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# 东营凹陷北带砂砾岩扇体勘探技术与实践

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**摘要:** 东营凹陷是东部陆相断陷湖盆一典型代表,其北部陡坡带特殊的构造背景,使沉积地层中各种成因的砂砾岩扇体极为发育,并成为勘探的重要目标。近几年,针对北部陡坡带6种成因的砂砾岩扇体进行了详细的地质地震相模式研究,确立了扇体在同层沉积的平面分布、纵横向演化及剖面组合模式,并针对扇体的复杂性,总结了识别与描述扇体的层位标定、横向往追踪、综合描述和预测技术及勘探方法,提高了该带的勘探效果,也为类似陆相断陷湖盆砂砾岩扇体勘探提供了成功的经验。

**关键词:** 东营凹陷;陡坡带;扇体;油气藏;勘探技术

**中图分类号:** TE111 **文献标识码:** A

## 1 前言

东营凹陷北部陡坡带地理上位于东起永安镇经垦利、利津向西到单家寺的弧形带。该带在下第三系沉积时期具有坡度陡、物源近及古地形起伏较大和构造活动强烈等特点。沉积地层中各种成因的砂砾岩扇体极为发育。扇体侧向上尖灭在生油深洼陷中,具有比较好的油源条件,同时其成藏条件也极其复杂。因此,有着比较曲折的勘探历程。在60年代至90年代初,砂砾岩扇体勘探以兼探为主,由于对扇体复杂性认识程度差、研究程度不够深入、也缺乏相应的技术手段,总的勘探效果不理想。近几年,三维地震工作的大量开展、地质认识程度的不断深化以及新技术的不断应用,使砂砾岩扇体勘探进入一个新的阶段,由过去的兼探对象上升为主探目标,相继发现了一系列不同类型的砂砾岩扇体油气藏,探明了一批优质储量,展示了良好的勘探前景,并形成了一套针对砂砾岩扇体的勘探技术,对类似湖盆砂砾岩扇体勘探有重要的参考价值。

## 2 砂砾岩扇体发育特征及成藏规律

### 2.1 砂砾岩扇体沉积类型及特征

东营凹陷北部陡坡带位于东营古湖盆的陡岸边缘(图1)。在早第三纪,东营凹陷北岸为一近东西走向的古断剥面,具有坡陡( $15^{\circ}\sim 30^{\circ}$ )、沟梁相间的古地貌特征。由于控制东营凹陷沉积的陈南基岩断裂在发育过程中次级断层持续活动影响,斜坡上形成了高低不平、宽窄不一的断阶。在这种特殊的构造背景下,在不同部位分别形成了浊积扇、辫状河三角洲、扇三角洲、近岸水下扇、陡坡深水浊积扇、近岸砂体前缘滑塌浊积扇等六类砂砾岩扇体<sup>[1,2]</sup>。

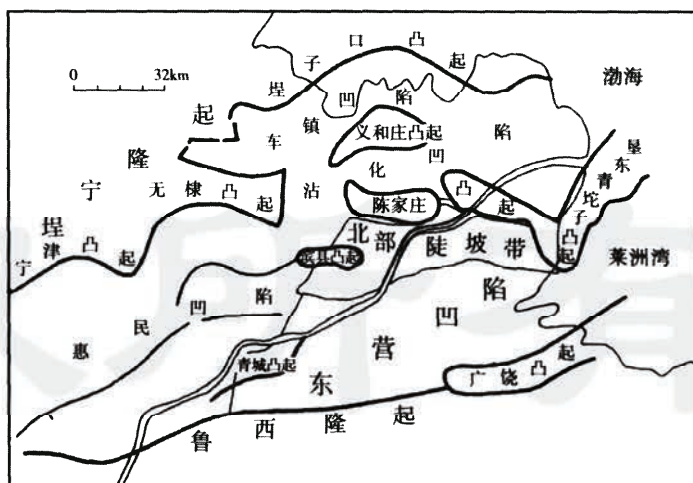


图1 东营凹陷区域构造位置图

Fig. 1 Regional structure outline map of Dongying Depression

## 2.2 砂砾岩扇体地震相模式

不同成因类型的地质体,具有特定的地震响应特征<sup>[3]</sup>。对于陡坡带的砂砾岩扇体,这种地震响应特征尤为明显。总结东营凹陷北带已钻探的各种砂砾岩扇体的沉积模式及其地震响应特征,建立了一套地震相识别模式(图 2)。

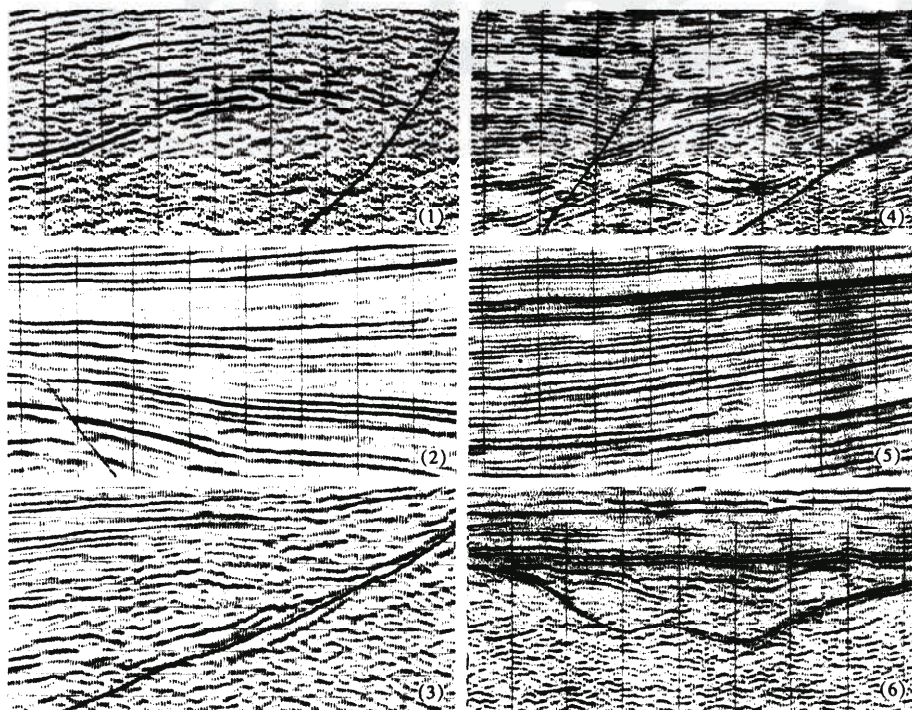


图 2 陡坡带砂砾岩扇体地震相图

Fig. 2 Seismic facies map of sandy-conglomeratic fans in the steep slope

1—陡坡深水浊积扇;2—滑塌浊积扇;3—近岸水下扇;4—扇三角洲;5—辫状河三角洲;6—洪积扇

## 2.3 砂砾岩扇体时空展布特点

### 2.3.1 构造运动控制古地貌,古地貌与古气候控制砂砾岩体的时空展布

伸展断陷构造运动产生并控制了东营单断盆地。在盆地发展过程中,边界断层活动的继承性和不均一性使古断面呈现沟、梁相间的古地貌。沿着这些大大小小的沟谷,发育季节性河流,携带的沉积物经断崖入湖快速卸载,沉积形成砂砾岩扇体。

东营凹陷北部陡坡带,在沙四末—沙三中时期砂砾岩扇体最为发育。但在不同时期不同部位砂砾岩扇体类型及展布特点也有较大差异。

(1)沙四后期 东营凹陷北部陡坡带由东部的永安镇向西部的胜北、郑南地区水体变浅,坡度变缓,相应地沉积类型由较大型的近岸水下扇向扇三角洲、冲积扇过渡。

(2)沙三早、中期 胜北地区深陷,发育了较东、西两侧更大规模的水下扇体。此时,西部地区的郑家和滨县两扇群由于古地形抬升而逐渐变小甚至消失;而东部的盐家地区的近岸水下扇仍继承性发育,但规模变小。

(3)沙三晚期 陡坡带由东向西水体变深,相应地在西部滨县、单家寺、王庄地区发育近岸水下扇(该区的水下扇持续至沙一期),而坨庄以东地区则广布三角洲体系。

### 2.3.2 陡坡带在横向上沟、梁相间起伏变化的特点,控制了 5 大扇群组合 10 个大的复合扇体

东营凹陷北部陡坡带由西到东发育十沟十一梁,发育了 10 个较大的扇体群(图 3)。可划分为 5 大组合。由



西到东依次为:滨南扇群组合、利津扇群组合、胜北扇群组合、盐家扇群组合和永北扇群组合。其中滨南扇群组合包括滨县扇群和单家寺扇群;利津组合包括郑家扇群、王庄扇群和宁海扇群;胜北组合包括坨120、125、坨121、123等扇群;盐家组合包括盐16、盐18扇群;永北是一特殊的扇体类型,自成体系。这些扇体群总体上表现为相带由西向东变窄、相变加快、纵向上叠合厚度增大。受构造运动及古地貌变迁的控制,陡坡带砂砾岩扇体在纵横向分布特点及沉积类型也发生过东西变迁,呈翘翘板方式过渡,具有一定的规律性。

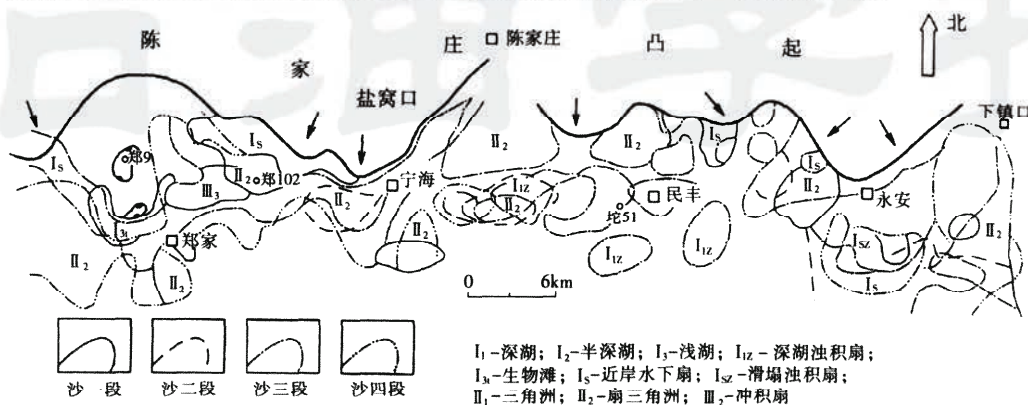


图3 东营凹陷北部陡坡带扇体分布图

Fig. 3 Fans distribution graph in northern steep slope in Dongying Depression

### 2.3.3 陡坡带的垂向剖面结构特点决定了砂砾岩扇体组合模式

东营凹陷北部陡坡带在有限后退型边界断裂条件控制下,形成了相应的古地貌形态。除横向上呈沟、梁相间的古地貌特征外,其剖面上的特征是,从边缘凸起向凹陷倾没的斜坡上发育了高低不一、宽窄不同的断阶。在这种构造背景控制下,扇体从盆缘至洼陷呈有规律的组合、迭置。表现为断阶外侧斜坡以冲积扇、扇三角洲砂砾岩扇体为主,断阶上则主要发育近岸水下扇砂砾岩扇体,局部发育洪积扇或辫状河流三角洲砂砾岩扇体,断阶内侧向湖盆倾没部位则主要发育近岸水下扇及浊积扇。

### 2.4 砂砾岩扇体成藏规律

通过近几年东营北带砂砾岩扇体发育特点及成藏条件的研究,认识到东营北带砂砾岩扇体具有以下成藏规律(图4)。

#### 2.4.1 沙四末—沙三中时期形成的扇体最有利于成藏

沙四末—沙三中时期发育的扇体规模较大,以水下扇体为主,埋藏适中,物性较好,又与主要的生油岩穿插

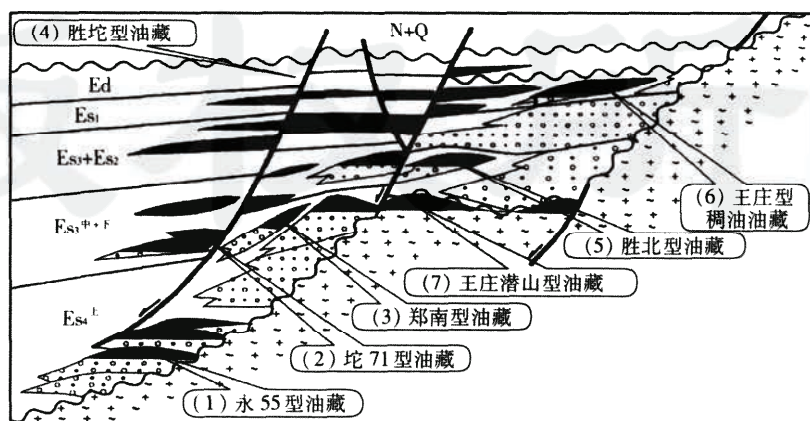


图4 东营凹陷北部陡坡带油藏模式图

Fig. 4 Reservoir model graph in northern steep slope in Dongying Depression

在一起,成藏条件最为有利。

#### 2.4.2 深入到生油岩中的扇体成藏条件最好

深水浊积扇及一些具滑塌性质的扇体,深入到生油岩之中,成藏条件最为有利;近岸水下扇直接与生油岩接触,也是很好的储集类型;扇三角洲砂体,一般不与生油岩直接接触,成藏条件略差,但当通过断层使其生、储、盖配置得当时,也是好的储集类型;靠近岸边的以红色沉积为主的冲积扇(洪积扇),物性差,远离油源,不利于成藏。

#### 2.4.3 扇中亚相最有利于储油

砂砾岩扇体油藏往往具有强非均质性,高产扇体一般均与扇中亚相和浊积扇体有关,如盐 16、永 921、坨 121、坨 71 等,坡降度较大的地区,扇根成份混杂,物性差,一般情况下可作为扇中亚相油藏的封堵层,如永 921、922 等就属此类油藏。

#### 2.4.4 具背斜圈闭条件的扇体油气往往富集高产

陡坡上的小型背斜构造形态往往与砂砾岩扇体有关,而且具有这种背斜构造形态的扇体储集条件通常都比较好,是最理想的圈闭类型,易形成富集高产油气藏。如盐 16、18、坨 71、121、123、利 371、561 等,都是扇体类圈闭中的高产井。

#### 2.4.5 在特定的地质条件下,水下成因扇体无需反倾亦可成藏

如永 921 扇群中的部分扇体,由于扇根岩性致密,造成侧向封堵成藏。

东营凹陷北部陡坡带,在主控断裂及次级同生断层的控制下,呈退积式发育一系列不同类型砂砾岩扇体,它们以不同方式与沙四上一沙三段油源直接或间接沟通,从而成为油气运移聚集的有利场所,并由湖盆至凸起,形成有规律的聚集。在陡坡下部主要发育与扇体有关的岩性油气藏。在断阶位置则主要发育与扇体有关的构造—岩性油藏,湖盆边缘则主要发育与扇体有关的地层超覆及不整合油藏。东营凹陷北部陡坡带扇体油气藏有规律分布,构成了陡坡带复式油气藏聚集模式,据此可以在不同部位有针对性地选择勘探目标。

### 3 砂砾岩扇体地震勘探技术

在搞清砂砾岩扇体发育特征及成藏规律的前提下,目前普遍适用的砂砾岩扇体勘探技术,主要是以三维地震为主的扇体识别及描述技术<sup>[1,4,5]</sup>。主要包括层位标定、扇体边界确定、扇体旋回体划分、储层预测、(岩性、物性、速度)厚度求取等内容。

#### 3.1 砂砾岩扇体识别技术

##### 3.1.1 层位标定技术

砂砾岩扇体顶底界面反射层位的标定是砂砾岩扇体识别、描述的关键。东营凹陷北带砂砾岩扇体速度均高于上覆围岩,扇体顶界面在负极性显示地震剖面上均对应波谷,正极性显示地震剖面上对应波峰。在东营凹陷北带主要采用了两种标定方法。即:VSP 资料标定法和合成记录标定法。

##### 3.1.2 时频分析技术

陡坡带砂砾岩扇体主要特点是纵向上厚度大、泥岩隔层小,为多期扇体叠置形成的多旋复合体,每一旋回体内部具有连通性,不同旋回体之间连通性差,多具独立的油水系统。应用时频分析进行扇体旋回体划分,主要是提取薄互层结构信息,通过傅立叶变换,将时间域的地震记录转换成频率域,分析其变化规律,从而研究地层结构,分析多期沉积旋回体的相互关系、空间展布。它包括垂直频率—时间谱扫描分析、水平频率—时间谱扫描分析等。

##### 3.1.3 GLOG 预测分析技术

GLOG 技术最大特点是可以得到反映速度变化的剖面,扇体与围岩速度差异大,经过 GLOG 标定扇体,甚至能对砂砾岩扇体小旋回单体进行精细标定和几何形态描述。在东营凹陷北带砂砾岩扇体勘探过程中应用该

技术取得了比较好的效果。如对王庄地区郑408等扇三角洲砂体的标定、追踪描述,效果比较理想。

### 3.2 砂砾岩扇体预测描述技术

#### 3.2.1 测井约束地震反演技术

测井约束地震反演是一种基于模型的波阻抗反演技术。这种方法利用测井资料,以地震解释的层位为控制,从井点出发进行外推内插,形成初始波阻抗模型;然后利用共轭梯度法,对初始波阻抗模型不断进行更新,使建立模型的合成记录最佳逼近于实际地震记录,此时的波阻抗模型便是反演结果。在东营凹陷北带砂砾岩扇体勘探过程中该技术应用较广,并取得较好效果,如永921扇体。

#### 3.2.2 扇体边界确定技术

砂砾岩扇体边界主要从地震剖面上直接确定,一般而言,根据扇体包络面形态,同相轴尖灭、迭置、极性反转、相位明显变弱基本能确定边界,特别是GLOG处理、道积分等技术给扇体划分、边界确定带来了方便。另外,针对特定的扇体求其门槛振幅和门槛频率可以更好的确定扇体边界。

#### 3.2.3 扇体储层厚度求取技术

陡坡带砂砾岩复合扇体叠合厚度大,一般大于 $\lambda/4$ ,应针对扇体特征、横向变化具体分析以确定其厚度求取方法。对厚度大于 $\lambda/4$ 的扇体,可直接从地震剖面、GLOG处理、道积分剖面上拾取。在确定砂砾岩扇体顶、底界面反射后,利用如下公式求取其厚度。

$$\Delta H = 1/2V \cdot \Delta t$$

式中  $\Delta H$  为储层厚度,m; $V$  为储层层速度,m/s; $\Delta t$  为储层地震双程反射时间。

相关分析校正公式为

$$y = 0.86587x + 7.10170$$

式中  $y$  为校正后的扇叶体厚度,m; $x$  为未校正扇叶体地震响应厚度,m。

对于厚度小于 $\lambda/4$ 的砂体,可采用振幅频率法求取其厚度。

其它新的技术,如测井技术、油气检测技术等也在砂砾岩扇体的勘探中进行了尝试性的应用,但还有待于今后进一步发展完善。

## 4 结 论

1. 东营凹陷北带在特殊的构造背景下,形成了浊积扇、辫状河三角洲、扇三角洲、近岸水下扇、陡坡深水浊积扇、近岸砂体前缘滑塌浊积扇等六类砂砾岩扇体。

2. 砂砾岩扇体类型多,时空展布复杂,构造运动控制古地貌,古地貌与古气候控制砂砾岩体的时空展布。

3. 东营凹陷北带沙四末—沙三中时期形成的扇体最有利于成藏,深入到生油岩中的扇体成藏条件最好,扇中亚相最有利于储油,具背斜圈闭条件的扇体油气往往富集高产,在特定的地质条件下,水下成因扇体无需反倾亦可成藏。

4. 在搞清砂砾岩扇体发育特征及成藏规律的前提下,针对不同区域和类型的扇体,要选择比较实用的扇体识别与描述技术,主要包括层位标定、扇体边界确定、扇体旋回体划分、储层预测、厚度求取等。

### 参 考 文 献

- [1] 刘泽容,等. 油藏描述原理与方法技术[M]. 东营:石油大学出版社,1993:21~32.
- [2] 姜在兴,等. 层序地层学原理及应用[M]. 北京:石油工业出版社,1995:18~33.
- [3] 张万选,等. 陆相地震地层学[M]. 东营:石油大学出版社,1993:130~154.
- [4] 王宝言,朱明,等. 含油气扇体勘探经验、技术与方法[A]. 胜利油田勘探开发论文集[C]. 北京:地质出版社,1997:38~45.
- [5] 杨凤丽,等. 埕岛油田河流相储层地震描述方法[J]. 石油学报,1999,20(4):24~28.

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PETROLEUM MIGRATION — ACCUMULATION FLUID DYNAMIC SYSTEM ANALYSIS IN WESTERN QAIDAM BASIN, CHINA ACTA 2000, 21(5): 12~15.

KANG Yong-shang, et al. (*Petroleum University, Beijing 102249, China*)

The basic principal of petroleum migration-accumulation fluid dynamic system analysis consists of firstly dividing the studied basin into different fluid dynamic systems, and then assessing petroleum migration-accumulation conditions of each system according to its type. This principal is applied to western Qaidam Basin which was vertically divided into three petroleum migration-accumulation fluid dynamic systems, including  $N_2^3-N_2^2-N_2^1$ ,  $N_2^1-N_1-E_3^2$  and  $E_3^2-E_3^1$ . These systems belong respectively to gravity-driven flow type, compaction-driven flow type and fluid compartment type. Petroleum migration-accumulation conditions are studied in the three systems. It is indicated that the further exploration should be focused on two layers, that is,  $N_1$  and  $E_3^1$ .

**Key words:** petroleum migration-accumulation; fluid dynamic system; pressure; temperature; petroleum exploration; Qaidam Basin

THE QUANTITATIVE IDENTIFICATION MODEL OF THE EVOLUTION DEGREE OF MIXING NATURAL GAS SOURCE MATERIAL AND THE APPLICATION OF THIS MODEL ACTA 2000, 21(5): 16~20.

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The evolution degree of sapropel-type Kerogen and humic-type Kerogen may be defined by the feature of gas components. But this method is not applicable for mixing gas source material including sapropel-type Kerogen and humic-type Kerogen. In this paper, a general formula applicable for mixing gas source material including sapropel-type Kerogen and humic-type Kerogen was built up, based on the formulas given by previous scholars. With this formula, it is identified that the natural gas of Tertiary in North Fault Block in Qaidam Basin is from the coal-bearing series of Jurassic and the natural gas in west depression is from the source rocks with II<sub>A</sub>-I Kerogen type of Tertiary.

**Key words:** gas; Kerogen type; evolution degree; quantitative model

GEOLOGICAL MODELING FOR INTEGRATED EVALUATION OF SANDSTONE RESERVOIR OF FLUVIAL FACIES ACTA 2000, 21(5): 21~26.

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Taking the reservoir geological modeling and reservoir quantitative evaluation modeling of Ng group in Miaobei, Jidong Oil-field as an example, directing against the complex block-fault area of fluvial deposition, to quantitatively study lithology, physical property and oil of reservoir, has been expounded, according to the technical clue of model constraining, drilling control and seismic extrapolate, using geostatistics technology and the information combination of geology, logging and testing, based upon 3-D logging-constrained inversion. In the meantime, by the effective superposition of structure, oil reservoir and oil-gas-water properties in 3-D space, the reservoir position and properties are described accurately and the 3-D video-model has been built up, which can quantitatively reflect the properties of oil and gas field. Through examination of practice, the precision of modeling has been largely raised. Thus, the credible geological basis has been provided for high-speed and high-effective oilfield development and for utilization of geological reserves. And the geological model has been also provided for numerical reservoir simulation to formulate the development plan and play an important role in the reservoir prediction.

**Key words:** reservoir geological modeling; reservoir quantitative evaluation; 3-D logging-constrained inversion; geostatistics; sandbody model; attribute model

EXPLORATION TECHNIQUE AND PRACTICE OF SANDY-CONGLOMERATIC FANS IN THE NORTHERN PART OF DONGYING DEPRESSION ACTA 2000, 21(5): 27~31.

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Dongying Depression is a typical continental rift basin in eastern China. Against the background of the special structure of

the northern steep slope, many kinds of sandy-conglomeratic fans have been formed in the strata, which become the major exploration target now. On the basis of integrated studies of geologic and seismic faces about six kinds of those fans, the paper presents the areal distribution in the same formation, evolution in horizontal or vertical direction and combined mode of sections. On account of the fans complexity, author summarized the exploration technique and methods of identifying, tracing, describing and predicting the horizons representing fans, which have lead to exploration effect in this area and provided successful experience for the exploration of this kind of fan.

**Key words:** Dongying Depression; steep slope; fan; reservoir; exploration technique

IDENTIFYING TYPES OF CARBONATE RESERVOIR BASED ON ELECTRICAL CONDUCTION EFFICIENCY ACTA 2000, 21(5): 32~35.

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This paper puts forward a method to distinguish reservoir types in carbonate formation based on the electrical conduction efficiency. Relationships between the rock electrical conduction efficiency and the cave size, fracture width, and throat diameter are presented. These relationships show that, 1) In the condition that only fractures and caves exist, the electrical conduction efficiency of the rock increases rapidly along with the increasing of fracture width, especially when caves are small; 2) When only throats and caves exist, the electrical conduction efficiency of the rock increases along with the increasing of throat diameter; 3) The electrical conduction efficiency of the rock decreases along with the increasing of cave size. Thus, the rocks electrical conduction efficiency is high when fractures exist in rocks, while low when caves exist. Electrical conduction efficiency can be used to distinguish types of carbonate reservoir. This method has been applied in the Ordovician carbonate reservoir located in the middle of the Tarim Basin of China with good results.

**Key words:** well logging; well logging interpretation; carbonate rock; reservoir type; electrical conduction efficiency

RESEARCH SIGNIFICANCE OF MACRO-ALGAE FOSSILS IN THE STUDY OF SEDIMENTARY FACIES IN ANSAI OILFIELD ACTA 2000, 21(5): 36~38.

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A large number of limnetic macro-algae fossils were found in the Chang6 reservoir in Ansai Oilfield, which proved the existence of macro-algae in the Mesozoic. The limnetic macro-algae grow mainly in mountain streams, brooks and lakes. Because of a little bit rapid flowing in the streams or brooks, macro-algae fossils were not easily preserved. Therefore they were essentially preserved in lakes, where the water body is relatively calm. Macro-algae fossils are liable biological markers of freshwater lakes and typical underwater biocoen.

Macro-algae fossils in the Chang6 reservoir in Ansai Oilfield have mainly six genera that can be divided into four categories. Different structures of the four categories reflect different depth and degree of calmness of the water-body, and represent four sedimentary regions, which instructed the division of sedimentary micro-facies and the output combinations.

**Key words:** macro-algae; ecological environment; sedimentary facies; Ansai Oilfield

## OIL FIELD DEVELOPMENT

THE ECONOMIC EVALUATION METHOD OF RECOVERABLE RESERVES AND STIMULATION MEASURES IN HIGH WATER-CUT MATURING FIELD ACTA 2000, 21(5): 39~44.

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Water flooding reserve can be classified into different stages according to water cut and oil production variations. To pursue more benefits from water flooding reserve, it is necessary to analyze the important adjusting measures and make correct economic evaluation in accordance with characters of different stages so as to take measures in response to the main influence factors. This paper mainly analyses the recoverable reserves of high water-cut stage and economic evaluation methods of well stimulation, expounds the economic analysis of pattern encryption adjustment and introduces the calculating methods of economic recoverable reserves and economic production of well stimulation. Through many years' practice, there have been a lot of evaluation methods