DISTRIBUTION OF ARENACEOUS FORAMINIFERA ALONG CHINA COAST AND ITS CONTROLLING FACTORS*

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In recent years, foraminiferal faunas began to play an important role in the study of sea level change and coastal evolution in China. Foraminifera are well known to have two groups in terms of the test composition: calcareous and arenaceous. Arenaceous foraminifera occur mainly in marine-continental transitional environmends such as coastal marshes, estuaries, lagoons, etc. along with deep sea and higher latitude areas. As generally thought, "a principal characteristic of the marginal-marine fauna ···is their arenaceous character"[1], and "coastal deposits of low-salinity estuaries, embayments and lagoonal water bodies are, as a rule, characterized by a dominance of agglutinated foraminifera"[2]. This can also be applied to Quaternary strata of similar depositional environments[3]. However, this conclusion mainly drawn from the North-American data is not true in China. As shown by statistics of Quaternary marine transgression strata on the China coastal plains, the marine-continental transitional deposits are 2.38 times as thick as the marine ones[4], and the hyposaline deposits such as coastal, estuarine and lagoonal deposits are much more than normal marine deposits. In spite of the expected high percentage of arenaceous forms, only 19 out of 539 samples of Quaternary marine-transgression deposits taken from 32 bore-holes on coastal plains contain arenaceous foraminifera in small amounts, totalled less than one hundred specimens among more than ten thousand of foraminiferal tests, with calcareous forms exceeding 99.9% of the whole population.

In search of an explanation of the controversy, foraminiferal faunas in modern sediments of coastal zone were investigated along the coastline of China, ranging from the Hainan Island in the south to the Liaodong Bay in the north. A total of 23 genera and 45 species of arenaceous foraminifera have been found in 217 samples, being mostly cosmopolitans widespread in coastal zones all over the world of which the most representative are: *Miliammina fusca* (Brady), *Trochammina inflata* (Montagu), *Ammobaculites exiguus* (Cushman and Bronnimann) and *Jadammina macrescens* (Brady).

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Noteworthy is the uneven distribution of arenaceous foraminifera which are markedly decreasing from south to north both in taxonomic diversity and in abundance. In southern China there are 17 genera and 24 species in Guangxi Province, 10 genera and 20 species in Guangdong Province, whereas only *Miliammina fusca* (Brady) and *Trochammina inflata* (Montagu) occur frequently in Zhejiang and northwards, with all other species encountered fairly rare. If mesohaline (5 — 18‰) foraminiferal faunas from various stations are compared, it can be found that the percentage of arenaceous forms in total foraminiferal population is decreasing northwards, from approximately 90% in Guangxi coast to 10 — 20% in Jiangsu coast and below 5% round the Bohai Gulf (Table 1, Fig. 1). Certainly, the percentage may vary with the number of analysed samples, but the general trend remains the same. Thus, it is of great importance for paleoecological interpretation of foraminiferal fauna population to find out the factor accounting for this general trend.

Table 1

Comparison Between Species Diversity and Proportion of Arenaceous Foraminifera With Salinity and pH Value

Locality		Guangxi		West Guangdong		Middle Taiwan	South Fujian	North Fujian	Zhoushan Island	East Zhejiang
Number		A	B	C	D	E	F	G	H	I
Number of analysed samples		10	18	6	5	3	2	1	22	42
Arenaceous foraminifera	number of species	21	18	11	8	4	5	5	6	7
	%	88.2	91.0	90.0	55.6	18.4	43.5	61.3	4.0	16.9
Salinity (‰)	average value	3.52	7.69	5.20	6.27				8.4	5.1
	range	0.2 — 9.7	0.6 — 12.5	0.13 — 12.7	0.15 — 12.4				2.6 — 16	0.42 — 17.5
pH Value	average	6.29	6.59	6.94	6.62				7.01	7.08
	range	5.49 — 6.94	5.43 — 7.05	6.35 — 7.59	6.30 — 7.34				6.8 — 7.23	6.32 — 9.26

Locality		Northeast Zhejiang	Shanghai	Middle Jiangsu	North Jiangsu	East Shandong	Laizhou Bay	Ji Canal	Luanhe Estuary	Liaodong Bay
Number		J	K	L	M	N	O	P	Q	R
Number of analysed samples		9	13	30	28	3	2	5	11	15
Arenaceous foraminifera	number of species	4	7	7	5	4	1	0	8	1
	%	24.5	12.9	18.9	12.3	12.1	3.1	0	4.7	1.2
Salinity (‰)	average value	5.3	4.0	3.25	6.5	10.3	3.3	1.9	4.15	1.6
	range	5.3	0.05 — 8.7	0.6 — 9.8	1.3 — 16.0	4.7 — 16.4	0.5 — 6.1			
pH Value	average		7.54	7.89	8.21					
	range		7.21 — 9.81	7.10 — 8.55	7.01 — 8.85					

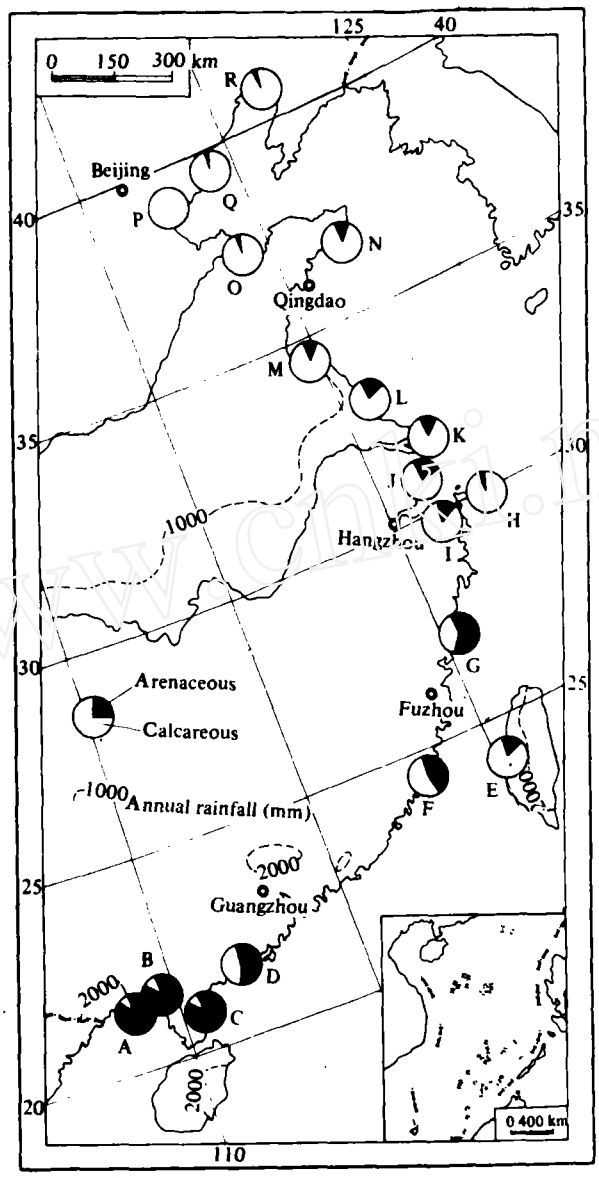

Fig. 1. Average percentage of arenaceous foraminifera in recent surface deposits along China coast. For more details see Table 1 (average percentage calculated for samples from oligo- and meso-haline environments.)

It is generally accepted that under marginal-marine conditions calcareous foraminifera are usually replaced by arenaceous ones with decreasing salinity. An example is the Rappahannock estuary in the east coast of North America, where the upper estuary (0.5 — 16 ‰) is inhabited by a foraminiferal fauna predominated by arenaceous forms such as *Ammobaculites crassus* Warren, while calcareous fauna represented by *Elphidium*

calvatum Cushman occupies the lower estuary (16‰)[5]. These two foraminiferal faunas have also been reported from the James estuary, again in the east of the United States, with the boundary running along the 14‰ isosalinity line[6]. Accordingly, when calcareous foraminiferal fauna was found in abundance in a low salinity lagoon at the north coast of the Mexico Gulf, it was considered as "a significant anomaly" and difficult to explain[2].

As a matter of fact, both calcareous and arenaceous foraminifera can live in water bodies of very low salinity[7]. As seen from the China coast, the salinity drops down from 12.5‰ to 2.6‰ along a mangrove transection at Yinglougang, Guangxi Province, and the proportion of arenaceous foraminifera is maintained within a range of 80 — 100%, while in estuaries or coastal zones in northern China arenaceous forms make up only 0.5% of the total population within the same salinity range. Thus, the proportion of arenaceous foraminifera is not really controlled by salinity. Moreover, if we use the measured salinity and foraminiferal data from our studied stations, and compare the average proportion of arenaceous foraminifera within different salinity ranges (Fig. 2a), we will find no correlation in between. In contrast, when average proportions of arenaceous foraminifera are compared between samples with different pH ranges, a close correlation is revealed (Fig. 2b).

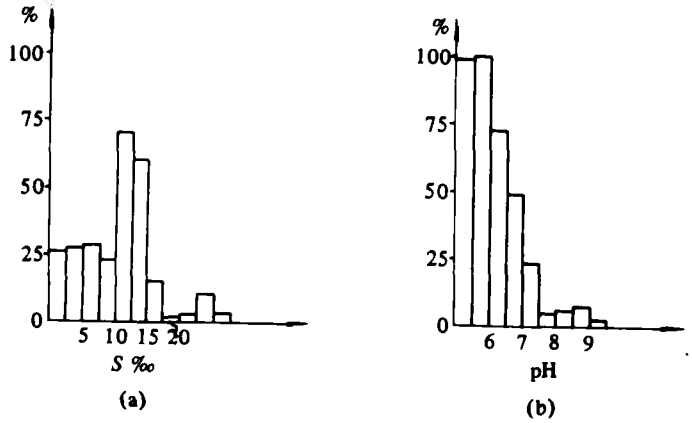

Fig. 2. (a) Relation between arenaceous foraminiferal percentage and salinity.
(b) Relation between arenaceous foraminiferal percentage and pH value.

It has long been found that concentration of calcium carbonate in water controlls the distribution of arenaceous foraminifera without $CaCO_3$[8]. The saturation of $CaCO_3$ in water is affected by salinity, temperature and hydrostatic pressure, and closely related to pH value as well[9]. Calcareous test begins to dissolve as pH value drops below 7.8[10], and the low salinity water in coastal condition is nothing else but mixed sea water (pH = 8.1) with natural rainwater (pH = 5.6) at various ratios. The water mixing reduces its salinity, pH value as well as concentration of calcium carbonate. In fact, the increase of the proportion of arenaceous foraminifera with decrease of salinity in estuaries or coastal zone is a result of the decrease of pH value and calcium carbonate saturation. This can be illustrated with an

example from a coastal transection crossing reed marshes in Zhenhai, Zhejiang Province, where arenaceous foraminifera comprise less than 0.5% of the total population beyond the dam with salinity of 1.4 — 2.2 ‰; while the pH value displays similar variations, from over 6.8 beyond the dam to less than 6.5 behind it. The above-mentioned northward decreasing tendency of arenaceous foraminifera in the total population of oligo-meso-haline coastal water in China is well correlated with the pH value. According to a recent study by YANG Shi-lun, the pH value in mud plain coast sediments of China remarkably decreases southwards from 8.6 at the Liaodong Bay, northern China, to 8.5 in north part of Jiangsu Province, 8.4 at the Changjiang River estuary, 8.3 at the Hangzhou Delta in southern China. The decrease tendency is related to different climatic and soil nature between southern and northern China. The low rainfall in northern China has brought about a great quantity of salinity accumulation in ground, higher pH value and mineralization in river water and, consequently, alkaline soil. On the contrary, southern China is characterized by acid red soil because of its higher rainfall, intensitive osmosis, lower pH and mineralization. The conspicuous difference in foraminiferal faunas between northern and southern China, in the final analysis, is ascribed to the climate. The same is true for estuarine and lagoonal foraminiferal faunas in the Mexico Gulf: the higher rainfall areas are predominated by arenaceous foraminifera, and the areas with lower rainfall by calcareous forms[11]. In general, climate is the major factor controlling the distribution of arenaceous foraminifera in recent coastal environments, as shown by the correlative increase in annual rainfall and in abundance of arenaceous tests from north to south of China (Fig. 1).

The conclusion is that the southward increase of arenaceous tests in modern coastal foraminiferal faunas resulted from the changing tendency of pH value and corresponding change of calcium carbonate saturation. Thus, it is of great significance to recognize their relation for the paleoenvironmental and paleoclimatic studies. The scarcity of arenaceous tests in Quaternary marginal-marine deposits in coastal plains of the middle and north parts of China was caused by higher pH value in water, aside from the taphonomic factors (a part of arenaceous tests can hardly be preserved in sediments). And the high pH values imply that the paleoclimatic condition at that time was not so hot and humid as in the present southern China. The predominance of miliolids in the Early Tertiary deposits of the Sanshui Basin, Guangdong Province, is also indicative of higher pH and lower rainfall, significantly different from the hot and humid condition at present in the same area.

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