

ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

Jinming Song

# Biogeochemical Processes of Biogenic Elements in China Marginal Seas



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## 中国边缘海生源要素的生物地球化学过程

宋金明 著

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ADVANCED TOPICS  
IN SCIENCE AND TECHNOLOGY IN CHINA

# ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

Zhejiang University is one of the leading universities in China. In Advanced Topics in Science and Technology in China, Zhejiang University Press and Springer jointly publish monographs by Chinese scholars and professors, as well as invited authors and editors from abroad who are outstanding experts and scholars in their fields. This series will be of interest to researchers, lecturers, and graduate students alike.

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## Preface

Marine biogeochemistry is the study of the interactions of the biology, chemistry, and geology of the ocean, i.e., the roles of distribution, transformation, removal, enrichment and dispersal of chemical components in the ocean controlled by marine biological processes. The marine biogeochemical process is one of the most important controlling procedures of global change. Marine biogeochemical process research in China has made progress in the past 20 years, although the biogeochemical study of biogenic elements in China marginal seas started relatively late.

The global research programs launched from the 1980s have greatly accelerated the development of marine biogeochemistry and made it one of the main concerns in the studies of oceanography. Since then, scientists from different fields throughout the world have been devoted to this study, and have made unprecedented progress, which was clearly shown in two aspects, i.e., an unparalleled cross-link between all the specific research fields in oceanographic research, and the systematic new results achieved up to date. Though the oceanic process is very complex, it has been understood more clearly than before. Nowadays, oceanic problems cannot be resolved using only the knowledge from one single field. We can say that, in the past 10 years, the progress in marine research was largely demonstrated by the development of marine biogeochemistry. Global oceanic evolution research, which consists of research of different regions, is concerned mainly with the ocean's role in the global climate and changing marine environment. So the regional response to global oceanic change is the groundwork of that research. China marginal seas, including the Bohai Sea, the Yellow Sea (YS), the East China Sea (ECS) and the South China Sea (SCS), have their particular environmental characteristics. Extending from the continental shelf to the continental slope, from tropical to temperate seas, with the input from world-famous rivers, and with many developing and developed cities located in the coastal regions, China's seas almost contain every kind of typical ecosystem, such as an estuarine ecosystem, a continental shelf ecosystem, an upwelling ecosystem, a coral reef ecosystem and a mangrove ecosystem. They are typical regions for studying marine bio-

geochemical processes. The biogeochemistry process of China marginal seas has been studied continuously with great effort by Chinese scientists and great achievements have been made in the field.

This monograph, which is the first book on the biogeochemistry of biogenic elements in China marginal seas in the world, deals with the variations and change mechanisms of biogenic elements such as carbon, nitrogen, phosphorus, silica, sulfur, oxygen, in China marginal seas. It is the main research achievement of the project on "The process and mechanism of ecosystem variation in China marginal seas" which is a "Fund for Creative Research Groups" of the NSFC (No. 40821004), "The degenerated mechanism of main biological resources under composite-pollutant stress in Bohai Bay" which is a National Key Project for Basic Research in China (No. 2007CB407305), "Chemical processes in the sediment-seawater interface and biogenic elements cycling of China's seas" which is a National Science Foundation for Outstanding Young Scientists in China project (No. 49925614), and the "100 Talents Project" of the Chinese Academy of Sciences (No. 2003-202). The monograph is a landmark in marine biogeochemistry development in China. It also lays a good foundation for further study in this field. It is believed that many scientists and others, who are concerned with the environment, will be interested in the book.

This monograph includes 6 chapters. Chapter 1 describes the basic status of China marginal seas, including the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea, and the research progress in marine biogeochemistry in China. From chapter 2 to chapter 5, the research results of biogeochemical processes on biogenic elements in China marginal seas including the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea are summarized. Chapter 6 provides the main key biogeochemical processes in China marginal seas, the prospects for biogeochemistry in China marginal seas, and the methods, concepts and focus on marine biogeochemical process research in China.

There were many people who contributed to the research effort over the past 30 years and their great work has contributed so much to a growing and dynamic field in China. Now, nobody should be in any doubt that the importance of marine biogeochemical processes has been recognized where it counts. Therefore, I want to acknowledge the contributions of the numerous people who made this monograph possible. I owe a special debt of gratitude to my colleagues and students, from whose insights and understanding I have benefited greatly and borrowed freely. These include Dr. Xuegang Li, Dr. Huamao Yuan, Dr. Ning Li, Dr. Peng Zhang, Dr. Liqin Duan, Dr. Yayan Xu and Dr. Sisi Xu. I also greatly appreciate the contributions of Dr. Xuelu Gao, Dr. Jicui Dai, Dr. Guoxia Zheng, and Dr. Xiaoxia Lü, for their diligent library research.

I thank Miss Hanfeng Lin, Mr. Ian McIntosh, Mrs. Helen (Yuehong) Zhang, and Mr. Jianzhong You at Zhejiang University Press, whose consistent encouragement, hard work, and careful attention to details contributed much to the

clarity of both the text and the figures. I also express my thanks to authors for permitting their papers published partly cited in this book. Finally, I am grateful beyond measure to my family and friends, without whose patience, understanding and forbearance this monograph would never have been written. I hope that it will be of interest to all those working in the field.

*Jinming Song*  
Qingdao, China  
August 8, 2009



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# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Basic Status of China Marginal Seas	1
1.1.1	The Bohai Sea	3
1.1.2	The Yellow Sea	23
1.1.3	The East China Sea	39
1.1.4	The South China Sea	50
1.2	Progress in Marine Biogeochemical Process Research in China	67
1.2.1	Progress in the Studies in Marine Biogeochemical Processes before 2000 in China	69
1.2.2	Progress in Biogeochemical Processes of Marine Carbon Cycles since 2000 in China	80
1.2.3	Biogeochemical Cycle of Biogenic Elements	94
1.3	Functions of China Marginal Sea Sediments in Cycles of Biogenic Elements	112
1.3.1	Biogenic Elements in China Marginal Sea Sediments	112
1.3.2	Chemical Environments of China Marginal Sea Sediments and Early Diagenesis of Biogenic Elements	114
1.3.3	Contribution of Settling Particles to Biogenic Element Recycling in China Marginal Seas	116
1.3.4	Contributions of China Marginal Sea Sediments in the Recycling of Biogenic Elements	119
1.3.5	Influences of Biological Productions in China Marginal Sea Sediments on the Recycling of Biogenic Elements	123
	References	127
<b>2</b>	<b>Biogeochemical Processes of the Bohai Sea</b>	<b>139</b>
2.1	Change Processes of Carbon in the Bohai Sea	140
2.1.1	Partial Pressure of CO <sub>2</sub> in Sea Water	140
2.1.2	Riverine Sources and Estuarine Fates of Particulate Organic Carbon in Seawaters	144

X Contents

2.1.3	Inorganic Carbon in Liaodong Bay Sediments of the Bohai Sea .....	147
2.1.4	Biogeochemical Process of Organic Carbon in Sediments .....	156
2.2	Distributions and Transformations of Nitrogen in the Bohai Sea .....	163
2.2.1	Nitrogen in Seawaters .....	163
2.2.2	Evolution of Nutrients and Primary Production .....	175
2.2.3	Nitrogen Forms and the Decomposition of Organic Nitrogen in Sediments .....	186
2.2.4	Sediment-Water Exchange of Inorganic Nitrogen .....	193
2.3	Biogeochemical Processes of Phosphorus and Silicon in the Bohai Sea .....	195
2.3.1	Distribution of Phosphorus and Silicate in Seawaters .....	195
2.3.2	Forms of Phosphorus and Silicon in Surface Sediments .....	197
2.3.3	Processes of Nutrients across the Sediment-Water Interface .....	206
2.4	Behaviour of Heavy Metals in the Bohai Sea .....	214
2.4.1	Distribution of Dissolved Heavy Metals in Seawaters .....	214
2.4.2	Dissolved Heavy Metal Pollution in Bohai Bay .....	219
2.4.3	Heavy Metals in Bohai Bay Sediments .....	223
2.5	Persistent Organic Pollutants in the Coastal Areas of the Bohai Sea .....	231
2.5.1	Distributions of Persistent Organic Pollutants in Sediments and Mollusks .....	232
2.5.2	Composition and Sources of Persistent Organic Pollutants .....	243
2.5.3	Potential Risk of Persistent Organic Pollutants .....	250
	References .....	252
3	<b>Biogeochemical Processes of the Yellow Sea .....</b>	<b>263</b>
3.1	Dynamic Processes of the Yellow Sea .....	264
3.1.1	Yellow Sea Currents .....	264
3.1.2	Water Exchange Between the Yellow Sea and the East China Sea .....	271
3.2	Carbon Biogeochemical Processes in the Yellow Sea .....	273
3.2.1	Carbon Processes across the Air-Sea Interface .....	273
3.2.2	Biological Carbon Fixation in the South Yellow Sea Seawater .....	282
3.2.3	Initial Carbon Fixed Production .....	290
3.3	Dimethylsulfide and Its Fluxes across the Sea-Air Interface of the Yellow Sea .....	295
3.3.1	Characteristics of Dimethylsulfide and Dimethylsulfoniopropionate .....	296
3.3.2	Sea-to-Air Flux of Dimethylsulfide .....	299

3.3.3	Source and Sink of Dimethylsulfide in the Microlayer ..	301
3.4	Biogeochemical Characteristics Nitrogen and Phosphorus in the Yellow Sea .....	303
3.4.1	Variations of Nitrogen and Phosphorus in Seawaters ...	303
3.4.2	Dry and Wet Fluxes of Nutrients .....	308
3.4.3	Nutrients in the South Yellow Sea Sediments .....	311
3.4.4	Nitrogen in the North Yellow Sea Sediments .....	323
3.4.5	Biogeochemical Processes of Phosphorus .....	332
3.5	Biogeochemical Processes of Jiaozhou Bay, South Yellow Sea ..	337
3.5.1	Behaviour and Variation of Carbon .....	337
3.5.2	Historical Variation of Nitrogen .....	347
3.5.3	Historical Variation of Phosphorus .....	366
3.5.4	Biogenic Silica in the Sediments .....	374
3.5.5	Nutrients (N, P, Si) in the Seawaters .....	381
3.6	Biogeochemical Characteristics of Heavy Metals in Yellow Sea Sediments .....	384
3.6.1	Distributions of Heavy Metals .....	384
3.6.2	Annual Variations .....	387
3.6.3	Controlling and Influencing Factors .....	388
3.6.4	Pollution Characteristics and Ecological Risk Evaluation .....	393
3.7	Biogeochemistry of PAHs and PCBs in the Yellow Sea Sediments .....	396
3.7.1	Polycyclic Aromatic Hydrocarbons in the Sediments of the Northern Yellow Sea .....	396
3.7.2	Polychlorinated Biphenyls in the Sediments of the South Yellow Sea .....	399
3.7.3	Contamination History of Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls in the 20 <sup>th</sup> Century .....	409
	References .....	418
4	<b>Biogeochemical Processes of the East China Sea .....</b>	<b>425</b>
4.1	Dynamic Processes in the East China Sea and Its Adjacent Ocean .....	426
4.1.1	Circulation and Sea-Air Interaction in the Southern Yellow Sea and East China Sea .....	426
4.1.2	The Kuroshio .....	428
4.1.3	Currents East of the Ryukyu Islands .....	430
4.2	Carbon Cycling in the East China Sea .....	431
4.2.1	Spatial Distributions of Inorganic Carbon in Seawaters ..	431
4.2.2	Organic Carbon (Dissolved Organic Carbon and Particulate Organic Carbon) in seawaters .....	440
4.2.3	Key Biogeochemical Processes of Carbon in Seawaters ..	443
4.2.4	Inorganic Carbon in Sediments .....	449

4.2.5	Biogeochemical Characteristics of Organic Carbon in Sediment .....	460
4.3	Nitrogen Variations and Budgets in the East China Sea .....	467
4.3.1	Seasonal Variations of Nitrogen in Seawaters .....	467
4.3.2	Nitrogen Distribution and Its Influencing Factors in the Sediment .....	475
4.3.3	Fluxes of Nitrogen .....	478
4.4	Phosphorus Biogeochemistry in the East China Sea .....	482
4.4.1	Distribution of Phosphorus in the Seawater .....	483
4.4.2	Distribution of Phosphorus in the Sediments .....	488
4.4.3	Phosphorus Burial Fluxes .....	490
4.4.4	Phosphorus Balance .....	491
4.4.5	Cycling of Phosphorus .....	494
4.5	Silicate and Biogenic Silica in the East China Sea .....	498
4.5.1	Spatial Distribution of the Dissolved Silicate in Seawaters .....	499
4.5.2	Distribution of Biogenic Silica in Sediments .....	504
4.5.3	Silica Balance on the East China Sea Shelf .....	506
4.6	Dissolved Oxygen and O <sub>2</sub> Flux across the Sea-Air Interface of the ECS .....	509
4.6.1	Dissolved Oxygen Distributions in Seawaters .....	511
4.6.2	O <sub>2</sub> Flux across the Sea-Air Interface .....	517
4.6.3	Factors Influencing Dissolved Oxygen Concentration ..	520
	References .....	523
<b>5</b>	<b>Biogeochemical Processes of the South China Sea .....</b>	<b>529</b>
5.1	Water Dynamical Processes in the South China Sea .....	529
5.1.1	Circulation and Eddies .....	532
5.1.2	Water Exchange via the Straits .....	537
5.1.3	Dynamics of the Mixed Layer and Thermocline of the South China Sea .....	539
5.2	Nutrient Budgets in the Seawaters of the South China Sea ..	541
5.2.1	Nitrogen Budgets .....	542
5.2.2	Phosphorus Budgets .....	543
5.2.3	Silicate Budgets .....	544
5.3	Biogeochemical Processes in the Pearl River Estuary .....	546
5.3.1	Nutrients in Coastal Waters of the Pearl River Estuary ..	546
5.3.2	Carbon in the Pearl River Estuary .....	555
5.4	Biogenic Elements in the Northern South China Sea .....	570
5.4.1	Carbon in the Northern South China Sea .....	570
5.4.2	Distributions of Inorganic Nutrients in the Northern South China Sea .....	575
5.5	Biogeochemical Processes in the Nansha Islands Waters .....	575
5.5.1	Coral Reefs and Their Affected Factors .....	577

5.5.2	Simulated Drift-Net Theory: The New Viewpoint on the High Productivity Supporting the Nansha Coral Reef Ecosystem .....	579
5.5.3	Nitrogen in Sediments of the Nansha Islands Waters ...	583
5.5.4	Carbon Cycling in the Nansha Coral Reef Ecosystem ..	590
5.5.5	Vertical Transferring Process of Major and Rare Elements in the Nansha Coral Reef Lagoons .....	605
5.5.6	Sulfide ( $-2$ Valence) in Lagoon and Off-Reef Sediment Interstitial Waters .....	616
	References .....	620
<b>6</b>	<b>Prospects for Marine Biogeochemical Process Research in China .....</b>	<b>627</b>
6.1	Marine Biogeochemical Process Research in China .....	627
6.1.1	Introduction .....	627
6.1.2	Focus on Marine Biogeochemical Process Research in China .....	631
6.1.3	Research Methods of China Marginal Seas' Biogeochemical Process .....	639
6.2	Main Key Biogeochemical Processes in China Marginal Seas ..	642
6.2.1	River Input .....	643
6.2.2	Coastal Anthropogenic Activities .....	646
6.2.3	Biological Pump .....	647
6.2.4	Ecological Disasters .....	648
6.3	Prospects for Biogeochemistry in China Marginal Seas .....	649
	References .....	651
	<b>Index .....</b>	<b>657</b>

## Introduction

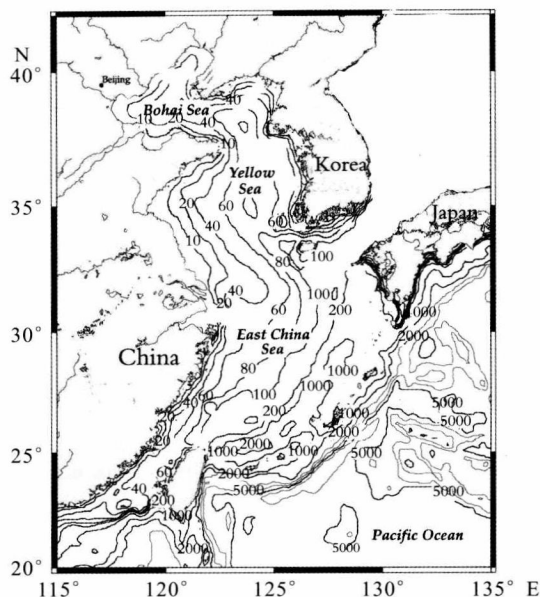
**Abstract:** In this chapter the basic status of China marginal seas, including the Bohai Sea, the Yellow Sea, the East China Sea, and the South China Sea, and the research progress into marine biogeochemistry in China are described. China marginal seas are typically an ideal area to study marine biogeochemical processes and the progress is significant, especially in biogenic elements such as carbon, nitrogen, phosphorous, and silica.

### 1.1 Basic Status of China Marginal Seas

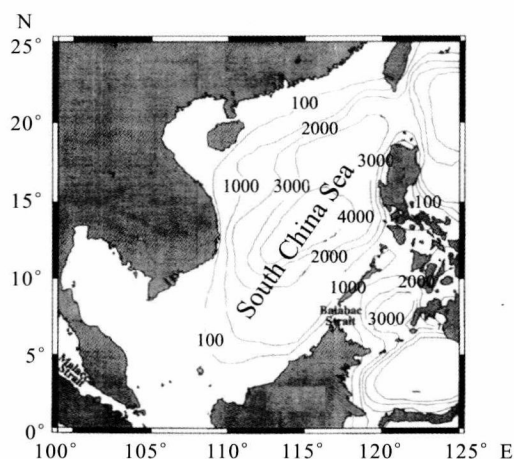
China marginal seas, which lie between  $15^{\circ}\sim 42^{\circ}$  N and  $105^{\circ}\sim 134^{\circ}$  E including the East China Marginal Sea (Fig. 1.1, Naimie et al., 2001) and the South China Marginal Sea (Fig. 1.2, Kuo et al., 2000) in the western Pacific Ocean, form one of the largest marginal seas in the world. The East China Marginal Sea includes the Bohai Sea, the Yellow Sea, the East China Sea, while the South China Marginal Sea is the South China Sea, extending from temperate, subtropical to tropical zones.

China marginal seas form one of the most productive parts of the world's oceans and have a total area of  $4.73\times 10^6$  km<sup>2</sup>, with a continental coastline of  $1.8\times 10^4$  km. The coastal ocean adjacent to three of the largest rivers in the world, the Huanghe River (Yellow River), the Changjiang River (Yangtze River), and the Zhujiang River (Pearl River), is quite active. Recent studies provided evidence that estuaries in China act as a source of nutrients and we can trace species to the ecosystem of the adjacent shelf region. For instance, the total nitrogen input from the Changjiang River was approximately  $7.8\times 10^9$  kg in 1997, which is a threefold increase over the level of 1968.

In the northern area (the Bohai Sea and the Yellow Sea), the seasonal variations of sea surface temperature (SST) are large and vary from 0 to 28 °C. In the East China Sea, the SST averages about 21 °C and ranges from 7 to 28 °C. In the southern area (north of the South China Sea), the



**Fig. 1.1.** Map of the East China Marginal Sea. Isobaths are in meters (Naimie et al., 2001) (With permission from Elsevier's Copyright Clearance Center)



**Fig. 1.2.** Map of the South China Marginal Sea. Isobaths are in meters (Kuo et al., 2000) (With permission from Elsevier's Copyright Clearance Center)

SST is high and its seasonal variation is small, varying from 21 to 29 °C. Figs. 1.3 and 1.4 (Chen, 2008) display the SST and sea surface salinity (SSS) of three regions in winter and summer. In winter, the salinity in the Bohai Sea, Yellow Sea, East China Sea, and South China Sea is 26‰~31.5‰, 31‰~31.5‰, 19‰~34.7‰, and 29‰~34.5‰, respectively. In summer, the salinity in the Bohai Sea, Yellow Sea, East China Sea, and South China Sea is 28.5‰~30.5‰, 29‰~32‰, 25‰~33.5‰, and 30.5‰~34‰, respectively. Seawater temperatures are much lower in winter (Fig. 1.4a) whereas salinity values are generally higher (Fig. 1.4b). Cooling and stronger wind-induced mixing, supplemented by coastal upwelling, generally causes the concentrations to markedly exceed those in summer (Figs. 1.4c~e). In general, a higher temperature (Fig. 1.3a) or salinity (Fig. 1.3b) corresponds to lower nutrient concentrations (Figs. 1.3c~e). On the other hand, a lower temperature or salinity corresponds to higher nutrient concentrations.

The monthly wind pattern is displayed in Fig. 1.5 (Lee and Chao, 2003). In winter (Fig. 1.5a), a northwesterly wind was observed in the Bohai Sea and the Yellow Sea. The wind was then roughly parallel to the coast. It became stronger and changed to a northerly wind in the East China Sea and the Taiwan Strait. It again changed to a northeasterly wind in the northern South China Sea. In spring, the wind became weaker and southerly in the Bohai Sea and the Yellow Sea. The wind then became easterly in the East China Sea toward coastal areas (Fig. 1.5b). In summer, the wind almost reversed in comparison to the winter season: a southeasterly wind in the Bohai Sea and the northern Yellow Sea, and a southwesterly strong wind in the South China Sea (circle in Fig. 1.5c). The wind in late fall gradually became similar to that in winter (Fig. 1.5d), and a strong northeasterly wind was observed on the Taiwan bank and in the northern South China Sea. In general, the wind is stronger during fall-winter (Figs. 1.5a and d) than during spring-summer (Figs. 1.5b and c) in the China seas. And the Taiwan Strait seems to have strong winds during the fall-winter season.

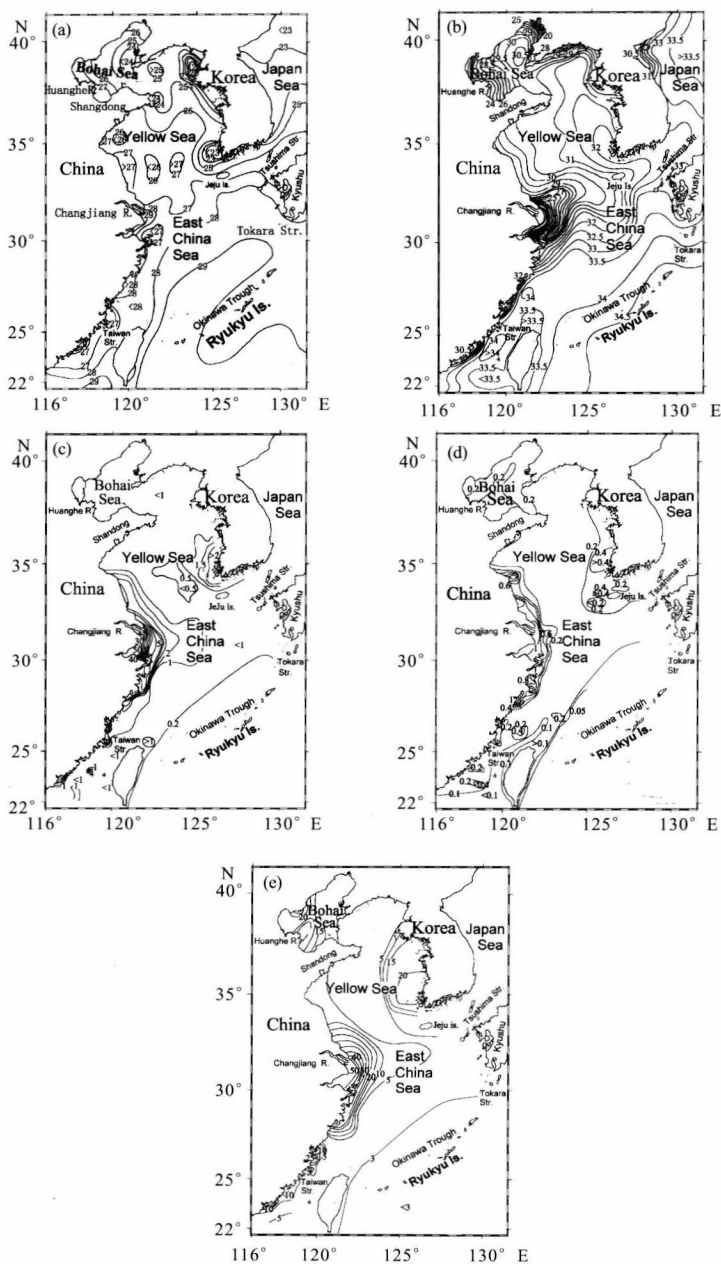
### 1.1.1 The Bohai Sea

The Bohai Sea is one of the main China marginal seas, which has its own particular state and hydrography characteristics. This includes the topography, chemical environment, hydrography, sediment pattern, riverine input, and biological characteristics.

#### 1.1.1.1 Topography

The Bohai Sea is a semi-enclosed continental shelf sea of the NW Pacific Ocean in northern China, located between 37°07' N to 41° N and 117°35' E to 121°10' E, with a surface area of  $77 \times 10^9 \text{ m}^2$ , an average depth of 18.7 m and a coastline of nearly 3,800 km. The size of the Bohai Sea is about 500 km from north to south and 300 km from east to west. The Bohai Sea is a





**Fig. 1.3.** Distributions of (a) temperature ( $^{\circ}\text{C}$ ), (b) salinity ( $\text{‰}$ ), (c) nitrate concentration ( $\mu\text{mol/L}$ ), (d) phosphate concentration ( $\mu\text{mol/L}$ ), and (e) silicate concentration ( $\mu\text{mol/L}$ ) at surface water in the East China Marginal Sea in August (Chen, 2008) (With permission from Springer)