

TECTONIC EVOLUTION AND
OIL-GAS RESERVOIRS DISTRIBUTION
IN ORDOS BASIN

鄂尔多斯盆地构造演化 与 油气分布规律

杨俊杰 著

石油工业出版社

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序 言

我以特别兴奋的心情读完了杨俊杰教授级高工所著的《鄂尔多斯盆地构造演化与油气分布规律》书稿及附图。这是一本迄今为止对鄂尔多斯沉积盆地石油、天然气地质论述比较全面、系统的专著。

杨俊杰教授级高工在鄂尔多斯盆地勘探开发第一线工作了四十多年，具有丰富的实践经验和理论素养。他经历了20世纪50年代延长油矿的小规模土法开采、70年代的长庆石油会战以及90年代的全盆地“南油北气”、“浅油深气”、“中油古气”综合勘探协调发展时期。他在长庆石油勘探局油气勘探和石油地质工作的领导岗位上，与全局勘探工作者一起埋头苦干，善于甩开钻探，巧于部署地层型、岩性型非背斜圈闭的评价井与开发井；并与全局工程技术工作者携手合作，研究、开发并形成了一整套适应于大面积、低渗透率油气藏的物探、钻井、压裂、酸化等开采与增产措施的配套工艺技术；使三叠系延长组探明石油地质储量为 $2.4 \times 10^8 \text{t}$ 的安塞油田、探明石油地质储量为 $2.5 \times 10^8 \text{t}$ 的靖安油田和奥陶系马家沟组灰岩探明天然气储量为 $3000 \times 10^8 \text{m}^3$ 的中部气田顺利投入开发。近年来，对石炭—二叠系砂岩天然气藏——神木、榆林、乌审旗和苏里格等气田的钻探评价工作亦正全面展开，可能有上万亿立方米天然气储量的地层—岩性圈闭巨型气田的雏形亦已在鄂尔多斯盆地中、北部展现。

作者在本书中将板块构造学说引入区域盆地构造研究，将有机地球化学理论引入烃源岩研究与油—源岩对比分析，将沉积相研究与层序地层学方法引入地层—岩性油气藏的研究，将油气评价和盆地模拟技术引入地质综合研究。特别具有创新意义的是：作者找出了侏罗系延安组储层分布规律为古地貌披盖河道砂油田、上三叠统延长组储层分布规律为内陆湖泊三角洲油田、石炭—二叠系煤系地层天然气砂岩储层分布规律为大型河流三角洲气田、下奥陶统马家沟灰岩储层分布规律为海相碳酸盐岩风化壳古潜台岩溶型气田。这些规律不但丰富了石油天然气地质理论，也为鄂尔多斯盆地进一步持续勘探大型地层—岩性型非背斜圈闭油气藏找到了一把入门的钥匙。

该书使我重温了一遍鄂尔多斯盆地百年来的石油勘探开发史。作者较好地总结了在该地区工作过的数代石油工作者的认识和经验，并加以上升提高。我相信，目前在盆地工作的长庆油田公司、延长石油管理局和新星石油公司华北局的科技工作者和石油天然气勘探开发工作者凭着他们的勤劳勇敢和聪明智慧，必能使鄂尔多斯盆地的石油、天然气工业在新的世纪继续呈现出蓬勃发展的局面。

本书内容丰富，资料翔实，是一本理论阐述和实践经验总结相结合的力作。其公开出版，将为石油、天然气科研工作者和高等院校石油专业师生们提供一本重要的参考和学习材料。

中国科学院院士



2001年12月

前 言

鄂尔多斯盆地亦称陕甘宁盆地。它位于中国大陆的中西部，是一个稳定沉降、拗陷迁移、扭动明显的多旋回沉积型克拉通类含油气盆地。

由于它位居全国第二大盆地，并且，曾因发现中国陆上第一个油田——延长油田激发生了陆相生油理论等原因，一直被大批石油地质学者、专家所关注，且坚持不懈地对其进行地质调查、科学研究和油气勘探工作。早期先辈的代表如王竹泉、谢家荣、潘钟祥、李四光、黄汲清，接着便是王尚文、李德生、田在艺、张传淦、关士聪、谢继哲等，后继者的代表有张文昭、甘克文、孙肇才、潘瑗、阴仲贤、毛希森、黄第藩、杨俊杰、李银德、李德渊、宋四山、朱义吾、宋国初、裴锡古等。

新中国建立之初，这里就被列为全国油气勘探的重点地区之一。50年代末，“两部（石油部、地质部）五省（陕西、甘肃、宁夏、内蒙古、山西）区域地质勘探规划”曾在该区酝酿。60年代，发现了工业性油气。70年代初，国务院、中央军委（70）81号文件决策进行石油勘探会战。80年代，油气勘探实行油、气兼顾，末期找到了中部大气田，奠定了该区大气区的发展前景。90年代，进入油、气协调发展阶段。回顾过去，该盆地油气勘探活动的不断深入乃是主流；展望未来，油气勘探活动的协调发展更是必然。

自80年代以来，这里的油气地质勘探工作者抓浅谋深、兼顾陆海、放眼全区、重点突破、协调油气、开拓发展，将有机地化技术引入烃源岩研究，将板块学说引入油区构造研究，将沉积模式引入储盖组合研究，将地震地层学引入地震成果解释，将资源评价技术引入地质综合研究，促成了生产、科研的空前繁荣局面。其中，赵重远、汤锡元等对盆地构造的研究，冯增昭、王英华、陈继新、王宇新、韩征等对寒武—奥陶系岩相古地理及成岩后生作用的研究，郝石生、贾振远等对碳酸盐岩有机质、古岩溶的研究，朱国华等对延长组储油层次生孔隙的研究，张国栋、王多云等对石炭—二叠系沉积环境及其油气储集体的研究，戴金星、徐永昌、陈安定、黄第藩等对煤型气地化判识指标及中部气田混源比的研究，杨俊杰、黄思静、张文正等对古生界储集体成岩后生的模拟实验，这些都是可以载入该盆地地质研究史册的典型成果。实践使我们体会到，这里既是中国油气协调发展的宝地，更是当代石油地质工作者展文、示武的乐园。

鄂尔多斯盆地构造稳定、地层平缓；地下油气储集体多变，渗透率极低，主要为隐蔽性油气圈闭；地面南部被著名的黄土高原覆盖（140000km²），北部为毛乌素沙漠、库布齐沙漠和鄂尔多斯草原。所以，该盆地又是油气综合勘探比较困难、比较复杂的地区。正因此，其油气勘探的“漫路求索”犹如在读一部油气地质百科全书、在写一部油气地质实践论。

经过半个世纪以来的油气地质综合勘探，盆地西部探明了侏罗系古地貌披盖河道砂油区、盆地东部拿下了三叠系内陆湖泊三角洲油区、盆地中部找到了奥陶系顶部风化壳岩溶古潜台大气田、盆地北部发现了上古生界气田群。目前，鄂尔多斯盆地已经成为我国重要的石油、天然气生产基地之一。其石油资源量为 $21.00 \times 10^8 \sim 85.88 \times 10^8 \text{t}$ ，天然气资源量为 $4.6 \times 10^{12} \sim 10.7 \times 10^{12} \text{m}^3$ ；2000年产油 $470 \times 10^4 \text{t}$ ，产天然气 $15 \times 10^8 \text{m}^3$ ，油气总量在全国居第

五位。所发现的中部气田地质储量 $2500 \times 10^8 \sim 3000 \times 10^8 \text{m}^3$ ，是中国已发现的最大气田，它的扩大和开发将对推动当代中国持续发展油气工业具有战略意义。

从鄂尔多斯盆地的油气勘探活动来看，一是地质思路要敏锐、正确，二是技术方法要先进、适用，三是组织领导要科学、严密。这里，地质理论是灵魂，工艺技术是关键，组织领导是核心。一般来说，正确的地质思路和勘探方向始终是激励、引导并推动工艺技术发展的源泉。正因如此，对于油气地质勘探工作者而言，“广博的学识、敏锐的思路、坚毅的性格、求实的精神、创新的意识”乃是成熟的标志。据此，人们才能从容驾驭全局、正确筛选靶区、合理布署力量、综合分析规律，从而及时捕捉战机，实现油气勘探的突破。

值鄂尔多斯盆地油气勘探深入发展之际，运用地质构造演化阶段论、沉积变迁因果观、油气分布盆控说，论证其构造演化、分析其成藏规律、总结其勘探经验、探讨其发展方略，对推动该区油气工业的可持续发展、丰富油气地质理论、激励油气勘探活动都具有重大理论意义与现实价值。

本书所列八章，展实事之文，立求是之言。地质构造部分力求系统，综合中有所发展；油气分布规律部分力求简明，归纳中有所创新；油气勘探部分力求真实，阐发中有所启迪。其第一章和第二章分析区域构造体系对鄂尔多斯盆地的地质影响，论证构造演化，划分构造单元，总结油气地质基本特征；第三章、第四章、第五章总结构造、沉积作用与油气分布的内在规律，阐释油、气成藏机理、油、气富集条件与勘探方法；第六章、第七章、第八章回溯油、气勘探历程，总结油、气勘探技术，探讨油、气勘探方略及油、气地质学发展前景。全书可谓是长庆地质人员不懈工作的写照，勤奋实践的见证，刻意学习的沉淀，漫路求索的结晶。

值此《鄂尔多斯盆地构造演化及油气分布规律》专著出版之际，我要向曾在该区工作过的石油地质先贤们鞠躬敬礼，我要向为本书欣然作序的中国科学院李德生院士表示诚挚的谢意，我要向对本书审稿、提出宝贵意见、提供多方帮助的田在艺院士、刘宝珺院士、任纪舜院士、戴金星院士、张国伟院士、郭尚平院士、张传淦教授、赵重远教授、陈荷立教授、李银德教授级高工、邸世祥教授、李德渊教授级高工、宋国初教授级高工、裴锡古教授级高工、朱义吾教授级高工、王声远教授级高工、刘池洋教授、周立发教授、何自新教授级高工、闵琪教授级高工、杨华高级工程师、荣春龙高级工程师、赵建新高级工程师、毛龙军高级工程师表示由衷的感谢。

半个世纪以来，鄂尔多斯盆地石油、天然气工业的巨大发展，渗透着几代工作群体的心血，凝聚着几代地质人员的智慧。我们坚信：鄂尔多斯盆地的油、气必将在新世纪迎来生产高峰期，为祖国石油、天然气工业的协调、持续发展作出更大贡献。

谨以此书献给鄂尔多斯盆地油气勘探 95 周年，献给长庆石油会战 32 周年！

杨俊杰
2002.5.

Preface

Locating in the mid – west mainland of China, Ordos Basin (also named Shaan – gan – ning Basin) is a cratonic petroliferous basin with stable subsidence, migrated depression and clearly twisted multicycle sedimentation.

Ordos Basin is the second largest basin in China, where the first oil field in China – Yanchang Oil Field was discovered, which created a theory of continental facies origin of oil. A number of geologists and experts paid close attention to the result and conducted an unremitting survey and scientific research on oil and gas exploration. Wang Zhuquan, Xie Jiarong, Pan Zhongxiang, Li Siguang and Huang Jiqing are regarded as the predecessor representatives of the group, and then, Wang Shangwen, Li Desheng, Tian Zaiyi, Zhang Chuangan, Guan Shicong, Xie Jizhe, the succeeding are Zhang Wenshao, Gan Kewen, Sun Zhaocai, Pan Yuan, Yin Zhongxian, Mao Xisen, Huang Difan, Yang Junjie, Li Yinde, Li Deyuan, Song Sishan, Zhu Yiwu, Song Guochu and Pei Xigu, et al.

Early in 1950' s, the area was listed as one of the major provinces for hydrocarbon exploration in the country. At the end of 1950' s, a program named Regional Geological Prospecting Plan in Five Provinces¹ by Two Ministries² was prepared. In 1960' s, commercial oil and gas flow were discovered. In early 1970' s, a policy was made to carry out a " Petroleum Campaign" by the State Council and the Military Commission of Central Committee. In 1980' s, a strategy of exploration for both oil and gas was conducted and in late 1980' s the Central Gas Field was found with a potential of big gas field in the area. In 1990' s, coordinated development of oil and gas was followed. Looking back to the past, there is a trend that the activities of hydrocarbon exploration in Ordos Basin were continuously intensified. Looking into the future, there is a necessity that coordinated development for hydrocarbon exploration in the basin will be forwarding.

Since 1980' s, the geologists have done their research work by thinking of deep formation while focusing on the shallow, dealing with marine facies as well as the continental, making big breakthrough on the basis of whole basin, conducting a coordinated development for both oil and gas. In their research, organic geochemical technology was introduced into hydrocarbon source rock study, plate tectonics into regional structural research, depositional model into the combination of reservoir and caprock study, seismic stratigraphy into seismic interpretation and reserves evaluation technology into comprehensive research of geology. All these found an unprecedentedly prosperous situation for the production and scientific research. Among those above mentioned, some achievements can be recorded in the history of geological study, such as the basin structure research by Zhao Chongyuan and Tang Xiyuan, et al., the lithofacies paleogeography of Cambrian and Ordovician and its diagenetic metamorphosis by Feng Zengzhao, Wang Yinghua, Chen Jixin, Wang Yuxin and Han Zheng, et al., the organic matter and palaeokarst of carbonate by Hao Shisheng and Jia Zhenyuan, the secondary pores of reservoirs in Yanchang Formation by Zhu

Guohua, et al. , hydrocarbon reservoirs of Carboniferous and Permian and their sedimentary environment by Zhang Guodong and Wang Duoyun, geochemical discriminant index of coal – type gas and the combination of source rock in the Central Gas Field by Dai Jinxing, Xu Yongchang, Chen Anding and Huang Difan, the simulation on diagenetic metamorphism of Paleozoic reservoirs by Yang Junjie, Huang Sijing and Zhang Wenzheng. Practically, Ordos Basin presents a favorable place for the coordinated development of hydrocarbon in China as well as a paradise of expertise exhibition for modern Chinese geologists.

Ordos Basin is featured as stable structure, gentle formation, extra – low permeability and changeable reservoirs mainly composed of subtle traps. It is covered by the well – known Loess Plateau (140000 km²) in the southern area and Maowusu Desert, Kubuqi Desert and Ordos Grasslands in the northern area. Therefore, it is a hard area for the comprehensive exploration of hydrocarbon. Due to its complexity, making hydrocarbon exploration in Ordos Basin is just like reading an encyclopedia of hydrocarbon geology and writing a book on geological practice.

Through 50 years' comprehensive exploration for hydrocarbon, oil provinces of paleogeomorphologic drape river channel sand of Jurassic have been found in the western Ordos Basin, inland lacustrine delta oil provinces of Triassic in the east, the Central Gas Field of weathering crust and karst on buried platform of top Ordovician in the central Ordos Basin and some gas field group of Upper Paleozoic in the northern Ordos Basin. At present, Ordos Basin becomes one of the most important bases for oil and gas production in China. Its resources are estimated at 2.1 to 8.588 billion tons for oil and 4.6 to 10.7 trillion cubic meters for natural gas. In the year 2000, 4.7 million tons of crude oil and 1.5 billion cubic meters of natural gas were produced. The total production of Ordos Basin is ranked No.5 in China. The Central Gas Field, with 250 billion to 300 billion cubic meters of reserves in place, is the largest gas field discovered in China. The expansion and development of it will be strategically significant to the continuous development of China's petroleum industry.

To all activities of hydrocarbon exploration in Ordos Basin, it is very important to have clear and correct geologic concepts, adaptable advanced technology, strictly and scientifically organized team, where geologic theory will be taken as soul, technology as key and organized system as core. Generally speaking, proper geologic concepts and clear exploration targets are always the forces to stimulate, lead and promote the technology to further development. Hence, a good petroleum geologist should be qualified with extensive knowledge, sharp intelligence, firm disposition, realistic approach and sense of creation. Only in this way can he have a control of overall situation, correct selection of target formation, reasonable deployment of exploration and comprehensive analysis of geological regularities, timely catching hold of opportunity to make breakthrough in oil and gas exploration.

On the occasion of the exploration of oil and gas in Ordos Basin goes into a further development, it has a great significance both in theory and reality to promote a continuous development for local oil and gas industry, enrich geological theory of petroleum and stimulate the exploration activity with the application of the concepts of geological tectonic evolution stages, cause and effect of sedimentation changes, basinal control of oil – gas distribution to testify its tectonic evolu-

tion, analyze the regularity of reservoir creation, sum up exploration experiences and make a discussion on the strategy of oil – gas fields development.

Presented in this book are eight chapters that focus on the truth and reality, the geologic structure study is systematic and innovative, the research on regularity of oil and gas distribution concise and creative and the discussion on oil and gas exploration practical and enlightening. Chapter One and Chapter Two are focused on the analysis of geological influence of regional structural system on Ordos Basin, demonstrating tectonic evolution, classifying structure units and summing up the basic geological features. Chapter Three, Chapter Four and Chapter Five sum up the inherent regularities of structure, sedimentation, oil and gas distribution, explaining the mechanism of reservoir creation, the condition of oil and gas concentration and exploration method. Chapter Six, Chapter Seven and Chapter Eight recall the history of oil and gas exploration in Ordos Basin, summarizing the technology and discussing the strategy for petroleum exploration, and the future of the development for petroleum geology. This book can be an exhibition for hard – working, assiduous practice, untiring learning and boundless exploring activities of Changqing geologists.

At the time when this book *Tectonic Evolution and Oil – gas Reservoirs Distribution in Ordos Basin* is published, I would like to express my respects to those geologists who used to work in Ordos Basin, my truthful thanks to Mr. Li Desheng, academician of the National Science Academy of China, who wrote the Foreword for the book, and my cordial thanks to the following academicians of Tian Zaiyi, Liu Baojun, Ren Jishun, Dai Jinxing, Zhang Weiguo, Guo Shangping, following professors of Zhang Chuangan, Zhao Chongyuan, Chen Heli, Li Yinde, Di Shiqiang, Li Deyuan, Song Guochu, Pei Xigu, Zhu Yiwu, Wang Shengyuan, Liu Chiyang, Zhou Lifa, He Zixin, Min Qi and following senior engineers of Yanghua, Rong Chunlong, Zhao Jianxin, Mao Longjun, for their help and advices to the manuscripts of this book.

Since the last half century, there has been a great development for oil and natural gas industry in Ordos Basin that is attributed to the painstaking effort and wisdom of many geologists and engineers of several generations. It is believed that a peak of oil and gas production in Ordos Basin will come with a coordinated sustainable development and contribution to China' s petroleum industry in the new century.

This book is presented both to the ninety – five years anniversaries of oil and gas exploration in Ordos Basin and thirty – two years anniversaries of Changqing oil and gas exploration campaign.

Yang Junjie
May, 2002

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第一章 鄂尔多斯盆地地质构造演化

第一节 地质构造格架

鄂尔多斯地块是华北克拉通的一部分，也是其中最稳定的一个块体。所以，要认识鄂尔多斯盆地的构造活动就必须首先了解华北克拉通的地质构造特征。

关于华北克拉通的中新生代地质构造特征，李四光称之为新华夏构造体系，认为是亚洲大陆与太平洋洋壳之间发生南北向左行扭动的产物；黄汲清等称它为滨太平洋构造域的一部分，认为是亚洲大陆与太平洋洋壳之间发生仰冲、俯冲运动的结果；后来，张裕明等在承认这种仰冲、俯冲运动的基础上，更加强调亚洲大陆边缘的热扩张作用，并且增添了印度洋板块与太平洋板块之间的对挤机制；赵重远力图将其构造发展纳入全球构造演变之中，使之相互印证^[1]。近年，任纪舜明确强调，“华北克拉通受古亚洲、特提斯、环太平洋三大构造域的交切、叠加与复合，构造面貌及演化甚为复杂，所发育的多旋回叠合盆地应是聚集油气的重要场所”^[2]。

总之，按“盆、岭”构造格局认识华北克拉通并分析鄂尔多斯盆地是当代中国地质学界的一种共识。

在分析一个地区的构造演化时，构造层次与构造期次同等重要。就构造层次而言，全球构造背景决定着海、陆分布及构造域；海、陆分布及构造域又决定着地块、造山带及其构造区；而地块、造山带及其构造区则决定着盆地、块断区和构造带。就构造期次而言，按时代可分为今、古、复合等变动期次。诚然，在分析中更应重点把握其主期次的研究。所以，对鄂尔多斯盆地的构造演化而言，一方面要注意全球构造的背景影响，另一方面也需重视相邻地区构造活动的直接作用；一方面要注意多次地壳运动的复合影响，另一方面更要重视燕山期、印支期地壳运动对其所起的主导作用。

一、古地理、古构造变迁与盆地的形成

鄂尔多斯地块属于华北古大陆的重要组成部分，其古地理演变被视为华北大陆古地理演变的缩影。表 1—1 综合列出了其本部及邻区的地层^[3,4]。

中、晚元古代，在陆核增生、陆壳固化的基础上形成了华北古陆，它以鄂尔多斯地块、冀鲁地块、燕辽地块为主体形成稳定性的沉积地区。其北是广阔的蒙古洋，其南是狭窄的秦岭海槽。来自秦岭洋壳的向北俯冲造成了华北古陆在青白口期的整体隆升；而楔入华北古陆的陕、豫、晋拗拉谷及贺兰拗拉谷则烘托出鄂尔多斯地块向独立沉积盆地发展的地质演化背景（图 1—1）。

寒武纪早期（猴家山期），华北古陆南缘及西南缘开始接受海相沉积。接着，发生了大规模华北海海侵，除阿拉善地块和鄂尔多斯地块北部以外，华北古陆大部被海水淹没，在呼和浩特、太原一线以东形成广阔的华北陆表海，产生碳酸盐及泥沙沉积；而银川、庆阳以西地区则为北祁连海水所波及，贺兰拗拉谷也继续活动沉降。横亘于华北古陆南北两侧的分别