亚诺斯盆地 Cabiona 区块油气成藏规律

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摘要: Cabiona 区块位于哥伦比亚境内亚诺斯盆地的前隆斜坡构造带上，是前陆盆地油气运移和聚集的重要场所，具有较为有利的油气成藏条件。在地层和构造特征分析的基础上，通过层序地层划分和沉积相研究，确定研究区主要目的层卡沃内拉组主要为三角洲沉积，以三角洲前缘和前三角洲沉积亚相为主，可进一步识别出水下分流河道、河口坝、席状砂和水下分流河道间 4 种沉积微相。应用现代石油地质学理论，从输导体系、圈闭特征和油气分布等方面开展研究，总结出远源复合输导，断层控制油气分布，构造位置控制油气聚集，储层物性影响油气富集的油气成藏模式，主要发育断背斜或背斜、岩性 - 断鼻、岩性 - 断层和断层 - 岩性 4 种类型油气藏。

关键词: 前陆盆地 前隆斜坡 成藏规律 成藏模式 亚诺斯盆地
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Cabiona 区块位于南美大陆东北部哥伦比亚境内亚诺斯盆地的中东部，面积为 348.28 km^2，三维地震覆盖面积为 256 km^2。亚诺斯盆地位于圭亚那地盾的西北部，是受安第斯褶皱带和圭亚那地盾共同控制形成的新生代含油气前陆盆地[1]，其烃源岩条件优越，上白垩统泥岩被称为“世界级”烃源岩[2]，而前隆斜坡构造带是前陆盆地油气运移和聚集的重要指向区[3]。Cabiona 区块位于前陆盆地的前隆斜坡构造带，距离生烃中心超过 100 km，油源供给不充足，且地层平缓，构造不发育，圈闭规模小。截至 2012 年 4 月 30 日区块内已钻井 19 口，其中 10 口获得油气发现。自 2006 年 10 月 10 日投产，天然能量开发，电潜泵采油，截至 2012 年 2 月 29 日已累积生产原油 16.95×10^4 t；目前生产井 5 口，平均产油量为 100 t/d，含水率达 90.2%。笔者结合区域地质认识，根据已有的三维地震资料和钻井资料，对 Cabiona 区块的油气成藏规律进行研究，以期为进一步的油气勘探开发提供参考。

1 地层及构造特征

1.1 地层特征

亚诺斯盆地是在前寒武系结晶基底(圭亚那地盾)上，历经古生代被动大陆边缘、中生代裂谷—弧后盆地和新生代前陆盆地 3 个构造演化阶段形成的，以新生代前陆盆地变形为主的非典型叠合盆地[4-8]。盆地基底由前寒武系岩浆岩和变质岩组成，古生界主要为被动大陆边缘浅海相碳酸盐岩沉积；中生代裂谷发育于三叠纪—侏罗纪，为陆相—滨浅海相沉积；中生代弧后沉陷发育于白垩纪，地层由老到新分别为白垩系下统乌内组、上统加切塔组及瓜达卢佩组，其中加切塔组海相页岩是亚诺斯盆地的主要烃源岩。晚白垩世以来为前陆盆地的形成阶段，受东科迪勒拉造山运动的影响，前陆盆地西侧形成一系列沉积、沉降中心，地层沉积较厚，向东部圭亚那地盾超覆减薄，直至尖灭；伴随海平面的降低，由海相沉积演变为海陆交互相直至陆相的河流和湖泊沉积。整体上亚诺斯盆地呈现出西厚东薄的不对称盆地结构特征，地层充填经历了海相—陆相—海相—陆相的演变过程。

Cabiona 区块地层发育不全，缺失古生界和中生界的三叠系、侏罗系及下白垩统，上白垩统超覆于结晶基底之上；新生界缺失古新统，其他层系保存完整。区块内主要发育 3 套不整合面，分别为基底与白垩系、白垩系与新生界、新生界与第四系之间的不整合面。上白垩统加切塔组烃源岩在区块内缺失，主要含油层系为新生界卡沃内拉组，其分布广泛，地层厚度为 240 ~ 320 m。

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1.2　构造特征

Cabiona 区块整体呈北东—南西向展布的长方形，西低东高、北低南高，东北部地层埋藏最浅，构造相对平缓。区块内发育 5 条北东—南西向、呈雁列式排列、延伸距离相对较远、与地层倾向相反的东倾正断层，断距为 12 ~ 46 m。受其影响，沿断层下盘发育一系列狭长低幅度断鼻构造，其规模均比较小，闭合幅度为 4.5 ~ 15 m，面积为 0.25 ~ 4.8 km^2。

2　沉积及储层特征

2.1　沉积特征

通过分析钻井及测井资料，根据岩性岩相突变面，在卡沃内拉组和米拉多尔组内识别出 5 个三级层序界面（SB2—SB6），并据此划分出 5 个三级层序（SQ1—SQ5），在各层序内部，根据最大海泛面（MFS）进一步划分出海侵体系域（TST）和高位体系域（HST）。其中主要目的层卡沃内拉组自下而上划分为 C8—C1 共 8 段，可识别出三角洲前缘和前三角洲 2 种沉积亚相（图 1）。

三角洲前缘亚相主要发育在 C7，C5，C3 和 C1 段，可进一步划分出水下分流河道、河口坝、席状砂和水下分流河道间共 4 种沉积微相，其中水下分流河道和水下分流河道间发育较为普遍。水下分流河道多为叠置砂体，是主要的储层发育段，岩性以中、细砂岩为主，泥质较少，自然电位曲线表现为低值箱形或齿化的箱形—钟形，反映了物源供应充足、沉积速度较快的特点。水下分流河道间以泥质沉积为主，偶见炭质泥岩，自然电位曲线表现为平直—微齿形高幅值特征，自然伽马为中—高值。

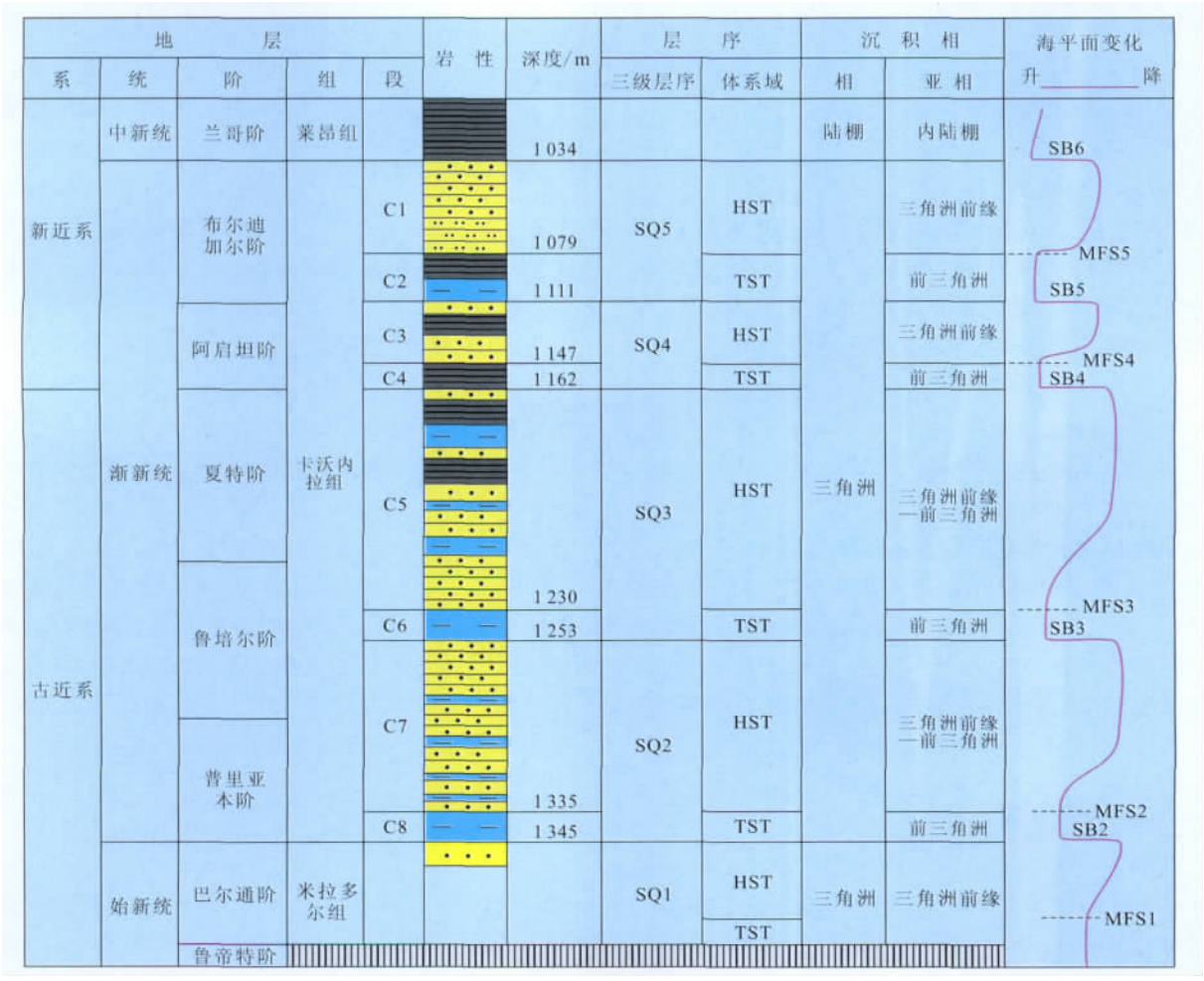

图 1　亚诺斯盆地 Cabiona 区块层序沉积演化

前三角洲亚相主要发育在 C8，C6，C4 和 C2 段，以大套泥岩和粉砂质泥岩为主，为盖层发育段，自然电位曲线表现为平直—微齿形相对高幅值特征，自然伽马为中—高值。

2.2　储层特征

Cabiona 区块的主要储层为渐新统卡沃内拉组

三角洲前缘亚相砂岩，储集空间类型为粒间孔隙。其中 C7 段为大套黄色砂岩夹浅灰色泥岩，砂岩厚度大且分布稳定，孔隙度为 20.5% ~33.8%。C5 段为黄色砂岩与绿灰色页岩夹浅灰色泥岩互层，地层厚度为 58 ~76 m，砂岩横向变化快，连续性较差，累积厚度为 24 ~37 m，单层最小厚度不足 3 m，孔隙度为 5.2% ~34.7%，渗透率为 0.1×10^{-3} ~$3\,290\times10^{-3}$ μm^2，储层物性较好，是研究区的主要产层。

3　油气成藏规律及模式

3.1　油气成藏规律

3.1.1　断层控制油气分布

Cabiona 区块发育的圈闭在平面上沿断层呈串珠状展布，油气藏分布于断层两侧，表明断层是圈闭形成的重要条件，也是油气垂向运移的主要通道；断层不仅影响圈闭的形成，也控制了油气的分布。

3.1.2　构造位置控制油气聚集

Cabiona 区块不同构造带之间的含油性存在差异，高构造带上的圈闭含油性好于低构造带上的圈闭，而位于同一条断裂带（构造带）上的圈闭含油性也存在差异，即构造高部位的圈闭油气充满度高，而低部位的圈闭含油性变差，甚至不含油，反映出油气向构造高部位运聚的特点。

3.1.3　储层物性影响油气富集

研究区卡沃内拉组 C5 段埋深为 1 128 ~1 342 m，埋藏较浅，其压实作用弱、砂岩固结程度差，整体储层物性良好，但是含油性存在明显差异。钻井资料统计表明，油层孔隙度一般大于25%，最高达 34.7%，而孔隙度小于 20% 的砂层多为干层。砂岩储层物性的差异决定着油气的富集程度，这与研究区远离生烃中心、油气充注动力不足有关。此外，砂体的油气充满度还与其规模、展布形态和压力等具有一定关系。

3.2　油气成藏模式

前陆盆地的不同叠加构造样式导致其油气成藏规律具有多样性[9-10]。由于亚诺斯盆地遭受多期次构造演化，形成了多种油气运移通道，断层、不整合面和连通砂体均为有效运移通道[2]。油气从烃源灶，沿不整合面—断层—连通砂体的复式输导体系长距离运移至东部斜坡带，最终在合适的圈闭中聚集成藏，其油气成藏模式具有远源复合输导，断层控制油气分布，构造位置控制油气聚集，储层物性影响油气富集的特征。输导体系可影响油气藏类型及规模，根据 Cabiona 区块独特的构造样式和沉积特点，确定其主要发育断背斜或背斜、岩性 - 断鼻、岩性 - 断层和断层 - 岩性 4 种类型油气藏（图 2）。

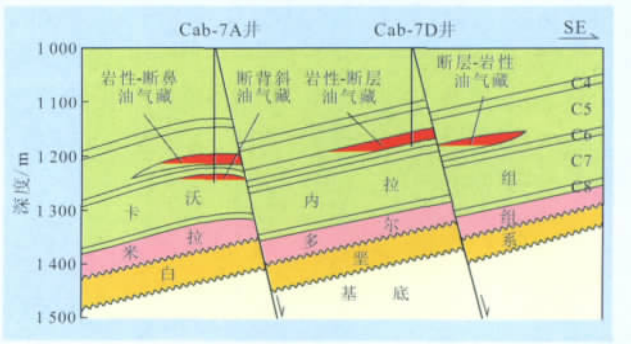

图 2　Cabiona 区块油气成藏模式

研究区卡沃内拉组 C7 段发育大套厚层块状砂岩，泥岩隔（夹）层不发育，主要发育断背斜或背斜油气藏。其上覆 C6 段以泥岩为主，厚度为 9 ~22 m，当断层的断距大于泥岩厚度时，断层上、下盘易于形成砂—砂对接，导致其侧向封堵性变差，使油气难以在断层上盘发育的断鼻圈闭中聚集成藏；而以上覆 C6 段泥岩作为盖层的断背斜或背斜圈闭则不受断层侧向封堵条件的影响，可形成断背斜或背斜油气藏。

C5 段发育三角洲前缘水下分流河道砂体，砂岩厚度较小、横向变化快，油气成藏受构造和砂体双重因素控制，主要发育复合油气藏。其中岩性 - 断鼻油气藏发育在断层下盘，鼻状构造背景成为油气充注和聚集的有利条件，油气藏边界受岩性边界和构造等值线控制；岩性 - 断层油气藏是受 2 条断层夹持所形成的，其上倾方向受断层和岩性边界共同遮挡形成圈闭，下倾方向由断层形成油气输导通道，使油气沿砂体运移至上倾较高部位聚集成藏；断层 - 岩性油气藏发育在断层上盘，下倾方向受断层切割与油源沟通，上倾方向由于砂体尖灭遮挡成藏。

4　结论

Cabiona 区块位于亚诺斯前陆盆地前缘斜坡构造带，其地层平缓、构造不发育、圈闭规模小、远离生烃中心，具有远源复合输导，断层控制油气分布，构造位置控制油气聚集，储层物性影响油气富集的油气成藏模式。主要储层为渐新统卡沃内拉组 C7 段和 C5 段发育的三角洲前缘亚相砂岩，其中 C7 段砂岩厚度大且分布稳定，C5段砂岩薄且横向变化快，

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较真武地区古水体要浅。

5 结论

从古生物特征、微量元素分析来看，高邮凹陷深凹带戴一段早期锶钡比值平均为 0.98，铷钾比值平均为 0.003 9，硼镓比值平均为 3.95，硼钒比值平均为 1.02，说明戴一段沉积初期水体尚保留一定咸度，随着地表径流的不断注入，湖水被淡化，逐渐由微咸水过渡为淡水。孢粉特征反映戴一段沉积时期总的气候是温带—亚热带型，温暖潮湿，后期湖区扩大。研究区泥岩颜色在纵向上的变化特征为深灰色—棕红色—灰色—深灰色，反映了古水深逐渐增加的过程；平面上靠近断阶带的灰色和深灰色泥岩比例低，向深凹带灰色和深灰色泥岩比例增加，并且富民地区的灰色和深灰色泥岩比例比真武地区的低，因而富民地区古水体较真武地区古水体要浅。

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储层物性的差异对油气富集程度具有一定的影响。研究区油气成藏的控制因素复杂，形成多种类型油气藏，C7 段以断背斜或背斜油气藏为主，C5 段主要发育岩性－断鼻、岩性－断层和断层－岩性 3 种复合油气藏。

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Wang Miao, Liao Yuantao, Deng Dafei et al. Reservoir characters and controlling factors of member one of Dongying group in fracture belt 1, Nanpu depression. ***PGRE*****, 2012, 19(4): 14-17.**

Abstract: Reservoir properties of member one of Dongying group in fracture belt 1 in Nanpu depression are studied by analyzing the data of petrophysical characteristics, combined with thin-section petrography and scanning electron microscopic (SEM). And, it is considered that they are controlled by sedimentation and diagenesis. The main reservoir rock type of the study area is feldspar-lithic sandstone, and the main pore type is intergranular porosity. The controlling effect of sedimentation on reservoir is analyzed from two respects: sedimentation controls reservoir lithology characters; and the microfacies types on reservoir lithology characters. The control of sedimentation on reservoir lithology characters is the foundation. Different provenance, different sedimentary environments and sedimentation process determine different lithological characters, which decide directly the petrophysical characteristics of reservoir. The petrophysical properties of submersed channel, mouth bar and turbidite fan channel are the best sedimentary micro-facies which can be good reservoirs. Composite reverse rhythmic are identified in sedimentary micro-facies, and homogeneous rhythmic petrophysical mode is more proper to form favorable reservoirs. Diagenesis influence on reservoir properties is revealed in three aspects: compaction, cementation and dissolution. A large number of interparticle dissolution pores are generated by dissolution which effectively improves the reservoir petrography.

Key words: reservoir characters; controlling factors; sedimentation; diagenesis; member one of Dongying group; Nanpu depression

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Zhang Juan. Study on fault-sealing in Pinghu oil and gas field, Xihu depression. ***PGRE*****, 2012, 19(4): 18-20.**

Abstract: Exploration practice showed that fault-sealing controlled the hydrocarbon distribution in Pinghu oil and gas field of Xihu depression, while the corresponding research had not been carried out. According to the sand-mud docking relationship on both sides of faults and smear gouge ratio calculation, fault-sealing evaluation of the main five faults in research area were studied, and the fault-sealing history in the key hydrocarbon migration period was reconstructed by the technology of layer flatten. The research results showed that fault-sealing in Pinghu Formation was better, and in Huagang Formation was weaker, when smear gouge ratio was more than 68 percent, fault side blocking were formed. Fault-sealing ability was changed by the various tectonic evolutionary stages and had relationship with tectonic stress field: in the faulted stage, the research area was mainly in tensile stress, and the faults was open; in the depression stage, some regions was mainly in compression-torsion stress, and the faults in the area was seal such as number 1 fault and in the north of number zero fault, fault-sealing in the other regions was weak.

Key words: fault mud ratio; mudstone smear potential; tectonic stress field; fault-sealing; Pinghu oil and gas field

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Chang Jianfeng, Xu Yaodong, Tian Tonghui et al. Reservoir fluid type identification for Archaeozoic reservoir in Chengbeigu 7 buried hills. ***PGRE*****, 2012, 19(4): 21-23.**

Abstract: The identification of reservoir fluid types is key to the calculation of oil and gas reserves, optimization of the development way, and decision of the key technology policy. So how to make clear the underground fluid types is of vital significance for reservoir development. Based on the fluid component analysis result and fluid phase behavior experiment of the well flow, and using a variety of statistical methods and fluid phase analysis method, we identify the reservoir fluid type of the Chengbeigu 7 buried hills. The results show that the reservoir fluid type of the Chengbeigu 7 buried hills is represented as the oil gas two-phase state in the original formation conditions. Combined with geologic research results, the reservoir fluid types of Chengbeigu 7 buried hills is condensate gas cap reservoir.

Key words: *reservoir type*; *condensate reservoir*; *gas cap*; *oil ring*; *fluid phase*

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Zhang Jinwei, Yan Aiying, Liu Wenxiu et al. Study on reservoir occurrence rule in Cabiona block of Colombia. ***PGRE*****, 2012, 19(4): 24-26.**

Abstract: Colombia, the fourth largest oil&gas production country in South America, is abundant of petroleum deposits. Cabiona block is located in the forebulge slope of the foreland basin Llanos in Colombia, where is expected to be preferential for hydrocarbon migration and accumulation. By stratigraphic correlation combining with sequcence and tectonic research, the sedimentary facies of the target formation Carbonera have been defined as deltaic facies, including two subfacies of delta-front and prodelta. Four microfacies of submerged distributary channel, inter-distribuary area, mouth bar and sheet sand are identified. On the base of hydrocarbon migration and distribution and trap features, reservoir accumulation mode is built, which is discribed as multiple migration with far source, fault controlled reservoir distribution, structure controlled accumulation, and reservoir properties controlled oil enrichment. Four kinds of oil reservoir are summarized as anticlinal reservoir, lithology-faulted nose-like reservoir, lithology-fault reservoir and fault-lithological reservoir. The results of the research are expected to be used in guiding the E&P work in Cabiona block.

Key words: foreland basin; forebulge slope; reservoir occurrence rule; reservoir accumulation mode; Llanos basin
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Yang Yanmin, Ao Lide, Liu Jinhua et al. Study on characteristics of connate water in the first member of Dainan Formation, deep concave belt of Gaoyou sag. *PGRE*, 2012, 19(4): 27-30.

Abstract: In recent few years, in the research of the exploration and the exploitation of the oilfield, the research on the paleosalinity, paleoclimate and palaeobathymetry is very limited. In this research, we use the result of the tests, such as the clay mineral, microelement, palaeontology and palynomorph, to infer the information of the paleosalinity, paleoclimate and palaeobathymetry. The characteristic of palaeontology shows that the environment of the deep concave belt of Gaoyou sag in the first member of the Dainan Formation is freshwater lake of continental facies, and by the analysis of the microelement, the paleosalinity of the research area changed from the brackish water to freshwater. And, we use the color of the mud stone to analyze the palaeobathymetry, and in the well, the color of the mud stone changed from the deep grey to brown, grey, and to deep grey again, this shows that the palaeobathymetry is increased in the process.
Key words: paleosalinity; paleoclimate; palaeobathymetry; paleo-water; Gaoyou sag
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Du Zhenjing. Analysis of hydrocarbon accumulation of buried hill in east Chengdao area. *PGRE*, 2012, 19(4): 31-33.

Abstract: In accordance with complicated geological framework and hydrocarbon accumulation rules and insufficient understanding for reservoir characteristic, comprehensive analysis of drilling, borehole logging, structure interpretation and testing data was put forward to study its structure and strata characteristics, petroleum distribution rules and master control factors for hydrocarbon accumulation. Result shows that the strata of research area are distributed irregularly as the result of multiphase tectonic movement and rollover. Strata in different structural zone or different place of the same structural zone have deviation. There is variable degree of petroleum enrichment in Archean, lower Paleozoic, upper Paleozoic, and Mesozoic along the vertical section. Lower Paleozoic has the most enrichment and petroleum mainly accumulates in high part of structure. Along the horizontal section, oil distribution horizon varies from older to newer and oil reservoir styles varies from fault block and residual hill to disconformity crossing the structural main part to the limb. Dissection of typical wells shows that the reservoir-cap relationship and lateral sealing condition are main control factors of hydrocarbon accumulation, and the hydrocarbon accumulation mode is herein constructed.
Key words: weathering crust; fault block and residual hill oil reservoir; oil distribution rule; main control factors of hydrocarbon accumulation; buried hill in east Chengdao area
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Jin Qiang, Wu Aijun, Jin Fengming et al. Estimation of source rocks by seismic attributes in the Damengzhuang sag, Wuqing depression. *PGRE*, 2012, 19(4): 34-37.

Abstract: It is rather difficult to conduct source rock evaluation in low degree of exploration area for shortage of drill-well data. Based on differences in the average amplitudes and energies between the source rocks and non-source rocks, an estimating method for identification of the source rocks is established by research on the sequence and seismic stratigraphy on the seismic profiles, i. e. to remove sandy contents in the source rock interval by seismic velocity spectrum plot, to establish relationship between the seismic attributes and TOC contents measured from the source rocks, and to estimate the source rocks on the seismic profiles. Therefore, source rocks in the upper forth member, lower and middle third member of the Shahejie Formation are estimated by this method. The TOC contents are distributed in the studied area as "west high and east low, and south high and north low", the belt in the southern studied area from well Jing-24 to well Wugu-1 is estimated as favorable place for oil and gas accumulation as high TOC contents in the source rocks.
Key words: source rocks; seismic attributes; quantitative estimate; seismic prediction; Wuqing depression
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Sui Shuling, Tang Jun, Jiang Yubing et al. Technical characteristics and applicable conditions analysis on seismic inversion traditional methods. *PGRE*, 2012, 19(4): 38-41.

Abstract: Different seismic inversion methods have different technical characteristics and applicable conditions. Seismic inversion methods usually applied in petroleum occupation, such as geological based model inversion, constrained sparse spike inversion, reservoir characteristic attributes inversion, frequency-divided inversion and geological statistics inversion, are analyzed in basic principles, technical keys, advantages and disadvantages. Technical characteristics and applicable conditions of these methods are also analyzed combined with some applying cases in different blocks, series of strata, reservoir feature and reservoir types. Researching results indicate that, in view of complicated geological designation, only proper seismic inversion methods are defined by optimizing, and inversion results obtained are combined with attributes analysis, can enhance the precision of reservoir description, and attain the aim of resolving complicated geological problems.
Key words: seismic inversion; reflection coefficient; impedance; seismic attributes; variogram; acoustic time
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