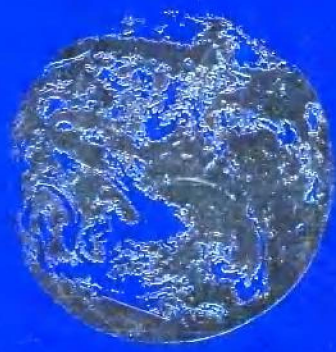


国家自然科学基金资助项目研究成果

下扬子区二叠纪古地理和地球化学环境

PERMIAN PALAEOGEOGRAPHY AND GEOCHEMICAL ENVIRONMENT IN LOWER YANGTZE REGION, CHINA

江纳言 等著
Jiang Nayan *et al.*

石油工业出版社
PETROLEUM INDUSTRY PRESS

国家自然科学基金资助项目研究成果

下扬子区二叠纪古地理和地球化学环境

江纳言　贾蓉芬　王子玉　齐敦伦
虞子冶　贺玉珉　陈小明　赵　林　等著
卓二军　张小弘　朱自力　朱仲秋

石油工业出版社

(京)新登字 082 号

内 容 提 要

本书是国家自然科学基金项目的研究成果，它是笔者近十年对下扬子区二叠系的研究总结。研究结论是建立在多次细致的野外调查和对巢湖二叠系剖面系统的微量元素、稀土元素、同位素、有机元素、生物标志化合物、粘土矿物、轻矿物、重矿物、石英颗粒表面等地球化学分析和大量的岩石薄片鉴定的基础之上。对化石与围岩、结核状燧石和层状燧石或硅质岩进行了地球化学方面的对比研究，对反映二叠纪古环境的重要岩类如"黑岩"、长石砂岩、结核状磷质岩、燧石的地球化学特征和成因均有新的认识和发现。发现了船山组上部古土壤和风化带，以及栖霞组 $\delta^{13}C$ 的平均值是地史上最高值和高含量的角鲨烯生物标志化合物。

本书共分八章。附 8 个图版、地球化学剖面综合描述和英文摘要。资料丰富、内容广泛。可供从事地质学、古生态学、沉积岩石学、沉积地球化学、有机地球化学和稳定同位素地质学等专业的科研、教学人员及从事石油、沉积矿产等生产技术人员参考。

图书在版编目(CIP)数据

下扬子区二叠纪古地理和地球化学环境/江纳言等著.
—北京：石油工业出版社，1994.8

ISBN 7-5021-1318-5

Ⅰ.下…
Ⅱ.江…
Ⅲ.①古地理学-二叠纪-中国②地球化学环境-比较-研究
Ⅳ.①P534.46②P596.2

石油工业出版社出版
(100011 北京安定门外安华里 2 区 1 号楼)
石油工业出版社印刷厂排版印刷
新华书店北京发行所发行
*
787×1092 毫米 16 开 14 印张 4 插页 329 千字 印 1—500
1994 年 8 月北京第 1 版 1994 年 8 月北京第 1 次印刷
定价：16.50 元

-ACHIEVEMENT OF RESEARCH PROJECT SUPPORTED BY NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA-

PERMIAN PALAEOGEOGRAPHY AND GEOCHEMICAL ENVIRONMENT IN LOWER YANGTZE REGION, CHINA

Jiang Nayan	**Jia Rongfen**	**Wang Ziyu**	**Qi Dunlun**	
Yu Ziye	**He Yumin**	**Chen Xiaoming**	**Zhao Lin**	*et al.*
Zhuo Erjun	**Zhang Xiaohong**	**Zhu Zili**	**Zhu Zongqiu**	

PETROLEUM INDUSTRY PRESS

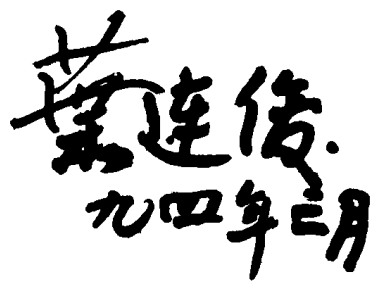
序　言

江纳言研究员是我国二叠系特别是下扬子区二叠系的沉积地层学专家之一。他对下扬子区二叠系地层的专注研究不下十余个春秋，做了大量的野外实地考察、室内研究和实验测试。近年来更十分注意国内外的学术交流和协作，了解当前国内外对二叠系研究工作的现状和趋势；对二叠纪研究的路子可谓心中有数。特别是对下扬子地区，他更是踏遍了山山水水，掌握了大量的第一手实践材料。

本专著是江纳言同志及其研究集体近五年来研究成果的总结。主要对两个方面进行了深入探讨：在岩相古地理方面和综合地层柱状图方面都取得了许多重要成果，有所发现、有所前进；提出了不少独到的见解；促进和提高了下扬子区二叠系的研究水平。例如：对船山组顶部古土壤层的发现，明确提出了龙潭组和大隆组是穿时地层单位；发现二叠系地层中含有较高含量的生物标记化合物——角鲨烯；发现栖霞组含有 $\delta^{13}C$ 的最高值；对二叠系的“黑岩”进行了沉积岩石学研究等等。

除了上述这些具体的重要贡献之外，本专著在一些对工作具有重要指导意义的思路方面，例如：在学术思想方面和技术路线方面，在新技术新方法的采用方面，以及在工作队伍的组织和多学科的协作共进方面，都很值得借鉴和学习。当前地球科学发展的一个明显趋势是单学科的深入和多学科的协作共进。江纳言同志负责的本专题的工作队伍不仅包括地层古生物学方面的专家，而且还有沉积岩石学方面，地球化学、有机地球化学及同位素地质方面，以及区域地质方面的专家。这当然就深化了对问题探讨的广度和深度。当前，地层学的研究领域已大大超出了生物地层学的传统范围，而正在向着综合地层学的方向进军。江纳言同志对巢湖地区两个典型综合地层柱状图的追究与制作，正是体现了地层学发展的这一时代趋势。由于地层学、地史学、古生物学、沉积学和沉积矿床学、大地构造学以及环境地质学的需要，岩相古地理学的发展，在研究思潮方面都在日新月异不断地展现出超前思想，这是非常需要的。本专著在岩相古地理工作设计思路上的明显之处，首先在于深入系统地研究区域地质情况及生物地层研究的新进展，并且深入剖析下扬子区二叠系的古构造、古生物岩相古地理诸单元的配置格局，以及在参照综合地层柱状图中所展示的岩性序列的基础上，经过综合分析，最后才对研究区岩相古地理轮廓及其各重要时间阶段的古环境状况进行划分、描述。显然，其所提供的图件及论述，都是论据充实的，工作成果是高水平的、先进的。

总之，本专著内容丰富，资料翔实，论述充分，观点新颖，有所前进。是一卷高水平的论著，具有丰硕的理论和实践意义。愿以此向同行介绍。



PREFACE

As one of the specialists in the Permian system of China, especially in the Permain sedimentary strata of the Lower Yangtze Region, Prof. Jiang Nayan has devoted his recent more than ten yeas to the study of these strata, and has done a lot of work, making field on-the-spot investigations, indoor researches and experimental tests. During the recent years, he pays special attention to academic exchange and coordination both at home and abroad, with an intimate knowledge of the present situation and tendency in the Permian research work over the world; it may well be said that he has a pretty good idea about the best way to make a study on the Permian System. Especially, after traversing across every mountain and every river in the Lower Yangtze Region, he has grasped a vast amount of firsthand practical material and information.

This monograph is a research summary of Dr. Jiang and his study group over the recent five years, in which deepgoing exploration has been made mainly in two respects-lithofacies-palaeogeography and synthetic stratigraphical column; both of them have brought forth a number of valuable achievements, with new findings and advancements to some extent. This monograph has put forth quite a few original views which might contribute to the promotion and enhancement of research level on the Permian System of the Lower Yangtze Region. These may be exemplified by the discovery of paleosol layers at the top of the Chuanshan Formation, the suggesion that the Longtan and Dalong Formations are diachronous stratigraphical units; the recognition of pronounced biomarkers of the upper part of Permian strata, the high $\delta^{13}C$ values of the Qixia Formation procured by the authors' laboratory being the recorded maximum in the authors' file, the sedimentary petrological research on the "black rocks" of the Permian System, and so on.

In addition to the significant contributions as mentioned above, it is also worthwhile to pay attention to the new thoughts set up in this monograph, which are apparently instructive for further research work. At present, multidisciplinary cooperation appears to be one of the current tendencies in the development of geosciences. The working team of Dr. Jiang includes a number of specialists not only in stratigraphical palaeontology and sedimentology, but also in geochemistry, organic geochemistry, isotope geology and regional geology. This, obviously, would help explore the problem at a deepgoing level. The pre-

sent study of stratigraphy has gone by far beyond the familiar traditional ideas and is marching toward the coordination of synthetic stratigraphy. Dr. Jiang's work on the two typical synthetic straigraphical packages of the Chaohu District is just a reflection of today's advancement in the development of stratigraphy. In respect to the current stratrgraphical thought, their depiction of lithofacies-palaeogeography shown here in the monography obyiosuly meets today's requirements of stratigraphy, historical geology palaeontology, sedimentology, sedimentary mineral deposit, geotectonics and environmental geology. Regarding the designing thought in the lithofacies-palaeogeographical depictions, it is obvious that these were all products of synthetic studies based on their new understandings, the reset Permian palaeostructure, and the patttern of lithofacies-palaeogeographical units of the Lower Yangtze Region. On these bases the monograph makes a convincible classification and description of the lithofacies-palaeogeographical units and a palaeoenvironmental depiction of the Permian rocks in different chronological stages in the study area. Obviously, all the plates, figures and discussion presented in this monograph are fully supported by new surveying results of the authors themselves.

To sum up, this monograph has made advancements to some extent in its rich content, fully accurate firthand information, ample discussion and many a novel points of view on the Permian rocks of the Lower Yangtze Region. Here I would like to recommend our colleagues this volume of monograph for both of its valuable practical significance and theoretical considerations.

Prof. Ye Lianjun
Academician Chinese Academy of Sciences
Chairman of Sedimentological Society, China
March 1994

前　言

在全球地质历史中，无论在生物的演化或在沉积环境的变化方面，二叠纪是一个重要的转折时期．在这个重要转折阶段形成的二叠系中，不仅出现了吸引世界许多地质学家的重要地质现象，如有关生物演化、全球环境变化和地质事件等，更重要的是大量聚积了石油、煤、天然气的可燃性矿床和磷、锰等许多非金属和金属矿产．而这些重要的地质现象的出现和沉积矿产的形成与二叠纪的地球化学环境有着十分密切的关系．笔者承担的国家自然科学基金资助的课题"中国南方二叠纪古地球化学环境的研究"(1993～1996)就是试图进行古地球化学环境与重要地质现象、生物演化和沉积矿产的关系等方面的研究．

巢湖平顶山和鬼门关两处二叠系不但地层出露好，而且有较好的生物地层工作基础(安徽省地质局区调队，1983)．笔者在进行前一项国家自然科学基金资助课题(1989～1991)时也曾将此两处剖面作为主要研究对象并取得一定的成果(江纳言等，1991；王子玉，1992；陈小明等，1992)，因此上述两处剖面已具备了深入开展古地球化学环境研究的较好基础．

在前后两项课题的研究基础上，并结合前人的资料(见参考文献)，确立了研究剖面所在的下扬子地区二叠系的构造和古地理单位体系，编制了下扬子地区二叠纪几个地质时期的古地理图．在生物地层划分和对比方面，汲取了近年来在二叠系古生物研究方面的新进展，并依沉积学和沉积地球化学的观点提出下扬子地区二叠系的长石砂岩段与上覆产安德生菊石群(*Anderssonoceras*)页岩的地层序列组合，由于在区域分布上关系密切可作区域地层对比依据，明确地提出龙潭组和大隆组是穿时的岩石地层单位的新认识．根据本区二叠系碳酸盐岩地层(栖霞组)几乎都是由生物颗粒和灰泥所组成的实际情况，从古生态学的观点提出了由具有明确环境意义的生物颗粒组合与顿哈姆(Dunham R J，1962)的碳酸盐岩结构分类名称结合构成的成因—结构复合命名，这种新的复合岩石命名对二叠系相分析有明显的实用意义。对于标志二叠纪古地理环境有巨大变化的长石砂岩段除了进行了岩石和矿物学研究外，还进行电镜石英颗粒表面和胶结物的微量元素及粘土矿物物源分析等项较深入的研究。以标志二叠系古环境特色的"黑岩"为主要研究对象，采用以X射线衍射法为主，配合红外光谱法和电镜法系统地对二叠系粘土岩类进行了详细的粘土矿物类型、形态和含量的研究，以及包括生物标志化合物在内的有机地球化学特征的研究和稀土元素、微量元素及常量化学组分等多项分析。这些综合研究除了得出全剖面较详细、较系统粘土岩的粘土矿物和地球化学特征外，对反映二叠纪古环境特色"黑岩"的成因类型进行了深入的研究并在"黑岩"中发现了具有重要地质意义的角鲨烯等生物标志化合物。此外，对碳酸盐岩进行系统的碳、氧同位素分析，得出了碳、氧同位素与沉积环境、生物和成岩作用，特别是与生物组合的密切关系，并测定了二叠纪古海洋的温度，在栖霞组中获得了 $\delta^{13}C$ 在地史分布上的最高平均值。通过岩石、矿物和包括稀土元素在内多项目的化学组分等方面的综合分析，在二叠系沉积之前（船山灰岩之顶）确定了有重要古环境意义的由风化铁壳、古土壤和淋滤带所组成的较完整的古风化带。在T/P界线的白色粘土中得出了可以反映非正常沉积成因的地球化学特征。除上述外，对全剖面进行了 MnO/TiO_2，$Sr/Ca\times10^2$，$MgO/Al_2O_3\times10^3$，B 和 C/S 等多项相指标的研究和讨论；对反映二叠系沉积特色的燧石和结核状磷质岩也进行了多项综合研究，对化石和围岩进行了稳定同位素和化学组分的

对比分析，这些研究使古环境分析、燧石和磷质岩成因和矿产资源的预测及地球化学采样等方面分别获得了新的认识和有实用价值的结论。

参加本项研究工作的有中国科学院南京地质古生物所江纳言、王子玉、陈小明、卓二军、姚婉圭、朱宗秋、虞子冶、刘云、傅启龙、杨学长、朱自力、张小弘和任玉皋等；中国科学院地球化学研究所贾蓉芬、赵林。地质矿产部南京综合岩矿测试中心贺玉珉和宫元勋等；安徽省地质局区测队齐敦伦和南京大学现代分析中心王银喜。

除第七章中二、三部分由贾蓉芬执笔，其余由江纳言主笔。王子玉、齐敦伦、贾蓉芬、贺玉珉、虞子冶和陈小明等修改了有关章节；王子玉和卓二军参加了部分图表的制作；张小弘承担电脑打字和杨荣庆清绘了部分图表。中国沉积学会理事长、中国科学院院士叶连俊研究员审阅了全文并作序。中国科学院院士盛金章研究员，国际地层委员会二叠系分会主席金玉玕研究员，沉积学报编委、中国科学院南京地质古生物研究所唐天福研究员着重审阅了二叠系地质、岩矿和沉积环境分析部分。南京大学方中教授、杨杰忠副教授着重审阅了地球化学部分并提出宝贵意见。作者在此一并感谢。

INTRODUCTION

In global historical geology, the Permian is an important turning period whether in respect of organic evolution or in changes of sedimentary environments. In the Permian System, which was formed in such an important turning period, the occurrences of various geological phenomena attract all geologists over the world, such as organic evolution, global changes in environments, and geological events; more important is the accumulation in large quantities of combustible mineral deposits such as oil, coal and natural gas, together with abundant nonmetallic and metallic mineral deposits such as phosphorus, manganese, etc. As a matter of fact, the occurrences of these significant geological phenomena and the forming of these sedimentary mineral deposits are most closely related to the Permian geochemical palaeoenvironment. The research project supported by the National Natural Science Foundation and undertaken by the authors, under the title of "Study on the Permian Geochemical Palaeoenvironment of South China (1993-1996)" is just to make an attempt at studying the relationships of geochemical palaeoenvironment with significant geological phenomena, organic evolution and sedimentary mineral deposits.

In the Chaohu area, the two localities-Pingdingshan and Guimenguan are possessed of a well-exposed Permian System, with a better foundation of biostratigraphical research work (Regional Investigation Team, Geological Bureau of Anhui Province, 1983). While carrying out a preceding research project (1989～1991) supported by the National Natural Science Foundation, the authors also took these two sections as the main objects of study with certain achievements (Jiang Nayan, *et al.*, 1991; Wang Ziyu, 1992; Chen Xiaoming, *et al.*, 1992). Therefore, these two sections are provided with a better foundation for making researches on the geochemical palaeoenvironment.

On the basis of the recent two successive research projects, in combination with information from previous scholars (see the attached references), the authors have established the Permian structural and palaeogeographical unit system of the Lower Yangtze Region in which the sections under study are located, and worked out several palaeogeographical maps representing different geological ages of the Permian in this region. In biostratigraphical division and correlation the present study has drawn the new developments in Permian palaeontological

researches during the recent years, and put forth the stratigraphical sequence association of the Permian feldspathic sandstone member and the overlying shale yielding the *Anderssonoceras* fauna in this region from the viewpoints of sedimentology and sedimentary geochemistry. In addition, due to their close relation in regional distribution which may be taken as an evidence for making regional stratigraphical correlation, a new understanding has been definitely put forth that the Longtan and Dalong Formation are diachronous lithostratigraphic units. Based on the actual situation of the Permian carbonate strata (Qixia Formation) in this region almost all composed of biograins and lime mud, and from the viewpoint of palaeoecology, the authors propose an origin-texture compound nomenclature system composed of the name of the biograin association which has definite environmental significance, in combination with the name of the carbonate texture according to R J Dunham's (1962) classification. This new compound petrological nomenelature is obviously of practical significance for facies analyses of the Permian. For the Feldspathic sandstone Member indicating the great changes in Permian palaeogeographical environments, petrological and mineralogical researches have been made, in combination with deepgoing researches by means of electron microscope analyses on the surface of quartz grains, the trace elements of cements and the source of clay minerals. Taking the "black rocks" indicating the characteristics of the Permian palaeoenvironment as the main object of study, and mainly applying X-ray diffraction, in coordination with infrared spectroscopic analysis and electron microscopy, systematic and detailed studies have been made on the types, morphology and content of the clay minerals in the Permian. lime mudstone together with researches on organic geochemical characteristics including biomarkers, and analyses of various items including rare earth elements, trace elements and invariable primary elements. These synthetic studies have achieved a relatively detailed and systematic understanding about the clay minerals in the lime mudstone and their geochemical characteristics throughout the section. By means of deepgoing research on the genetic type of the "black rocks" which reflect the charcteristics of the Permian palaeoenvironment, some biomarkers with essential geological significance have been discovered from these rocks, such as squalene. In addition, from systematic carbon and oxygen isotope analyses of the carbonate, this study has made clear the close relationships of carbon and oxygen isotopes with sedimentary environment, organisms and diagenesis, especially with life assemblages; the study also has determined the Permian palaeotemperature of the seawater, and obtained from the

Qixia Formation the maximum mean value of $\delta^{13}C$ ever distributed in historical geology. Through synthetic analyses of rocks, minerals and various items of chemical components including rare earth elements, a relatively complete palaeozone of weathering prior to the deposition of the Permian (at the top of the Chuanshan Limestone) has been determined, which is composed of weathered ferricrust, palaeosol and leached zone, with essential palaeoenvironmental significance. From the white clay at the T/P boundary, the study has found out its geochemical characteristics which might reflect the abnormal sedimentary genesis, with discussion on this origin. Besides these as mentioned above, this project also makes a research and discussion on the whole section with various items of facies targets including MnO/TiO_2, $(Sr/Ca)\times10^3$, $(MgO/Al_2O_3)\times10^2$, B and C/S, and a synthetic research with various items on the cherts and nodular phosphate rocks which reflect the Permian sedimentary characteristics, together with a comparative analysis on the stable isotopes and chemical components of the fossils and their enclosing rocks. These researches have achieved new understandings and conclusions with practical values in many respects such as palaeoenvironmental analysis, genesis of cherts and phosphate rocks and geochemical sampling for further studies.

From the aforementioned various items of research work, despite the achievements of some new progress, with the presentation of some new understandings, new methods and new materials, there still exist quite a few problems awaiting further studies, and there must be some mistakes or shortcomings in the achievements of this project, for which any criticisms and corrections are cordially invited.

Participants in the research work of this project include Jiang Nayan, Wang Ziyu, Chen Xiaoming, Zhuo Erjun, Yao Wangui, Zhu Zongqiu, Yu Ziye, Liu Yun Fu Qilong, Yang Xuechang, Zhu Zili, Zhang Xiaohong and Ren Yugao from Nanjing Institute of Geology and Palaeontology, Academia Sinica; Jia Rongfen and Zhao Lin from Institute of Geochemistry, Academia Sinica; He Yumin, Yo Ziye and Gong Yuanxun from Nanjing Comprehensive Rock and Mineral Test Center, Ministry of Geology and Mineral Resources; Qi Dunlun from Regional Geological Surveying Party, Geological Bureau of Anhui Province and Wang Yinxi from Contemporary Analysis Center, Nanjing University.

In the course of compilation, the full text was written by Jiang Nayan, except for Parts 2～3 of Chapter 7, which was written by Jia Rongfen. The related chapters and sections were separately revised by Wang Ziyu, Qi Dunlun, Jia

Rongfen, He Yumin, Yu Ziye and Chen Xiaoming. Wang Ziyu and Zhuo Erjun made part of the maps and tables; to Zhang Xiaohong undertook the computerized typewriting. The author is grateful to Yang Rongqing for his fair drawing of part of the maps and tables; especially to Professor Ye Lianjun the prominent sedimentologist, academician of Chinese Academy of Sciences and chairman of Sedimentological Society of China for going over the full manuscript and writing the preface, to Professor Sheng Jinzhang, academician of Academia Sinica, Professor Jin Yugan, chairman of Subcommission on Permian, International Commission on Stratigraphy, and Professor Tang Tianfu from Nanjing Institute of Geology and Palaeontology, Chinese Academy of Scienees, member of Editorial Board, Acta Sedimentologica Sinica for emphatically going over the sections on Permian geology, rock-mineral and sedimentary environment analyses, and to Professors Fang Zhong and Yang Jiezhong of Nanjing University for emphatically going over the section on geochemistry and offering valuable opinions.

目　录

PERMIAN PALAEOGEOGRAPHY AND GEOCHEMICAL ENVIRONMENT IN LOWER YANGTZE REGION, CHINA

第一章　地质概况和区域古地理基本轮廓

一、地质概况

本文研究的下扬子区二叠系代表性剖面位于中国东部安徽省巢湖市周围的山区，研究工作实测了平顶山和鬼门关两处剖面和银屏山补充剖面(图 1—1)。

安徽巢湖地区地理上位于长江下游地区，构造上属于华南板块的东部北缘或位于下扬子断块(The Lower Yangtze Fault Block)的北缘。华南板块的东部在构造上的稳定性次于华北板块和川黔断块，黄汲清(1979)将这一地区划为扬子准地台。震旦纪和整个古生代下扬子区基本上连续下沉，形成了较大厚度的沉积地层，仅南京地区整个古生代地层厚度超过 3 千米。与北邻的华北板块(或中朝陆块)以及与南面接壤的华夏陆块比较，二叠纪下扬子区的沉降幅度较大。整个二叠纪期间下扬子区基本上处在连续下沉的海洋环境，除龙潭组有海陆过渡相的沉积外，沉积了二百至近千米的海相岩系。

华南板块的东部在构造上可以再分为下扬子断陷带(The Lower Yangtze Fault — Depression Belt)，江南断隆带(The Jiangnan Fault — Upwarding Belt)和江南断陷带(The Jiangnan Fault — Depression Belt)。其中江南断隆带可以视为是中国西南地区的扬子地台向东的延伸部分，二叠纪时这一带内，特别是赣北地区，沉积了类似扬子地台上的碳酸盐岩，不过在这一带还包括有在二叠纪最初期(隆林期)和龙潭期按岩相分布规律推断存在的剥蚀区——“江南陆地”。此带向东转东北方向尖灭，在安徽休宁地区出现栖霞组上部的零星露头。这一事实说明江南断隆带的东部在二叠纪最大的海进期(栖霞期)同样为海洋环境，不过

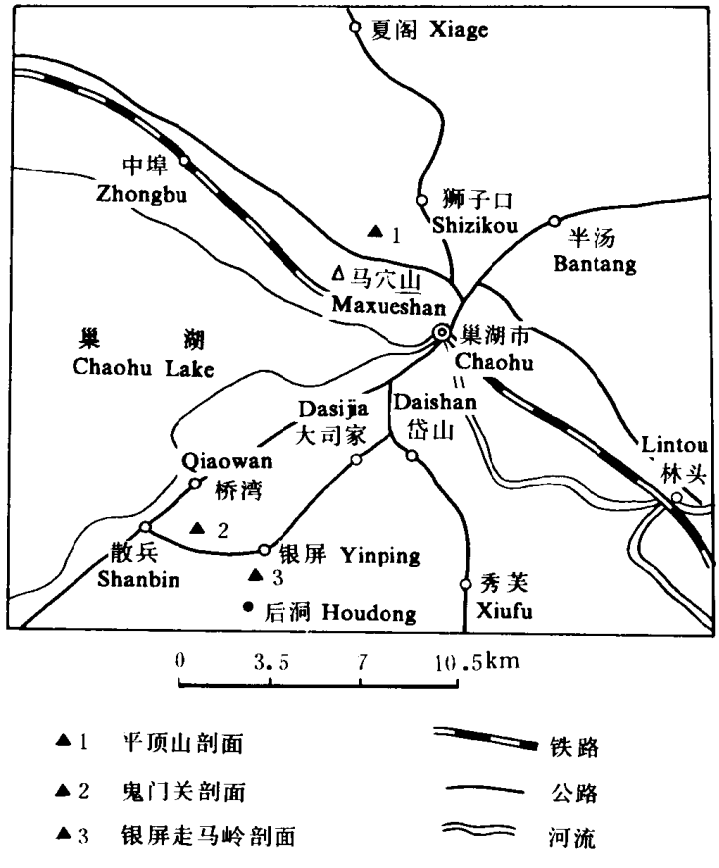


图 1—1　研究剖面位置示意图

Fig. 1—1　Sketch showing the locations of the main research sections of Permian in Chaohu, Anhui Province, China.
1—Pingdingshan section; 2—Guimenguan section; 3—Yinping section