

DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN SURFACE SEDIMENTS OF THE EAST CHINA SEA AND THE HUANGHAI SEA

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ABSTRACT

Distribution of 21 species of planktonic foraminifera in more than 200 surface sediment samples from the East China Sea and the Huanghai Sea was studied quantitatively. As a result, the proximity to the ocean (or the distance from the coast) and the water currents (Kuroshio with its branches and coastal currents) have been found to be the main factors controlling the distribution pattern of specimen abundance, test size and species assemblages. Three assemblages have been distinguished by a Q-mode factor analysis: the Kuroshio assemblage dominated by *Neogloboquadrina dutertrei*, *Globigerinoides ruber*, *G. sacculifer* and *Pulleniatina obliquiloculata*; the Coastal Current assemblage dominated by *Globigerinita glutinata* and *Globigerina bulloides*; and the transitional assemblage in between.

Planktonic foraminifera are extensively used in marine geological study. Studies on their distribution in surface sediments of the East China Sea and the Huanghai Sea, one of the widest continental shelves in the world, should be of help to paleoecological and paleoceanographic investigations. A total of over 200 grab or core-top samples were analysed in the present study. Each sample was washed over a 280-mesh (0.055 mm) screen and then studied for planktonic foraminifera quantitatively and qualitatively. The samples were provided by the Second Institute of Oceanography, Hangzhou, and the Marine Geology Survey Bureau, Shanghai. Data for stations off the west coast of Korea were taken from the literature^[1].

I. ABUNDANCE AND TEST SIZE

The abundance of planktonic foraminifera in the surface sediments of the East China Sea and Huanghai Sea increases with increasing water depth^[2,3]. Figure 1 shows that the planktonic foraminifera increase in relative abundance (percentage of planktonic foraminifera in total foraminiferal number) from the northwest to the southeast. Thus, the planktonic foraminifera are more than 95% in the Okinawa Trough (water depth > 700 m); more than 90% on the slope (water depth > 150 m); 70-90% at shelf margin (water depth 100-

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150 m); and $<30\%$ within the inner shelf shallower than 50 m. The ratio between benthonic and planktonic foraminifera which varies with water depth has been used as a paleobathymetric indicator since the late fifties of this century. The pattern of the planktonic foraminifera distribution in the East China and Huanghai Seas provides further evidence for the usefulness of this indicator. The abundance of planktonic foraminifera, however, is also controlled by water currents. The Kuroshio with high salinity and warm temperature originating from the Equatorial Pacific increases the abundance of planktonic foraminifera in the east part of the East China Sea. As shown in Fig. 1, the high concentrations of planktonic foraminifera are located at the places where the Kuroshio, Taiwan, Tsushima and Huanghai Sea Warm Currents flow through. On the other hand, the areas of lower relative abundance ($<10\%$) are controlled by the coastal currents. Two abnormally high concentrations encountered in the Changjiang River and Qiantang River estuaries may be related to tides that bring planktonic foraminifera into the river mouths in large amounts.

Particularly interesting is the northern limit of planktonic foraminifera distribution in the Huanghai Sea. It is reasonable to expect an absence of oceanic organisms such as

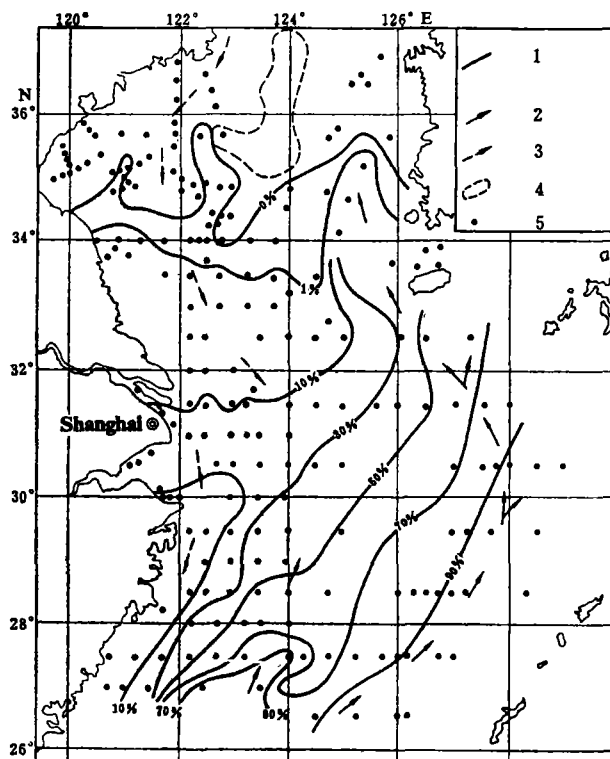


Fig. 1. Relative abundance of the planktonic foraminifera (percentage of planktonic foraminifera in the total foraminiferal number) in surface sediments of the East China Sea and Huanghai Sea.
1—Proportion of planktonic foraminifera; 2—warm current; 3—coastal current; 4—cold water mass; 5—station.

planktonic foraminifera in the low temperature and low salinity waters originating from the semiclosed basins of Bohai Sea and North Huanghai Sea. Indeed they are found to be absent in the Bohai Gulf and North Huanghai Sea, as well as in areas beneath the Huanghai Sea Cold Water Mass and the Huanghai Sea Coastal Current in the South Huanghai Sea, but they are present in more or less significant numbers in areas influenced by the Huanghai Sea Warm Current (see Fig. 1). Hence the current pattern is believed to determine the distribution limits of planktonic foraminifera in the Huanghai Sea.

Also noteworthy is the variation of the test size of planktonic foraminifera in the studied area. As is well known, the test size of planktonic foraminifera is related both to the water temperature and to the proximity to the ocean^[4]. The maximum size of planktonic foraminifera in the East China Sea exceeds 1 mm only on the continental slope and in the trough: it is 0.3–1.0 mm at the margin of the shelf (water depth 100–150 m); 0.3–0.8 mm in the mid-shelf (water depth 50–100 m); less than 0.3 mm in the inner shelf (less than 50 m); and <0.2 mm in the Changjiang River and Qiantang River estuaries. This indicates that the planktonic foraminiferal test is gradually getting bigger towards the south-east to the open ocean and the Kuroshio warm current. As to the Huanghai Sea, only very small-sized tests of planktonic foraminifera are found in its southernmost part.

II. ASSEMBLAGES

Thirty-two species (subspecies) of planktonic foraminifera belonging to 11 genera are recognized in surface sediments of the East China Sea and Huanghai Sea. These are: *Orbulina universa* d'Orbigny, *Globigerinoides conglobata* (Brady), *G. ruber* (d'Orbigny), *G. sacculifer* (Brady), *G. tenellus* Parker, *Sphaeroidinella dehiscens* (Parker et Jones), *Globigerina rubescens* Hofker, *G. quinqueloba* Natland, *G. falconensis* Blow, *G. bulloides* d'Orbigny, *G. digitata* Brady, *G. calida* Parker, *Globigerinella aequilateralis* (Brady), *G. adamsi* (Banner and Blow), *Globigerinita glutinata* (Egger), *G. iota* Parker, *Neogloboquadrina pachyderma* (Ehrenberg), *N. dutertrei* (d'Orbigny), *N. hexagona* (Natland), *Pulleniatina obliquiloculata* (Parker et Jones), *Globorotalia inflata* (d'Orbigny), *G. hirsuta* (d'Orbigny), *G. truncatulinoides* (d'Orbigny), *G. menardii menardii* (d'Orbigny), *G. menardii neoflexuosa* Srinivasan, Kennett and Bé, *G. crotonensis* Conato and Follador, *G. scitula* (Brady), *G. pumilio* Parker, *G. tumida* (Brady), *Candeina nitida* d'Orbigny, *Turborotalita hunilis* (Brady) and *T. clarkei* (Rögl and Bolli).

The common species of planktonic foraminifera in the East China Sea and Huanghai Sea can be divided into four groups according to their areal distribution: 1. species found in areas more than 150 m deep, including *G. tumida*, *G. crotonensis*, *G. hirsuta*, *G. truncatulinoides*, *S. dehiscens*, *G. falconensis*, *G. iota* amongst others; 2. species distributed mainly in areas beyond the 100 m isobath and in areas beneath the Taiwan Warm Current, like *O. universa*, *N. pachyderma* and *G. pumilio*; 3. species found in areas with water depth

more than 50 m, such as *P. obliquiloculata*, *G. sacculifer*, *G. conglobata*, *N. dutertrei*, *G. menardii*, *G. aequilateralis* and *T. humilis*; 4. species spread all over the East China Sea including its inner shelf and the southern part of the Huanghai Sea, e.g. *G. ruber*, *G. bulloides*, *G. quinqueloba*, *G. glutinata*, etc. As is well known, different species of planktonic foraminifera tend to live at different depths in the water column^[5,6]. The "shallow-water" species living predominately in the upper 50 m are mainly spinose forms; the "intermediate-water" species including both spinose and non-spinose forms are living in the upper 100 m, but predominately from 50 to 100 m; the "deep-water" species are exclusively non-spinose forms whose adult stages occur usually below 100 m. The depth preference of various species groups observed in bottom sediments of the East China Sea can be attributed to the above mentioned depth habitats of living populations in water.

In order to ascertain the influence of environmental factors on taxonomic composition of planktonic foraminiferal assemblages, factor analysis was adopted in the present study. In result, a Q-mode factor analysis of relative abundance data for 19 common species (>0.18 mm in size) in 84 surface sediments samples has distinguished three assemblages of planktonic foraminifera (see Table 1). The first assemblage (principal factor 1; dominated by *N. dutertrei*, *G. ruber*, *P. obliquiloculata*, *G. sacculifer*) occurs in an area characterized by the Kuroshio and its branches; the second assemblage (principal factor 2; dominated by *G. glutinata* and *G. bulloides*) is distributed in the coastal current area; and the third assemblage

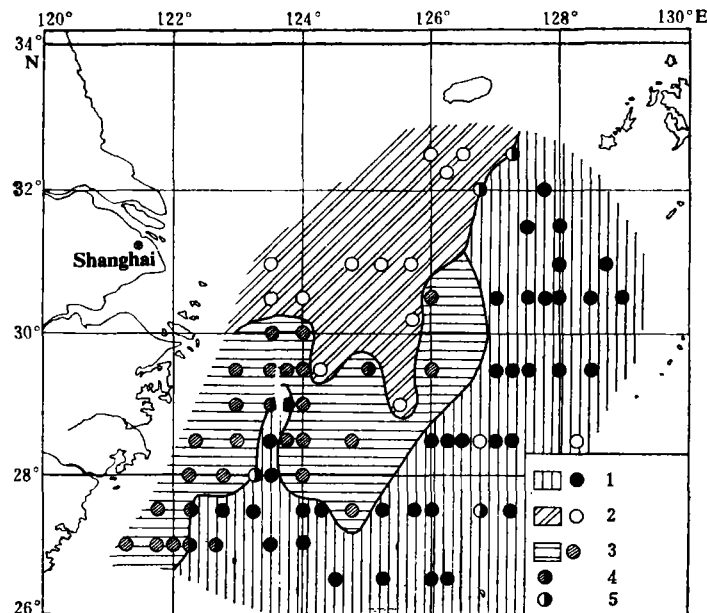


Fig. 2. Map showing results of Q-mode factor analysis of planktonic foraminifera (>0.18 mm) in surface sediments of the East China Sea (from Wang *et al.*, 1980).
1—Principal factor 1; 2—principal factor 2; 3—principal factor 3; 4—transition 1/3; 5—transition 1/2.

principal factor 3; dominated by *G. bulloides* and *G. ruber*) is found in the transitional area in between (see Fig. 2).

Table 1
Average Percentage of 19 Species of Planktonic Foraminifera (>0.18 mm) in the Three Groups of Surface Sediment Samples from the East China Sea Revealed by Factor Analysis

Species	Principal Factor 1 (%)	Principal Factor 2 (%)	Principal Factor 3 (%)
<i>Neogloboquadrina dutertrei</i>	27.84	7.28	12.98
<i>Globigerinoides ruber</i>	16.99	19.61	25.17
<i>Pulleniatina obliquiloculata</i>	15.95	2.74	4.12
<i>Globigerinoides saccaliger</i>	13.11	4.94	10.23
<i>Globigerina bulloides</i>	8.55	16.30	35.47
<i>Globigerinita glutinata</i>	3.52	37.66	4.97
<i>Globorotalia menardii</i>	2.45	0.65	0.21
<i>Globigerinoides conglobata</i>	2.17	0.79	1.12
<i>Globorotalia inflata</i>	1.93	0.62	0.04
<i>Globigerinella aequilateralis</i>	1.35	0.36	1.98
<i>Orbulina universa</i>	0.48	0.20	0.09
<i>Globorotalia truncatulinoides</i>	0.41	0.04	...
<i>Globigerina rubescens</i>	0.28	1.49	1.11
<i>Neogloboquadrina pachyderma</i>	0.23	0.19	0.13
<i>Globigerina falconensis</i>	0.19	1.34	0.17
<i>Globorotalia tumida</i>	0.17
<i>Sphaeroidinella dehiscens</i>	0.11	...	0.30
<i>Globorotalia scitula</i>	0.08
<i>Globigerinoides tenellus</i>	0.06	0.41	0.49

Coulbourn *et al.*^[1] have calculated average values of water temperature (t) for 29 species of planktonic foraminifera living in the North Pacific. When the percentage of an individual species (P_i) shown in Table 1 is multiplied by the average temperature (t), the product will give a calculated water temperature (T) reflected by each of the assemblages:

$$T = \sum P_i \cdot t.$$

Table 2 shows the results of the calculations. The slight differences in calculated temperature reflected by the three principal factors suggest differences in oceanographic environments.

Table 2
Calculated Water Temperature (see text)

Principal Factor	Calculated Average Water Temperature(°C)	Oceanographic Environment
1	19.7	warm current area
2	16.3	coastal current area
3	17.4	transitional area

Nevertheless, all of the three assemblages have their first six abundant species in common

(see Table 1), suggesting that the entire East China Sea belongs the Equatorial Pacific zone^[4] in terms of planktonic foraminiferal zoogeography. Consequently, the temperature difference between the three assemblages must not be very significant.

An alternative is that the test transport rather than temperature difference is responsible for the three assemblages. For example, on the basis of data from the Celtic Sea, northwestern Gulf of Mexico, Persian Gulf and Andaman Sea, Murray^[4] concluded that "planktonic foraminiferids are essentially oceanic and it seems clear that their presence in shelf sediments is often due to transport from an oceanic source." Since the test size of planktonic foraminifera in the East China Sea sediments is decreasing from the first assemblage in the southeast to the second assemblage in the northwest, a test transport mechanism may account for differences between assemblages both in test size and in taxonomic composition. Investigations of living specimens in planktonic tows, however, are needed for a definite conclusion.

III. CONCLUSIONS

The distribution of planktonic foraminifera in sediments on a wide continental shelf of a marginal sea such as the East China Sea is dictated mainly by its current pattern and bathymetry. The water depth, the distance from the coast and the proximity to the ocean determine the abundance, test size and, maybe, the taxonomic composition of planktonic foraminifera assemblages in shelf sediments. Water currents with various temperatures and salinities seriously affect the distribution pattern.

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