

# 东濮凹陷文留中央地垒带 泥岩裂缝性油气藏研究

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[摘要] 从烃源岩、沉积建造条件、裂缝性质、裂缝保存条件等方面分析了泥岩裂缝性油气藏的形成条件, 探讨了泥岩裂缝性油气藏的形成机理, 分析了泥岩裂缝性油气藏的识别方法; 认为烃源主要来自自身体系, 沉积建造对油气藏形成有明显控制作用, 泥岩裂缝的发育是成藏的关键因素, 盐岩封闭对形成这种类型油气藏有着得天独厚的条件; 烃源岩内的油气以混相涌流方式顺层向裂缝储集层中富集成藏; 泥岩裂缝性油气藏的识别应综合考虑地质、测井、地震和钻井等方面的信息。最后阐述了东濮凹陷文留中央地垒带沙三段泥岩裂缝性油气藏形成的特点及分布规律。

[关键词] 东濮凹陷; 泥岩; 裂缝性油气藏; 地震识别; 沉积建造; 形成机理

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泥岩裂缝性油气藏是指由泥岩裂缝作为油气储集空间的油气藏, 它是隐蔽油气藏<sup>[1]</sup>的一种。目前世界含油气盆地中, 泥岩裂缝性油气藏以美国和前苏联较多。美国的东西部及南部的墨西哥湾诸盆地、前苏联西西伯利亚盆地等已有大量泥岩裂缝性油气藏发现。在我国, 目前江汉、渤海湾、松辽、四川及西部的柴达木、酒西等盆地中均发现了泥岩裂缝性油气藏, 并已形成工业产能。胜利油田的济阳拗陷是距东濮凹陷最近的泥岩裂缝性油气藏形成工业产能的地区。目前济阳拗陷已有数十口井获得工业油流, 已成为一个重要的后备储量阵地。这些事例说明泥岩裂缝性油气藏也是勘探活动中应该受到充分重视的一种油气藏类型。

## 1 泥岩裂缝性油气藏的形成条件

东濮凹陷泥岩裂缝性油气藏的勘探起步比较晚, 直至2000年11月, 部署在中央隆起带文留潜山构造上的文古2井(图1), 在3110.49~3115.35m井段取心证实, 泥岩岩心表面和裂缝可见明显的沥青和原油, 用力挤压可见原油自裂缝中渗出, 从而发现了沙三<sup>2</sup>层系泥岩裂缝性高压油气藏。这一钻探成果开辟了东濮凹陷一个新的找油领域, 并相继在文300井(电解3011.6~3185.0m井段泥岩裂缝性油层85.7m/9层)、文403井(图1)(电解泥岩裂缝性气层7m/3层)发现了泥岩裂缝性油气层, 进一步预示了文留中央地垒带上泥岩裂缝性油气层的连片分布。泥岩裂缝性油气藏具有独特的形成条件和过程, 和常规砂岩油气藏<sup>[2]</sup>有较大差别。

1) 烃源主要来自自身体系 与砂岩油气藏的形成

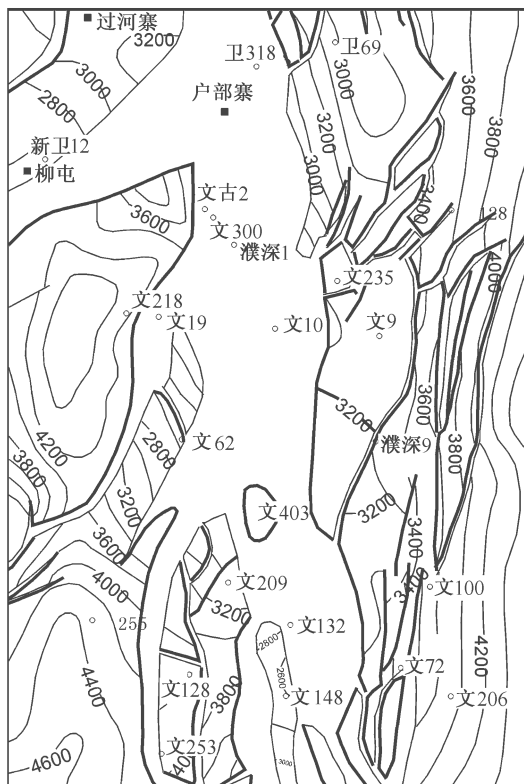


图1 文留北部T<sub>1</sub>构造图

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不同, 泥岩裂缝性油气藏的油源除少部分来自上、下围岩外, 大部分来自自身体系。目前我国形成工业产能的油气田多属这种情况。东濮凹陷多年勘探证实, 凹陷内烃源岩系发育, 主要有沙一段、沙三段烃源岩及石炭-二叠系煤系烃源岩。从烃源岩分布状况、生油指标分析, 凹陷内大部分沙三段地层已进入生烃门限, 具有较强的生烃能力, 沙一段在埋藏深的洼陷中心及文南等地区也已进入低熟油生成阶段, 石炭-二叠系地层也已进入二次成烃阶段。这说明东濮凹陷泥岩裂缝性油气藏的形成有良好的物质基础。

2) 沉积建造条件对油气藏形成有明显控制作用 盆地的沉积建造条件对泥岩裂缝性油气藏的形成富集起着明显控制作用 (图2)。泥岩裂缝性油气藏不可能在频繁的砂泥岩互层地层发育, 而主要发育在厚层的泥岩展布稳定区, 也就是说在一些水体较深的深湖相或半深湖相区及三角洲前缘前端或前三角洲最易形成这类油气藏。东濮凹陷烃源岩发育的沙一段、沙三段沉积期, 除凹陷边缘及南湖、桥口以南地区水体环境较浅外, 北部的东西两洼及中央隆起带基本上处于半深水或深水沉积环境, 有利于泥岩裂缝性油气藏的形成。

另外东濮凹陷和中国东部第三系其他盆地一样缺乏硅质沉积, 泥岩多富含钙质、灰质成分, 这种岩性具有较大的脆性和潜在的造缝能力, 对泥岩裂缝的形成十分有利。

3) 泥岩裂缝的发育是成藏的关键因素 泥质岩类油气藏成藏的关键因素是泥岩中要有裂缝储集层。它和普通的储集层差别较大, 一般属低孔低渗类型。孔隙度变化范围一般 1%~5%, 渗透率一般小于  $0.05 \times 10^{-3} \mu\text{m}^2$ 。非均质性相当明显。它的产状一般有 5 种, 即纵向裂缝 (延伸受岩性限制, 可穿层)、层间裂缝 (发育在不同岩性界面, 或为泥岩叶片状破碎的页理缝)、鸡笼状裂缝 (为三维多边形网格状裂缝)、剪切缝、微裂缝。这些裂缝的成因主要与成岩收缩作用、异常高压和构造作用有关。

东濮凹陷是一个张性断裂发育的盐湖盆地, 历史上经历过多次构造运动。这对砂泥岩地层裂缝形成比较有利。目前发现的卫 799 块气田、南湖气田砂岩储集层裂缝就相当发育。

东濮凹陷有别于渤海湾其他盆地的最大特色是盐岩发育。盐岩主要发育在中央隆起带上。地震资料显示, 盐岩由于受基底拱张运动及断层活动影响, 出现许多小的褶皱及盐岩的不规则流动现象。这对盐间的泥岩裂缝产生十分有利。从岩性分析, 东濮盐间泥岩多为纯度较高的油页岩、钙质或灰质泥岩, 脆性大, 在盐岩的不规则运动下很容易产生裂缝。分析认为, 文古 2 井、文 300 井等钻遇的盐间泥岩裂缝主要是这种成因。

异常高压形成的裂缝主要指岩石在一定埋深处于封闭压力条件下, 由于烃类生成、粘土矿物脱水、水热增加、自生矿物充填孔隙、胶结作用等产生异常高压, 当其达到临界破裂压力时即发生破裂, 产生裂隙。东濮凹陷经多年勘探证实, 由于盐岩发育等多种原因, 高压油气藏分布广泛, 都不同程度地分布着超压带, 尤其是深层沙三段地层, 超压带分布更为广泛。这些超压带分布区往往是良好烃源岩分布区, 若出现厚层泥岩分布, 很容易形成一定规模的泥岩裂缝性油气藏。

成岩收缩缝是与岩石体积缩小相伴的扩张或拉张裂缝, 在储集层中较普遍, 其成因一种是脱水作用形成, 一种是矿物相变形成, 即粘土矿物由蒙皂石转化为伊利石时形成的水平方向的微裂缝。这种收缩缝在东濮凹陷也存在, 只是过去研究较少, 目前还没有一个全面认识。

4) 保存条件 泥岩裂缝性油气藏由于非均质性严重, 对圈闭条件要求有其特殊的一面。断裂发育有利于泥岩裂缝产生<sup>[3]</sup>, 但断层发育密度大的地区并不利于这种类型油气藏保存。另外, 厚层泥岩展布

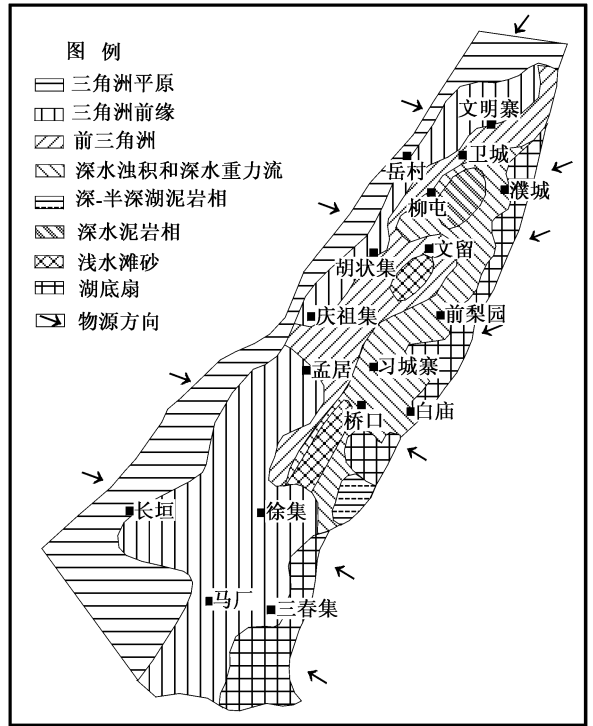


图2 东濮凹陷沙三段3砂组岩相古地理图

区往往更易形成这种类型油气藏, 而砂岩发育地区寻找泥岩裂缝性油气藏较为困难。东濮凹陷盐岩发育区由于盐岩封闭条件好, 对形成这种类型油气藏有着得天独厚的条件。

## 2 泥岩裂缝性油气藏成藏机理及识别

1) 成藏机理 综上所述并结合前人研究成果, 笔者认为, 东濮凹陷泥岩裂缝性油气藏的成藏模式是在泥质岩超压微裂缝带内, 受地层应力和超压作用, 微裂缝局部扩大形成有效的储集空间, 在应力释放的同时, 在超压泥质岩微裂缝带内产生顺层压差, 在压差负压驱动下, 泥质烃源岩内的油气便以混相涌流<sup>[4]</sup>的方式顺层向裂缝储集层富集成藏。

混相涌流是一种重要的油气运移机制, 其条件是存在封闭系统和超压, 当压差大于封盖岩石破裂强度时, 油气水一起脉冲式地涌出, 产生混相涌流, 这种条件与泥质岩油气藏的形成条件是一致的。张义刚等在进行混相涌流模拟实验中发现, 混相涌流可以使油气大大富集。实验中压力由 30 MPa 降至 15 MPa, 并采用了不同气油比, 结果发现油气尤其是油在涌流后浓度提高可达 100 倍。这一实验很好地说明了混相涌流使泥质岩中油气富集成藏的过程。

断层对泥质岩油气藏的控制作用可以用地震泵原理解释<sup>[5]</sup>。断层的作用就象一个泵一样, 由较深部位抽出热液并驱入有较低正应力的易进得去的张开的裂隙中, 流体沿生长断层的流动是突发性、周期性的。泥质岩受断层影响发生破碎, 在超压泥质岩微裂隙带内产生顺层压差, 从而驱动油气向断层方向富集。泥质油气藏的保存条件也是至关重要的, 对靠近断层带的泥质岩油气藏尤其如此。Hoper 指出断层具有开启和封闭的双重性, 对于活动中的开启断层, 已形成的泥质岩油气藏中的油气便会沿断层发生二次运移而被破坏, 保存下来的均是由断层封挡形成的。

2) 泥岩裂缝性油气藏的识别 泥岩裂缝性油气藏因其成因的特殊性, 在识别时需要各方面理论技术的综合运用, 总结主要有以下几方面: ①地质信息。结合其他油田的勘探实践, 泥岩裂缝成藏主要的勘探标志是断层转换带和断层末端, 包括末端交汇区是产生裂缝最有利的部位; 不同沉积相的过渡带, 以及大型三角洲砂体、水下浊积砂体、近源浊积扇砂体相的前缘与泥岩过渡带的突出、急弯、内凹等部位是产生重力滑剪裂缝的有利区带; 异常超压带是寻找这类油气藏的有利场所; 富钙质、灰质以及有机质的岩相带, 有利于形成泥岩裂缝; 烃源岩厚度大、生油潜力大的层系有利于形成该类油气藏; 压实条件是泥岩裂缝性油气藏形成的必要条件(压实成岩后泥岩才有较大的脆性)。②测井信息。应用测井信息识别裂缝、裂缝方向及裂缝性油气藏是裂缝性油气藏测井识别评价的一个重要组成部分。在裂缝性油气藏中, 各种测井方法对裂缝都有不同程度的响应, 特别是裂缝识别测井(包括成像测井等), 不仅能够识别裂缝, 而且能够确定裂缝的延伸方向, 长源距声波测井可以识别裂缝面的倾角; 电阻率时间推移测井能够发现有效裂缝渗透层; 自然伽马能谱测井可以识别具有高自然伽马的裂缝性地层; 双侧向-微球聚焦测井、电磁波传播测井、井眼补偿中子测井、密度测井、声波测井等, 都可为识别泥岩裂缝性油气藏提供可靠的信息资料。由于探测岩石体积不同, 受裂缝孔隙度非均匀分布的影响程度也不一样, 利用它们之间的差异也能够识别裂缝渗透层。分析裂缝延伸方向可以指导裂缝性油气藏的井位布署, 沿着裂缝发育方向寻找高产油气带。③地震信息和钻井信息。目前东濮凹陷主要构造带已实现三维地震覆盖, 充分利用三维地震资料进行构造、断层的精细解释, 利用三维地震资料进行地震相、沉积相的划分研究等, 对泥岩裂缝性油气藏勘探无疑会起到推动作用。另外各种地震新技术, 比如三维可视化技术、地震相干分析技术的研究运用, 对精细预测泥岩裂缝发育区也有较好的效果。在寻找泥岩裂缝性油气藏时, 钻井技术也不容忽视, 通过它不但可发现异常超压带的存在, 而且可优化钻井工程, 提高保护油气层意识, 这些无疑都会加快这类油气藏的勘探发现。

## 3 泥岩裂缝性油气藏的分布规律

根据东濮凹陷勘探实践及地层发育特点, 泥岩裂缝性油气藏的分布有以下特点: ①在油层高压区及超高压区是寻找泥岩裂缝性油气藏的有利区。勘探证实东濮凹陷东西两洼、卫城以南、桥口以北的中央隆起带沙三段属高压、超高压分布区, 是寻找泥岩裂缝性油气藏的有利区。沙一段西洼南部、东洼及文

南等地区存在高压区 (图 3), 也是寻找泥岩裂缝性油气藏的有利区。②层系上沙三<sup>2</sup>层系、沙三<sup>3</sup>层系、沙三<sup>4</sup>层系是寻找泥岩裂缝性油气藏的有利层系。从东濮凹陷地层发育特点分析, 沙三<sup>2</sup>层系、沙三<sup>3</sup>层系、沙三<sup>4</sup>层系盐岩发育, 盐间泥岩在高温高压下具有较好的生油气能力, 并且受盐岩封盖, 油气保存条件好, 是寻找这类油气藏的有利层系。在无盐区, 沙三<sup>2</sup>层系上部地层、沙三<sup>3</sup>层系上部地层泥岩发育, 厚度大, 对形成这类油气藏有利。③中央隆起带盐岩发育层系及发育区是寻找泥岩裂缝性油气藏最有利场所。中央隆起带盐岩主要发育在沙三<sup>2</sup>层系、沙三<sup>3</sup>层系、沙三<sup>4</sup>层系 (沙一段也有分布), 这 3 个层系埋深基本上都在生油门限内, 具有良好生油气能力, 其保存条件也不错。更重要的一点是中央隆起带由于基底拱张、断层发育, 导致盐间泥、页岩裂缝发育, 十分有利于形成泥岩裂缝性油气藏。④部分泥、页岩标志层是寻找泥岩裂缝性油气藏的有利层段。从东濮凹陷泥、页岩标志层岩性分析, 多为含钙质、灰质较重的泥岩、页岩标志, 这些标志层在构造运动下极易产生裂缝。所以生油层系中的泥、页岩标志层也是寻找这类油气藏有利层段。⑤构造转换带是寻找泥岩裂缝性油气藏的有利场所。东濮凹陷勘探证实, 两个主要的构造转换带, 即邢庄-文濮结合部及南湖-白庙构造转换带已发现砂岩裂缝性油气藏, 它也是寻找泥岩裂缝性油气藏的良好场所。

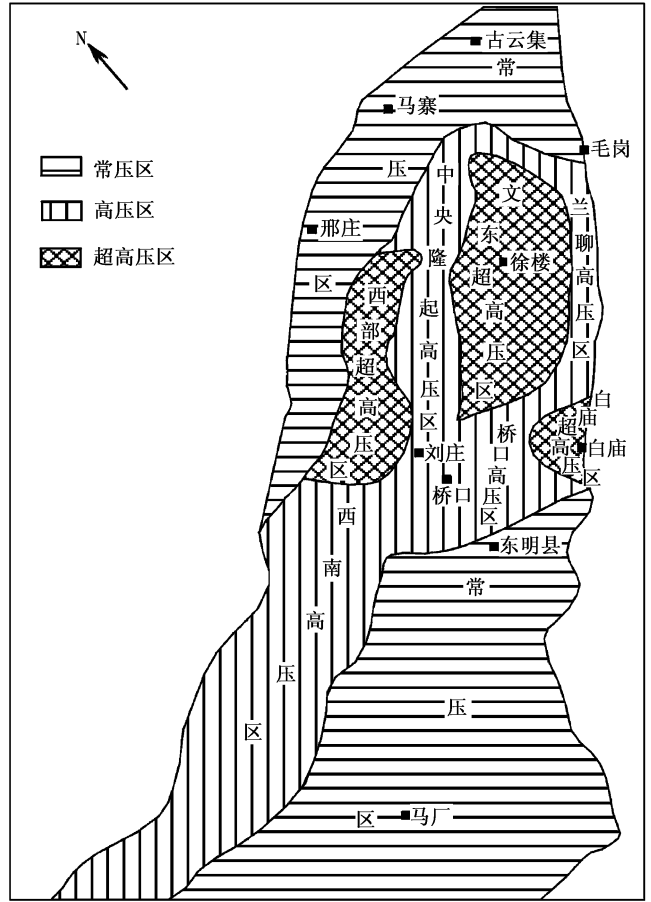


图 3 东濮凹陷沙三<sup>3</sup>层系压力分布图

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**MAIN ABSTRACTS**

**273 Method and Practice of Subtle Reservoir Exploration**

——By Taking Biyang Depression for Example

JIANG Shu (CNOOC Research Center, Beijing 100027; China University of Petroleum, Beijing 102249)  
WANG Hua (China University of Geosciences, Wuhan 430074)

**Abstract:** The success of subtle reservoir exploration in marine and continental basin (depression) is because of the existence of sedimentary and structural slope breaks, while it is at initial stage in the fault basin without slope break. Through a study of Biyang Depression, methods and techniques are established for exploration of subtle reservoirs in the fault and lake basins without slope break. The methods and techniques are based on principle of “point line plane body plane line point” of sequence stratigraphical study, the subtle reservoirs are predicted in combination with the conditions of hydrocarbon accumulation, of which the integration of microscopic and macroscopic seismic and geology is deployed by means of seismic interpretation; 3D visualization and log constraining inversion.

**Key words:** subtle reservoir; fault basin; lake basin; slope break; oil and gas exploration; Biyang Basin

**278 Structural Style and Trap Type of Zhenwu Wubao Fault Zone in Subei Basin**

QIU Xu ming (Jiangsu Oilfield Branch Company, SINOPEC, Yangzhou 225009)

**Abstract:** The structural type of Zhenwu Wubao fault zone in Subei Basin includes sinistral step arrangement of major fault, its end is divergent, fold upward occurs in the sinistral cross location, pinnate fault is grown at both ends of the major fault. These structural styles are formed because of the inverse extension and deposition and right side torsion of the structural zone. According to the structural style of the stratum, characters of the fault and its combination correlations, the trap types of the fault zone can be classified into 4 types, such as trap of roof like fault nose, forward fault fault nose trap, horst block trap and stepped fault block trap.

**Key words:** Subei Basin; Gaoyou Depression; structural type; hydrocarbon exploration

**281 The Geochemistry Characteristics Near the Earth Surface in Deep Basin Gas Reservoirs of Northern Ordos Basin**

ZHU Hong quan (Chengdu University of Technology, Chengdu 610059; Southwest Branch Company, SINOPEC, Chengdu 610081)

**Abstract:** The upper Palaeozoic reservoirs in the northern Ordos Basin are deep basin gas reservoirs. It can be divided into gas reservoirs and water areas from the south to north. Gas areas distribute in the south near source and hydrocarbon accumulation are controlled by the distribution and physical properties of the sandstones, pressure in the gas reservoirs indicates negative abnormality without marginal water and bottom water. The upward and microscopic diffusion of hydrocarbon is weak, near surface geochemistry background field is low, the water area is distributed in the north, which is far from the source rocks, and its hydrocarbon accumulation is controlled by the structure, pressure in the gas reservoirs is normal with marginal water and bottom water. Hydrocarbon is strongly diffused upward, where near surface geochemistry background field is relatively weaker. Based on the characters stated above, the geochemistry characteristics and abnormal patterns between gas and water areas are established for gas water interface of deep basin reservoirs. The abnormal pattern is that the steep background area is the gas water interface of the deep basin gas reservoirs, and the gas reservoirs in the water areas are mainly the circular and semi circular abnormal patterns.

**Key words:** near surface; geochemistry character; deep basin gas reservoir; abnormal pattern; gas water interface; Ordos Basin

**289 The Mudstone Fracture Reservoirs in Central Wenliu Graben of Dongpu Depression**

HUANG Long wei (Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550002; Zhongyuan Oilfield Branch Company, SINOPEC, Puyang 457001)

**Abstract:** The mudstone fracture reservoir forming conditions are analyzed, its forming mechanism is discussed and the method for recognizing the mudstone fracture reservoirs are analyzed from the aspects source rocks, deposition construction conditions, fracture property and its preserved conditions. It is considered that the source rocks are mainly from the system itself, the deposition con

struction has evident constrain for hydrocarbon accumulation, the mudstone fracture growing is the key factor for hydrocarbon accumulation, the sealing of salt rock has the particular condition for the hydrocarbon accumulation, oil and gas in the source rocks are enriched and accumulated along the fracture reservoirs by way of miscible shove, the geologic information, logging information, seismic information and well drilling information shall be integrally considered for the mudstone fracture reservoirs. Eventually the characteristics and its distribution rules for forming the mudstone fracture reservoir in Ess of central Wenliu graben of Dongpu Depression are described.

**Key words:** Dongpu Depression; mudstone fracture reservoir; seismic recognition; depositional construction; forming mechanism

### 296 Analysis on Oil and Gas Exploration Potential in Chenjiazhuang Uplift

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**Abstract:** The hydrocarbon migration conditions and gas reservoir distribution laws in Chenjiazhuang Uplift Area are analyzed. It is considered that the activities at the late stage of sedimentation of Minghuazhen Formation stops and effectively reduces the overflow and diffusion, which are the basic conditions for shallow gas reservoir formation in Chenjiazhuang Uplift, while the gas reservoir distribution is controlled by the tectonic background and sedimentary facies belt. Through analyzing the exploration potential, it is considered that mid Chenjiazhuang Uplift and Yanjia Area are the zones where hydrocarbon is enriched, its exploration orientation shall be focused on the recognized class I potential area, in Shengbei fault conditions of hydrocarbon accumulation are excellent and exploration degree is relatively low, potential is higher for mid shallow gas exploration at the second step, and the study of hydrocarbon accumulation shall be emphasized in west Chenjiazhuang, while the traps in Guantao Formation are the targets for further exploration.

**Key words:** Chenjiazhuang Uplift; natural gas; hydrocarbon exploration; oil bearing system; potential for exploration; seismic exploration; key technique

### 300 The Characteristics of Natural Gas Accumulation in Zhujiadun Area of Yancheng Depression

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**Abstract:** The natural gas source in Yancheng Depression is mainly from the Mesozoic Palaeozoic. The vertical migration conditions for E1f is the same with that of K2t, Type I cap rock is developed in E1f2 and upper of E1f1. Type II cap rock is developed in K2t, mid porosity and low permeability reservoirs are developed in E1f, low porosity and extremely low permeability reservoirs are grown in K2t. based on the analysis of hydrocarbon accumulation period, in the studied area, the extension time of gas injection is longer, which happens in late Eocene Neocene, especial at the late period of late Eocene and at the end of Neocene there existed 2 major oil and gas packing process, of which the 2nd is dominated. Because the period of transformed by Wubao movement is earlier than that of the 2 major packings of Yancheng natural gas, thus these traps are the beneficial positions of natural gas accumulation.

**Key words:** natural gas; property of hydrocarbon accumulation; fluid wrap; fracture; reservoir; cap rock; Yancheng Depression

### 304 Application of 3D Fluorescence Analysis Technique in Hydrocarbon Exploration in Huqing Oilfield of Dongpu Depression

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LU Xin hua (China University of Geosciences, Wuhan 430074; Zhongyuan Oilfield Branch Company, SINOPEC, Puyang 457001)

**Abstract:** The basic principle of a 3D fluorescence test technique is used. Based on the analysis of aromatic compositions of crude oil, the crude oil in Huqing Oilfield of Dongpu Depression is divided into 5 types and source rocks are divided into 3 types according to its main parameters of emitting wave length, main excitation wave length, primary and secondary peak fluorescence strength. It is considered that the crude oil distributed in different fault blocks at the second step of Huqing Oilfield is the outcome of mixture of low mature mature oil in the early hydrocarbon genetic cyclic period.

**Key words:** organic geochemistry; 3D fluorescence; aromatics; type of crude oil; type of source rock; hydrocarbon exploration; Dongpu Depression

### 307 Characteristics of Upper Palaeozoics Sandstone Reservoirs in the Middle of Ordos Basin

ZHANG Xiao li (Changan University, Xi'an 710054)

**Abstract:** The upper Palaeozoic sandstone reservoirs in Ordos Basin are mainly consisted of delta distributary channel sandstones, the rock types are mainly of quartz sandstones, debris quartz sandstones and debris sandstones, composition maturity and structural maturity are mid poor, porosity