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黄河口凹陷渤中34区明化镇组下段油气输导体系

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摘要:通过对渤海湾盆地黄河口凹陷渤中34区输导体系特征及其与中浅层油气成藏规律关系的研究表明,对油气运移起重要作用的输导体系主要有断层和砂体,油气的富集受控于断层和砂体的分布,且断层与砂体耦合接触关系既决定了输导体系的有效性,也决定了浅层明化镇组下段(明下段)油气藏的形成与分布。通过建立断层与砂体耦合接触半定量静态模型,证实断层与砂体的接触面积是影响油气充满度、储量丰度和油柱高度的重要参数,指导了渤中34-B构造的井位部署,渤中34-B-3D井砂体的含油气性预测结果与实钻吻合较好。实践证实,断层与砂体耦合接触关系半定量描述方法对成熟探区开拓勘探空间、寻找潜在油气藏具有重要的理论和应用价值。

关键词:断层 输导体系 断层与砂体耦合接触关系 油气运移 黄河口凹陷

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油气运移的输导体系是连接烃源岩与圈闭的"桥梁",其决定着油气运移的路径和方向,并将成藏要素与成藏作用有机地结合,控制着油气的成藏[1]。断层、不整合面及渗透性砂体均可作为油气运移的输导通道,这些输导要素在三维空间内的组合及配置共同控制了油气的成藏特征及其分布规律[2-5]。然而,目前关于输导体系的研究仅限于区域的定性描述,缺乏在区块范围内的精细解剖以及对油气分布控制作用的研究,尤其是断层与砂体耦合接触关系,断层—砂体半定量、定量研究对浅层油气藏分布、油气充满度及油柱高度的影响等研究相对薄弱。笔者以渤海湾盆地黄河口凹陷油气富集程度相对较高的渤中34区为例,系统研究其明化镇组下段油气运移的输导体系,建立研究区断层与砂体耦合接触关系的半定量研究思路及方法,并指导油气滚动勘探获得突破,对黄河口凹陷以及相似地区浅层油气藏的勘探具有重要意义。

1 区域地质概况

黄河口凹陷位于渤海湾盆地济阳坳陷的东北部,其北侧为渤南凸起,南侧为垦东—青坨子凸起和莱北低凸起,东侧为庙西凹陷,西邻沾化和埕北凹陷,是近东西向控凹断裂和北北东向走滑断裂共同控制下形成的新生界北断南超的箕状凹陷。其二级构造单元可划分为渤中25-1构造带、西北次洼、西南次洼、西南缓坡带、中央隆起带、东部次洼和东部断阶带等[6]。

渤中34区位于黄河口凹陷的中央隆起带,被凹陷2大生烃中心所包围,是油气运移的有利指向区,具有晚期、近源、优势成藏的特征[1,6]。其古近系沙三段和沙二段、沙一段发育2套主力烃源岩;以沙二段和沙一段辫状河三角洲砂体、东营组滩坝砂体、馆陶组辫状河砂体及明下段浅水三角洲砂体为主要储层。根据已发现井的油气分析结果表明,平面上渤中34区油气主要沿构造高部位及构造脊富集,表现出南北分带的特征,以渤中33-1次隆带为界,以南油气主要富集于深层,以北油气主要富集于浅层;纵向上,研究区含油层系较多,主要集中于沙二段、沙一段、东营组及明下段,其中明下段已探明石油地质储量占总探明储量的56%,其次为沙二段及东营组,分别为35%和9%。从油气分布与烃源岩的位置关系可以看出,研究区明下段为他源型油气藏,由于远离烃源岩,油气输导体系特征及油气运移成为制约其油气藏分布的关键问题。

2 油气输导体系

在沉积盆地中,断裂、不整合面和渗透性地层(如骨架砂体)等构成油气的运移网络,其不同的配

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置方式构成流体复式输导体系。渤中34区的油气输导体系主要包括2类，分别为具有运移能力的断层输导体系和具有较好物性条件的砂体输导体系。

2.1 断层输导体系

研究区断层非常发育。中生代末期燕山运动和始新世—渐新世喜马拉雅运动使区内北东—北东东向雁行式断层与北东东—近东西向断层发育，构成'Z'字型网格状构造。在新近纪近南北向引张作用影响下，部分早期断层继续活动，并形成众多新的东西向断层[7-8]。根据研究区断层规模及断穿层位，可将其划分为2类，分别为断穿古近系、新近系继承性活动的大断层和受晚期新构造运动影响形成的次级断层。其中前者与深部近于直立的走滑断层共同控制沙河街组和东营组圈闭的形成（图1），该类断层将深部烃源岩与浅层储层相沟通，构成油气垂向输导体系，使油气在深、浅层圈闭中富

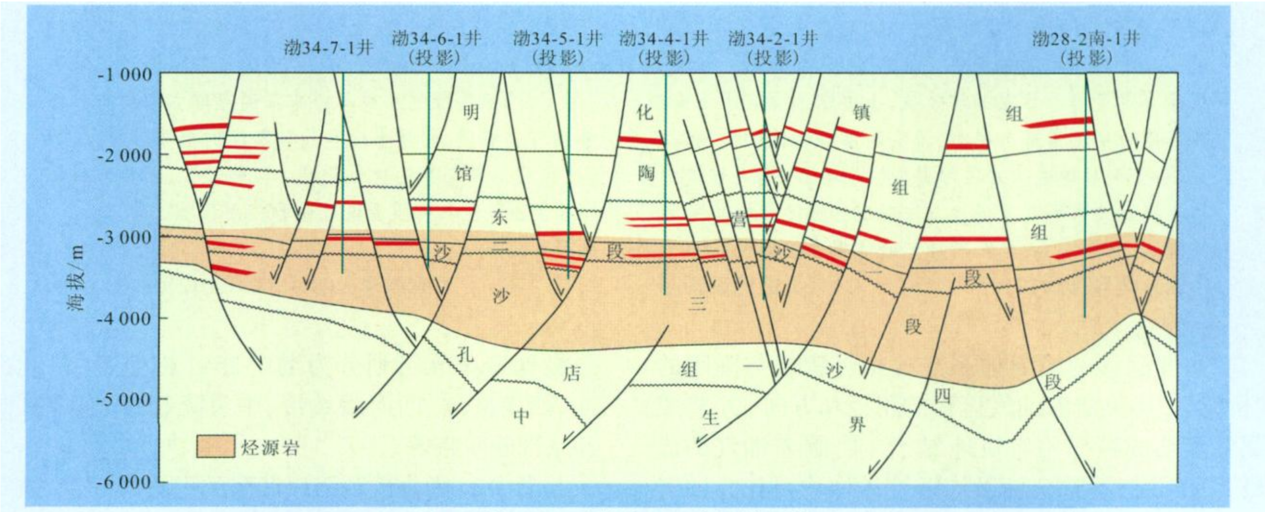

图1 黄河口凹陷渤中34区断层输导体系

集形成大型油气田，例如探明石油地质储量超过亿吨的渤中28-34油田群即为受该类断层控制形成的。而受晚期新构造运动形成的次级断层主要指与大断层伴生或由于差异压实作用在新近纪发育的断层，其断距小、延伸距离短，对地层沉积无明显的控制作用，且该类断层与早期断层相互切割，沟通了沙河街组烃源岩与浅层储层，构成油气从烃源岩运移至浅层圈闭的输导体系，对研究区明下段油气的运移和聚集起到一定的输导作用。

2.2 砂体输导体系

砂体的分布特征明显受沉积相展布的影响，决定了油气侧向运移方向及油气藏分布[9]。渤中34区主要发育4种类型砂体，分别为沙二段和沙一段辫状河三角洲砂体、东营组滩坝砂体、馆陶组辫状河砂体和明下段浅水三角洲砂体，不同层系砂体对油气输导及油气藏分布的控制作用存在较大差异。

研究区油气主要来自沙三段烃源岩。沙二段和沙一段为辫状河三角洲沉积，砂体厚度较大、分布较广，且直接覆盖于沙三段烃源岩之上，油气运移条件优越、富集程度较高，其油气藏分布主要受控于砂体厚度及其物性的变化。东营组滩坝砂体的分布受古水下隆起控制，分布广，单砂体厚度小于10 m，其油气藏分布主要受控于圈闭的有效性。而馆陶组和明下段砂体在纵向上距烃源岩较远，其分布特征对油气聚集的控制作用与邻近烃源岩的砂体不同：在馆陶组沉积时期，整个黄河口凹陷均为辫状河沉积，砂体多呈厚层、块状，最大单砂体厚度为120 m，含砂率一般大于60%，骨架砂体是油气侧向运移中最主要的输导通道；在明下段沉积时期，渤中34区发育浅水三角洲沉积，浅水三角洲砂体与滨浅湖厚层泥岩互层，砂泥比配置合理，使其具有比河流相更有利的储盖组合关系，是目前黄河口凹陷明下段最主要的勘探层系。

3 断层与砂体耦合接触关系

研究表明，断层与砂体耦合接触关系决定输导体系的有效性，也决定了他源型油气藏的形成与分布[10-11]。剖面上，断层与砂体共形成4种断层—岩性接触关系，分别为正向正断层、反向正断层、反屋脊式和屋脊式，其中反屋脊式对于浅层油气的聚集最为有利，而屋脊式则最差（图2）。平面上，断层与河道砂体形成垂直接触、斜交接触以及无接触共3种接触关系，断层与边滩砂体形成双向面接触、双向点接触、单向面接触、单向点接触以及无接触共5种接触关系，其中垂直接触和双向面接触最有利于

浅层油气的聚集(图2)。断层与砂体的耦合接触关系控制了油气的运移方式及分布规律。目前对断层与砂体耦合接触关系的研究仅为定性分析,缺乏定量研究,为此笔者尝试建立研究区断层与砂体耦合接触关系半定量描述的思路及方法,并在此基础上探讨其对含油气性的影响。

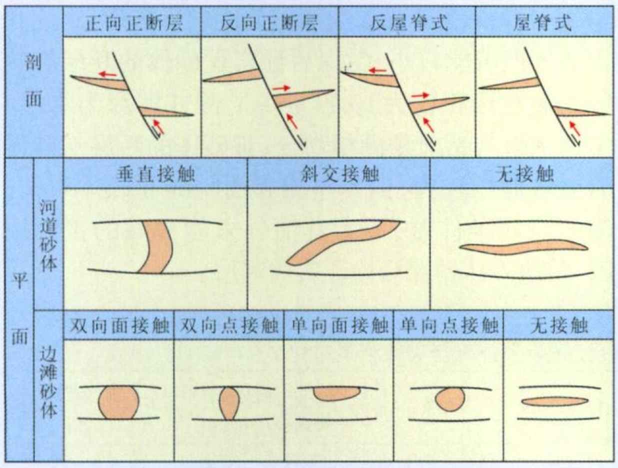

图2　断层与砂体耦合接触关系

3.1　断层与砂体耦合接触关系半定量描述方法

勘探实践证实,研究区断层与砂体的接触面积对明下段油气藏的含油气面积及充满度具有控制作用,而对断层与砂体耦合接触关系进行半定量描述是钻探前预测砂体含油气性的一种方法。该方法主要利用断层与砂体耦合接触关系半定量静态模型(根据已钻探含油气构造建立的断层与砂体接触面积和含油气性之间的关系)来推测未知模型(尚未钻探构造)的含油气性(图3)。以明下段浅水三角洲砂体为例,其假设条件为:①排除油气倒灌的可能性;②断层为油气垂向输导通道,砂体为油气横向输导通道;③断层与砂体的接触排除断面附近地震资料的影响。

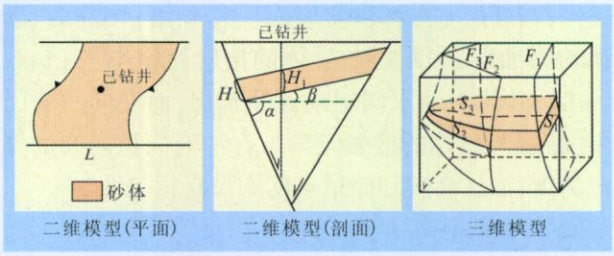

图3　断层与砂体耦合接触关系半定量静态模型

L 为断层与砂体的接触长度,km;H 为断层与砂体的接触宽度,m;H_1 为井点钻遇的储层厚度,m;β 为砂体与水平基线的夹角,(°);α 为断层的倾角,(°);F_1、F_2、F_3 分别为断层;S_1、S_2、S_3 分别为断层 F_1、F_2、F_3 与砂体的接触面积,m·km

断层与砂体耦合接触关系半定量静态模型中断层与砂体接触面积的计算公式为

$$H=\frac{H_1\sin(90-\beta)}{\sin(\alpha+\beta)} \tag{1}$$

$$S_0=S_1+S_2+S_3 \tag{2}$$

$$S_1=HL \tag{3}$$

式中:S_0 为多条断层与砂体的接触面积之和,m·km。

3.2　勘探实例

3.2.1　半定量静态模型建立

渤中 34-A 构造位于渤中 34 区北部,是受多条断层夹持形成的垒块构造,与渤中 34-B 构造(未钻探)具有相似的圈闭条件。因此,基于渤中 34-A 构造 3D 井区断层与砂体的耦合接触关系建立静态模型,3D 井区目前已有 1 口预探井和 6 口开发井,其中渤中 34-A-3D 井于明下段钻遇 7 套主要砂体,其中 5 套为油层,仅埋深为 1 114 和 1 225 m 的砂体钻遇油水界面,各砂体的含油面积及各项参数见表 1。

利用断层与砂体耦合接触关系来研究 3D 井区断层与砂体的接触面积与含油气性之间的对应关系。从相关性来看,断层与砂体的接触面积与含油气面积内的油气充满度、储量丰度具有明显的正相

表1　渤中 34-A-3D 井断层与砂体耦合接触关系统计

砂体名称	含油气性质	砂体厚度/m	L/km	α/(°)	β/(°)	H/m	断层与砂体接触面积/(m·km)	含油面积/km²	圈闭面积/km²	油气充满度,%	油柱高度/m	储量丰度/(10^4 m³·km⁻²)
3D-1114	含油水层	5.3	0.88	72	8	5.35	4.71	0.34	4.45	7.6	12	4.37
3D-1225	油水同层	4.4	2.08	72	12	4.31	8.97	1.81	2.37	76.4	24	43.94
3D-1244	油层	4.4	7.73	72	11	4.40	34.01	4.08	4.72	86.4	20	109.07
3D-1263	油层	9.0	2.13	72	10	9.00	19.17	0.19	0.52	36.5	18	23.48
3D-1673	油层	5.8	3.37	72	9	5.80	19.55	1.01	1.19	84.9	28	28.45
c15-1254	油层	6.9	4.28	72	10	6.83	29.23	2.26	4.45	50.8	35	57.64
c-1233	油层	6.0	3.53	72	11	5.94	20.97	1.08	1.52	71.1	30	61.75

关性；当断层与砂体的接触面积大于15 m·km时，砂体均为油层；当断层与砂体的接触面积小于15 m·km时，砂体为油水同层或含油水层；而在同一圈闭中，断层与砂体的接触倾角与含油气面积内的油气充满度、油柱高度和储量丰度均没有相关性。

3.2.2 应用效果

根据渤中34-A构造建立了断层与砂体耦合接触关系半定量静态模型，在此基础上对渤中34-B构造的设计井——渤中34-B-3D井预测砂体的含油气性进行预测。其中断层与砂体的接触宽度、断层倾角、砂体与水平基线的夹角以及断层与砂体接触长度等参数均为已知条件，预测砂体的厚度可根据已钻砂体与地震振幅属性之间的响应关系来确定（表2）。结果表明，预测设计井将钻遇5套砂体，其厚度分别为8，10，5，5和10 m；断层与砂体的接触面积分别为39.28，42.57，33.84，14.21和47.22 m·km；含油气面积内的油气充满度为70%（参考渤中34区断块型圈闭含油气面积内油气充满度的平均值）；其中Ⅳ砂体的断层与砂体接触面积最小，仅为14.21 m·km，低于油层与水层之间的界限值，因此其含油气性可能较小，钻探后证实Ⅳ砂体的断层与砂体的接触面积仅为10.89 m·km，测井解释为水层，实钻结果与钻前预测相吻合；Ⅲ砂体的断层与砂体的接触面积较大，但其与相邻圈闭的Ⅱ砂体对接，侧向封堵条件差，成为其油气未能成藏的主要原因；其他砂体钻探后均证实为油层。

表2 渤中34-B-3D井断层与砂体耦合接触关系预测与实钻结果对比

砂体名称	预测砂体厚度/m		L/km		α/(°)		β/(°)		H/m		断层与砂体的接触面积/(m·km)		油气充满度，%	
	预测	实钻	预测	实钻	预测	实钻	预测	实钻	预测	实钻	预测	实钻	预测	实钻
Ⅰ	8	5.4	4.91	4.91	75	75	8	8	8.00	5.40	39.28	26.51	70	38
Ⅱ	10	8.9	4.30	4.30	76	76	10	10	9.90	8.81	42.57	37.88	70	83
Ⅲ	5	5.0	4.27	4.27	79	79	9	9	4.95	4.95	33.84	21.13	70	70
Ⅳ	5	2.5	4.40	4.40	77	77	11	11	4.95	2.47	14.21	10.89	70	85
Ⅴ	10	9.0	4.77	4.77	78	78	10	10	9.90	8.91	47.22	42.50	70	100

4 结束语

黄河口凹陷渤中34区油气输导体系主要由断层和砂体组成，油气的富集程度受断层和砂体的分布控制，断层与砂体耦合接触关系决定了油气输导体系的有效性，从而控制了浅层明下段油气藏的形成与分布。通过建立断层与砂体耦合接触关系半定量静态模型，证实了断层与砂体的接触面积是影响油气充满度、储量丰度和油柱高度的重要参数，可根据这些参数对砂体的含油气性进行预测，同时对成熟探区开拓勘探空间、寻找潜在油气藏也具有重要的理论和应用价值。

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Abstract: Martaban Basin located in Andaman Sea, is a typical back-arc strike slip and extension basin. The tectonic evolution of Martaban Basin is closely related with the oblique convergence of the Indian beneath the Myanmar plates. Its depocenter is controlled by the Mergui and Sagaing strike-slip faults and the main sources are from the Irrawaddy River in the north and Salween River in the northeast respectively. From the analysis of characteristics of petroleum geology, the Martaban Basin comprises two mature hydrocarbon source rocks and one biological gas source rock. The Middle Miocene hemipelagic shales overlie the Oligocene-Lower Miocene reef limestones and shallow marine sandstones, which comprise good reservoir-seal assemblages. The Pliocene-Pleistocene delta front sandstones interbedded with shales are the main pays of shallow biogas. The trap types are mainly faulted-anticlines, faulted blocks, reef traps and structural-stratigraphic combined traps. Faults and unconformities are the favorable migration pathways. Future exploration should typically be oriented at faulted blocks and horst in the center area of basin for the shallow biogas, and the western volcanic uplifts, central inherited uplifts and structural terraces in eastern ramp region for the thermogenic gas respectively.

Key words: back-arc strike slip and extension basin; petroleum geology feature; exploration direction; Martaban Basin; Andaman Sea

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Liu Xinjin, Song Guoqi, Liu Huimin et al. Study of conglomerate reservoir types and distribution in north slope zone, Dongying depression. *PGRE*, 2012, 19(5): 20-23.

Abstract: There are several conglomerate reservoir types in the eastern north steep slope zone in Dongying depression, whose distribution has an ordered sequence. By the dissection of different conglomerate traps, the basic characteristics of these reservoirs and controlling factors of their ordered distribution are discussed. On the basis of reservoir characteristic and distribution law, the ordered reservoir combination pattern includes under-salt condensate gas reservoir, fan root lithologic reservoir, structural-lithological reservoir, and the digenesis trap reservoir that is sealed by difference of physical properties. The reservoir series, that are in order of under-salt gas play, deep zone thin oil play, medium-deep thin oil play, and shallow layer heavy oil play, are distributed ring-shaped around the subsidence centre of the basin. Every reservoir type had its particular hydrocarbon accumulation controlling factors. The main pool controlling factors of deep condensate gas and thin oil lithologic reservoir are the sealing capacity of fan root, the one for medium-deep structural-lithologic reservoir is development of small anticlinal traps, and the heavy oil is thick, which is the key controlling factors for shallow layer reservoir that is sealed by difference of physical properties. Different exploration plans are designed according to the reservoir characters and oil distribution law.

Key words: conglomerate; reservoir types; evolutionary series; controlling factor; Dongying sag

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Liu Qidong. Sand-body distribution of the E_1f_3 member and its relationship with hydrocarbon migration in the northern slope of Gaoyou sag. *PGRE*, 2012, 19(5): 24-26.

Abstract: The E_1f_3 member is featured by serious reservoir heterogeneity and complex hydrocarbon migration pathways. Based on the study of sedimentary microfacies and stratigraphic correlation of the sand sets, we analyze comprehensively the hydrocarbon migration pathway by integrating oil and gas show of drilling data in this paper. The result indicates that there are 3-5 subaqueous distributary channels in every sand subset in the north slope of Gaoyou sag, and the study shows that the subaqueous distributary channel and channel-mouth bar are more available for the reservoir property, and its sand-body distribution controls the spread of the high quality reservoir. Further analysis reveals that the hydrocarbon migration pathways are different between the inner and the outer slope. In the inner slope, the hydrocarbon migration pathways are influenced by the distribution of subaqueous distributary channel, and in the outer slope, the hydrocarbon migration pathways are controlled by both the tectonic zone and the sand-body distribution. So, different prospecting tactics in the inner and the outer slope should be considered.

Key words: E_1f_3 member; sand-body distribution; oil and gas show; hydrocarbon migration; north slope of Gaoyou sag

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Zhang Xintao, Niu Chengmin, Huang Jiangbo et al. Hydrocarbon migration of Bozhong34 in Lower Minghuazhen Formation, Huanghekou sag, offshore Bohai sea. *PGRE*, 2012, 19(5): 27-30.

Abstract: The characteristics of migration system and its relationship with the distribution of middle shallow hydrocarbon reservoir in the Bozhong34 block of the Huanghekou sag in the offshore Bohai Bay Basin show that, the faults and sandbodies dominate the hydrocarbon migration system in the block. The distribution of sandbodies and faults are not the only factor that controls hydrocarbon enrichment in the study area. The spatial and temporal configurations of faults and sandbodies also control the effectiveness of migration system, thus determine the formation and occurrence of the oil reservoirs in the middle shallow layers. Through the static model of faults and sandbodies, the contact area of faults and sandbodies is important parameter controlling oil-gas filling degree, reserves abundance, and oil column height. Moreover, it guides the well position of Bozhong34-B and reservoir prediction. Quantitative study about configurations of faults and sandbodies with petroleum accumulation model has important value in theory and field application for expanding exploration space and locating the potential reservoir.

Key words: faults; migration system; configurations of faults and sandbodies; hydrocarbon migration; Huanghekou sag

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Wu Changwu, Xiong Liping, Huang Yanqing. Hydrocarbon distributon and control factors on accumulation in Bonaparte basin. *PGRE*, 2012,19(5):31-33.

Abstract: Bonaparte basin is a gas prone basin in which Sinopec hold 3 blocks interests. It baffled blocks exploration and development efficiently of these existing blocks and the acquisition of new blocks that the main control factors of hydrocarbon accumulation and potential are not so clear. The author points out the main control factors of hydrocarbon accumulation and the potential of Bonaparte basin through the research of petroleum geology and the hydrocarbon distribution. Hydrocarbon dose unequally distribute in this basin, the west part of basin is mainly small and medium oil fields but the east part of basin mainly contains giant gas fields. The kerogen type, maturity and preservation condition determined hydrocarbon type. In the west part of basin, the reactivation of faults leads to the lost of hydrocarbon and the scale of oil fields is small. But, in the east part of basin, the structure reinforced in late Miocene leads to the gas fields grow giant. Sub-basins in this basin have different main control factor of oil-gas accumulation. Preservation condition is the main control factor of oil-gas accumulation of Vulcan sub-basin, for the Calder Garben, the main control factor is the reservoir quality, and the trap is the main control factor of the east slope of the basin. Bonaparte basin still has good potential for exploration especially in medium and small structural traps, faults related traps, lithologic traps and salt related traps.
Key words: oil & gas distribution character; main control factor of oil-gas accumulation; source rock; preservation condition; reservoir quality; trap condition; Bonaparte basin
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Yu Jianghao, Liao Yuantao, Lin Zhengliang et al. Research on temporal diversity of settlement characteristics of Paleogene, Fushan Sag. *PGRE*, 2012,19(5):34-38.

Abstract: Tectonic is very active in Cenozoic of Beibuwan Basin, Fushan Sag located in margin of Beibuwan Basin, whose regional tectonic of Paleogene is very complicated and research level is low, without study of tectonic subsidence history. Application of EBM basin modeling system for subsidence history in Fushan Sag, the back stripping analysis shows that: Fushan Sag has successively suffered rift period, transformational period and depression period, the changing of subsidence rate emerges "episode" characteristic; west secondary depression sedimentation rate is higher than which in east secondary depression since chasmic I episodic period, but from the chasmic III episodic, the east secondary depression sedimentation increased, so, the sedimentation rate is higher than which in west secondary depression. From the location of the center of subsidence, at the early period of chasmic, the subsidence center is located in the Huang Tong region of western depression, but at the advanced of chasmic(chasmic III episodic), the center of subsidence gradually migrates to the Bailian region of eastern depression, then, the regional center of subsidence continues migration to the northeast. Vertical sedimentation rates of the east and west secondary depression are different, besides, regional subsidence center migrates from west to east of Paleogene in Fushan Sag, reflecting the east and west secondary depression in Fushan Sag having space-time diversity in the characteristics of subsidence; Research finds that the tectonic activity diversity of secondary depression and Fushan Sag suffered by regional asymmetric extension effect is inner mechanism which has caused this space-time diversity of east-west settlement.

Key words: subsidence evolution; asymmetric tensile; diversity mechanism; occurrence mechanism; episodic tectonic; Fushan Sag
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Wang Ping, Chang Anding, Dong Anguo et al. Reservoir rock type cluster analysis of $Chang_2{}^1$ oil and gas-bearing member, south-east of Ordos Basin. *PGRE*, 2012,19(5):39-42.

Abstract: Based on the main criteria of terrigenous clastic rock classification and nomenclature at present in China, the clastic fine sandstone-mudstone may be divided into 11 types. Taking core logging into account, especially rock fragment logging and practical lithologic logging interpretation in work, we regard 11 rock type as respective independent object, and formed the object collection, then, after the data treatment and standardization, we count the Chebyshev's distance and implement the cluster analysis, which indicates that, when $0.256\,4<\lambda<0.423\,1$, the 11 rock type of series of fine sandstone-mudstone can be generalized as 5 rock types: mudstone, muddy siltstone, siltstone, silty fine sandstone, fine sandstone. The filed practice of $Chang_2{}^1$ oil and gas-bearing member in the south-east of Ordos Basin has proved that the method for rock type classification can both meet the needs of scientific research and field application, it is the optimum selection.

Key words: $Chang_2{}^1$ oil and gas-bearing member; terrigenous clastic rock; rock type classification; cluster analysis; optimum selection; Ordos Basin
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Zhang Liqiang, Yang Wan. Characteristics of red mudstone and its significance in recognition of sequence boundary of Es_4 in Dongying depression. *PGRE*, 2012,19(5):43-46.

Abstract: In the study of sequence stratigraphy underground, the sequence boundary's identification is mainly based on the seismic section with low vertical resolution, log data with high multiple solution and so on, but ignoring rocks' paleo-weathering characteristic which is relative to unconformable surface. Therefore, it leads to the ambiguity of stratigraphic sequence correlation. Based on the study of petrology, geochemistry and paleo-weathering characteristics about the red mudstone in Es_4 Yong 82 well of Dongying