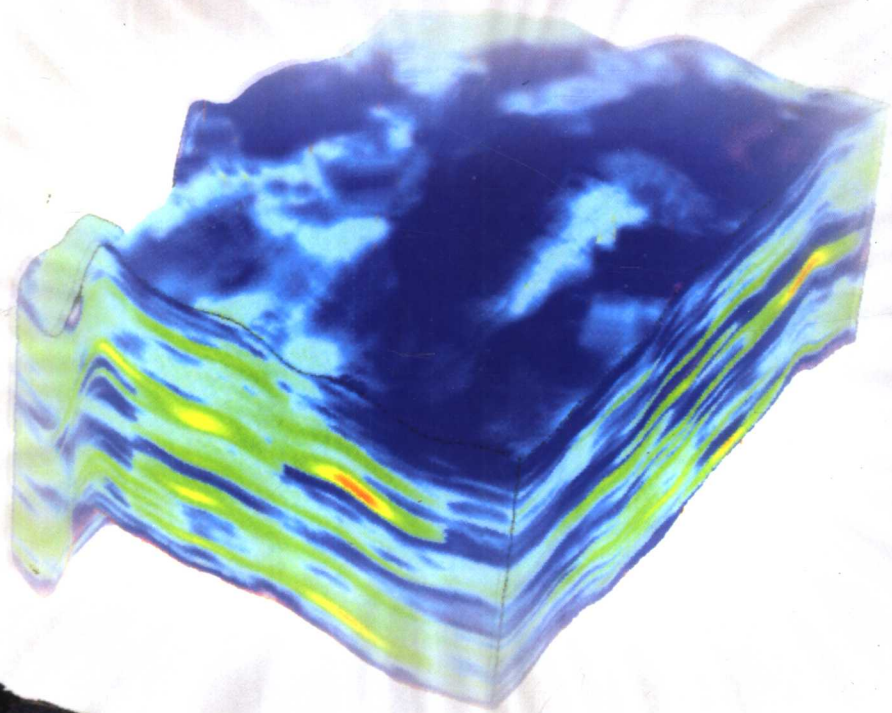
大型陆相断陷盆地层序地层与隐蔽油气藏研究

——以济阳坳陷为例

潘元林　李思田　等著



石油工业出版社
Petroleum Industry Press

大型陆相断陷盆地层序地层与隐蔽油气藏研究

——以济阳坳陷为例

潘元林　李思田　等著

石油工业出版社

Study of Large – scale Continental Rift Basin Sequence Stratigraphy and Subtle Oil and Gas Reservoir

—Taking Jiyang Depression for Example

Pan Yuanlin Li Sitian *et al.*

Petroleum Industry Press

内 容 提 要

本书是以胜利油田与中国地质大学合作进行的"济阳坳陷第三系沉积、构造及含油性"研究成果为基础编写的。书中概括地论述了层序地层学的主要概念和研究方法，影响层序发育的主要控制因素，济阳坳陷各级层序界面的主要特征，古近系层序地层等时格架的特征和三级层序的体系域构成；分析了同沉积断裂对层序和低位体系域沉积体系的控制作用以及主要沉积体系的特征和分布，建立了三种类型断陷盆地的层序地层模式；分析了砂砾岩隐蔽油气藏的形成条件，揭示了"断裂坡折带—低位扇"控制岩性油气藏形成和分布的规律，建立了三种类型斜坡带的油气藏分布模式，以大量的勘探实例验证了层序地层研究的应用效果。

本书对陆相盆地层序地层和隐蔽油气藏研究具有重要参考价值，可作为陆相含油气盆地层序地层和隐蔽油气藏研究以及有关大专院校教学的参考书。

图书在版编目(CIP)数据

大型陆相断陷盆地层序地层与隐蔽油气藏研究——以济阳坳陷为例/潘元林等著. —北京：石油工业出版社，2004. 12
ISBN 7-5021-4857-4

Ⅰ. 大…
Ⅱ. 潘…
Ⅲ. ①陆相-地层层序-研究
②陆相-断陷盆地-油气藏-形成-研究-济阳市
Ⅳ. ①P539.2 ②P618.130.2

中国版本图书馆 CIP 数据核字(2004)第 119568 号

出版发行：石油工业出版社
（北京安定门外安华里 2 区 1 号 100011）
网 址：www.petropub.cn
总 机：(010)64262233 发行部：(010)64210392
经 销：全国新华书店
排 版：北京乘设伟业科技排版中心排版
印 刷：石油工业出版社印刷厂印刷
2004 年 12 月第 1 版 2004 年 12 月第 1 次印刷
787×1092 毫米 开本：1/16 印张：15.75
字数：296 千字 印数：1—3300 册
书号：ISBN 7-5021-4857-4/TE·3411
定价：48.00 元
（如出现印装质量问题，我社发行部负责调换）

序

我有幸读到《大型陆相断陷盆地层序地层与隐蔽油气藏研究——以济阳坳陷为例》专著的书稿，感到十分欣喜和敬佩。这是一本以先进的层序地层理论方法与前缘的三维地震技术相结合的油气勘探力作，是一项属于基础地质学科的理论与油气勘探实践相结合的产物，又是一项高等院校科学研究与重点企业生产需要相结合的成果。本专著所涉及的地区规模虽然不是很大，但在以上所提的几个方面确实做出了令人瞩目的成果。

进入新的世纪以来，我国在全面实现小康社会和可持续发展的进程中，自然资源，尤其是油气资源的短缺，已经成为我国经济、社会发展的制约因素。当然，我国油气资源的保障并不限于国内，但就当前和近期来说，东部陆相盆地的油气藏仍然是十分重要的安全保证。因此，在东部含油气盆地勘探方面，任何新的理论和技术的发展及产量的提高，都具有重要的意义。这些发展和提高对国内相同类型和不同类型盆地油气勘探的示范和启发作用更是不容低估。

层序地层学理论和方法，是正确认识沉积地层和划分沉积地层单元并进行地层对比的一种新的理论和方法，具有学术理论和生产应用两个方面。应用这种理论和方法，可以按照沉积地层的充填序列进行各级地层单元的划分和等时对比，揭示各种沉积体系的空间分布规律，指导各种砂砾岩体非构造油气藏的勘探。十多年来，层序地层学理论与三维地震技术相结合指导国外海相盆地的油气勘探，在一些盆地取得了令人瞩目的成果。同时，应用这种理论和方法，与其他地层研究方法相结合，可以使地层时代对比和界线划分对比等基本研究得到显著的提高。

层序地层学理论和方法引入中国后，各油田企业和高等学校及研究单位纷纷将这一源自海相盆地的理论和方法试用于中国的陆相含油气盆地，对许多盆地进行了不同尺度的层序地层学研究，在应用方面取得了一定效果。

非构造油气藏，是含油气盆地油气藏序列的重要组成部分，蕴藏着丰富的油气资源。以渤海湾盆地为代表的陆相断陷盆地，具有分割性强、沉积幅度大、多物源、近物源、沉积速度快和沉积相变化大的特点，各种非构造油气藏更为发育，特别是砂砾岩体岩性、地层油气藏具有巨大的勘探潜力。由于在地层中分布的不确定性和隐蔽性，且具有较大的圈闭识别难度，故也称为隐蔽油气藏。中国的很多含油气盆地，特别是以渤海湾盆地和松辽盆地为代表的经过几十年勘探开发的油气盆地，隐蔽油气藏的发现与勘探更具有重要意义。

济阳坳陷是渤海湾盆地的一个次级盆地，也是著名的富油气盆地。以济阳坳陷为主要勘探阵地，诞生并建立了中国第二大油田——胜利油田。经过近40年的勘探开发，逐步进入以岩性油气藏为主的隐蔽油气藏勘探阶段。虽然在济阳坳陷勘探的初期就已发现这类隐蔽油气藏，但并没有将它作为重点勘探对象，对其成藏控制因素和分布规律也缺乏较系统的研究和认识。

层序地层学理论和方法，为揭示砂砾岩体隐蔽油气藏的成藏和分布规律提供了理论认识的依据和研究途径。20世纪末，胜利油田与中国地质大学合作进行“济阳坳陷第三系沉积、构造及含油性”研究，以指导隐蔽油气藏勘探为目的，将层序地层和沉积、构造研究与隐蔽油气藏成藏研究紧密结合，在大量单井和层序分析以及地震剖面的层序界面的识别、追踪和层序解释基础上，建立了整个坳陷古近系的三级层序等时地层格架，揭示了由同沉积断裂活动形成的断裂（构造）坡折带控制低位体系域沉积体系的发育和“断裂坡折带—低位扇”控制砂砾岩岩性油气藏群的规律。应用这些认识指导济阳坳陷砂砾岩体隐蔽油气藏的勘探，已取得了显著的效果。

胜利油田与中国地质大学的合作，为我国大型陆相断陷盆地层序地层和隐蔽油气藏合作研究及对隐蔽油气藏勘探的指导做出了很好的范例。《大型陆相断陷盆地层序地层与隐蔽油气藏研究——以济阳坳陷为例》就是在这项合作研究的基础上编写的。对含油气盆地及其勘探的研究具有重要的参考价值。我愿竭诚推荐这一专著，并借此机会对专著的全体作者表示由衷的敬意。

2004.9.于北京

前　言

在一个含油气沉积盆地内，按照沉积的本来面貌准确地划分和对比地层，建立等时地层格架，是正确认识盆地构造发育和沉积充填演化、油气的生成、运移和聚集分布规律、油气藏特征，进行油气藏描述，高水平勘探开发油气田的基础。但是，在层序地层学理论和方法出现之前，要做到这一点非常困难，尤其是复杂的陆相断陷盆地，由于其复杂的地质结构造成盆地强烈的分隔性和沉积的复杂多变。不论是全盆地（坳陷），还是其中的一个凹（洼）陷内，都很难做到按地层沉积的时间序列进行精细划分和等时对比。比如，在济阳断陷盆地或其中某一个凹陷范围内，即使古近纪湖相为主的沉积地层，按传统的岩石—生物地层划分方法，也只能做到“段”的基本等时划分和对比，段内地层的进一步细分对比，就常有穿时现象发生。最典型的是东营凹陷东、中部的古近系沙三上亚段大型三角洲，其前三角洲亚相泥岩及其中的滑塌浊积岩，就曾被划分为沙三中亚段；三角洲前缘砂体的井间地层对比，很少考虑甚至根本不考虑其前积特征，穿层现象就更普遍。又如，同一个沙三段梁家楼扇体，从不同的方向出发进行对比，曾分别划归沙三上亚段和沙三中亚段。岩石—生物地层划分和对比方案，虽然在油气勘探、开发早、中期曾起了重要作用，但到了油气勘探进入以岩性、地层油气藏为主要对象，油气田开发进入高含水、必须按流动单元细分层注水调整阶段，就表现出明显的不适应。

以各种砂砾岩体为储集体、非构造圈闭为聚集场所的各种岩性、地层油气藏，是陆相断陷盆地为数众多、油气资源丰富、勘探潜力很大的重要油气藏类型。它们的空间分布具有较强的不确定性，大部分岩性圈闭通常又夹持在未变形或变形微弱的正常沉积岩层之间，具有很强的隐蔽性，圈闭的识别难度较构造油气藏大得多，因此称它们为隐蔽油气藏。虽然早在济阳坳陷勘探初期就已发现了这种隐蔽性很强的岩性油气藏，在后来30多年的勘探历程中也陆续有所发现，但其大部分的发现都具有偶然性，有些则是兼探发现的。虽然也知道它们主要发育在沙三段，但对它们的成藏和空间分布的具体规律及其主要控制因素却并未真正认识，在厚度达700～1200m的沙三段内进行岩性油气藏的勘探，主要的目标区带并不明确，加上以往识别岩性圈闭的技术手段比较缺乏或不成熟，严重地制约了砂砾岩体隐蔽油气藏勘探的发展。正确认识砂砾岩体隐蔽油气藏的成藏和分布规律，研究开发砂砾岩体隐蔽圈闭的预测、识别和描述技术，已成为深化济阳坳陷油气勘探的关键。

层序地层学理论和方法的创建和应用，使解决地层单元的等时划分和对比、

揭示砂砾岩体隐蔽油气藏的成藏和分布规律成为可能。层序地层学是正确认识沉积地层的一种新理念，是划分、对比沉积地层的一种新方法。其核心内容是按沉积地层的充填序列进行地层的划分和对比，并建立等时地层格架。20 世纪 80 年代，层序地层学理论和研究方法基本形成以后，立即被一些跨国大石油公司广泛应用，虽然只有不到 20 年的应用历史，但却取得了一系列令人瞩目的勘探新发现，在南美洲东部深海裂谷盆地和非洲西部、南部的深海盆地，相继发现了与浊积岩、盆底扇或河道砂岩有关，可采储量达几亿甚至十几亿吨的特大油田。层序地层学与三维地震相结合，已被 Exxon 等跨国大石油公司公认为“权威性的找油工具”。

层序地层学理论和方法引入中国后，首先得到各油田企业和有关大学及研究单位地学研究者们的广泛重视，纷纷将这一源自海相盆地的理论和方法尝试着应用于我国的陆相含油气盆地，对许多盆地都进行了不同程度的层序地层学研究，在应用方面也取得了一定效果。但是，以往陆相断陷盆地层序地层学的研究，多局限于其中的某一个凹陷，甚至更次一级的洼陷，研究范围最大也仅 5000km^2 左右，其研究精度，大部分划分到三级层序，有的甚至只划分到二级层序。尚未见到包括几个凹陷的坳陷级大型断陷盆地层序地层研究成果的报道，也很少见到以服务于砂砾岩体隐蔽油气藏勘探为目的、通过层序地层研究揭示其成藏规律的有关报道。

济阳坳陷是渤海湾盆地的一个次级盆地。整个坳陷被其间的凸起分隔为东营、惠民、沾化和车镇等四个凹陷，每个凹陷又被分割为几个次一级的洼陷，它们都是古近纪断陷盆地。由于凸起的分隔和构造活动的差异，各凹陷以湖相沉积为主的古近系沉积特征也不尽相同。

济阳坳陷的油气资源十分丰富，是中国著名的富油气坳陷之一。从 1961 年发现第一个油田——东辛油田之后，经过 30 多年的勘探，具有一定储量规模的主要构造油气藏基本都已被发现，于 20 世纪 90 年代初逐步进入以砂砾岩岩性油气藏为主的隐蔽油气藏勘探阶段。20 世纪 80 年代中期以来，三维地震技术和测井新技术的普遍应用以及地质建模、模式识别、测井约束反演、储层预测、油藏描述、油气层保护和改造等多项勘探技术的研究开发和推广应用，基本解决了砂砾岩隐蔽油气藏的勘探技术手段。因此，研究和揭示砂砾岩隐蔽油气藏成藏和分布规律，成为砂砾岩隐蔽油气藏勘探必须解决的关键问题。

为此，首先以东营凹陷中、北部为解剖对象，应用层序地层学和岩相古地理等理论和方法，对古近系沙三段—沙四上亚段岩性油气藏进行了研究。而后，于 1997—1999 年，胜利油田与中国地质大学合作，以服务于砂砾岩隐蔽油气藏勘探，揭示其成藏和分布规律为目标，应用层序地层学、现代构造地质学、成藏动力学等理论和方法，进行了“济阳坳陷第三系沉积、构造及含油性”系统研究。该项研究

在对1840口井单井相和层序对比分析，对约40000km地震剖面精细层序地层解释以及大量其他相关研究的基础上，建立了全盆地四个凹陷统一的三级层序等时地层格架和三种类型的层序充填模式。研究发现：深断陷型三级层序也具有低位体系域、湖扩展体系域和高位体系域等三层结构；低位体系域发育各种碎屑岩沉积体系（统称低位扇）；由同沉积断裂发育而形成的“断裂坡折带”控制了低位扇的发育和分布，各种成因的低位扇体常沿断裂坡折带成群分布；湖扩展体系域是优质烃源岩的发育层位，其中生成的油气，以成烃超压为主要动力从烃源岩排出，直接进入低位扇储集体，形成岩性油气藏，或通过断层或不整合面运移到断裂带上的其他圈闭中形成多种类型油气藏，如构造—岩性油气藏、地层油气藏或构造油气藏，从而揭示了“断裂坡折带—低位扇”控制砂砾岩岩性油气藏群形成和分布的规律。上述研究成果陆续应用于勘探实践，有效地指导了济阳坳陷古近系砂砾岩体隐蔽油气藏的预测和勘探，使这类油气藏的探井成功率提高了11%～25%。其中探明的石油储量也逐年增加，仅砂砾岩体隐蔽油气藏探明的石油储量在全盆地年度探明石油储量中的比例，就从1997年的约13%提高到2003年的45%。加上潜山、火成岩等隐蔽油气藏，最近五六年，各种隐蔽油气藏每年探明的石油储量已占同期全盆地探明总石油储量的60%以上，个别年份甚至高达80%左右，成为保证济阳坳陷探明石油储量持续稳定高速增长的主要领域及支撑济阳坳陷油气勘探的重要支柱。大部分砂砾岩体隐蔽油气藏探明石油储量都已投入开发，并产生了巨大的经济效益。

该书即是以此项研究和应用成果为主，并综合济阳坳陷部分地区以往的层序地层研究和应用成果而编写的，目的是将济阳断陷盆地层序地层研究成果以及用以指导砂砾岩体隐蔽油气藏勘探实践的经验介绍给读者，供从事类似盆地层序地层研究和砂砾岩体油气藏勘探的科研和管理者参考。

该书由潘元林、李思田、林畅松、郑和荣等共同确定编写提纲。初稿由“济阳坳陷第三系沉积、构造及含油性”项目的以下主要研究人员分工编写：前言，潘元林；第一章第一、三、四节，李思田，第二节，林畅松；第二章第一节，郑和荣、潘元林，第二节，李思田，第三节，宗国洪；第三章第一节，冯有良，第二节，陆永潮，第三节，李思田；第四章，林畅松，任建业；第五章第一节，林畅松，第二、三、四节，冯有良、邱以钢、潘元林；第六章，郑和荣、李思田；第七章，宗国洪、隋凤贵、潘元林；第八章，李思田。全书由潘元林统稿，经李思田和林畅松复审定稿。

胜利油田地质科学研究院东昌惠勘探研究室和沾车海勘探研究室的部分同仁为本书的编写提供了部分典型沉积体系和勘探应用实例的素材，综合室曹建军为本书加工了部分图件，在此对他们表示感谢！

特别感谢著名地质学家、中国科学院院士、中国地质大学教授王鸿祯先生，不顾年老体弱，在百忙之中为本书作序。

还要感谢中国石油化工股份有限公司科技开发部对本书编写和出版的大力支持。

任何一项研究，任何一部科技著作或论文，都不可能完美无缺，该书也是如此，其中难免有不足甚至不当之处，敬请读者批评指正，个别观点也可以提出来进行讨论。

作者

2004 年 9 月

Preface

As for an oil and gas basin, the correct division and comparison of the strata according to the original sedimentation and establishment of isochronous stratigraphic configuration are the basis for correct understanding of the basin structural and sedimentary development, the law for oil and gas sourcing, migration and accumulation, the oil and gas reservoir characteristics, the oil and gas reservoir description and the effective exploration and development of oil fields. However, it is difficult to do such work prior to development of the sequence stratigraphical theory and method, especially for the complicated rift basin of continental facies. It is difficult to make precise division and isochronous comparison according to the stratigraphic sedimentary time sequence either for one whole basin or one of the depressions in the basin, because the complicated geological structure causes the basin strongly separated and the sedimentation complicated and variable. For example, in Jiyang Rift Basin or one of the depressions in the basin, only the basic isochronous division and comparison can be made in the section by using the traditional rock-biological stratigraphic division method, even if the sedimentary stratum is mainly of ancient lacustrine facies. Errors may appear frequently if the further detailed division and comparison are made in the section. The most typical example is the large-scale delta of Paleogene Es_3 upper sub-section in the eastern and central parts of Dongying Depression. The delta subfacies mudstone and the fluxoturbidite in the delta used to be divided into the Es_3 middle sub-section. Cross-hole strata of delta frontal sand body were compared without taking into account the sedimentary characteristics, thus causing errors frequently. For another example, the fan body of Liangjialou in the same Es_3 section, when compared from the different directions, used to be divided into Es_3 upper sub-section and Es_3 middle sub-section. The rock-biologic stratigraphic division and comparison method, though it played an important role in the early and middle stages of oil and gas exploration and development, is obviously inadequate when the oil and gas exploration is focused on the stratigraphic and lithologic oil and gas reservoirs and development of oil field enters the high water-cut stage to conduct layered water injection for adjustment according to the flowing units.

The various lithologic and stratigraphic oil and gas reservoirs, which use the sand-gravel rock body of various kinds as the reservoir body and non-structural traps as the

accumulation place, are the important oil and gas reservoirs in the continental-facies rift basin, numerous in quantity, rich in oil and gas resources and great in exploration potential. There is a great uncertainty in the space distribution of such reservoirs. Most of the lithologic traps exist between the normal sedimentary rock layers that are not deformed or weakly deformed. It is much more difficult to identify such traps as compared to the structural oil and gas reservoirs since they are concealed. Therefore, they are called subtle oil and gas reservoirs. Such lithologic oil and gas reservoirs with strong subtlety were found even in the early exploration stage of Jiyang Depression. The reservoirs of this kind have been discovered continually in the following three decades of exploration process. However, most of the discoveries were made accidentally while some of the discoveries were made in exploration of other reservoirs. Although it is known that they developed mainly in Es_3 section, it remains unclear about the law of their migration and accumulation and space distribution as well as the main controlling factors. The main target zone is not clear either for exploration of the lithologic oil and gas reservoirs within Es_3 section with a thickness of 700 – 1200 meters. Additionally, the technology for identification of lithologic traps was inadequate and immature in the past, seriously impairing the development in exploration of sand-gravel body subtle oil and gas reservoirs. The correct understanding of the law for distribution as well as migration and accumulation of sand-gravel body subtle oil and gas reservoirs and the study of technology for prediction, identification and description of sand-gravel body subtle traps hold the key to strengthening the oil and gas exploration of Jiyang Depression.

Creation and application of the sequence stratigraphic theory and method makes it possible to solve the isochronous division and comparison of stratigraphic units and unveil the law for migration and accumulation as well as distribution of sand-gravel rock body subtle oil and gas reservoirs. Sequence stratigraphy is a new conception to correctly understand sedimentary strata and a new method to divide and compare sedimentary strata. The core of sequence stratigraphy centers division and comparison of the strata according to the sedimentary stratigraphic infilling sequence and establishment of the isochronous stratigraphic configuration. The sequence stratigraphic theory and its research method is basically shaped in the 1980s and immediately used by some major multinational oil companies. The theory and method have made remarkable discoveries in exploration though they have been used for less than 20 years. The giant oil fields with the reserves, ranging from millions of tons to billions of tons and related to fluxoturbidite, basin bottom fan and channel sandstone, have been found in the deep-sea rift basins in the eastern part of South America and the deep-sea basins in the western and

southern parts of Africa. Combined with 3D seismic exploration, sequence stratigraphy is regarded by major multinational oil companies like Exxon as "authoritative tool for search of oil."

The sequence stratigraphic theory and method, when introduced into China, attracted extensive attention from geologists at oil field enterprises as well as the related universities and research institutions. They have used the theory and method originated from the basins of marine facies for China's oil and gas basins of continental facies. They have made sequence stratigraphic study of many basins and achieved certain application results. However, the past sequence stratigraphic study of continental rift basin is mostly limited to a certain depression or even more secondary sag with the maximum research scope of ± 5000 square kilometers. As for the research precision, they are divided into three stages of sequence but some of them are divided into two stages. There have been no reports about the sequence stratigraphic research results of a large-scale rift basin that covers several depressions. There are also little reports that the migration and accumulation law is unveiled through the sequence stratigraphic research for the purpose of sand-gravel subtle oil and gas reservoir exploration.

Jiyang Depression is a secondary basin of Bohai Bay Basin. The whole depression is divided into four sags of Dongying, Huimin, Zhanhua and Chezhen by the uplifts in the depression. Each sag is divided into several secondary ones. They are all the Paleogene rift basins. Each sag is mainly of Paleogene lake facies with the sedimentary characteristics quite different from each other owing to separation by uplifts and difference in structural activities.

Extremely rich in oil and gas resources, Jiyang Depression is one of the famous oil-enriched basins in China. However, this area has come under exploration for more than three decades since the first oil field in the area was found in 1961. Nearly all the oil and gas reservoirs of the main structures with a certain amount of reserves have been discovered in the area. The exploration stage for subtle oil and gas reservoirs, which are mainly sand-gravel rock lithologic ones, started from the 1990s. The 3D seismic technology and new logging technology have found wide application since the middle of the 1980s, including a number of exploration technologies such as geological modeling, identification of pattern, logging restricted inversion, reservoir prediction, oil and gas reservoir description, and oil and gas layer protection and stimulation. They have been used as the exploration technologies for the sand-gravel rock subtle oil and gas reservoirs. Therefore, the study of the migration-accumulation and distribution law for sand-gravel rock subtle oil and gas reservoirs holds the key to exploration of such reservoirs.

As a result, the central and northern parts of Dongying Depression are first set as the research targets. The sequence stratigraphic and lithofacies palaeogeographic theory and method are used to study the lithologic oil and gas reservoirs of Paleogene $Es_3 - Es_4$ upper sub-section. Later in 1997-1999, "Tertiary sedimentation, structure and oil and gas characters of Jiyang Depression" was brought under the systematic study in collaboration with Shengli Oil Field and China Geological University. With application of the theories and methods developed in sequence stratigraphy, modern tectonic geology and migration and accumulation dynamics, the study project is aimed at serving sand-gravel rock subtle oil and gas reservoir exploration and understanding the migration-accumulation and distribution law of suck reservoirs. This project has involved analysis of 1840 wells and detailed sequence stratigraphic interpretation of 40,000-kilometer seismic profiles as well as a large quantity of other related data. The study project has established the unified three-stage sequence isochronous stratigraphic configuration and the three types of sequence infilling pattern for the four depressions in the basin. The study has the following discoveries: The three-stage sequence of deep rift depression is also the three-layer structure of low-level system tract, lake-expanded system tract and high-level system tract. The low-level system tract develops the detrital rock sedimentary system of various kinds (called low-level fan). "Fault slope-folded zone" caused by development of fault in the same sedimentation controls development and distribution of low-level fan. The low-level fan bodies of various origins are distributed in groups along the fault slope-folded zone. The lake-expanded system tract is the development level of high-quality hydrocarbon source rock. Owing to hydrocarbon expulsion caused by the dynamics of overpressure, oil and gas generated from the high-quality source rock either enters directly into the low-level fan reservoir body to shape the lithologic oil and gas reservoirs or migrates into other traps through the fault or unconformity surface to shape the oil and gas reservoirs of various types, such as structural-lithologic oil and gas reservoirs, stratigraphic oil and gas reservoirs and structural oil and gas reservoirs. Therefore, the study indicates that "fault slope-folded zone-low-level fan" controls migration-accumulation and distribution law of sand-gravel rock lithologic oil and gas reservoirs The above-stated research results have been used in exploration practice and effectively guided prediction and exploration of the Paleogene sand-gravel rock subtle oil and gas reservoirs in Jiyang Depression, thus enabling the success of exploration well in the oil and gas reservoirs of such kind to grow 11% -25% percent with the annual proven oil reserves rising year by year. The proportion of the oil reserves proven from the sand-gravel rock subtle oil and gas reservoirs to the total annual proven reserves in the whole

basin were raised to 45 percent in 2003 from about 13 percent in 1997. With addition of the reserves from buried hill and igneous rock subtle reservoirs, the annual proven oil reserves from subtle reserves have exceed 60 percent of the total annual proven oil reserves in the whole basin in the past five or six years, even as high as about 80 percent in some individual years. It has become the main field for the sustainable and rapid growth of proven oil reserves in Jiyang Depression and an important pillar in oil and gas exploration in the area. Most of the proven oil reserves from sand-gravel rock subtle reservoirs have been put into development, achieving great economic results.

Focused on the results achieved in the study project, this book is written and compiled on the basis of the results achieved from the sequence and stratigraphic study and application of some parts in Jiyang Depression in the past. The purpose is to brief readers about the sequence stratigraphic research results of Jiyang Rift Basin and the experiences in exploration of sand-gravel rock subtle oil and gas reservoirs guided by the research results. This book can be used as a reference for those who are engaged in scientific research and management of basin sequence stratigraphic study and sand-gravel rock oil and gas reservoir exploration.

The outline of this book is written jointly by Pan Yuanlin, Li Sitian, Lin Changsong and Zheng Herong. The book is written and compiled by the following researchers from the project of "Tertiary Sedimentation, Structure and Oil Character." The concrete division of writing and compilation for this book is as follows: Pan Yuanlin is responsible for Preface, Li Sitian responsible for the first, third and fourth sections of Chapter One, Lin Changsong responsible for the second section of Chapter One, Zheng Herong and Pan Yuanlin responsible for the first section of Chapter Two, Li Sitian responsible for the second section of Chapter Two, Zong Guohong responsible for the third section of Chapter Two, Feng Youliang responsible for the first section of Chapter Three, Lu Yongchao responsible for the second section of Chapter Three, Li Sitian responsible for the third section of Chapter Three, Lin Changsong and Ren Jianye responsible for Chapter Four, Lin Changsong responsible for the first section of Chapter Five, Feng Youliang, Qiu Yigang and Pan Yuanlin responsible for the second, third and fourth sections of Chapter Five, Zheng Herong and Li Sitian responsible for Chapter Six, Zong Guohong, Sui Fenggui and Pan Yuanlin responsible for Chapter Seven, and Li Sitian responsible for Main Knowledge and Conclusion. Pan Yuanlin makes examination of the whole book. Li Sitian and Lin Changsong make re-examination and determination of the whole book.

The colleagues from Dongchanghui Exploration Office and Zhanchehai Exploration

Office of Geological Research Institute of Shengli Oil Field provide the materials of some typical sedimentary systems and exploration cases for writing and compilation of this book. Cao Jianjun from Coordination Office handles some of the figures and mappings in the book. Gratitude is extended to all of them.

Special gratitude is extended to Mr. Wang Hongzhen, famous geologist, academician at China's Academy of Sciences and professor at China Geological University. He wrote the preface of this book though he was busy with his work and in poor health.

Gratitude is also extended to Technological Development Department of Sinopec Corp. for its enormous support in writing and publication of this book.

Any research project or any of science books or theses cannot be perfect. Neither is this book. Any corrections from readers are appreciated. Readers are also welcome to raise their individual opinions for discussion.

Authors

Sep. 2004

目　录