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A RESEARCH ON THE BENTHIC ECOLOGY ENVIRONMENT, ANTARCTIC OCEAN: I . MAXWELL BAY AND ADMIRALTY BAY*

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Abstract Analyzing the information on benthic organisms and geochemistry, obtained from the Chinese First Expedition on Antarctic Ocean and its succeeded works and comparing with that of other oceans, this paper shows that in the circumstances of the researched area benthic organisms are rich. However, the prodsperity of the organisms is limited below 5－10 cm of the profiles in which the environment is mainly dominated by sulfate reducing reaction. On the condition of low temperature in Antarctic Ocean, the solubility of carbonates is higher than that of other latitudes of oceans, but the concentration of calcium in overlying water and pore water of the benthic environment is not higher than that in other oceans, which results in the difficulty for the crustaceas and mollusks to obtain sufficient calcium carbonate to form their solid shell as well as to bring about the lower ratios of these animals both in abundance and biomass in the researched ocean. Futhermore, there is a positive relationship between the distribution of sedentary polychaetes and temperature in overlying waters. That might demonstrate that the animals had still not quite adapted to the bitterly cold of Antarctic Ocean. Besides, research proposes that although there is no microorganism being detected below the depth of 5 cm in M6 station, there happens sulfate reducing reaction, so at least there should be sulfate respiring bacteria existed below the depth.

Key words Antarctic Ocean, benthic ecology

Introduction

The ecosystem of the Antarctic Ocean is an independent unit much different from any other oceans. Bounded by Antarctic Convergence, this region has a very obvious endemic distribution characteristic in its benthic fauna, and is one of the most uniform system in the world (Picken, 1985). In addition, the benthic ecological environment might influence the incubation of Antarctic Krill which has got widely noticed over the world.

Because of the pecularity of benthic ecology in Antaretic Ocean and its significance in the ecological study, Antarctic benthic ecology has been studied in various ways by almost all of the contries which have explored Antarctic Ocean. But preceeding researches were still

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not beyond the interaction within the benthic community, or at most included some limited parameters in physioceanography and sedimentology (e. g. temperature, salinity, granularity); the biogeochemistry research which has been rapidly developed in recent years has not been extended enough to this field. Besides, investigated area is also limited for the severe climate of the Antarctic Ocean.

Since Chinese First Antarctic Ocean Expedition of 1984—1985, we have done some preliminary researches on Antarctic ecology, especially on krill ecology (Zhang *et al.*, 1989; Xia et al., 1989; Cheng *et al.*, 1990). Beginning with the research in Antactic bays, this paper deals with benthic ecological environment based on biogeochemical thought and method.

Material and Methods

Sampling processes and measurements of pH, Eh, alkalinity, acid volatile sulfide, organic carbon and organic nitrogen in the sediments had been shown in literature (Cheng *et al.*, 1987). For pore wate and overlying water, calcium concentration was determined by flame atomic absorption spectrophotometer with a precision better than 5%; iron and manganese concentrations were measured by polarspectrophotometer JP — 1A and the precision was better than 1%; sulfate cncentration was analysed by deposition method;

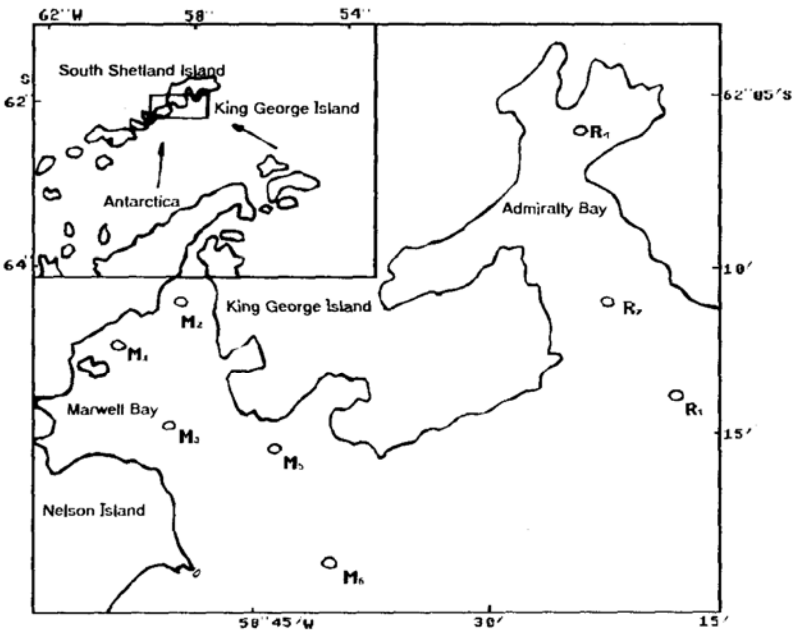

Fig. 1. The Smpling Locations.

precision was better than 0. 5 $mmol/cm^3$. Sampling locations are shown in figure 1.

Result and Discussion

1. Discription of the Benthic Community

Benthos: there are high benthic biomass and abundance, in which polychaete and echinodermate animals are the most dominant species; mollusks and crustaceas that are usually dominant species in other latitude oceans have a relatively less percentage Table 1. Besides, what is noticed is that the abundance of the main macrobenthos animals appears in different horizontal distribution pattern in the two researched bays. The biomass and abundance of polychaetes show obvious increase from inside to outside for Maxwell bay, and the animals in Admiralty bay show a opposite distribution pattern (Fig. 2).

Table 1. Horizontal distributions of the biomass and abundance of benthic animals.

Station	Total		Polychaeta		Mollusc		Crustacean		Echinoderm		Others	
	A	B	A	B	A	B	A	B	A	B	A	B
M1	164	692	47	428	13	48	0.40	64	51	44	52	108
M2	126	824	90	760	13	24	1.6	24	21	8	0.08	8
M3	159	1288	119	768	2	112	2.24	120	13	40	21	248
M5	309	1224	230	1056	0.16	40			14	40	63	88
R1	82	272	37	224	0.96	8	0.80	8	34	16	9	16
R4	422	1248	165	1104	0.04	8	0.40	16	1.56	12	254	108

* A—Biomass (g/m^2), B—Abundance(ind. /square meter).

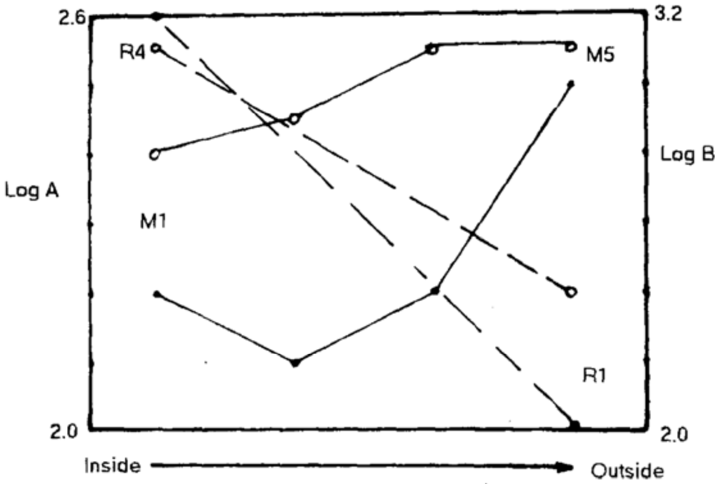

Fig. 2. Horizontal distribution of the benthic animals in the two bays.

The vertical distribution of benthos shows an obvious regularity as well; below the depth of 10~15 cm, biomass and abundance decrease sharply (Tang *et al.*, 1989). By observation in situ, the survivals below this depth are mostly the roots of macrosponges (*Ancince* sp., *Tetillidae* sp.,).

Microorganisms: We have only got the information in Maxwell bay. It is shown in Table 2 that the numbers of microorganisms are not lower than those in other latitude areas, while below the depth of 5 cm there was no living bacteria being detected in M6 station.

Table 2. The comparison of microorganism numbers in different oceans (ind. /g).

Antarctic Ocean					Chang Jiang Mouth (June, 1980)			
St.	Layer cm	Corg. %	Heter. Bact.	Filiform Fungi	St.	Water Depth	Sediment Type	Bacteria * 1000
M1	Surface	0. 77	20000	50	G8001	30m	Muddy Silt	93. 3
	10		2000					
	25		2000		G8003	22m	Muddy silt	270. 0
M6	Surface	0. 54	340	35	G8004	17m	Muddy Silt	175. 0
	5		0	0				
	10		0	0	G8005	27m	Muddy silt	509. 5
	15		0	0	G8008	37m	Mudium sand	68. 9
S3 *	Surface	0. 33	50	0	G8010	48m	Silt clay	394. 0
	10		0	0				
	25		0	0	G8009	62m	Fine Silt	614. 0
S21 *	Surface	0. 45	100	0	G8011	60m	Muddy Silt	165. 7
	10		100	0				
	25		100	0	G8025	33m	Fine silt	77. 8

Bays in ZheJiang, China, (* 1000)									
Regions	Hangzhou	Daiju	Yangan	Daichen	Dongji	Xiangshan	Shanmen	Yueqin	Ranges
July	3. 8	6. 3	7. 6	5. 1	7. 1	3. 9	6. 0	7. 7	0. 17—22
Annual Average	4. 0	20. 5	14. 1	9. 3	6. 3	5. 5	5. 7	7. 0	

*. Slope, water depths are 450 and 330m respectively.

2. *Environment Anaylasis*

The inhabitant state of organisms should be the results of which organisms adapted to their circumstance and in fact, both of them could be reflected each other. Environmental parameters are shown in Table 3. From the table we can find that except for R4 station which has a higher sand content in the sediment, the researched sediments are all with silt clay, and the salinity in overlying sea water are also quite similar (S = 34 about); DOC shows some variations though the content are generally high ($> 5 \times 10^{-3}$), which demonstrates that DOC is ample in bottom sea waters. Range of pH value is much narrow; Eh value shows some variation but not great (Fig. 2). The change of temperature in overlying seawater suggests different tendance, from inside to outside of bays; it gets gradually increased in Maxwell bay but decreased in Admiralty bay. That may indicate that the benthic animals have thermotaxas; namely, the animals have not fully adapted to the severe cold environment of Antarctic Ocean. Besides, chemical measurement shows that there exists high acid volatile sulfate content below the depth of 5 cm in the researched sediments, which tells that the sediments are in anoxic state (Berner, 1981). Actually the author observed in situ that there is a stratum of dust about 0. 5 cm in thickness on the surface of sediments that may impede the DOC into sediments and make a discrepancy of

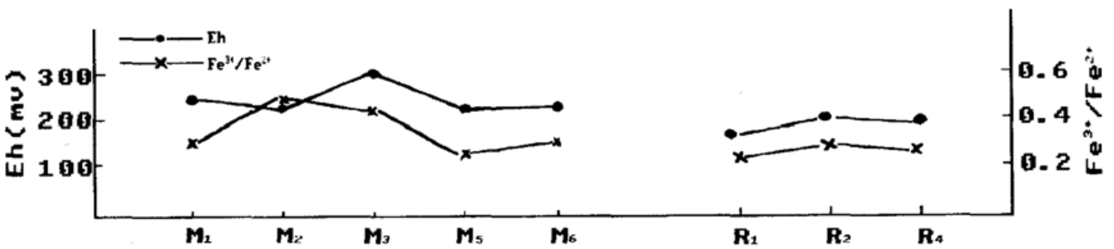

Fig. 3. Redox condition in the benthic environment.

environment in sharp surface sediment and below.

Effection of oxidants may control the function of microorgasnisms (Jean-Pierre *et al.*, 1977) and further affect the whole benthic environment. In addition, compounts which will act as dominant oxidant in the sediments have different chemical forms in various environments; and change of the chemical forms reflect the information of environmental condition (Cheng and Wang, 1989). Here, the authors discusse the benthic environment based on the variation of the chemical forms of the dominant oxidants in the sediments.

Table 3. Environmental oparameters.

ST.	Granularity(%)			pH	Temperature(t C)		Surface DOC	water S	Bottom DOC	water S	Samp. D. * m	Depth m
	Sandy	Silt	Clay		Sed.	Ov. water						
M_1	7	54	38	7.46	0.2	0.8	7.90	34.220	7.40	34.254	100	106
M_2	2	52	46	7.52	1.5	2.0	7.60	33.917	6.94	34.164	150	218
M_3	19	47	34	7.59	1.5	2.0	7.31	34.009	5.39	34.507	380	406
M_5	9	54	36	7.50	0.8	2.5	7.56	33.998	6.62	34.246	194	326
M_6	10	57	33	7.47	0.5	1.5	7.54	34.012	5.36	34.442	421	504
R_1	11	57	32	7.54	1.0	1.5	7.41	34.115	5.22	34.496	465	522
R_2	7	57	32	7.54	1.0	1.5	7.56	33.953	5.57	34.497	351	430
R_4	45	39	16	7.56	1.0	4.0	7.45	34.026	5.64	34.484	380	402

Surface sediments: Chemical analysis indicate that there is certain amount of dissolved surfide (HS^-, S^{2-}, S^0), from the surface down to depth (Fig. 4). That means that dissolved oxygen has been below the detected limitation ($<10^{-6}$mol/dm^3)(Berner, 1981)

Our previous work had proposed that within the depth of 0 ~ 5 cm. there mainly happened the reducing reaction of oxyhydroxides of iron and manganese in the researched envirnoments (Cheng and Wang, 1989, Wang and Cheng, 1990). This refelcts that oxygen and nitrate, which act as dominnat electron acceptor in the decomposition of organic matters in comparatively oxic sediment, have been depleted. Therefore, the labile organic matters that can become the food of benthic organisms are well off in the environment.

Subsurface benthic environment: It is implied by the geochemical information that the environment may be controlled by the sulfate erduction reaction. The products of the

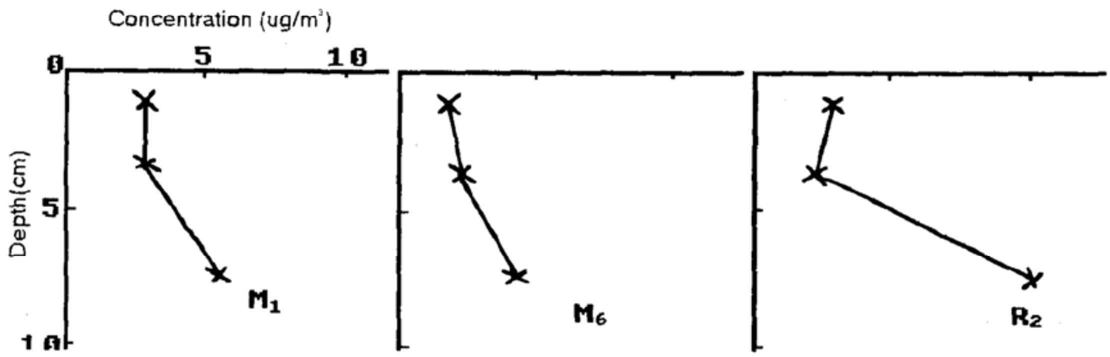

Fig. 4. Vertical distribution of sulphide in interstitial waters.

reaction will be toxic for most of the benthic communities. (Goldhaber and Kalan. 1974), therefore it's the keypoint to elucidate the cheical state of sulfate in benthic environment research.

The redox state sulfate can be judged by its dynamical character in marine sediments. The dynamic reaction of sulfate reduction has been researched in details and its shows the first order reaction (such as Goldhaber and Kaplan, 1972) In stable condition, it is reasonable that the burried depth is correspondent to the reacted time in the sediment. Drawing a daigram with the burried depth vs. the log concentration of sulfate in corresponding pore water (Fig. 5), we can find that there is a linear relation between them, which reveals that at least below the depth of 5～10 cm, the benthic environments have

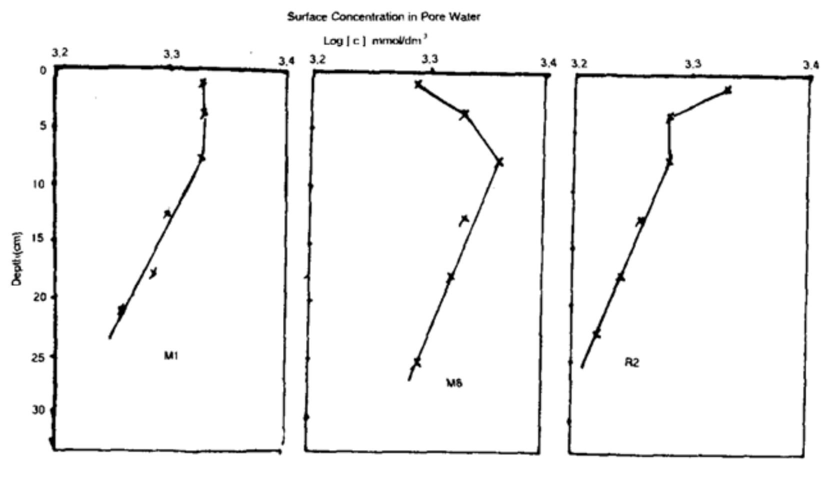

Fig. 5. Dynamic characteristics on sulfate reduction in the benthic environmnet.

been dominated by sulfate reducing reaction.

Approach to Ecological Factors

From above discussion, it can be deduced that under researched benthic environmnet some of the ecological factors would be the controlling factors.

Temperature and calcium concentratiom: Information shows that there is certain relationship between the distribution of polychaetes and the temperature in overlying water, namely, the increase in abundance and biomass of the polychaetes is correspondent to the increase of temperature in overlying water. While we lack a further information about the composition of polychaetes that this relation would be not so strict. Other than that, interested is the relationship between the distribution of crustaceas and mollusks and calcium concentration in pore water of surface sediment (Fig. 6). It's in such a good correspondence that the authors still analysed the information in Liveston bay (nearby Maxwell Bay) and

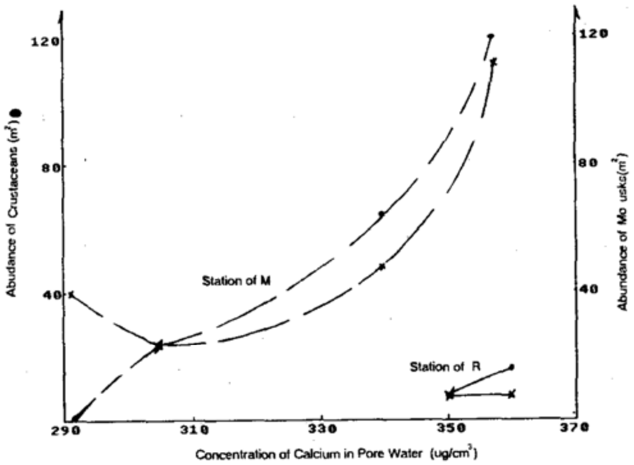

Fig. 6. Relationship between calcium concentration in pore water and inhibitant state of the crustaceas and mollusks in benthic environment.

also got a same conclusion (to be published).

Calcium carbonates: It is necessary to constitute the shell of some crustacea and mollusks. Under low temperature of Antarctic ocean there is a higher dissolubility of the carbonates than those in other oceans; while the calcium concentrations both in surface pore water and overlying water are not higher than that of other oceans (Table 4), which would result in the limitation to the development of crustaceas. With same reason, the development of mollusks which also need calcium carnonates to constitute the shell has the same problem (Fig. 6).

It could be estimated, according to Liebig's Law, that under the benthic environment of the researched ocean, the dissolved calcium concentration had approached its low limitation that brought about the comparatively less amount of crustaceas and mollusks in Antarctic ocean. Actually, the authors had measured the carbonates in sediments over a area of 100 thousand square kilometers in Western Antarctic ocean and found the result was very much lower than those in other latitude oceans. Obviously, the significant will not only be limited to this research but it elucidates the problem.

Table 4. Calcium concetrations in surficial pore water in different latitude oceans (mg/dm³).

Antarctic Ocean			Pacific Ocean *			Chang Jiang Mouth of East China Sea * *		
Station	Depth(m)	Conc.	Station	Depth(m)	Conc.	Station	Depth(m)	Conc.
M_1	106	336	3154	5660	372	6	56	393
M_2	218	304	3233	5973	438	9	97	402
M_3	406	357	3246	5974	398	17	41	407
M_5	326	291	3363	6282	398	19	64	396
M_6	504	345	3361	5340	394	23	48	382
M_1(Ov. W.)	106	374	4011	5950	390	35	59	385
R_1	522	350	3875	3240	448	38	57	410
R_2	430	349	3953	3896	370	40	11	256
R_4	402	360				33(1)	37	416
R_2(Ov. W.)	430	374				35(1)	55	410
L_1	851	382				38(1)	57	410
L_3	155	368				36(1)	50	410
L_5	200	358				40(1)	9	256

* Shisikina, 1980; * * Li Yan *et al.* (1983).

Vertical changes of the environment: Table 2 demonstrates that there is a similar verticle distribution for macrobenthos; that is, that the animals mainly amass over the depth of 10 cm. The amount below this depth is less than 10 % of the total biomass.

It is lived mostly within surface sediment for the benthic crustaceas and mollusk, however the distribution of polychaetes is closely related to itsbenthic environment. In East China Sea, polychaetes may be found in a huge quantity below the depth of 10cm (Sun and Dong, 1985). Comparing with the environmrntal analysis, we understand that it is in the circumstance that sulfate is reduced strongly below the depth in the researched profiles. Becuase the products such as HS *et al.* are toxic to the animals, that have largely impeded the development of the sedentary polychaetes.

Effects of environment on microorganisms: The information shows that the numbers of microoganisms are directory related to the contents of organic materials, in the surface sediments (table 1). As a matter of fact, it expresses the restrainability of edible materials on the microorganisms in the researched ecological system as well as the function of miroorganisms on the decomposition of organic matters.

The sulfate reducing reaction proposed in the environmental analysis is known as to be only carried on by catalysis of sulfate - respiring bacteria (SRB) in surface earth environments (such as Aller, 1982), but we have not found microorganisms below the depth of 5 cm in M_6 station, however, our chemical analysis reveals that with the change of alkalinity, pH and so on in pore waters of the researches columns accmpanies the decrease in organic carbon content in bulk sediments as well as sulfate concentration in the pore water (Cheng and Wang, 1989). That reveals that there still are organic matters being oxidized below 5 cm of M_6 station. Although the organic decomposition reflected by the changes in organic carbon content and other parameters is not so intensive as it is in M_1 station, the relation between the changes of organic carbon content and sulfate concentration also shows that it indeeds happeded with the sulfate reducing reaction. Therefore, there should be microorganisms existing below the depth of 5 cm in M_6 station.

Conclusions

Below the depth of 5 cm in researched columns, benthic environments are dominated by sulfate reducing reaction, which impedes the development ov benthic animals.

The relationship between temperature in overlying water and the distribution of polychaetes is atttributed to that the animals are not quite adapted to the severe cold environmnet.

Insufficient calcium carconate in the benthic environment results in the distribution characteris of benthic animals, which the percentage of crustaceas and mollusks are comparatively less than that of other latitude oceans in both abundance and biomass.

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