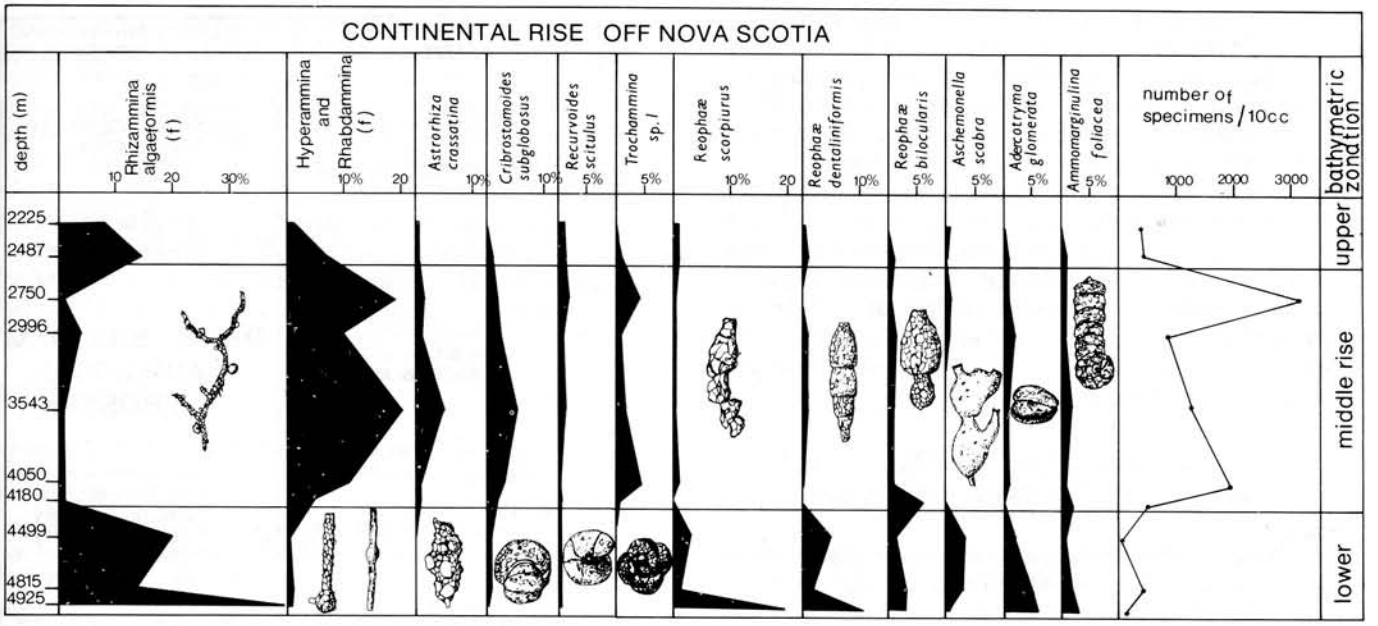

Figure 1. Percentage occurrences of selected agglutinated species along a depth transect on the continental rise off Nova Scotia. The distribution of these taxa reflects the nature of the substrate, and the hydrographic regime. The symbol (f) indicates fragments.

pelagic sediment, and provides a stable, oligotrophic environment for benthic organisms. No evidence of turbidites or winnowing was observed in the boxcores collected. The agglutinated fauna in this region is dominated by species of Komokiacea and Astrorhizidae, which have branching tubular tests and live in the flocculent surface layer. Some of these taxa have an erect epifaunal life position. These taxa form the trophic morphogroup of primary suspension feeders, according to Jones and Chernock (1985). Other common genera on the Nares Abyssal Plain are *Adercotrema*, *Reophax*, and *Nodellum*. These genera possess a coiled or elongate chamber arrangement and prefer an infaunal mode of life. They belong to the morphogroup of sediment-dwelling herbivores and detritivores and are most common 1-2 cm below the sediment surface (Schroder, 1987). At the Panama Basin Site, branching tubular species comprise up to 90% of the fauna. Nearly all living specimens were found in the upper 2 cm. Lituolids and ammodiscids also live mainly in the surface layer. Below 5cm, the living fauna consists mainly of *Reophax*.

Another example of a relatively tranquil environment is the upper continental rise off Nova Scotia. The region between 2200m and 2500m lies above the influence of the Western Boundary Undercurrent (WBUC). The sediment contains abundant light particles such as diatom shells, fragments of planktonic foraminifera and organic debris. These components suggest a lack of strong bottom currents, although some downslope transport is indicated by the occurrence of calcareous slope foraminifera. At this site, the assemblage is dominated by the suspension-feeding species *Rhizammina algaeformis* (Fig. 1). At a relatively tranquil location at 4185 m on the continental rise, the assemblage contains a large proportion of species which utilize fine-grained material in the construction of their tests.

Disturbed Environments

The western margin of the North American Basin is characterised by two zones of increased current velocity (Tucholke *et al.*, 1985). The WBUC flows in a southwesterly direction along the middle continental rise between 2500 and 4000 m. Abundant intact planktonic foraminiferal tests, coarse detrital sand and reduced numbers of diatom tests form a relatively coarse grained substrate that has been winnowed by currents. The agglutinated component is diverse and includes reworked specimens. The assemblage contains a large proportion of species which utilize coarse-grained material in the construction of their tests, reflecting the coarse nature of the substrate. The fauna is dominated by robust, non-branching species of Astrorhizidae and a number of lituolids and trochamminids (Fig. 1). These groups are epifaunal, and constitute the morphogroup of surface-dwelling herbivores, detritivores and omnivores (Jones and Chernock, 1985).

The second zone of high currents is the lower continental rise (below 4200m) south of Nova Scotia which was studied in detail at the HEBBLE Area. This region is subjected to brief periods of disturbance by "benthic storms" which are caused by the interaction between a southwesterly mean flow and eddies and rings of the Gulf Stream. The sediment is relatively coarse grained, with increasing sand content (>50%) towards the base of the continental rise (Driscoll *et al.*, 1985). The agglutinated assemblage on the lower rise consists of branching specimens of *Rhizammina* and abundant specimens of the infaunal genus *Reophax*. Detailed examination of as-

semblages at the HEBBLE Area by means of factor analysis (Kaminski, 1985) revealed an end-member assemblage characterized by *Reophax*. This assemblage was dominant in box-core samples with a thick, finely laminated surface layer visible in X-radiographs, which was apparently deposited after a benthic storm.

In a recolonization experiment in the deep Panama Basin, the most effective colonizers were species of *Reophax*. Unexpectedly, the branching tubular forms were found to have limited dispersial capability. The common occurrence of *Reophax* in recolonization trays and at the HEBBLE Site support the idea of this genus being opportunistic and capable of invading newly deposited sediment after a benthic storm.

Paleoenvironmental Analysis of Agglutinated Foraminifera – An Example from ODP Site 646

Agglutinated foraminifera are common components of Paleogene assemblages, but the fossil record of agglutinated foraminifera in Neogene sediments of the North Atlantic is poor, due to decomposition of the organic cement binding the test (Schroder, 1987). The only DSDP/ODP site in the North Atlantic which contains well-developed Neogene assemblages of agglutinated foraminifera is Site 646 in the Labrador Sea (Kaminski *et al.*, in prep.). This site was drilled on the northwest flank of the Eirik Ridge, a prominent sediment drift lying southwest of Greenland at water depths between 3 and 4 km. The Eirik Ridge lies in the pathway of Denmark Straits Overflow Water, which comprises much of the WBUC in the Irminger Basin. Benthic foraminiferal assemblages from Site 646 allow us to interpret the depositional environment and water mass history of the Eirik Ridge (Fig. 2).

The upper Miocene sediments at the base of Hole 646B contain an assemblage dominated by *Nuttallides umbonifera*, which suggests the presence of southern-source bottom water. Characteristic accessory species in this assemblage are agglutinated foraminifera with smooth, finely finished tests, such as ammodiscids and *Bathysiphon*. These organisms are present in greater proportion in modern environments that are relatively undisturbed by bottom currents. Species restricted to this assemblage, *Ammodiscus* and *Glomospira*, have been identified as epifaunal detrital feeders (Jones and Chernock, 1985) and presumably have a low tolerance for disturbed environments.

Above the "R3" reflector at 680 mbsf, the sedimentation rate increases and there is sedimentological evidence for weak bottom currents (Fig. 2). Between 671 m and 651 mbsf a distinct change in the benthic foraminiferal assemblage occurs. *Nuttallides umbonifera* becomes rare, and the assemblage is dominated by a coarse species of *Rhizammina*. Since this form is an epibenthic suspension feeder, it presumably requires moving bottom currents to supply it with food. However, this genus is sessile and cannot escape the effects of strong bottom currents. Other agglutinated forms in this unit include *Psammosphaera*, *Lagenammina*, *Trochammina*, *Recurvoides*, and *Cyclammina pusilla*. This assemblage displays closest affinities to assemblages recovered from the pre-glacial sediments of Sites 344 and 345 in the Norwegian-Greenland Sea. The accessory calcareous benthic species in this assemblage are typical of modern North Atlantic Deep Water. The faunal turnover is interpreted as representing the initiation of Denmark Straits Overflow.

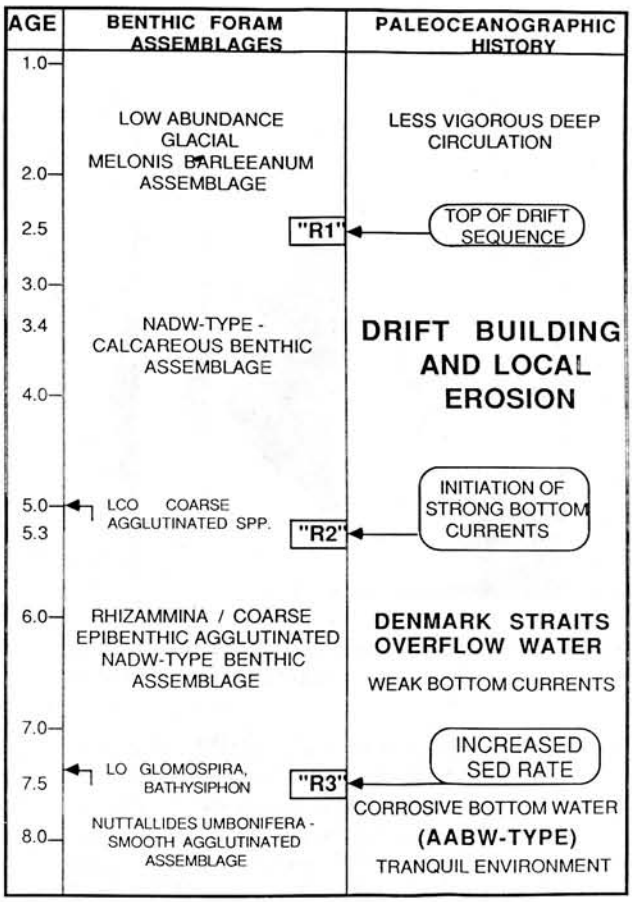

Figure 2. Summary of benthic foraminiferal assemblages and deep water history of the Eirik Ridge Site 646.

The "R2" reflector delineates the base of the sediment drift. Above this level, the benthic assemblage contains a greater proportion of NADW species, and the coarse *Rhizammina* and associated agglutinated species disappear. This faunal change may reflect a change in water mass properties of Denmark Straits Overflow Water, and/or higher bottom current intensities, which would have inhibited *Rhizammina* and resulted in increased ventilation of the deep environment.

CONCLUSIONS

Our comparison of tranquil and disturbed habitats indicates that the composition and trophic structure of agglutinated foraminiferal communities are influenced by the depositional environment. Components of the local substrate are reflected in the tests of agglutinated foraminifera. Tranquil environments are dominated by

suspension feeders with branching, fragile tests, and contain a large proportion of finely agglutinated forms. Disturbed environments with strong bottom currents are characterised by robust, coarse-grained epifaunal and infaunal species. Elongate species of *Reophax* are well suited for colonizing substrates after physical disturbance of their habitat.

We can use information on the life position and trophic structure of agglutinated assemblages to help interpret the Miocene depositional environment at the Eirik Ridge. Before 7.5 Ma, an assemblage dominated by *Nuttallides umbonifera* and smooth agglutinated species points to a tranquil environment with southern-source deep water. After 7.5 Ma northern-source deep water is present over the Eirik Ridge, and the benthic assemblage consists mainly of coarse-grained, epifaunal agglutinated taxa which display affinities to the Norwegian-Greenland Sea. The onset of drift sedimentation at 5.3 Ma is accompanied by a change to a predominantly calcareous assemblage. This faunal turnover is intrepreted as indicating increased ventilation of the deep Labrador Sea.

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