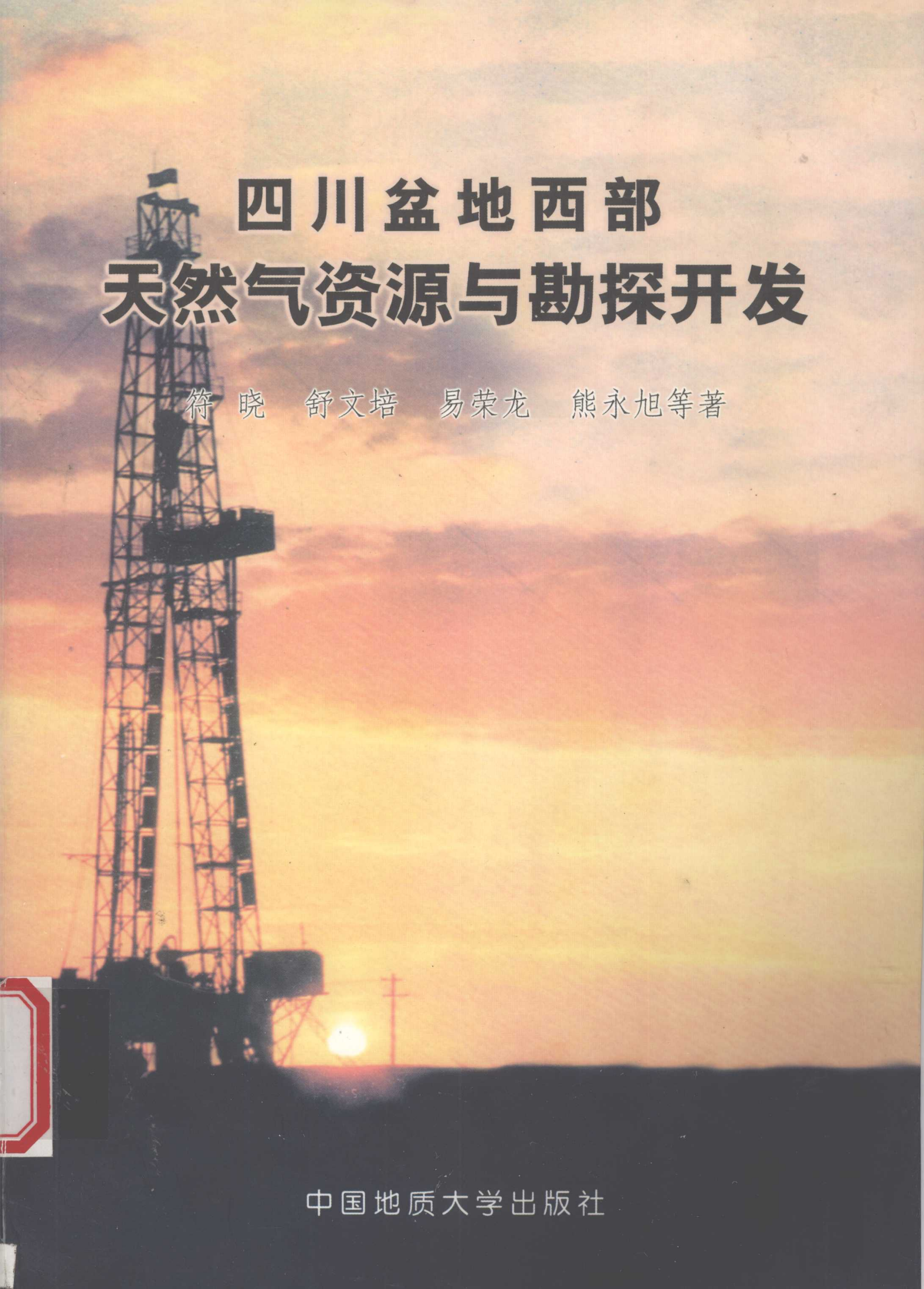




四川盆地西部 天然气资源与勘探开发

符晓 舒文培 易荣龙 熊永旭等著

中国地质大学出版社

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序

在能源领域,人类经历了以柴薪为主和以煤炭为主的时代后,从 20 世纪 70 年代开始,又进入了以石油为主的时代。随着经济和科学技术的发展,特别是人类对生活质量和自然环境要求的日益提高,天然气作为优质、洁净的燃料和原料越来越引起人们的重视。

据第十五届世界石油大会预测,21 世纪中叶天然气年供应量将达到 50 亿~62 亿吨油当量,超过 54 亿~58 亿吨的石油供应量,世界将由石油能源时代发展为以天然气为主的能源时代。21 世纪中叶我国天然气年产量预计将达到 $500 \times 10^8 \sim 1\,000 \times 10^8 \text{ m}^3$,成为世界产气大国之一。四川盆地是世界上最早发现和利用天然气的地区,建国 50 年来经过艰辛的勘探与开发,取得了重大的成果,探明储量和产量都居全国首位,并建成了我国当前最大的天然气生产基地。21 世纪四川盆地的天然气工业将进一步发展,保持可持续发展的势头。

随着天然气工业的发展,天然气地质学作为地球科学领域中一门新的分支学科,迄今已取得了丰硕的成果,并出版了许多有关天然气地质学的专著。

符晓等著此书是一部论述四川盆地西部陆相天然气资源基本地质特征及勘探开发的专著,内容包括“资源地质篇”、“勘探篇”、“开发篇”三部分。“资源地质篇”全面阐述了川西前陆坳陷天然气地质基本条件和天然气成藏的机制;“勘探篇”详细地概括川西前陆坳陷主要气田的勘探历程和地质属性;“开发篇”以新场气田为例,精练地总结了新场气田勘探开发的成功经验,基本上解决了致密砂岩气田勘探开发中的国内外难题。

全书从天然气资源地质分析入手,在对大量实际资料综合研究的基础上,提出了“动态生聚,气化成藏”的天然气立体成藏新模式,对川西及其他类似前陆盆地天然气的勘探开发很有借鉴意义。并指出了川西前陆坳陷天然气勘探的新领域和寻找大气田的思路。该书既有丰富实践、又有理论创建,总体上反映了我国当前天然气地质研究与勘探开发的先进水平。

本书的主要作者是长期在生产第一线从事天然气勘探与开发的勘探家,川 19 井中坝气田重大发现后,曾经参与川西前陆坳陷天然气深、中、浅三领域的三次重大突破的实践。新场气田发现后,主持气田(42km^2)的开发技术工作,与气田同仁一起经过艰苦奋斗,把新场气田逐步建设成一个日稳产天然气 $100 \times 10^4 \text{ m}^3$ 的大气田,为德阳和成都地区工农业、生活用能源及化工原料提供了重要保障。在川西前陆坳陷的天然气勘探与开发领域中作出了重要贡献。

总之,该书是我国石油地质勘探家的辛勤劳作,勇于实践,勤于思考,不断开拓的结晶。该书的出版将为我国天然气地质理论与勘探开发做出新的贡献。值此该书问世之际,特为序,表示祝贺!

中国科学院院士

刘宝瑞

2001 年 8 月 16 日

前言

四川盆地西部(川西)天然气资源与勘探开发所涉及的范围,东起龙泉山,西抵龙门山,北至广元、旺苍一带,南到雅安、洪雅等地,总面积约 $6 \times 10^4 \text{km}^2$ 。

地质构造上,川西处于扬子板块西缘。在加里东期—海西期,为四川块体与松潘—甘孜块体的交接地带。印支运动以来,川西坳陷经历了前陆盆地的发生、发展、萎缩三个阶段,最后形成了现今的成都平原及其周缘的丘陵、山地特征。研究区为四川的工农业较发达区,人口稠密,水资源丰富,交通便利,是目前我国西部大开发的重点地区之一。天然气作为清洁、高效能源和优质化工原料,必将起着举足轻重的作用。

川西是我国发现和利用天然气最早的地区。据史籍记载,西汉年间,在川西邛崃就钻成世界上第一口气井——“临邛火井”;公元 76 年至 88 年间,在成都双流等地开凿天然气用于熬盐。1945—1947 年钻成海棠铺构造第一口探井,井深 1 157.8m,为干井。

解放后 1950 年,时任西南地质调查所所长的黄汲清教授就亲自率队开始在龙门山前开展石油地质调查。这期间孙万铨等一批石油地质学家的野外调查,为川西地区的石油地质工作奠定了基础。

20 世纪 50—60 年代,川西地区的找油气工作,一直局限在龙门山冲断带前缘及龙泉山一带开展。主要围绕追索、勘探厚坝中侏罗统沙溪庙组油砂岩、矿山梁志留系沥青矿,钻探了海棠铺构造和龙泉山构造,但未取得有工业意义的发现。

20 世纪 70 年代以来,由于石油天然气地质理论的发展和物探、钻探、测试技术的进步,川西的油气勘探工作取得了四次重大突破。

对川西前陆坳陷的认识和勘探经历了半个世纪的艰难曲折,终于取得了丰硕的油气勘探、开发成果和理论认识上的飞跃。

川 19 井取得了发现中坝气田重大突破后,第一作者有幸参与了川西凹陷内深、中、浅层油气三次重大突破的实践。川合 100 井实现了川西坳陷东坡合兴场须家河组须二气藏的重大突破。川孝 106 井实现了中深层红层次生气藏的重大突破。川孝 153 井实现了浅层红层次生气藏的重大突破。新场气田发现后,又受托在新场气田(42km^2)开发中主持技术工作。与公司同仁一起经过艰苦奋斗,把新场气田逐步建设成一个大气田。获得地质储量超过 $300 \times 10^8 \text{m}^3$,可采储量超过 $150 \times 10^8 \text{m}^3$ 。目前日稳产天然气 $100 \times 10^4 \text{m}^3$ 。为川西德阳、成都地区的工农业、生活用能源及化工原料供应提供了重要保障。

西南石油地质局在川西坳陷中段除发现中坝气田外,还找到了十余个气田和含气构造:孝泉气田、新场气田、合新场气田、丰谷气田、洛带气田、马井气田,鸭子河含气构造、中江含气构造、东泰含气构造、新都含气构造等(图 1-1)。

四川石油管理局在川西坳陷的北段和南段,总计找到十多个油气田和含气构造:高家场油田、八角场气田、九龙山气田,平洛坝气田、大兴西气田、白马庙气田,观音寺含气构造、汉王场

含气构造、柘坝场含气构造、文兴场含气构造、魏城含气构造等,另外还发现了河湾场、周公山两个海相气田(图 1-1)。

这些勘探成果,展示了川西地区 $6 \times 10^4 \text{km}^2$ 范围内的油气资源的美好前景和巨大潜力。

从川西坳陷最新算出的 $6\,000 \times 10^8 \sim 14\,000 \times 10^8 \text{m}^3$ 资源量来看,目前已找到的油气资源,只是其中的少部分,还有大部分的油气资源等待勘探、开发。经过解放以来近 50 年的勘探开发,老一代的石油地质工作者不畏艰苦,几经曲折,贡献了自己的青春,获得了丰硕成果,为石油地质事业划上一个圆满的句号;我们相信现今年轻一代石油地质工作者面对 21 世纪的机遇与挑战,将会在川西油气勘探开发中迎来新的辉煌。

回顾地矿、石油部门几十年来,特别是近 20 多年来在川西的勘探开发历史,经过了艰难曲折,获得了丰硕成果,开拓了一片新天地。在川西这片肥沃的土地上,犹如蜀锦添花。川西陆相油气田,特别是侏罗系、白垩系红层致密砂岩气田的勘探、开发,为我国陆相油气理论,注入了大量新的生动资料和信息。

我们试图通过编写《四川盆地西部天然气资源与勘探开发》这本书,研究川西油气勘探的理论和方法,总结油气勘探成果,探索天然气开发的道路,充实、发展、完善我国的陆相油气理论。这无疑对今后进一步的勘探开发,迎接 21 世纪的机遇与挑战,是很有意义的。同时,对我国其他与川西地质构造条件类似地区的油气资源勘探,也将是一个借鉴。

笔者数十年长期在石油地质勘探的第一线工作,书中涉及的资料、观点和理论,不免有失偏颇,请专家、读者不吝指正。本书编写过程中,参考了西南石油局川西坳陷“七五”、“八五”、“九五”国家重点科技攻关项目成果和发表的文章,也引用了四川石油管理局的一些成果和文献,对这些成果和文献的作者,深表谢意。

本书除署名作者外,第二章由丘东洲教授主笔编写,第三章由林宗满高工主笔编写,第十二章由邓绍云高工主笔编写,英文部分由彭玉娥副译审翻译,插图清绘由邵谊华、卜晓红完成,在此一并致谢。

笔者

2000 年 8 月

Preface

The range of natural gas distribution, exploration and development of West Sichuan Basin starts from Longqian Mountains in the east to Longmen Mountains in the west, from Guangyuan and Wangcang in the north to Ya'an and Hongya in the south, with a total area of $6 \times 10^4 \text{ km}^2$.

In geotectonics, West Sichuan is situated on the west margin of the Yangtze Plate. During Caledonian-Hercynian Period, West Sichuan was the conjugated belt between Sichuan and Songpan-Ganzi masses. Since Indosinian movement, the West Sichuan Depression has undergone the formation, development and shrinking stages of foreland basin, and developed into present Chengdu Plain and its peripheral hilly and mountainous landform. West Sichuan is a well developed region both in industry and agriculture. It has dense population, rich hydraulic resources and convenient traffic, and now it has become one of the focal targets in the campaign of developing West China. Its natural gas resources, as a kind of clean and efficient energy resources and high quality industrial chemical, will play a decisive role.

West Sichuan was the earliest region in discovering and utilizing natural gas. According to historical records, as early as Western Han Dynasty, the world's first gas well —— "Linqiong Fire Well" —— was drilled in Qionglai; in 76 ~ 88 A. D, gas wells were drilled to boil salt. The first deep well was drilled in 1945—1947 with the depth of 1 157.8 m, and it was a dry one.

In 1950, Professor Huang Jiqing, the head of the Institute of Southwest Geological Survey, led a team to make petroleum geological survey in the piedmont of Longmen Mountains. Petroleum geologists Sun Wanquan and others, as the members of the team, took part in the survey and laid the foundation in petroleum geology for West Sichuan.

From the 1950s to the 1960s, oil and gas exploration was limited in the frontal zone of Longmen Mountains thrust belt and Longqian Mountains, aiming at tracing and exploring Shaximiao Formation oil petroliferous sandstone of the Middle Jurassic and the Silurian Kuangshanliang bitumen. Haitangpu and Longqian Mountains structures were drilled at that time but no commercial discovery was made.

In the 1970s, with the development of the theory of petroleum geology and the improvement of geophysical exploration, drilling and test technology, four significant breakthroughs in oil and gas exploration were made in the area. Experienced half a century of difficulties and setbacks, abundant results were obtained in oil and gas exploration and development, theoretical knowledge leap was also achieved.

After the discovery of Zhongba Gasfield through Chuan-19 Well, I was lucky to take

part in three important discoveries. The first one was the discovery of Xu-2 gas pool of the Xujiahe Formation in Hexingchang on the east slope of West Sichuan Depression through Chuanhe-100 Well; the secondary was the important breakthrough of redbeds secondary gas pools in mid – deep strata through Chuanxiao-106 Well; the third one was the discovery of the secondary gas pool in shallow redbeds through Chuanxiao-153 Well. I was appointed to take charge of technological work of Xinchang Gasfield development. After several years of hard work, I, together with my colleague, built the gasfield into a big and modern gasfield with geological reserves over $300 \times 10^8 \text{ m}^3$, recoverable reserves more than $150 \times 10^8 \text{ m}^3$ and gas output $100 \times 10^4 \text{ m}^3$ per day. The gasfield are now the important guarantee of energy source for industry, agriculture and daily life of Deyang and Chengdu regions.

Except Zhongba Gasfield, the Southwest Bureau of Petroleum Geology has discovered ten gasfields and gas-bearing structures such as Xiaoquan, Xinchang, Hexinchang, Fenggu, Luodai, Majing Gasfields, Yazihe, Zhongjiang, Dongtai and Xindu gas-bearing structures in the central section of West Sichuan Depression; in the north and south sections, the bureau has also discovered more than ten oil and gas fields and gas-bearing structures as Gaojiachang Oilfield, Bajiaochang, Jiulongshan, Pinluoba, west Daxing, Baimamiao Hewanchang, Zhougongshan Gasfields and Guanyingshi, Hanwangchang, Zhebachang, Wenxingchang, Weicheng gas-bearing structures (Fig. 1 – 1). These gas(oil) fields and gas-bearing structures show that hydrocarbon resources have shown magnificent prospects and enormous potential within an area of $6 \times 10^4 \text{ km}^2$ in West Sichuan Depression.

According to the newly calculated $6 \times 10^{11} \sim 14 \times 10^{11} \text{ m}^3$ resources extent of the depression, the discovered resources occupy only a small part, and most of the resources still remain to be explored. In nearly 50 years of oil and gas exploration and exploitation, the senior petroleum geological workers overcame countless difficulties, went through all sorts of hardships, and achieved abundant results. The youngsters in this realm are now facing the chance and the challenge of the new century. They will be bound to make more brilliant contribution to oil and gas exploration and development of West Sichuan.

View the history of hydrocarbon exploration and exploitation of the region, the petroleum geological workers of both the Ministry of Geology and Mineral Resources and the Ministry of Petroleum Industry had worked hard in this area for several decades, especially for the past twenty years. They overcame various kinds of hardships and setbacks, and achieved fruitful results. The exploration and exploitation of continental facies oil and gas fields in this region, particularly the exploration and development of the gasfields in Jurassic and Cretaceous secondary red bed dense sandstone have provided a lot of new and vivid data and information for the theory of China's continental facies oil and gas fields. This has

opened a new field for China's oil and gas exploration. Just as adding flowers to the brocade —— it has made perfection still more perfect for West Sichuan.

This book *Natural Gas Resources in West Sichuan Basin and its Exploration and Development* is aim to study the theory and the practice of oil and gas exploration, summarize the experiences of the past years in this area and explore the ways for gas exploration and development so as to substantiate, develop and perfect the theory of China's continental facies oil and gas. We hope that it will be helpful for further oil and gas exploration in future, and be a reference for hydrocarbon exploration of other places that have similar geological conditions to West Sichuan. Since I have worked in forefront for many years, faults and errors of the data, the viewpoint and even the theory in this book are unavoidable. I hope that all readers and specialists will not stint your criticisms. I am deeply grateful to the authors of the results, the documents and papers of the state's key task projects of the Seventh, the Eighth and the Ninth "Five-Year-Plan" relating to West Sichuan's oil and gas exploration carried out by the Southwest Bureau of Petroleum Geology, and also the authors of the results and documents of Sichuan Petroleum Administration for using and referring their results and documents in my book.

Excepting signed authors, Chapter two was written by Prof. Qiu Dongzhou, Chapter three was written by Senior Engineer Lin Zongman, Chapter twelve was written by Senior Engineer Den Shaoyun, and English translation was done by Miss Peng Yu'e, the charts were drawn by Shao Yihua and pu Xiaohong. Here I shall express my thankness to them all.

The author
August, 2000

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——以新场气田(42km²)开发为例

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EXPLOITATION PART

— Take the Exploration of Xinchang Gasfield (42 km²) for Example

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资 源 地 质 篇

第一章 川西前陆拗陷的地质构造特征

川西与川南、川东地区同属我国最重要的天然气工业基地。但川西天然气多产于陆相红层，又有别于川东与川南的海相碳酸盐岩产气层。因此，着重研究印支期以来前陆盆地的地质构造特征，对天然气资源勘探开发具有导向意义。

第一节 川西前陆盆地的构造背景与构造区划

一、区域构造背景

川西拗陷与川北拗陷一起同属四川盆地西北部自晚三叠世以来的前陆盆地。

川西拗陷在中三叠世以前具有台地性质。其基底的岩性、时代以及盖层的岩性、时代基本与四川盆地中、东部相同，均属扬子板块的西部。因此，与盆地其他区块有相同的地质构造演化历史。在晋宁期前形成的结晶基底与变质基底上，经历了震旦纪、寒武纪和奥陶纪的碳酸盐岩台地发育阶段，加里东运动形成北东东向的大型乐山—龙女隆起带。其西翼志留系海相砂、页岩由南东向北西渐次增厚，是良好的生、储油层系。晚古生代海侵接受了一定厚度的台地型碎屑岩、碳酸盐岩和含煤沉积。而后广覆着早中三叠世海相碳酸盐岩及蒸发岩沉积。经海西及印支早期构造作用，浅海台地隆升、剥蚀，形成广泛的区域不整合面，奠定了前陆盆地的基础。与结晶基底较为刚性的川中隆起相比，其基底在力学性质上较软弱，这始终影响着川西前陆拗陷的形成与形变特征。

川西拗陷的西侧，龙门山为相对活动带，有早震旦世的火山碎屑岩；寒武系—奥陶系碳酸盐岩；巨厚的志留系海相笔石页岩及碎屑岩；泥盆系呈带状分布，在唐王寨向斜厚度巨大，但变化急剧；二叠系具有深水硅质沉积和玄武岩。这些现象表明龙门山区在澄江期、加里东期和海西期均有拉张断裂活动及隆凹转换，它是松潘—甘孜块体和四川块体间的交接带。

早三叠世开始，松潘—甘孜块体沿龙门山早期破裂带与四川块体一道下沉，形成三叠纪北特提斯洋北侧的被动大陆边缘。发育了巨厚的海相复理石建造和浊积岩。

晚三叠世后期扬子块体向西俯冲带动陆内重新聚合、褶皱及龙门山仰冲。受推覆体载荷影响岩石圈挠曲下弯，四川块体西部形成前陆盆地。其后继续渐进挤压，使川西前陆盆地转化为构造拗陷，成为四川构造盆地内的一个重要构造单元。

二、川西前陆盆地的结构与构造区划

前陆类盆地在我国中西部地区十分发育。

前陆类盆地的基本结构是由三个部分组成：一侧为冲断、推覆强烈的活动翼；中部为强烈下沉的深拗陷，又称“前渊”；另一侧为构造舒缓的稳定翼（斜坡）及其相依存的隆起区，