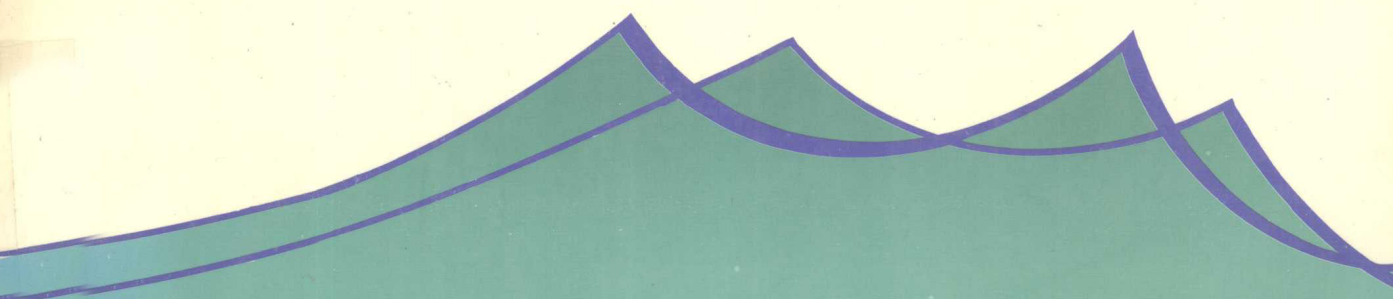
海洋生物地球化学研究论文集

（1986—1993）

洪华生



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Marine Biogeochemistry Research Papers

洪华生 编

Edited by

Hong Huasheng

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内 容 简 介

本书是一部有关海洋生物地球化学研究的论文专集，书中汇集洪华生博士回国以来在从事海洋生物地球化学研究和建设这一交叉新学科的过程中，与她培养的年轻助手和研究生八年来所取得的主要成果。其中涉及海洋生态系中生原要素C、N、P和金属元素的生物地球化学研究、海洋主要界面元素的生物地球化学过程，以及微型海洋生物的作用机制和动力学问题。

本书可供大专院校海洋学科、环境学科师生参考，也可供有关科技人员阅读。

To The Memory of

Professor Li Faxi

谨以此书献给我的老师

—中国海洋化学奠基人

李法西　教授

序　言

我一生值得庆幸的是过了而立之年还能有机会赴美攻读海洋学博士学位，从此，我与海洋科学结下了不解之缘；但不幸的是，在我1984年底学成归来不久，国内导师－原厦大海洋系李法西教授却离开人间。然而老师生前寄托的厚望及深切的教诲，却不断地鞭策和鼓舞着我："瞄准前沿，勇于开拓；投身大海，联系实际；团结协作，取长补短；培养人才，甘当人梯"，成为自己几年来奋斗的座右铭。

弹指间八年过去，在海洋生物地球化学这一新学科的建设上，有许多往事值得回顾和总结。可喜的是，在投身于大海风浪中，我同年轻助手和研究生们一起得到锻炼成长。到目前为止，我们已承担十多项国家、省级科研课题，在国内外刊物发表论文55篇；已培养出该学科研究方向博士生2名，硕士生4名。正如我的学生戴民汉博士在博士论文序中所道："对于海洋生物地球化学这门交叉学科的朦胧感觉是在导师洪华生博士启蒙下得以消失。"我们所取得的成果已得到国内外同行的普遍认可。这一切，可以告慰九泉之下的李法西教授，他的事业后继有人。

新学科往往因人类生存和发展的实际需要而诞生。随着经济社会发展，人类面临资源短缺和环境恶化问题，海洋成为当代新兴开发领域。然而，原已形成各自体系的海洋化学、海洋生物、海洋水文和海洋地质学，依旧独立"作战"，已难以适应认识和解决当前面临的综合性海洋开发和保护问题的需要。于是，80年代初，正处于这些学科交叉点上的海洋生物地球化学这一新分支学科便应运而生。至90年代，该学科已成为国际间区域合作和全球性研究的热门课题。

八年来，围绕着台湾海峡、福建罗源湾、广东大亚湾、九龙江河口及厦门西海域等的生产力开发和环境问题，我们采用宏观的生态学研究方法，结合微观的分子水平上的研究，着重探讨①海洋环境中生原要素C、P的生物地球化学循环　②海洋金属元素的生物地球化学　③微型海洋生物的作用机制及动力学问题。研究涉及海洋主要界面（海水一固、海水一生物、海水一河、海水一气等）的生物地球化学过程，从而有效地推动了我国这一新学科的发展。

本书将概述上述研究内容的初步成果，全书共分四个部份。

第一部份：

碳的生物地球化学，共收集9篇。碳的生物地球化学循环是海域生物生产力的基本要素，又是涉及全球气候变暖，人类排放CO_2去除的重要环节。

在闽南—台湾浅滩渔场上升流区生态系研究重点课题中，一方面对该海域多种形态碳在各储库中的储量进行估算，揭示了该海域碳循环快，周转时间短的规律以及细菌和溶解有机碳在该上升流生态系碳循环中的重要作用；另一方面对生态系食物链中各级生物的生产力、产量及转换效率进行探讨，在此基础上进一步估算渔场资源量，为该海域渔业资源评估和开发提供科学依据。此外，还采用了自制沉积物捕获器进行通量和新生产量的估算，尝试将动力箱式模式和数值计算模式应用于近海生原要素循环的研究中。

在罗源湾和大亚湾这些重要水产养殖基地，采用有机标记物和同位素示踪等先进手段，进一步揭示颗粒碳的来源、可利用性以及在贝类、碎屑食物链中的重要作用。

第二部份：

磷的生物地球化学，收集8篇。生原要素的生物地球化学过程是因补充机制和生物生态结构的不同而异。营养盐可提供性，对生产力的限制和输入速率，还取决于不同形态间的转换以及内部的再循环速率，归根结底，主要是速率问题。

针对台湾海峡南部和九龙江河口低溶解无机磷的特点，我们从宏观生态系角度对磷在这些海域的补充机制，存在形态及转换以及对海域生产力的调控作用进行探讨。证实了季风及地形诱导上升流是台湾海峡南部磷的主要补充机制。在此高生产力海域中，溶解有机磷是最主要的形态。厦门九龙江河口水体具有高硅特征，颗粒磷是该海域磷的主要形态，并与颗粒上有Fe、Si参与的物理化学过程密切相关。然而在罗源湾这一河流输入少而主要受潮流影响的海湾，沉积物磷的释放及水体中营养盐的再生和循环是维持生产力水平的主要过程，因此不同于九龙江河口，氮是该海域生产力的主要控制因子。

第三部份：

微型生物作用机制及动力学问题，共6篇。微型海洋生物（主要是浮游植物和细菌）在元素形态间的转化、运移和循环中充当了重要角色，其作用日益受到重视，如所谓的“生物泵”，即海洋初级生产者浮游植物所生产碳的垂直转移，目前被认为是海洋表层去除CO_2的主要途径。因此海水－生物界面的作用机制及动力学问题研究是当前的热点之一。

在中加（加拿大）合作的围隔式受控生态系研究中，实验揭示了悬浮颗粒特性及去除与生物活性的密切关系。厦门西海域的现场工作和培养实验也表明了以浮游植物为媒介进行的溶解有机和无机磷之间的转换，其速率快，周转时间短。

在采用无载体^{32}P同位素示踪法对浮游植物和细菌吸收磷酸盐的动力学过程研究表明，浮游植物对磷的吸收速率和吸收速率常数因浮游植物种类而

异。厦门港浮游植物对溶解无机磷有较高的吸收速率，能使该低磷海域生产力保持一定的水平。水体磷酸盐浓度和光强、温度对吸收磷速率有影响，从而可能使磷成为该海域赤潮的诱导因子之一。

对于不同形态磷的生物可利用性问题，我们通过用不同溶解有机磷化合物进行藻类培养实验，表明某些有机磷化合物可被藻类直接利用，当水体溶解无机磷降低到一定浓度时，浮游植物体内碱性磷酸酶活力可突增，它提供了浮游植物直接利用溶解有机磷的条件，当今，人类活动对有机污染物的排放日益增多，营养盐有机形态的可利用性和与无机形态间转换的动力学问题值得重视。

第四部分：

金属元素的生物地球化学，共１２篇。海水中的金属元素含量低，而且易被沾污，因此在方法上我们作了一些探索，如建立Sep-Pak C_{18}柱反向液相色谱富集 FIA-FAAS系统来进行海水少量样品的快速直接测定方法等。

某些微量金属元素对生物具有毒性和营养性；反过来，生物活动对微量金属的分布、形态及去除起着直接和间接的作用。如在高生产力的秘鲁近岸和台湾海峡南部的上升流区，我们分别测得Fe和As的非热力学平衡形态Fe^{2+}和As^{3+}占有相当比例，与生物介入的氧化还原过程有关，另外，在有机物和微生物富集的微表层，亦发现溶解Cu的富集。

悬浮颗粒物质是绝大多数天然及人为物质从河口到大洋，由表层进入海底的主要载体，是许多元素生物地球化学过程的主要控制者。我们收集颗粒物质所进行的研究表明，在九龙江河口悬浮颗粒的迁移输送过程中，金属元素的弱结合部分含量增加，这种“自生”过程对悬浮颗粒的特征和对元素的生物地球化学循环起着重要作用。

海洋生物地球化学这一新学科的发展涉及许多新理论，新概念和新手段，我们只是迈开了可喜的第一步。今后必须在结合海洋开发和环境保护的实践中，不断发展和创新，为这一年轻学科的壮大成长做出我们应有的贡献。

在我们工作中，承蒙许多前辈的热情支持和同仁的真诚帮助，在此表示衷心的感谢；我们的工作还有不足之处，敬请指教。

洪华生

1994年6月于厦门大学

Preface

"Life is a dream, making a dream a reality." It was a dream for me to have the opportunity to go abroad to pursue my Ph.D. degree at the Graduate School of Oceanography, University of Rhode Island, U.S.A. in 1980 when I was thirty six years old. My life has been closely related to marine science since then. Unfortunately, my home director-Prof. Li Faxi form the of Department of Oceanography at Xiamen University, passed away shortly after I came back to China at the end of 1984 with my degree. However I have been constantly inspired and urged on by the expectations and instructions that Prof. Li gave me:"Aim at the forward position, be bold in making innovations; throw yourself into the ocean, link theory with practice; unite and cooperate with other people, draw on each other's merits; train others for the profession, serve as their ladder." These words have become my motto during my years of struggle.

Eight years have passed in a flash. When I recollect the past, I find that there are many things that are worthy of review about the construction of the new discipline, biogeochemistry. It was a pleasure for me to train and grow up together with my young assistants and graduate students while "throwing ourselves into the ocean". To date we have undertaken more than 10 state and provincial programs and published 55 papers in national and international journals. Two Ph.D. and four M.S. degrees have been granted. One of my students, Dr. Dai Minghan said in his thesis preface that under the enlightenment of his director, Dr. Hong Huasheng, the obscure feeling of biogeochemistry disappeared. Our achievements have been generously acknowledged by national and international experts. All these things might comfort Prof. Li in his grave because his undertakings have produced qualified successors.

A new discipline is usually born because of the need of mankind to survive and develop. Mankind is faced with problems of resource shortages and environmental deterioration along with the development of the economy and society. Now the ocean has become a newly exploited field. However, the branches of knowledge- marine chemistry, marine biology, marine hydrology and marine geology- had formed their own systems respectively so that it was difficult for them to recognize and cope with the integrated marine exploitation and protection problems independently. Hence the new discipline-biogeochemistry, which is at the junction of the above subjects, was naturally born at the beginning of the 80s. And it had become a popular program of international regional cooperation and global study by the early 90s.

During these eight years, we cencentrated on the regional primary production and environmental problems of Taiwan Strait, Luoyuan Bay in Fujian, Daya Bay in Guangdong, Jiulong Estuary and Xiamen Western Sea. Using macroscopic ecological methodology and microscopic methods at the molecular level, we studied

1. biogeochemical cycling of bioactive elements C, P
2. biogeochemistry of metal elements
3. effecting mechanism and dynamics of marine microorganisms

The studies involved the biogeochemical processes taking place at the main interfaces in marine environments (seawater-particle, seawater-organism, seawater-river, seawater-atmosphere), effectively promoting the development of biogeochemistry in our country. This book collects the preliminary results of the above studies. It is divided into four parts.

Part One:

Biogeochemistry of carbon. 9 papers

Biogeochemical cycling of carbon is a basic element of primary production in the ocean. Carbon dioxide

plays a major role in global warming. And the sink of half of this anthropogenic carbon dioxide is still unknown. In the program, Minnan-Taiwan Bank Fishing Ground Upwelling Ecosystem study, the amounts of various species of carbon in the various reserviors were estimated, suggesting the rapid cycling of carbon in this region and the important role of bacteria and dissolved organic carbon. The production, output and rates of the organisms in the food chain were discussed. The resource of the fishing ground was further estimated. Above all, we used sediment traps to estimate flux and new production, and applied dynamic box model and numeric model in the biogeochemical cycling study.

In the important aquaculture base such as Luoyuan Bay and Daya Bay, the source, availability and role in the food chain of particulate carbon were revealed by means of using organic indicators and isotope tracers.

Part Two:

Biogeochemistry of phosphate. 8 papers.

Biogeochemical processes of bioactive elements varied with the change of outer supplying and inner cycle. The availability of nutrients and their limitation to production are controlled by transformation and recycling rates.

In the southern Taiwan Strait and Jiulong estuary, dissolved inorganic P was low. So we concentrated on P, its supplying, species, transformation between species and control on production were studied using macroscopic ecological methodology. It was identified that upwelling was the main source of P and dissolved organic P was the main species in the southern Taiwan Strait. But in Jiulong Estuary, particulate P was the main species in relationship to the physi-chemical processes taking place in particles involved Fe and Si. However in Luoyuan Bay, the release of P from sediments and nutrients recycling were the key processes to maintain the production level. N became the controlling factor of

production in this region, which was different from that in Jiulong Estuary.

Part Three:

Microorganism effecting mechanism and dynamics. 6 papers.

Microorganisms(mainly phytoplankton and bacteria) play an important role in the transformation, transport and cycling of bioactive elements. The vertical transport of C produced by phytoplankton, so called "organism pump", was thought of as a chief way of removing CO_2 from surface water. Therefore the study of effecting mechanism and dynamics at the seawater-organism interfaces drew more and more concern.

In the China-Canada cooperating controlled ecosystem study, the relationship between the characteristics of suspended particulate and biological activity was revealed. The study *in situ* in Xiamen Western Sea and culture experiments demonstrated the rapid transformation between dissolved organic and inorganic P with the medium of phytoplankton.

Using carrier-free ^{32}P radiotracer to study the dynamics of P uptake by phytoplankton and bacteria led to the conclusion that the uptake rate was high in this region and varied with various phytoplankton species. And it was also influenced by the concentration of P in the water, light intensity and temperature so that P might become an inducing factor of red tide in Xiamen Western Sea.

As to the biological availability of different species of P, we applied phytoplankton culture experiments with additions of various dissolved organic P. The results of the experiments indicated that alkaline phosphatase activity of phytoplankton would suddenly increase making directly uptake dissolved organic P possible when dissolved inorganic P decreased to a low level in the water. Such problems as nutrient species transform dynamics should be a concern at present

because anthropogenic organic pollution is increasing.

Part Four:

Biogeochemistry of metal elements. 12 papers.

The concentration of metal elements is so low in the seawater that there are many difficulties when measuring them. We tried several methods, such as applying Sep-Pak C_{18} reverse-phase liquid chromography and FIA-FAAS system to directly and rapidly determine trace metals in small amounts of sea water.

Some trace metal elements have toxicity and nutrition to organisms; on the other hand, their distribution, species and scavenging are directly and indirectly influenced by biological activities. In the upwelling region located in Peru near-shore and southern Taiwan Strait, we found that Fe^{2+} and As^{3+}, which were non-thermodynamic equilibrium species, were not low in the water, indicating organisms involved redox processes. Higher concentrations of dissolved Cu in the microlayer with abundant organic matter and microorganisms was also found.

Suspended particles are the carrier for most natural and anthropogenic matter transported from estuaries to the ocean and from surface water to the sea bottom. They are the chief controllers of biogeochemical processes. Our study on particulate matter demonstrates that the amount of weak combining metal increases in the process of particulate matter transport in Jiulong Estuary. Such a "hydrogenous" process has an important effect on the characteristics of particulate matter and elements' biogeochemical cycling.

The development of marine biogeochemistry involves many new theories, concepts and methods. We have only just begun. From now on we should try to contribute to the development of this new discipline in the process of linking the theory with the practice of marine exploita-

tion and environmental protection.

We are very grateful to our seniors and friends for their sincere support and help. Special thanks to Prof. Dana R. Kester who has shown a great deal of concerns about my career.

Your advice and suggestions are always welcome.

Director *Huasheng Hong*
Environmental Science Research Center
Xiamen University
Xiamen, Fujian, PRC.

目　录

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