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国家重点实验室

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主 编 罗志立

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# 龙门山造山带的崛起 和四川盆地的形成与演化

Uplift of Longmen Mountain Orogenic Belt  
and the Formation and Evolution of Sichuan Basin

主 编 罗志立

副主编 赵锡奎 刘树根 宋鸿彪

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## 内 容 简 介

龙门山造山带为青藏高原东界,是国内外研究特提斯域和大陆构造的热点地区,四川盆地占有扬子板块的突出部位,是中国南方最大产气的克拉通盆地,也是研究中国大陆盆地的关键地区,为许多国内外地学工作者逐鹿的地域。本专集的作者在完成“六五”、“七五”、“八五”国家科技重点攻关项目、四川省科委重点攻关项目、国家自然科学基金项目以及成都理工学院与澳洲墨尔本大学国际合作等科研项目后,从大量公开发表和最近刚完成的一些项目报告中,精选了 50 篇文章,就上述地域的地质问题从多学科角度展开了详细的综合论述。资料翔实,图文并茂,观点新颖,而且是历经 15 个春秋,辛勤的集体创作。其研究思路和有关论述可供从事大地构造学、盆地分析、区域地质工作及其勘探油气藏科技人员和大专院校师生参考。

## 龙门山造山带的崛起和四川盆地的形成与演化

主 编 罗志立  
副 主 编 赵锡奎 刘树根 宋鸿彪  
责任编辑 卢奇勋 袁顺生  
周兴泰 赵成永

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## 序

《龙门山造山带的崛起和四川盆地的形成与演化》是罗志立教授自1978年以来,在改革开放方针指引下带来的社会进步和科学繁荣的时代,他与他的同事和学生们在完成“六五”、“七五”、“八五”国家科技重点攻关项目、四川省科委重点攻关项目、国家自然科学基金项目和成都理工学院与澳洲墨尔本大学国际合作等科研项目后,从大量公开发表的文章和新近刚完成的一些项目报告中选辑的。共有文章50篇,90多万字,分4编组成,是一本国内外地学工作者经历15个春秋集体合作的一部专集,具有鲜明的中国大陆构造特色。

本专集重点研究地区为龙门山造山带和四川盆地,前者是国内外研究青藏高原东界的特提斯域和大陆构造的热点地区,后者是占有扬子板块的突出部位,并是中国南方最大产气的克拉通盆地,因而处于研究中国大陆构造的关键地区,为许多国内外地学工作者逐鹿的地域。本专集研究思路清晰并有所创新,例如造山带的隆升与前陆盆地的沉降相结合、构造活动带的塑性变形与前陆盆地的脆性变形相结合、盆地深部结构与造山带中浅层运动关系相结合的研究思路和方法,在国内处于领先地位。深入研究本区的地质特色,提出的“峨眉地裂运动”和“C-型俯冲带”的学术观点,贯穿于专集各编中。自发表以来,在国内地学界引起强烈的反响,它不仅有丰富中国大陆构造学的理论意义,而且有对油气勘探的实际指导意义。在板块构造理论指导下,划分出中国含油气盆地类型,提出扬子古板块和松潘—甘孜边缘海的概念,以及从“岛弧”演化成地台等论点,是国内发表较早的文章,对传播板块构造理论和认识中国大陆地质结构有开拓意义。在创立的地裂运动和C-型俯冲论点的指引下,对中国地壳运动划分出三个地裂期、松辽盆地为塌陷盆地成因机制的认识,以及从C-型俯冲发展成L-型俯冲和T-型俯冲的论点,具有崭新的地质概念,无疑将对研究中国大陆构造理论作出应有的贡献。在大地构造基础理论结合油气勘探

实际研究方面，对礁块发育在川东和川中的预测、中国陆相生油二元论、在中国寻找大气田要重视煤成气和古隆起的文章，这在国内多属首倡，有重大的科学意义和实用价值。这本专集是罗志立教授从事地质工作 45 年的后 15 年同参与项目攻关的人员，在共同目标鼓舞下，由不同单位和不同专业的专家集体完成的；面对复杂的地质问题，团结战斗，互相支持进行综合研究攻关的精神，是值得发扬的。上述特点和成果，是本专集的作者在学习国外先进理论的同时，密切联系中国地质实际，走自己的道路，创立中国地质特色科学理论的尝试。对他们不畏艰辛敢于攀登的开拓精神，值得鼓励和赞许。

本专集拥有丰富的地质、地球物理和地球化学资料，对中国造山带和含油气盆地有许多精辟的论述，可视为研究中国大陆构造和油气勘探方面一份重要著作，可供构造学家、石油地质工作者及油气勘探大专院校师生参考。

中国科学院院士 郭令智

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## 前 言

龙门山造山带主要指前龙门山推覆构造带,它北起广元,南达天全,全长约 500km,宽约 30km,位于扬子板块西缘和松潘—甘孜褶皱区分界线上,既是青藏高原的东界,又是四川盆地西缘。北东与秦岭褶皱系相交,西南与攀西裂谷带相截,且位于古特提斯洋东延地域,成为中国少有的经向造山带。龙门山前山带具典型推覆构造特征,为中国在推覆构造勘探油气的重要领域;龙门山后山带是中国南北地震带经过地区,是四川灾害地质发生的场所,又是世界著名的九寨沟和黄龙风景区所在地,还是黄金和铀矿等内生矿床富集带。由于它的地理位置和大地构造位置突出,环境地质和矿床地质的重要性,历来为中外地质学家所瞩目,成为国内外构造地质研究工作的热点地区。

在龙门山造山带前缘发育的中生代四川盆地,占有扬子古板块的主体部位,是中国南方最大的陆相盆地,也是中国天然气工业基地。它的基底由前震旦系的“弧核”组成,发育巨厚的海相和陆相地层组成的盖层,有变形较强的川东南褶皱区,也有变形微弱的川中地块,以及沉降很深的川西前陆盆地。其地史演变的长期性和复杂性,以及区域构造样式的丰富多彩,是国内大型盆地罕见的。

龙门山造山带的形成与四川盆地发育密切相关。这是我们近十多年来研究龙门山造山带隆升与川西前陆盆地沉降的关系,后龙门山岩石的塑性变形与前陆盆地岩石脆性变形的机制,以及深部岩石圈运动与中浅层地壳变形相结合的研究思路得出的认识。因而《龙门山造山带的崛起和四川盆地的形成与演化》,就被选作本专集的书名。

本专集选录的文章,多是参加国家“六五”、“七五”、“八五”科技重点攻关项目、四川省科委重点攻关项目、国家自然科学基金资助项目和成都理工学院与墨尔本大学国际合作科研项目完成后,公开发表或刚写就的文章。这些文章具有鲜明的中国地质特色,是以板块构造理论为指导,结合中国西南地质实际提出的“峨眉地裂运动”和“C-型俯冲带”两个构造学术思想为中心展开的。在第Ⅰ编总论中,是国内较早的应用板块构造理论划分中国含油气盆地,以及首次提出扬子古板块、松潘—甘孜边缘海和扬子板块基底为两弧夹一盆的概念。在研究地壳运动特征方面,率先强调地壳的拉张运动,并提出中国划分三大地裂期的论点,创建的“峨眉地裂运动”理论,已被国内外许多地学者所采纳和共识。本编文章的论述为以后各编提供了阅读本专集的区域构造背景。在第Ⅱ编龙门山造山带研究方面,提出C-型俯冲观点,它既不同于A. W. Bally 的与B-型俯冲带配套的A-型俯冲带的概念(1975, 1980, 1984, 1992),也不同于朱夏引用欧洲华力西期造山带底流(subflauenz)的模式(Ampferer, 1906),用来表述中国A-型俯冲带;它是在中国大陆已拼接和前陆盆地形成后的晚中生代至新生代,其主动力来自于盆地内的深部地壳结构潜滑插入造山带的俯冲模式,因而具有中国大陆地质构造演化特色;其后的研究进一步发展的C-型俯冲概念,又在中国中西部划分出单向龙门山型俯冲(L-型俯冲)和双向天山型(T-型俯冲)俯冲模式。在第Ⅲ编四川盆地的形成和发展方面,提出川中基底不是古陆核而是一个古“弧核”的论点;从地史演化观点阐明四川克拉通盆地发育过程的认识,在许靖华主编的世界沉积盆地系列丛书的《中国沉积盆地》(朱夏主



编) 专辑中发表, 引起国内外同行的重视。在第Ⅳ编四川盆地油气藏特征及其它三编中有关石油地质勘探的论述, 多有创见和新意。如用峨眉地裂运动观点, 在 1981 年提出的川东上二叠统有生物礁块发育的预测, 1984 年从川中、川南过渡带发现的地震反射地球物理异常可能是礁块的论断, 均先后得到验证。又如最早提出要重视勘探中国煤成气的建议、中国陆相生油二元论的观点和松辽盆地可能为塌陷成因机制的认识, 以及中国寻找大气田的方向中要特别重视古隆起的论断, 多具有勘探指导意义和科学理论价值。从两点论看这些文章, 其中许多论点和认识, 在当时有创见性并颇具影响; 经过十多年实际的检验, 证明它们仍具有生命力和科学价值; 从前瞻本区今后研究动向, 其中有些论点, 尚有指导意义和参考价值。但在认识地质规律的长河中, 随着社会的发展和科学的进步, 许多论点很可能被修正甚至抛弃, 本专集愿作正确认识前进道路中的铺路石。因而我们选录的文章, 除按发表时间排列目录, 还注明了课题来源、刊物出处以及是否得过奖励。请读者按文查找、追踪学术思想发展的轨迹, 并希批评指正。

本专集文章的作者, 大多是我们十多年来共同承担科研项目的作者, 有 50 年代在巴山蜀水找油找气的战友, 有 80 年代成都理工学院与我亲密合作的教师, 也有我带过的研究生而现已成为后起之秀的青年教师, 还有与我们友好合作的墨尔本大学同行。我们在认识客观世界中, 有共识也有差异, 本专集未作任何处理, 请读者判读。本专集的出版将为我们过去密切合作、共同战斗的友谊, 留下愉快的回忆和永恒的纪念!

中国自 1978 年以来实行的改革开放政策, 不仅带来了社会的繁荣和进步, 也带来了科学的春天, 地质科学因而有了蓬勃的发展。本专集入选的文章是在这个祥和而宽松的背景下完成的, 故选用文章的时限, 绝大多数是 1978 年以后发表的, 但也有一篇例外, 那就是作者 1958 年发表在《石油勘探》上的《川中油区下侏罗统的储油条件》一文, 该文认为川中侏罗系储层为裂缝产油的论点, 这本是一个学术不同的见解其后又被实践证实的论点, 但在那时学术观点和政治观点混淆不清的年代, 给许多人带来不幸, 故特选此文以兹为鉴。

最后, 愿将此专集献给已故的中国著名石油地质学家陈賡总地质师和尊敬的李承三教授、边兆祥教授, 并以此悼念在学术思想上鼓励和帮助过我的尹赞勋、李春昱和朱夏等老前辈。并藉以怀念与我 50 年代共同战斗在巴山蜀水而英年早逝的陈炳华等高级工程师。没有前辈的引路和支持与同辈的协作配合, 要想在认识地质长河中添砖加瓦, 几乎是不可能的。最后衷心感谢中国科学院院士黄汲清教授和翁文波教授为本专集题词、郭令智教授为本专集作序。

罗志立

于 1994 年 2 月 10 日

## PREFACE

The orogenic belt of Longmen mountains, which is 500 km Long and 30 km wide from northern Guangyuan to southern Tianquan, is referred to as the nappe structure of the front range of the mountains. The belt is situated on the boundary between the eastern Qinghai-Tibet plateau and western Sichuan basin and divides the Songpan-Ganzi geosynclinal folded system from Yangtzi paraplatform. The belt is located in the eastern part of the Paleo-Tethys, which intersects the Qinling folded belt northeastwards and meet with the Kangdian axis southwestwards. It is a seldom seen meridional orogenic belt. The front range of Longmen mountains is characterized by the typical features of a nappe structure and is an important area of gas and oil exploration in China. The hinterland of Longmen mountains coincides with the north-south earthquake belt of China, which is a site of geological hazard in Sichuan. The area is an enriched zone of endogenetical deposits, such as gold, uranium, etc., and is famous for the scenic spots called Huanglong and Jiuzhaigou. Due to its special geographical and tectonic position and its important significance on environmental geology as well as ore deposits, the structural belt of Longmen mountains has been noted by both the domestic and international geological society, and has become a focus-studying area for structural geology.

The Mesozoic Sichuan basin, developed in front of the Longmen mountains, occupies the major part of the Yangtzi Palaeoplate. It is the biggest continental basin in South China and is also the gas industrial base of China. The basin includes a basement consisting of pre-Sinian "arc nucleus" and extremely thick cap rocks, composed of marine and continental strata. The basin can be divided into the following three major regions; a folded zone with intense deformation in southeastern Sichuan, a land mass with weak deformation in central Sichuan, and a deep foreland basin close to the Longmen mountains. In other large scale basins in China one rarely finds such a long-term and complex geological history with so varied regional tectonic patterns like that developed in the Sichuan basin.

The formation of the orogenic belt of Longmen mountains is closely related to the evolution of the Sichuan basin. This opinion arose from the following studies carried out more than 10 years; the studies of interaction between the uplift of Longmen mountains and the subsidence of the foreland basin, of the mechanism of plastic deformation of the rock in the hinterland of the mountains and of brittle deformation in foreland basin, and of the relationship between the movement of the deep lithosphere and the structure of the uppercrust. Therefore, this book was named "Uplift of Longmen Mountains orogenic belt and the formation and evolution of the Sichuan Basin".

Most of these theses, which are selected into this special issue, have been published previously. Some of them belong to the key research subjects assisted by the State or by the National Natural Science Foundation during the period of 6th, 7th and 8th 5-year plans. Others belong to the key subjects of the Committee of Science and Technology of Sichuan, as well as to the cooperation plan of Chengdu Institute of Technology with Melbourne University. These theses are characterized by the distinctive features of the geology of China, and focus on the two concepts of the geological structure; "the Emei taphrogenesis" and "the C-subduction zone", which developed from the combination of geological Practice in southwestern China and the theoretical instruction of the plate tectonics. This special issue contains four parts. Part I is a general outline. The theory of plate tectonics was early applied in China to the classification of Chinese petroliferous basins, and the concept was presented for the first time, that the Yangtze paleoplate tectonic, Songpan-Ganzi marginal sea and the basement of Yangtze platform make up such a structural pattern as two island arcs with a basin in between. With respect to investigating the features of crust movement, the extensional movement was emphasized and three major stages of taphrogenesis in China was suggested. Then the theory of "Emei taphrogenesis" was set up, which has been adapted and acknowledged by the geological society. These papers provide a background of regional tectonism for understanding other theses occurring in the subsequent parts. In part II, the focus of discussion is the Longmen mountains. The concept of the C-subduction zone was propounded as a new concept that different from both the A-subduction zone proposed by A. W. Bally (1975, 1980, 1984, 1992) which is associated with B-subduction zone, and the model of subfluent of variscides cited by Zhu Xia to describe A-subduction zones in China. The C-subduction zone was formed by the process that the lower lithosphere in the basin plunged down the orogenic belt during late mesozoic to cenozoic, when the continents has been matched and foreland basin had been formed, thus, the C-subduction zone is characteristic for Chinese tectonic evolution. This idea about C-subduction was further expanded and applied to identify the two models; unilateral Longmen mountains subduction (L-subduction) zone and bilateral Tian mountains subduction (T-subduction) zone. In part III, the formation and development of the Sichuan basin was discussed. The argument that the basement of central Sichuan is not a "Paleo-continental nucleus" but a "paleo-arc nucleus", was put forward. The knowledge about the development processes of the Sichuan craton basin, Viewed in the light of geological evolution, was taken into the special issue of "Sedimentary Basin of China" (edited by Zhu Xia) which was included into the collection "Sedimentary Basins of the World" (edited by Xu Jinghua), and provoked much attention among geologists. In part IV and the other parts mentioned above, the discussions around the characteristics of accumulation and exploration of oil and gas have many creative viewpoints. For example, in light of the theory of Emei taphrogenesis, the prediction of upper Permian reefs in eastern Sichuan in 1981, and the suggestion that the anomalous seismic reflection possibly reflects reefs in the transition zone between the Middle and South Sichuan in 1984,

were all verified one after another. Additionally, the first suggestion to lay stress on coal-related gas exploration in China, the dualism of continental petroleum origin in China, the idea that the formation of the Singliao basin may be caused by collapse, as well as the proposal to pay attention to paleo-uplift for seeking some bigger gas fields, all of these have a realistic practical significance with respect to exploration as well as a theoretical scientific value. Looking back on these theses from the viewpoint of dialectic, many of the proposed arguments and ideas were creative and widely influential at that time, and are still admissible and valuable today, after verification by practice for more than ten years. Some of them yet have instructive and referential effect to future studies. However, in the process of understanding the geological laws, some ideas will be antiquated or modified along with the social development and scientific advance. Hence, this special issue should be regarded as a paving tile on the way leading to the truth. These theses in this book are not only compiled according to the time of publishing, but also are annotated with the publications which carried them, the research subject to which the theses belong, as well as awards if obtained. Readers can trace the process of development of these academic philosophies, following the sequence of the theses. The authors welcome any comments, criticisms and suggestions.

The majority of the authors in this special issue have taken part in the above mentioned researches. Some of them were my old friends who worked together with me to explore possible oil and gas accumulations in Sichuan during the 1950s, some are the colleagues of the Chengdu Institute of Technology who collaborated intimately with me in the 1980s, some are my graduate students who have become the outstanding young teachers. and the others are the copartners from Melbourne University with whom we had a productive cooperation. The opinions on various viewpoints to the objective reality, in accordance with ours or divergent, have all been kept in their original appearance in the book, allowing the readers to make their own judgement. This book will preserve a pleasant reminiscence and be a eternal souvenir for our close cooperation and friendship!

The policy of reform and opening to the world that has been practiced in China since 1978, have brought about not only social prosperity and advance, but also a scientific springtime and thus a vigorous development of the geological science, These theses in this book were completed in a very peaceful and free environment. For this reason, almost all theses in this book were published after 1978. The only exception, entitled "Jurassic Reservoir Conditions in the Petroleum Province of Central Sichuan", was published in the journal "Petroleum Prospecting" in 1958. In this paper, the author proposed that the oil in Jurassic reservoirs is produced from fractures. This was at the time only an academic opinion and was later confirmed to be right. However, it brought much misfortune to many researchers, caused by the confusion of academic and politic opinions. This paper should be taken as a lesson of that time.

Finally, the authors wish to dedicate this book to the memory of the famous geologist Chen

Ben and highly estimated professors Li Chengsan and Bian Zhaoxiang , to the pioneers Yin Zanzun, Li Chunyu and Zhu Xia, who gave us their encouragement and help, and also to Senior Engineer Chen Binghua who collaborated with me in Sichuan during the 1950s. Without the guide and support of the foregoing generation of geologist and the concurrent efforts of my present colleagues, it would be almost impossible to do my small part to help add knowledge to the process of understanding the geological laws. At last, very thanks the inscription written by professor Huang jiqing and Weng Wenbo and the preface written by professor Guo Lingzhi for this book.

Luo Zhili

1994. 2



# 目 录

## 第 I 编 总 论

扬子古板块的形成及其对中国南方地壳发展的影响.....	罗志立(1)
试论中国油气盆地的形成和分类.....	罗志立(13)
中国西南地区晚古生代以来地裂运动对石油等矿产形成的影响.....	罗志立(20)
略论地裂运动与中国油气分布.....	罗志立(40)
试论上扬子地台的峨眉地裂运动.....	罗志立等(48)
The Emei Taphrogenesis of the Upper Yangtze Platform in South China .....	Luo Zhili, et al. (61)
黔中早二叠世晚期织金拉张盆地原型分析.....	赵锡奎(78)
试论松辽盆地新的成因模式及其地质构造和油气勘探意义.....	罗志立等(93)
郯庐断裂带嘉山—合肥段形成机制探讨.....	吴天蒙等(103)
龙门山北段印支期碳酸盐重力流沉积与峨眉地裂运动.....	王多义等(116)
试评 A-俯冲带术语在中国大地构造学中的应用 .....	罗志立(123)

## 第 II 编 龙门山造山带的崛起

On the Mechanism of the Longmen Mountain Thrust Belt and its Influences on Formation of the Qinghai-Xizang Plateau and Accumulation of Hydrocarbon .....	Luo Zhili (131)
试论中国型(C-型)冲断带及其油气勘探问题 .....	罗志立(140)
龙门山中北段地史发展的若干问题.....	龙学明(149)
川西拗陷的沉降与龙门山的崛起.....	崔秉荃等(157)
彭县海窝子须家河组第四段研究.....	杨季楷(164)
龙门山形成动力机制的地球化学信息.....	张志兰等(170)
龙门山推覆构造变形特征.....	林茂炳等(179)
龙门山中北段遥感图像解译的新发现.....	张金熔等(188)
龙门山中北段重磁场特征与深部构造的关系.....	宋鸿彪等(195)
龙门山造山带的崛起和川西前陆盆地的沉降.....	罗志立等(204)
一种新的陆内俯冲类型——龙门山型俯冲成因机制研究.....	刘树根等(220)

Tectonic evolution of the NE Margin of the Tibetan Plateau; Evidence from the Central Longmen Mountains Sichuan Province, China .....	P. H. G. M. Dirks, et al. (230)
The Evolution of the Western Sichuan Foreland Basin, SW, China .....	Shefa Chen, et al. (249)
Strustural Observation from the Wenchuan-Mouwen Metamorphic Belt, Longmen Mountains, China ...	Brenton A. Worleyet, et al. (265)
A Preliminary Assessment of Thermal History and Tectonic Development in the western Sichuan Foreland Basin and Longmen Mountoins Thrust-Nappe Belt, Sichuan Province, China .....	D. Arne, et al. (285)
试论 C-型俯冲带及对中国中西部造山带形成的作用 .....	罗志立等(288)
试论龙门山冲断带大陆科学钻探选址问题.....	罗志立等(304)
龙门山冲断带的分区及其演化.....	龙学明等(317)
龙门山冲断带西侧印支燕山期花岗岩类岩石年代学研究.....	袁海华等(330)
四川盆地西缘冲积扇形成的构造背景分析.....	李元林(338)
地球物理方法在龙门山造山带分析中的应用.....	宋鸿彪(346)
龙门山 C-型俯冲模式数值模拟研究 .....	李天斌等(357)
磷灰石裂变径迹技术及其在龙门山冲断带研究中的应用.....	刘树根等(369)

### 第Ⅲ编 四川盆地的形成和演化

试从扬子准地台的演化论地槽如何向地台转化的问题.....	罗志立(379)
川中是一个古陆核吗? .....	罗志立(386)
Formation and Development of the Sichuan Basin .....	Wang Jinqi, et al. (394)
川北晚二叠世大隆期岩相分异的古拉张背景.....	宋子堂等(418)
四川盆地早古生代的古构造特征及其演化.....	赵锡奎等(422)
四川盆地晚古生代至中三叠世古构造演化特征及找气意义.....	金以钟等(435)
四川盆地中生代构造组合叠加及其对含油气构造的控制作用...	乐光禹等(455)

### 第Ⅳ编 四川盆地油气藏特征

川中油区下侏罗统的储油条件.....	罗志立等(481)
国外天然气成因的研究及对四川勘探实践的意义.....	罗志立等(485)
川中内江—合川一带地震反射异常的发现及其勘探意义.....	罗志立等(498)
从地裂运动观点研究川南和川西南古断裂对二叠系储层控制.....	罗志立等(504)
中国陆相生油二元论—兼论中国陆相生油论的发展.....	罗志立(517)

川南阳新统碳酸盐致密储层的非均质性及其储层模式.....	罗 平等(521)
中国寻找大气田的前景及方向.....	罗志立(533)
四川盆地与国内外盆地对比及寻找大—中型气田方向讨论.....	罗志立(544)
加强四川盆地浅层天然气勘探是解决当前四川天然气能源短缺 的一项重要策略.....	罗志立等(558)
后 记.....	赵锡奎等(562)

# Contents

## Part I . GENERALIZATION

On the Occurrence of Yangtze Old Plate and its Influence on the Evolution of Lithosphere in the Southern Part of China .....	Luo Zhili( 1 )
A Discussion on Formation and Classification of Hydrocarbon-Bearing Basin in China .....	Luo Zhili( 13 )
Taphrogenesis since Late Paleozoic and its Influence on Forming Minerals as Hydrocarbon etc. in SW China .....	Luo Zhili( 20 )
A Discussion of Taphrogenesis and Hydrocarbon Distribution in China .....	Luo Zhili( 40 )
On Emei Taphrogenesis of the Upper Yangtze Platform .....	Luo Zhili, et al. ( 48 )
The Emei Taphrogenesis of the Upper Yangtze Platform in South China .....	Luo Zhili, et al. ( 61 )
Analysis of Late Early Permian Zhijin Tensional Basin Prototype in Central Guizhou .....	Zhao Xikui( 78 )
A Discussion on New-origin-model and Tectonics of Songliao Basin to Hydrocarbon Exploration Significance .....	Luo zhili, et al. ( 93 )
The Research of the Forming Mechanism of Jiashan-Hefei Section in Tanchen-Lujiang Fracture Zone .....	Wu Tianmeng , et al. (103)
Carbonate Gravity Flow Sediments Related to Emei Taphrogenesis During Indian Epoch in the Northern Section of Longmen Mountain .....	Wang Duoyi, et al. (116)
Comments on the Term of A-Subduction to be Applied to the Tectonics in China .....	Luo Zhili(123)

## Part II . THE UPLIFTING OF LONGMEN MOUNTAIN OROGENIC BELT

On the Mechanism of the Longmen Mountain Thrust Belt and its Influence on Formation of the Qinghui-Xizang Plateau and Accumulation of Hydrocarbon .....	Luo zhili(131)
A preliminary Approach on C-Subduction and its Hydrocarbon Prospecting .....	Luo zhili(140)
Several Questions of Geochronic Evolution in the Mid-Northern Segment of Longmen Mountains .....	Long Xueming (149)