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Deep-sea foraminiferal distribution of the central and eastern portions of the South China Sea

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Abstract: In 1991, the eruption of Mount Pinatubo, Philippines covered the South China Sea with a west-trending ash fan. The four layers studied in the central and eastern portions of the South China Sea reveal that the eruption has affected only the cores that were taken near the Island of Luzon. The study also shows that the major controls in the distribution of foraminifera in the study area include environmental stability, selective dissolution and water circulation.

INTRODUCTION

The eruption of Mount Pinatubo, Philippines in 1991 has resulted into a number of environment-related investigations. Most of these dealt with the nature and distribution of ash, lahars and the casualties and damage to properties (e.g., Arboleda *et al.*, 1995; Remotigue and Rodolfo, 1995; David *et al.*, 1996; Paladio-Melosantos *et al.*, 1996; Agapay *et al.*, 1997). These investigations were mostly concentrated in the vicinity of Mount Pinatubo and nearby areas and provinces.

A number of studies were also made on the distribution of the ash in South China Sea (Wiesner *et al.*, 1995; Wiesner and Wang, 1996). Research on the impact of the eruption on the South China Sea's foraminiferal communities, as well as the recolonization patterns of these communities, has been going on for several years (Hess and Kuhnt, 1996; Kuhnt, 1996).

Prior to the eruption of Mount Pinatubo, the South China Sea has already been the subject of numerous studies involving its morphology, shallow structures and sea-floor spreading history. However, despite this interest, very few studies concerned the distribution patterns of foraminifera (e.g., Cushman, 1921; Graham and Militante, 1959; Militante-Matias, 1992a, 1992b; Zamoras, 1996; Hess and Kuhnt, 1996; Zamoras and Militante-Matias, 1997; Marquez, 1997).

This work focuses on the central and eastern portions of the South China Sea. The main objectives are to document the pre- and post-eruption distribution of foraminifera and identify the possible controls in their distribution. The paper also looks into the impact of the eruption on the foraminiferal communities.

SAMPLE COLLECTION AND PROCESSING

The 16 sediment cores used for this study were collected by the *R/V Sonne* during its December 1996 cruise (Fig. 1). The sub-cores, about 4 cm^3, were taken from the top and bottom of the two recent beds of the cores (Fig. 2). These two beds are

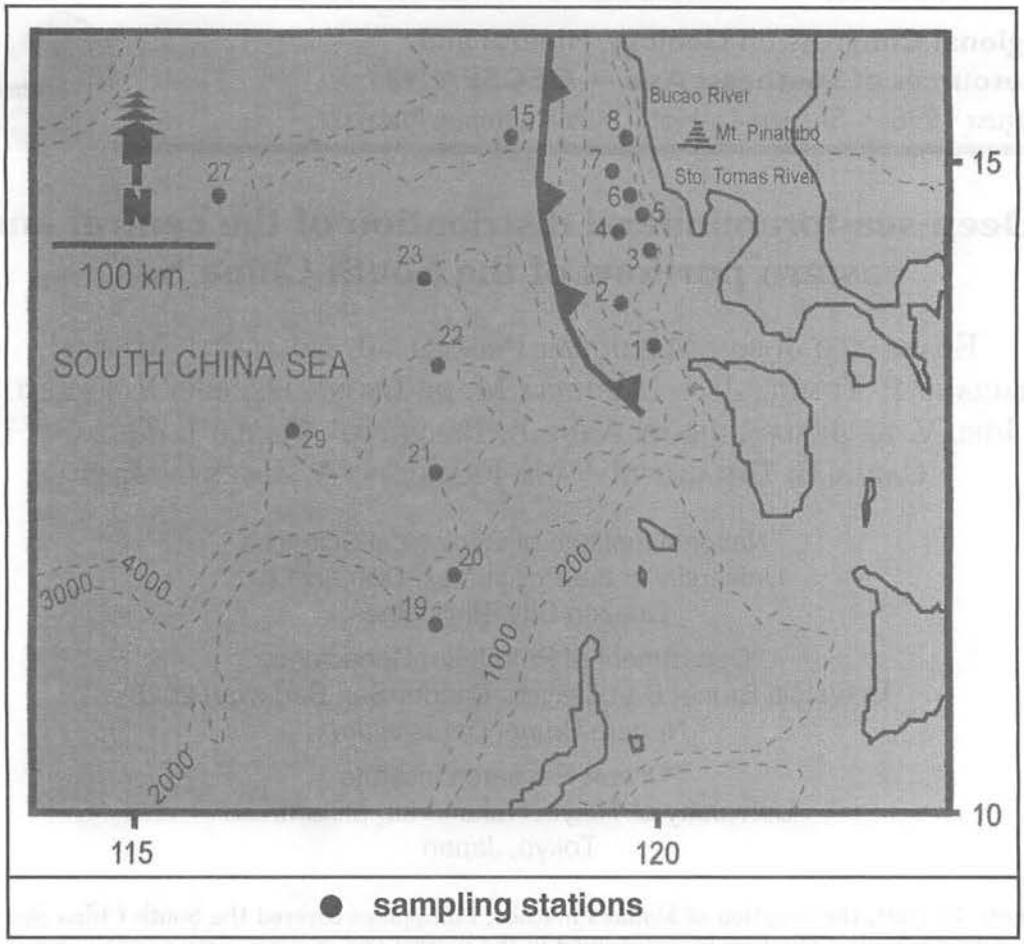

Figure 1. Bathymetric map of the South China Sea showing the locations of the cores used in this study. Dashed lines = depth in meters.

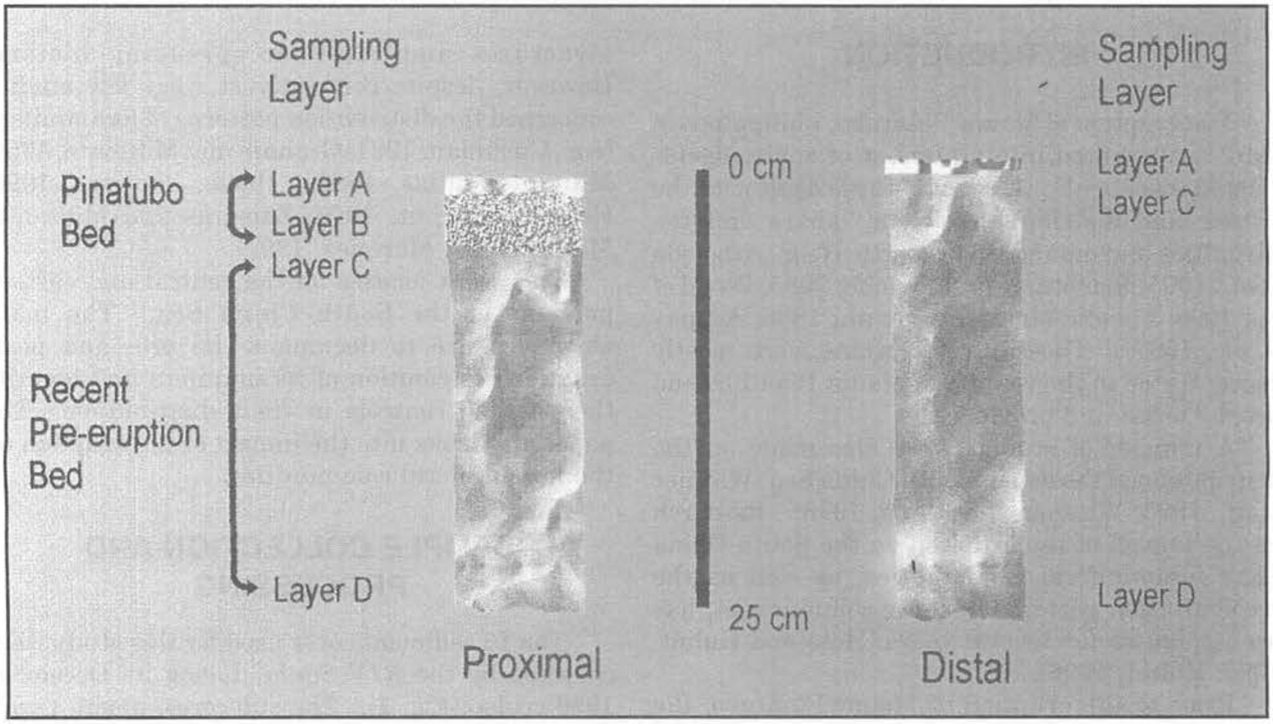

Figure 2. Generalized sediment profile and location of the sampling layers in the sub-cores. The 16 cores used in this study were taken from proximal to the distal parts of the ash fan.

Table 1. Average absolute abundance of planktonic foraminifera in the South China Sea.

CORE NUMBER	DEPTH (m)	ENVIRONMENT	AVERAGE ABSOLUTE ABUNDANCE			
			Layer A	Layer B	Layer C	Layer D
19	1918	UPPER BATHYAL	400	400	400	no data
8 2 3 4 5 7 6 20	2286 2371 2412 2511 2512 2515 2576 2918	LOWER BATHYAL 1	217	88	261	326
1 21 22 15	3326 3586 3843 3943	LOWER BATHYAL 2	120	39	190	156
23 27 29	4152 4224 4334	ABYSSAL	2	no data	8	3

the Pinatubo ash layer (Layer A, top and Layer B, bottom) and the underlying pre-eruption clay-silty clay unit (Layer C and Layer D, the top and bottom, respectively).

Foraminifera were separated from the sediments by individual picking using a Meiji zoom stereo microscope. Whenever possible a minimum of at least 200 specimens were collected. All benthonic foraminifera were identified and counted. Individual species of planktonic foraminifera were not quantitatively identified. However, total counts and recognizable planktonic foraminiferal species were noted. The foraminiferal assemblages considered in this study represent both the dead and living assemblages.

RESULTS AND DISCUSSION

Planktonic Foraminifera

A decrease in the average abundance of planktonic foraminifera with increasing depths for all layers has been observed (Table 1). The abundance of planktonic foraminiferal tests in the upper bathyal may indicate the closeness of these foraminifera to their source. This observation may also indicate areas of high organic production (Bandy and Arnal, 1960; Stehli and Creath, 1964). The decrease in the deeper waters, on the other hand, may be related to the calcite lysocline and carbonate compensation depth which is reported to be at 3,000 meters and 3,800 meters, respectively (Rottmann, 1979; Thunell *et al.*, 1992; Calvert *et al.*, 1993).

At depths 2,286 to 2,918 meters, the average abundance for the pre-eruption layers (Layer C and Layer D) is much higher than Layer A and Layer B (Table 1). Moreover, the lowest number of individuals is noted in Layer B. The low number of individuals might have resulted because of the dilution brought about by the high influx of sediments as a consequence of the volcanic eruption. Also consider that in Layer A, this effect of dilution is not pronounced. It appears that the clastic sedimentation rate may actually be returning to normal conditions.

The distribution map of planktonic foraminiferal abundance shows an overall northeast low abundance trend (Fig. 3). Planktonic foraminifera move with the water masses and are dependent on the current. It has been pointed out that the abundance of planktonic foraminifera could be used to determine the direction and extent of water transport, provided that there are no variations in clastic sedimentation rate (Stehli and Creath, 1964).

For the pre-eruption layers, the reported sedimentation rate is almost uniform at 2.7 to 5 cm/1,000 years (Fuglseth, 1991; Kuehl *et al.*, 1993). Complications, then, are considered very minimal. The observed northeast low trend in Layer C and Layer D may be related to the general northeast flow direction of the surface waters (Fig. 4).

It should be pointed out that at a first order of approximation, the same trend is also observable

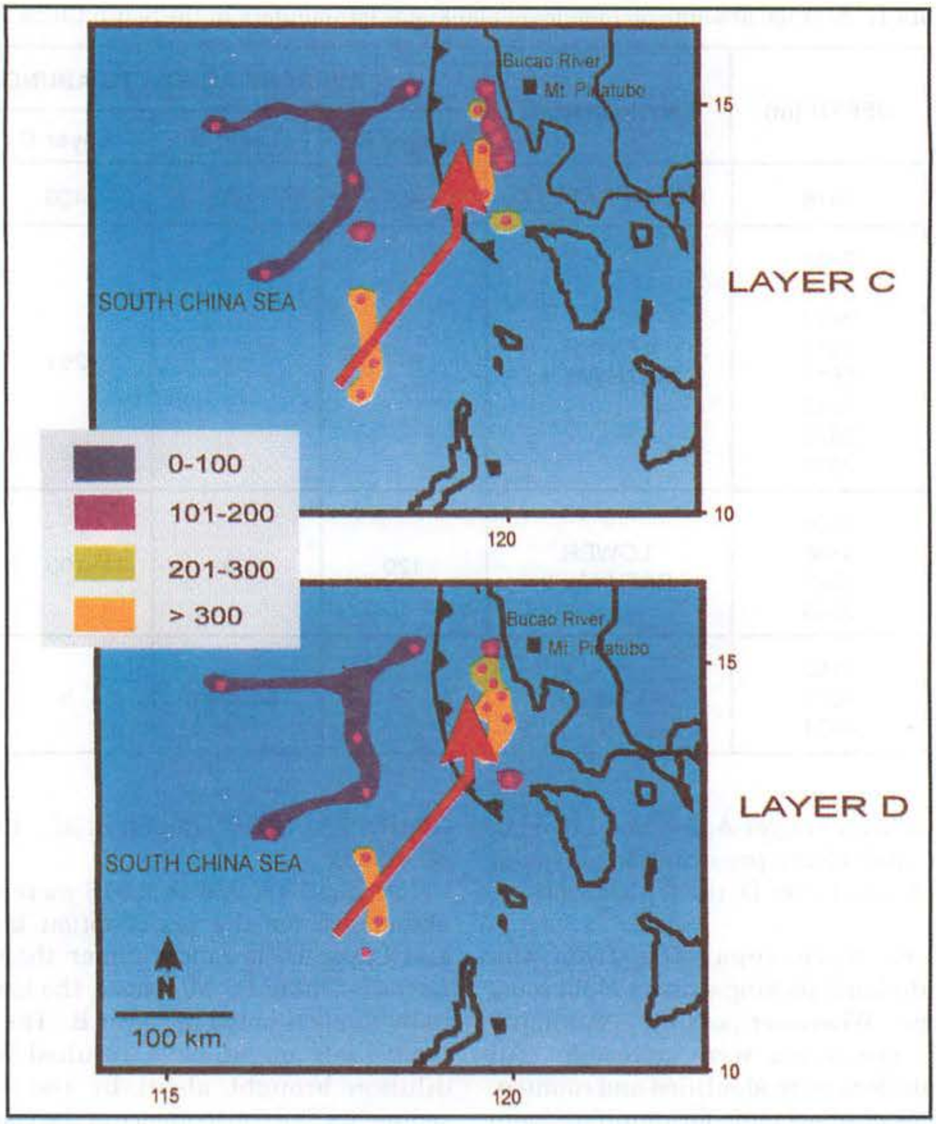

Figure 3. The absolute abundance distribution map showing the overall northeast low abundance trend (arrow).

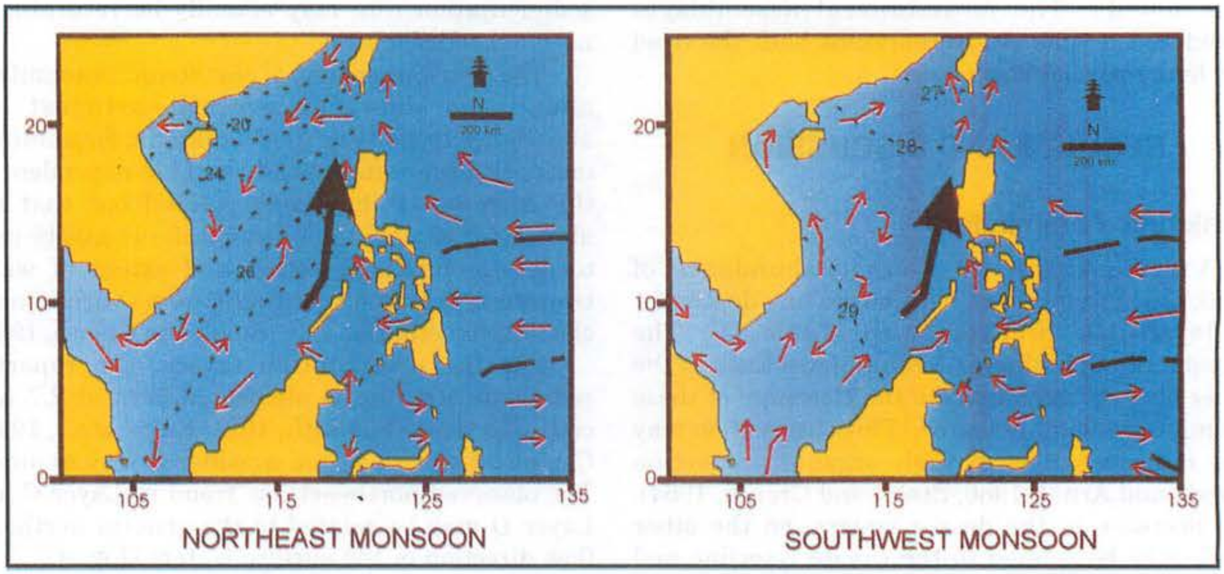

Figure 4. Surface circulation patterns and temperatures in the South China Sea during the northeast and southwest monsoon. Dashed lines = temperature; red arrows = circulation pattern; black arrow = general direction of the circulation pattern.

Table 2. Grain size distribution and absolute abundance of benthonic foraminifera in the South China Sea.

CORE NUMBER	DEPTH (m)	LAYER A		LAYER B		LAYER C		LAYER D	
		Grain Size	Abundance	Grain Size	Abundance	Grain Size	Abundance	Grain Size	Abundance
19	1918	silty clay	75	silty clay	108	silty clay	111	no data	no data
8	2286	silty clay	6	silt	5	clay	21	clay	42
2	2371	silt	19	silt	120	clay	182	clay	163
3	2412	clay	16	silt	20	silty clay	80	clay	121
4	2511	silt	1	sand	0	clay	80	clay	138
5	2512	silt	1	sand	5	silty clay	105	silty clay	63
7	2515	silt	37	sand	2	silty clay	99	silty clay	36
6	2576	silt	23	sand	0	clay	126	clay	6
20	2918	silty clay	72	no data	no data	clay	136	clay	94
1	3326	silty clay	30	silty clay	43	clay	36	clay	48
21	3586	silt	68	no data	no data	clay	176	clay	65
22	3843	silt	46	no data	no data	clay	14	clay	16
15	3943	silt	8	silt	146	silty clay	148	silty clay	128
23	4152	silt	45	no data	no data	clay	42	clay	0
27	4224	clay	30	no data	no data	clay	23	clay	15
29	4334	no data	no data	no data	no data	clay	9	clay	23

in Layer A and layer B. However, complications should be considered since clastic sedimentation in these layers varies. In fact, higher rates of sediment accumulation have been observed (Wiesner *et al.*, 1995; Wiesner and Wang, 1996).

Benthonic Foraminifera

In this work, no distinct trend is observed with respect to the substrate. Layer B seems to correspond with the substrate at depths 2,511-2,576 meters (Table 2). However, this trend is not controlled by the substrate, but by the effect of the eruption. The eruption has caused massive sedimentation and the high influx of sediment might have diluted the benthonic foraminiferal population. Also, ash is not favorable as habitat for the survival of the foraminifera.

In this case, consider that: (1) the deep water temperatures are relatively cold ranging from 1.7°C to 3°C (Calvert *et al.*, 1993; Kuhnt, 1996); (2) the waters are also fairly well ventilated (dissolved oxygen content > 75 mm) (Wyrtki, 1961; Linsley *et al.*, 1985, Kuehl *et al.*, 1993; Calvert *et al.*, 1993), and; (3) salinities slightly increase with depth from 34.5‰ to 34.6‰ between water depths 500 meters and 1,500 meters (Miao and Thunell, 1994).

Lagoe (1976) has pointed out that stable environments support high diversities while areas of wide environmental fluctuations are populated by species that adapt to the physical stresses of the system. Based on the data, the South China Sea can be considered as a stable environment. This might help explain the generally high diversities noted in the pre-eruption layers as opposed to Layer A or layer B at depths 1918 meters to 3,943 meters (Table 3) (Fig. 5). The eruption of Mount Pinatubo might have caused a physical stress to the environment resulting to lower diversities.

Core No. 8 shows lower diversities for all layers (Table 3) (Fig. 6). This core was taken near a submarine canyon that taps the mouth of the Bucao River (Siringan and Ringor, 1995). The presence of the Bucao River-submarine canyon system might have induced fluctuations in the environmental conditions in this location.

The diversities in the abyssal depths of Layer B, Layer C and Layer D are quite low. This may indicate that at these depths, the environment is unstable or extreme in some way. On the other hand, the high diversities noted in Layer A might suggest that the environmental conditions at these depths are changing, probably becoming more or less stable.

For the cores taken east of the Manila Trench (Cores 1, 2, 3, 4, 5, 6, 7 and 8) significant differences in the abundance and diversity are observed between the foraminiferal assemblages before and after the eruption of Mount Pinatubo (Table 2 and Table 3). The pre-eruption assemblages of these cores show high abundance and diversity compared to the post-eruption assemblages (Table 2 and Table 3). On the other hand, cores taken west of the Manila Trench (Cores 15, 19, 20, 21, 22, 23, 27 and 29) have been less affected by the ash fall. Also, most of the pre-ash fall foraminiferal communities are still present (Marquez, 1997).

Table 3. Species diversity of benthonic foraminifera in the four layers.

CORE NUMBER	DEPTH (m)	DIVERSITY			
		Layer A	Layer B	Layer C	Layer D
19	1918	1.46	1.44	1.49	no data
8	2286	0.68	0.70	0.97	0.56
2	2371	0.5	1.47	1.38	1.42
3	2412	1.07	0.94	1.25	1.22
4	2511	0	0	1.32	1.33
5	2512	0	0.46	1.38	1.07
7	2515	0.14	0	1.31	1.06
6	2576	0.63	0	1.11	0.68
20	2918	1.17	no data	1.18	1.22
1	3326	0.85	0.85	1.42	1.41
21	3586	1.33	no data	1.57	1.38
22	3843	1.03	no data	0.83	0.89
15	3943	0	0.89	0.82	0.57
23	4152	1.23	no data	0.91	0
27	4224	0.98	no data	0.69	0.6
29	4334	no data	no data	0.80	0.75

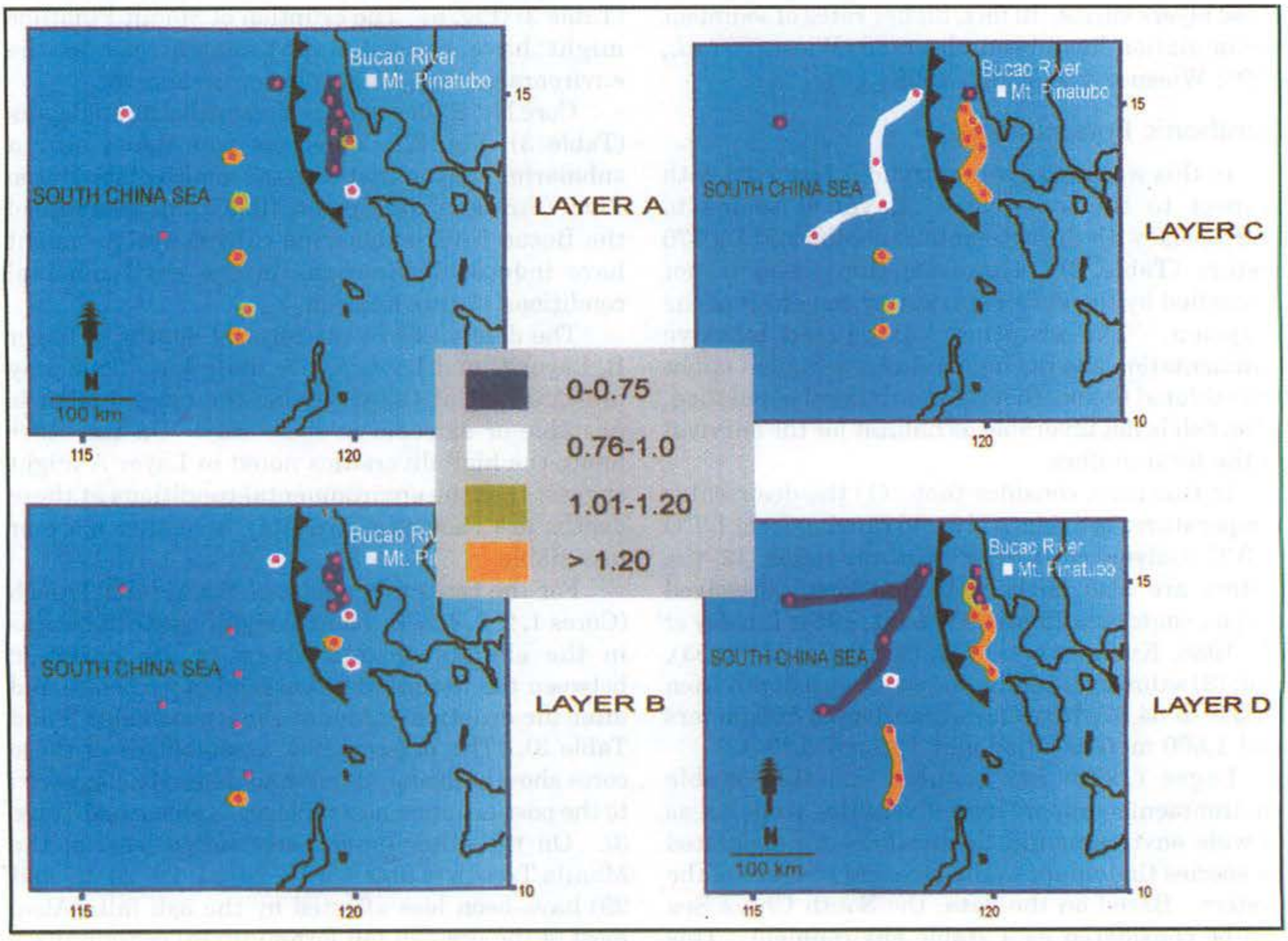

Figure 5. Species diversity map of the benthonic foraminifera in the four layers.

CONCLUSIONS

Environmental stability, selective dissolution and water circulation are postulated as some of the major controls affecting the distribution of recent to sub-recent deep-sea foraminifera in the central and eastern portions of the South China Sea. The layers studied have shown that the effect of the eruption is evident only in the cores taken close to the Island of Luzon.

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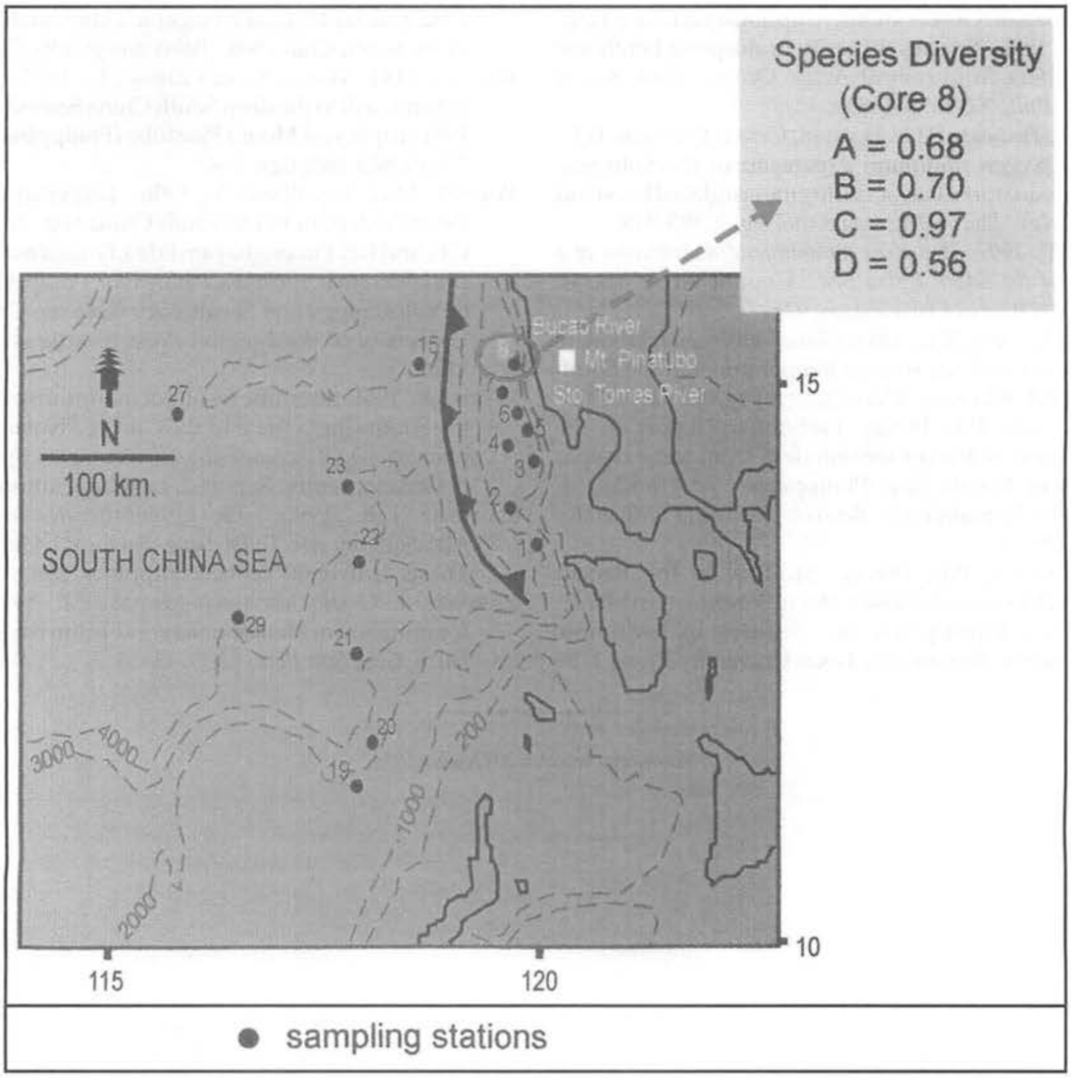

Figure 6. Low species diversity values were observed in Core No. 8.

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