中国古代深海沉积和遗迹化石群落

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内 容 简 介

本书以最新的沉积学理论，首次论述了中国加里东、海西和印支三个时期几个主要造山带的深海重力流沉积，特别是浊流沉积以及深海牵引流沉积的成因类型和特征、沉积作用方式及其时空展布和相模式，系统阐述了块体流和深海牵引流成因的各种原生沉积构造类型，并运用沉积-构造学的研究方法，讨论了重力流沉积体系形成的构造环境。本书的特色是沉积学与古遗迹学紧密结合，以丰富的实际资料概括出不同成因类型浊积岩系中遗迹化石组合与古生态环境间的相关模式，对于利用遗迹化石群落进行古生态环境研究具有指导意义。

本书可供沉积学、古遗迹学和构造地质学及其相关学科的科学工作者、大专院校师生和生产技术人员参考。

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序

通常认为，沉积学奠基于19世纪中期，而现代沉积学则以P.H.Kuenen和C.I.Miglorini于1950年发表“粒序层理由浊流形成”一文作为发端。所以有这种看法，不仅因为浊流理论创新了深海碎屑沉积物研究，而且因为浊流理论为沉积学建立了新的方法学——将现代沉积、古代岩石和实验室的实验相结合的综合研究方法。20世纪后半期，沉积学在理论研究和应用两方面都获得了巨大发展，成为地质科学的一门成熟学科。

经历最近半个世纪地质发展的人们都会记得，20世纪50年代和60年代，居于主导地位的地槽学说以垂向振荡运动作为复理石成因的一种解释，而很少理会浊积岩复理石的见解。60年代后期至70年代初诞生的板块构造理论是地质科学的一场革命，浊流理论很自然地融入新的地质科学理论，而且深海大洋沉积和造山带沉积研究得到空前发展。

我国地质学家于20世纪70年代开始研究板块构造，同时开始造山带沉积学研究。《中国古代深海沉积和遗迹化石群落》一书的作者，就是近20年来从事这一领域研究的优秀学者的代表。

据我所知，本书的作者，长期以来坚持野外的细致考察，对新的科学文献系统地加以研究，陆续发表过多篇论文，现在《中国古代深海沉积和遗迹化石群落》一书作为多年研究工作的总结终于面世。我衷心祝贺该书的出版。

从书的内容可以看出，本书围绕我国早古生代、晚古生代和早中生代造山带的有关地区开展了古代深海沉积、重点是浊流和其他重力流沉积的系统研究，从多方面深入论述不同类型的浊流沉积体系的成因、特征和时空分布，最终概括出多种沉积模式类型。在深海牵引流沉积方面，特别是对内波、内潮汐沉积的形成及其保存条件提出了新的见解，并发现诸多新类型的内波、内潮汐沉积。

在研究深海沉积的同时，作者还开展了深海环境遗迹化石的研究。在不同成因类型的浊流沉积以及半远洋沉积中发现的遗迹化石属的数量之多，在我国尚属首次。尤其突出的是，在西秦岭泥盆系舒家坝组的深海沉积中竟发现了42个遗迹化石属。在晚古生代早期一个组的地层中，如此大量的、形态规则的、复杂的遗迹化石的发现，在国内外均属罕见。作者采用沉积学和古遗迹学结合的新思路来论述沉积环境和古生态是本书最显著的特色之一，它使古遗迹学被赋予了极其鲜明的沉积学意义，也使造山带沉积学的研究在深度

和广度上都有了重要扩展。

此外，本书还提出了一系列新的认识，例如对深海环境原生沉积构造的综合研究、利用遗迹组合对宿主岩系含氧状况的判别、*Nereites* 遗迹相具有深水和浅水型遗迹化石混生现象的认识、*Zoophycos* 遗迹相所指示的半深海沉积是有利的生油层位以及从沉积学角度来阐明构造环境等。

本书是我国学者在这一领域的第一部系统的学术专著，展示了我国学者在该领域的新水平。我相信，本书的出版必将在沉积学界和古遗迹学界产生积极的影响，并将推动这一领域的研究更加广泛深入地开展。

孙枢

2002年5月8日

Foreword

Sedimentology is generally believed to make a start in the middle 1850s, however, the modern sedimentology was not founded until 1950 when P. H. Kuenen and C. I. Miglorini published their paper, "Grain sequences formed by turbidite". This is because that the turbidite theory has contributed much not only to innovate the research of abysmal classic sediments but also to lay a foundation of a novel methodology for sedimentology, a comprehensive research method integrating modern sediments, ancient rocks and room experiments together. Since the late 20th century, sedimentology both in theory and in practice has tremendously progressed and become a mature discipline of geosciences.

People experienced the recent half-century development in geology can not forget that during the 1950s to the 1960s of the last century the geosynclinal theory dominating in geology interpreted the flysch genesis as a result of vertical oscillation and seldom paid attention to the explanation of turbidite flysch. The plate theory born in the late 1960s and early 1970s aroused a revolution in geosciences. Since then the turbidite concept has naturally mixed with the newly-formed geological theory and researches on abysmal and orogene deposits have progressed tremendously.

Geologists in China started to investigate plate structure and orogene sedimentology in the 1970s. The authors of "Paleo-Abysmal Deposits and Ichnocoenoses in China" are representatives of the outstanding scholars engaged in this research field in recent 20 years.

The authors, as far as I know, have carried on field investigations for many years, studied the new scientific literature systematically and published a couple of papers concerned. Right now the monograph, "Paleo-Abysmal Deposits and Ichnocoenoses in China" as a summary of many-years research work, has finally come out. I sincerely congratulate the publication of this monograph.

It can be seen from the monograph that systematical investigations are concentrated on paleo-abysmal deposits, especially on turbidite and other gravity current deposits in such areas of China, where Early and Late Paleozoic as well as Early Mesozoic orogenes are developed. The monograph discusses at different view of points the genesis, characteristics and time-space distribution of different turbidite depositional systems in details, and finally summarizes varieties of sedimentary models. Some novel concepts on abysmal tractive currents, especially the formation and reservation of internal-wave and internal-tide deposits are raised in the monograph, together with many new types of internal-wave and internal-tide deposits.

Meanwhile, the authors also studied ichnofossils in abysmal environments and it is rare that so many ichnofossil species are firstly reported in different turbidite and hemiabysmal deposits in China, especially 42 species of ichnofossils discovered in the Shujiaba abysmal deposit of the West Qinling Devonian system. It is exceptionally seldom both in China and abroad that such abundant

and complicated ichnofossils with regular forms are found only in one formation of the lower series of the Upper Paleozoic system. One of the distinguishing features of this monograph is to investigate sedimentary environments and paleo-ecology on the basis of the integration of sedimentology and palichnology, which makes palichnology a distinguishing sedimentology sense, deepens and widens researches of orogene sedimentology.

In addition, a series of novel interpretations are raised in this monograph, such as comprehensive research of protodepositional structures in the abysmal environment, the oxygen-bearing identification of host rock series by applying ichnolite assemblages, the *Nereites* ichnofacies as a facies indicator to the coexistence of both deep-and shallow-water ichnofossils, the hemiabysmal deposit indicated by *Zoophycos* as a favorable petroleum-producing bed and the application of sedimentology in interpreting structural environments.

This work is the first systematical academic monograph that demonstrates a novel level of Chinese scholars in this field. I believe its publication will surely produce an active impact on the sedimentology and palichnology circles as well as advance their researches greatly.

Sun Shu

8 May, 2002

前　言

我国古代深海沉积的研究是随着浊流和其他重力流沉积研究的兴起、发展和深化而逐步向前推进的。人们认识上的突破必然带来观念上的更新，它引导着沉积学家去重新审视在沉积学方面的某些传统看法，尤其是造山带沉积学这一在我国20世纪70年代尚处于空白领域的基础研究工作开始被引起重视，于80年代成为一个新的研究热点，并获得了蓬勃发展。

古代深海沉积物的来源，总的说来不外乎两大类。一类是通过侧向加积作用，主要由浊流和其他重力流以及深海牵引流搬运而来；另一类则是通过垂向加积作用，主要由小于0.01mm的细粒物质和深海浮游生物的直接沉积以及化学和生物化学作用直接沉淀的部分沉积物。众多的沉积物类型，极大地丰富了深海沉积的研究内容，尤其是前者，突破了传统的"沉积分异"理论的束缚，这对于正确认识深海沉积物的搬运、沉积作用方式，建立沉积充填演化序列、沉积作用模式和判断古海洋盆地性质，进而探讨相关造山带构造环境的空间展布和演化，以及揭示有关深海沉积矿产资源的分布规律都具有重要的意义。

古遗迹学是近30年来地质科学中新兴的一门边缘学科。该学科专门从事地质历史时期生命活动遗迹的研究。由于遗迹化石形成后，不再被搬运而系原地埋藏，故更能准确地反映沉积条件和古生态环境而倍受沉积学者的重视。我国遗迹化石的研究工作始于20世纪80年代初，而深海遗迹化石的研究是随着古代深海沉积的工作广泛开展发展起来的，并成为深海沉积研究领域的重要组成部分。

消亡于造山带中的古海洋，特别是半深海斜坡—深海环境形成的沉积岩系，由于其中实体化石的贫乏，且多系异地搬运而失去指相意义。因而保存于其中丰富的遗迹群落，就成为指示深海环境特征的极其重要的古生物标志。地质记录中的深海遗迹群落大都赋存于浊流沉积体系内，因此，利用遗迹化石，尤其是遗迹化石组合和遗迹相恢复造迹生物生活期间的古环境特征是完全可能的，并且现已成为判识深海沉积相乃至亚相的一个极为重要的标志。

采用沉积学与古遗迹学相结合的思路和方法，开展造山带沉积地质学研究不仅对推动沉积学和古遗迹学的发展起了促进作用，也为我国古代深海沉积积累了丰富的遗迹化石资料，特别是对古海盆的海水深度、含氧状况、沉积速率、水动力条件等，这些仅通过沉积学研究尚难以完全解决的许多古生态问题，将带来新的启示和新的认识。为此，我们从80年代中期至今先后向中国科学院和国家自然科学基金委员会提出申请自然科学基金项目共6项，均获批准。它们的名称及编号分别是：

（1）新疆准噶尔盆地石炭、二叠纪浊积岩研究，编号：R850577；

（2）新疆博格达山晚古生代浊流和其他重力流沉积的研究，编号：4870112；

（3）西秦岭印支期大陆边缘的沉积作用演化及其构造环境，编号：49070107；

（4）浊积岩型金矿容矿岩系的沉积-构造模式，编号：49172105；

(5) 造山带深水沉积体系遗迹化石组合与古环境恢复,编号:49472116;

(6) 浊流沉积体系中主要遗迹组合形成的古生态环境,编号:49672127。

本书论述的地区包括新疆、甘肃、内蒙古、浙江、贵州等省区;涵盖的地质时代从早古生代—中生代的奥陶纪、泥盆纪、石炭纪、二叠纪和三叠纪,即包含有加里东、海西和印支三个时期的造山带;论述的内容侧重于古代深海块体流沉积,与此同时,也注意了深海底流活动的牵引流沉积,以及所发现的深海远洋沉积。在浊积岩的研究类型上,既包含有陆源碎屑和火山碎屑浊流沉积体系,又包含混积型浊流沉积体系;在沉积模式上既有有扇的,又有无扇的;它们随其构造环境的不同各具特色,充分表现构造对沉积的控制作用。尤其值得注意的是,不同成因类型的深海浊流沉积体系中遗迹化石组合存在着明显的差异,这种差异揭示了古生态对遗迹化石形成的控制作用,从而使利用遗迹组合恢复古生态环境的理想成为现实。

近20年来在执行6项自然科学基金项目的过程中,确有不少新的发现,也纠正了过去某些错误的观点,从而带来了认识上的突破。概括起来,在本书中最突出的有以下几个方面:

(1) 书中所列的大量实际资料都是项目组全体成员通过野外实地考察直接获取的,这是一项十分重要的前提和基础性工作。

(2) 古代深海沉积地层中所见到的原生沉积构造,除深海环境所独具有的之外,还发现诸多长期以来被误认为只有滨、浅海环境才具有的那些沉积构造(除暴露沉积构造和雨痕外),它们的发现不但加深对深海环境中水动力系统复杂性的认识,也提示出在重塑古环境时必须重视各种相标志的综合解释,也包含利用遗迹化石组合和遗迹相,从而为排除沉积环境和相的多解性发挥特殊作用。

(3) 研究地区所发现的浊积岩系的判识标志已远远超出早期研究阶段认为的那些典型浊积岩范畴。许多不具鲍马层序特征、甚至不显递变层理的块状砾岩、块状砂岩乃至块状泥岩很多都属浊流成因。从而扩大了对浊积岩研究的思路和研究方法。

(4) 主要由海底喷发提供并组成的火山碎屑浊积岩系与陆源碎屑浊积岩系在沉积特征上有着较大的差异,说明两者之间浊流形成过程中的流体性质和水动力条件不完全相同;两类浊积岩系中的遗迹相虽相同,但所赋存的遗迹化石组合却截然不同,反映它们形成的海盆性质及其古生态环境都有着巨大区别。

(5) 古代深海浊流沉积模式在研究区识别出扇与非扇两类,而无扇沉积模式中又进一步识别出盆地平原型、断裂斜坡裙型和缓坡型等3种特征不同的沉积作用模式。它们判识的主要依据是按其相类型、相组合、相序特征和相组合在空间上的展布,以及古流向等要素综合确定。

(6) 古大陆边缘的浊积岩系和稳定地块中凹陷区内的浊积岩系存在着显著的差异,具体表现在沉积厚度、地层产状和岩石变质程度,以及遗迹化石的形体和潜穴管粗细程度等方面都有极大的差别。这是构造环境控制沉积作用的直接反映。

(7) 西秦岭北带仅属于中泥盆统的舒家坝组内所发现的42个遗迹属说明,在晚古生代早期遗迹化石群落的丰度和分异度并不逊于中、新生代,且遗迹化石也具规则复杂多样的形态,从而揭示了造迹生物的发展、演化并不完全遵循"渐进论"的观点。

(8) 鉴于当今对 *Zoophycos* 和 *Nereites* 两个遗迹相在环境认识上的混乱,明确了它们各

自所代表的沉积学意义。指出 *Zoophycos* 遗迹相不应包括可形成浊流的任何环境；*Nereites* 遗迹相才是深海浊流环境中遗迹化石群落的惟一代表，并进一步指出该遗迹相普遍具有深水型和浅水型遗迹化石群落共生的特点。

(9) 在深海沉积与油气形成方面，通过对准噶尔盆地西北缘对比研究后，首次提出了石炭纪深海沉积的哈拉阿拉特组属于 *Zoophycos* 遗迹相的巨厚黑色泥岩段，是克拉玛依油区的重要油源之一。

(10) 浊积岩系杂砂岩中的常量元素组成与物源区和构造环境密切相关。通过对不同研究地区、不同类型的构造环境的大量岩样分析，以及与国内外众多相关数据的对比研究，提出了用于推断浊积岩系形成的板块构造环境的新的 $SiO_2/Al_2O_3 - K_2O/(Na_2O + CaO)$ 双变量判别图。

通过上述 6 项自然科学基金项目执行后所取得的进展可以看出，它们都围绕一个中心主题，就是从不同地区、不同成因类型不断深化对我国古代深海沉积的研究，而且也还加强了不同构造环境控制下浊流沉积体系的对比研究，并充分重视各类古海盆充填序列中的遗迹化石组合和遗迹相，以分别探讨它们各自的古生态环境。因此，确切地说，本专著是造山带沉积地质学和古遗迹学学科交叉研究的产物，也是上述 6 项基金项目的最终系统总结。

本书除第八章由方国庆执笔外，其余章节均由晋慧娟、李育慈执笔撰写完成，晋慧娟负责统编，李育慈审校。先后分别参加 6 项自然科学基金项目的具体研究人员除执笔者外，还有李菊英、李继亮、杨世倬、张晓宝、何海清、宋春晖等。应当指出，本专著的撰写自始至终得到了叶连俊、孙枢和刘宝珺三位院士的热情鼓励和特别关怀，杨式溥教授对部分遗迹化石的鉴定给予了精心指导，马福臣教授和田兴有教授给予了大力支持，中国科学院兰州地质研究所给予了极大的支持和经费上的全额资助；在野外考察中得到了陈文一教授、左国朝教授和金松桥高级工程师的热情帮助，在此一并表示衷心的感谢。

Preface

The study on paleo-abysmal deposits is gradually advancing with the rising, developing and deepening of investigations in turbidite and other gravity-current deposits. A breakthrough in knowledge will inevitably bring in the revolution in concepts, which guides sedimentologists to reconsider some traditional views in sedimentology, especially in the orogene sedimentology, which remained a blank in basic research during the 1970s in China and became a hot point and developed tremendously in the 1980s.

Generally, there are two sources for paleo-abysmal deposits, one comes with lateral accretion from the transportation mainly by turbidite and other gravity-currents such as the abysmal tractive current; and the other with vertical accretion from some chemical or biochemical precipitation deposits as well as from immediate deposits of < 0.01mm fine grains and abysmal planktons. Such various types of deposits greatly enrich the research of abysmal deposits, especially of the gravity-current deposit, which breaks the trammels of the traditional "depositional grading" theory and is of importance in better understanding patterns of the transportation and deposition of abysmal deposits, building up evolutionary sequences of depositional fillings, setting up the model of deposition and identifying paleo-sea basins so as to investigate the space distribution and evolution of structural environments of orogene concerned and probe into the distributional law of abysmal ore resources.

In the past 30 years, palichnology has become a rising frontier discipline of geosciences and it specifically studies the ichnolite of life in the geological history. Since ichnofossils are buried in situ without further transportation after their formation, they are thought highly of by sedimentologists due to their more accurate indications to depositional conditions and paleo-ecological environments. The study on ichnofossils in China started in the early 1980s, yet the investigation on abysmal ichnofossils did not advance until the wide-ranging development of studies on paleo-abysmal deposits and it has constituted the major part of abysmal deposit researches.

Paleo-seas disappearing in orogene, especially the depositional series formed in semiabysmal slope-abysmal environments, are usually meaningless in the facies indication due to the deficiency of fossils and heterogenetic transportation. Therefore, the abundant ichnocoenosis preserved in these deposits becomes an important paleontologic indicator to characteristics of abysmal environments. The abysmal ichnocoenosis in the geological record exists usually in turbudite deposits, hence, it is definitely possible to rebuild the paleo-environment in which trace builder once lived by applying ichnofossils, especially ichnofossil assemblages and ichnofacies. They have become an important indicator to identify abysmal depositional facies and even subfacies.

The sedimentological and geological research on orogene by means of the integration of sedimentology and paleoichnology has not only brought about a great advance in sedimentalogy and

paleoichnology but also accumulated abundant data of ichnofossils for investigating paleo-abysmal deposits in China, especially the water depth, oxygen-bearing state, sedimentation rate and hydrodynamic conditions of paleo-sea basins. To investigate such paleo-ecological problems that can not be solved only by sedimentological studies will certainly produce novel inspirations and cognition. Therefore, since the middle 1980s we have applied six natural scientific foundation projects to the Chinese Academy of Sciences and the National Natural Science Foundation of China and all of them have been approved. Their titles and the serial number are as follows:

(1) A study on the Carboniferous and Permian turbidite in Junggar Basin, Xinjiang, No. R850577.

(2) A study on the Late Paleozoic turbidite and other gravity current deposits of Mount Bogda in Xinjiang, No.4870112.

(3) Sedimentary evolution of the Indo-China continental margin along the western Qinling Mountains and its tectonic environment, No. 49070107.

(4) Sedimentary and structural models of turbidite gold-bearing rock series, No. 49172105.

(5) Ichnofossil assemblages of orogene deep-water deposits and their paleo-environment reconstruction, No. 49472116.

(6) Paleo-ecological environments for the formation of the major ichnofossil assemblages in turbidite deposits, No. 49672127.

The areas involved in this monograph are Xinjiang, Gansu, Inner Mongolia, Zhejiang and Guizhou provinces or autonomous regions and the geological age spans from the early Paleozoic to Mesozoic, such as Ordovician, Devonian, Carboniferous, Permian and Triassic, which contain Caledonian, Hercynian and Indo-China orogenes. The discussion lays particular emphasis on the paleo-abysmal block current deposit, on the tractive current deposit formed by the abysmal under current and on the discovered abysmal deposit. Types of turbidites in studies concerned contain both terrigenous detrital and volcanidetrital turbidite depositional system and diamictic turbidite depositional system. Their depositional models not only with fans but also without fans are characteristic of varieties depending on different structural environments, apparently indicating the structural control over the deposit, what's more important that the ichnofossil assemblage in the different abysmal turbidite depositional system with different genetic types is obviously different, this difference indicates the controlling factor of paleo-ecology over the formation of ichnofossils and makes the dream of restoring paleo-ecological environments by different ichnofossil assemblages come true.

During the past nearly 20 years' investigation of the six projects, quite a lot of new findings have been obtained and some mistaken views in the past have also been corrected, which produces some breakthrough in cognition. To sum up, the outstanding achievements in the present monograph are as follows:

(1) The large quantities of data shown in the monograph are directly gained from fieldwork by the team involved in these projects, which is prerequisite and essential for the basic research for all genuine knowledge can only come from practice.

(2) Besides those which are unique in the abysmal environment, some protodepositional

structures which had been for a long time in the past misunderstood to only appear in the shallow-sea environment (except exposed depositional structures and rain markers) have been discovered in paleo-abysmal depositional strata. This discovery not only deepens our understanding to the complexity of the hydrodynamic system in abysmal environments but also implies that during the restoration of paleo-environments the emphasis should be laid on the comprehensive interpretation of various facies indicators and on the application of ichnofossil assemblages and ichnofacies, which plays a specific role in the exclusion of the multi-explanation of depositional environments and facies.

(3) The identification indicators to the turbidite series found in the studied areas are far more than the typical turbidite category defined by the early research work. Many of blocky conglomerates, sandstones and mudstones without the Bouma sequence and even without graded bedding are now regarded to be of the turbidite genesis, which widens our thinking and methodology as turbidite is studied.

(4) The volcaniclastic turbidite system mainly formed by sea-floor explosion is quite different from the terrigenous detrital turbidite system in depositional features, suggesting their current properties and hydrodynamic conditions are not exactly the same during the formation of turbidite. Though the ichnofacies of their turbidite series is similar, their ichnofossil assemblages are quite different, suggesting a sharp difference in both their sea-basin properties and paleo-ecological environments.

(5) The model of paleo-abysmal turbidite deposits is identified as two kinds, with or without fans. Moreover, the kind without fans is further identified to have three depositional patterns with different features, namely the basin plain type, rift-linoform type and slow-slope type. The major identification bases are established comprehensively according to their facies types, facies combination, facies sequence properties, the special distribution of facies combination and the direction of paleo-currents.

(6) An apparent difference exists between the paleo-continental margin turbidite series and the turbidite series within the stable block depression. Specifically, their ichnofossil shapes and the size of burrows as well as their depositional depth, stratum occurrence and metamorphic degree of rocks are quite different, directly indicating the control of structure environments over deposition.

(7) The discovery of 42 ichnofossil species only in the Middle Devonian Shujiaba Formation along the northern zone of the West Qinling Mountains shows that the abundance and differentiation of ichnocoenoses in the early period of Late Paleozoic are by no means inferior to those of Mesozoic and Cenozoic. Moreover, these ichofossils are characteristic of complexity and variety of shapes, revealing that the development of trace-building organism evolution did not exactly follow the rule of the "progressive evolution".

(8) In view of the confusion in understanding the environmental indication of the *Zoophycos* and *Nereites* ichnofacies, their individual significance in sedementology is clarified in this monograph, namely the *Zoophycos* ichnofacies does not indicate any environment under which turbidite can be formed and the *Nereites* ichnofacies is the only representative for the ichnocoenose in the abysmal turbidite environment. Furthermore, *Nereites* is defined to be universally characteristic of the coexistence of shallow- and deep-water ichnocoenoses.

(9) With reference to the abysmal deposits and hydrocarbon formation, the investigation on the northwestern margin of Junggar Basin proposes at first time that the thick black mudstone of the *Zoophycos* ichnocoenose, which belongs to the Halaalate Formation of the Carboniferous abysmal deposit, is one of the major oil sources of the Karamay oilfield.

(10) The major elemental composition of greywacke in the turbidite series is closely related with source areas and structural environments. On the basis of the correlation investigation of numerous data concerned both at home and abroad as well as of analyses on the large quantities of rock samples collected from the different studied areas and various structural environments, a novel SiO_2/Al_2O_3-$K_2O/(Na_2O + CaO)$ bivariate identification diagram is put forward to deduce plate structural environments under which turbidite series is formed.

It can be seen from the progress made by the above-mentioned six research projects that it focuses on one theme, i.e. the investigation on the paleo-abysmal deposit in China progressively advances by means of studying various genetic types as well as different areas. The correlation study on various turbidite depositional systems controlled by different structural environments has also been strengthened and the ichnofossil assemblages and ichnofacies in filling sequences of various paleo-sea basins are fully stressed in this monograph and their individual paleo-ecological environments are discussed as well. Therefore, to be exactly, this monograph is an interdisciplinary product of orogene sedimentary geology and palichnology as well as a systematically final summary of the above-mentioned six natural scientific foundation projects. Such a monograph is rare not only in China but also in other countries of the world.

The monograph is written by Jin Huijuan and Li Yuci except for Chapter Eight, which is written by Fang Guoqing. The final manuscript is edited by Jin Huijuan and reviewed by Li Yuci. Besides the authors, Li Juying, Li Jiliang , Yang Shizhuo, Zhang Xiaobao, He Haiqing and Song Chunhui participated in the six natural scientific research projects, respectively. It should be mentioned that from the very beginning to the end the writing of this monograph has been enthusiastically encouraged and specifically concerned by Academicians Ye Lianjun, Sun Shu and Liu Baojun. We are grateful to Prof. Yang Shifu for the detailed guide to the identification of some ichnofossils, Profs. Ma Fuchen and Tian Xingyou for their great support, Lanzhou Institute of Geology, Chinese Academy of Sciences for its enormous help and financial support to the publication of this monograph, and Senior Engineer Jin Songqiao as well as Profs. Chen Wenyi and Zuo Guochao for their enthusiastic help in the fieldwork.

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