西湖凹陷平湖油气田断层封闭性评价

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摘要: 断层封闭性对西湖凹陷平湖油气田的油气分布具有重要的控制作用,对其开展系统的研究和评价是目前勘探实践的需要。利用断层泥比率、泥岩涂抹潜力及构造应力场分析等方法对平湖油气田 5 条主要断层进行了封闭性综合评价。结果表明: 当断层泥比率大于 60% 且泥岩涂抹潜力大于 4 时,基本达到断层侧向封闭条件。断层封闭性与构造应力相关,拉张应力期,断层开启; 挤压应力期,断层封闭。平湖油气田 0 号断层在平湖组 P_4—P_{12} 砂层组沉积时期封闭性好,在平湖组 P_1—P_3 砂层组沉积时期封闭性差; 在花港组沉积时期断层封闭性中等。1 号断层在平湖组沉积时期封闭性较好,在花港组沉积时期封闭性差。2 号断层在平湖组沉积时期封闭性较好,在花港组沉积时期封闭性好。4 号断层和 11 号断层在平湖组、花港组沉积时期封闭性均差。

关键词: 断层泥比率 泥岩涂抹潜力 构造应力场 断层封闭性 平湖油气田
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平湖油气田位于东海陆架盆地浙东坳陷西湖凹陷,为受平湖主断层控制形成的断块型油气藏,主要目的层为古近系平湖组和花港组,其中,花港组以油藏为主,平湖组以气藏为主[1-4]。平湖油气田成藏的主要影响因素为断层封闭性及其与油气运移关键期是否匹配。因此,研究主要断层的侧向封闭条件及油气运移关键期的断层封闭性,对平湖油气田的滚动勘探开发具有重要的指导意义。

目前断层封闭性定量评价的方法较多,主要有构造应力场分析法、断裂面两侧岩性配置及断裂面产状法和属性参数法及断裂活动分析法等[5],比较成熟的软件为 traptester。属性参数法是利用断层泥比率(*SGR*)和泥岩涂抹潜力(*CSP*)进行断层封闭性的综合评价。断层泥比率表示通过各种机理挤入断裂带的泥页岩的比例。围岩中泥页岩含量越高,则断裂带中泥页岩、断层岩泥化涂抹的可能性越大,其物性越差,排替压力越高,形成封闭的可能性越大; 反之则越小[5-9]。泥岩涂抹潜力表示沿断面某点某泥页岩层被涂抹的相对量值,与泥页岩厚度成正相关,与涂抹距离成负相关。构造应力场分析法是将断裂按地质力学理论和方法划分为压性、扭性、张性、压扭性和张扭性断裂,定性地分析断层的封闭能力。通常认为张性、张扭性断裂开启程度高,多为油气运移的通道; 张性断裂若产生断层泥,形成粘土封闭裂缝,也可对油气产生一定的封堵作用。

平湖油气田油气运移以侧向运移为主,砂泥岩对接关系和泥岩涂抹作用是影响研究区断层封闭性的主控因素,其次,区域应力场的变化对断层的侧向封闭能力具有不同程度的控制作用。因此,针对平湖油气田的主要断层,利用属性参数法与构造应力场分析法进行断层封闭性研究。

1 断裂发育特征

西湖凹陷的构造演化主要经历了断陷、拗陷及区域沉降 3 个阶段,而平湖油气田的断裂系统主要形成于西湖凹陷的断陷阶段(晚白垩世—始新世)[10],在拉张应力作用下,形成了以 0 号断层(平湖主断层)为主的一系列北北东—南南西向张性断裂体系。平湖油气田主要发育 14 条断层,其中 0 号、1 号、2 号、4 号、11 号等 5 条主要断层基本控制了研究区的油气成藏(图 1)。0 号断层为平湖油气田的主断层,平面上呈北北东—南南西向展布,延伸距离为 30 km 以上,断距达几百至上千米,对平湖油气田的构造、沉积及油气分布具有重要的控制作用。1 号和 2 号断层为放鹤亭地区的控藏断层,延伸距离为 10 ~ 20 km,对局部构造、沉积具有重要的控制作用,同时受其夹持形成的断块背斜构造是目前平

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湖油气田重要的开发研究区块。4 号和 11 号断层为平湖主断层的次级断层，受其分割形成了平湖油气田放鹤亭、八角亭及中山亭断块。因此，笔者重点对上述 5 条主要断层的封闭性进行研究。

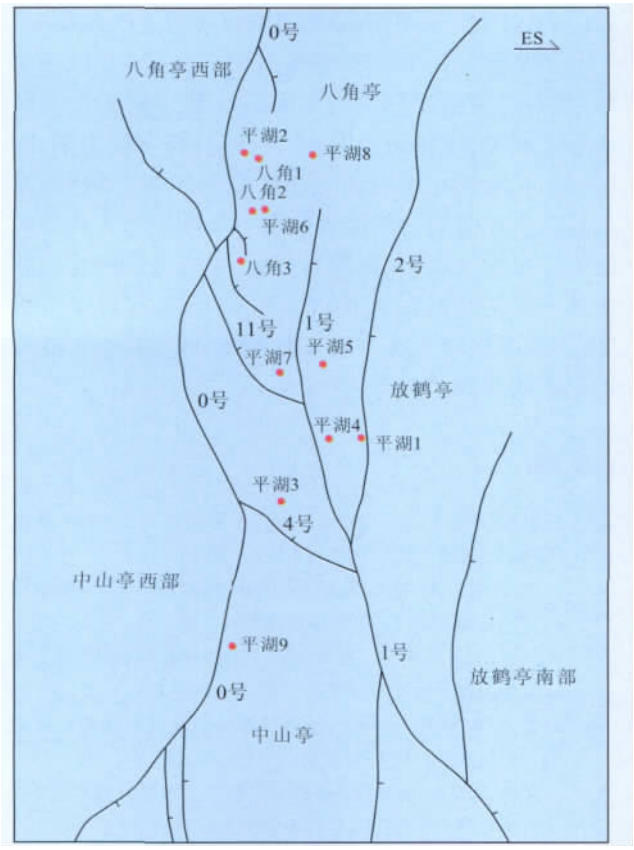

图 1　平湖油气田断裂系统示意

2　断层封闭性评价

以平湖主断层为例，论述平湖油气田断层封闭性的研究过程。具体步骤为：①选取研究区具有代表性的过平湖 6、平湖 2 及八角 3 井的连井地震测线进行断层封闭性研究；②统计平湖组、花港组各砂层组的砂岩、泥岩、地层厚度及断层断距等；③利用 traptester 软件进行断层泥比率和泥岩涂抹潜力属性参数的计算；④建立评价标准。通过计算研究区内 7 口探井钻遇及未钻遇油气层段的断层泥比率和泥岩涂抹潜力，确定利用 *SGR* 区分断层封闭的门限值为 25% ~30%，*SGR* 值越大，则封闭性越好。此外，综合盖层封闭性的评价标准[5,11-12]，确定了平湖油气田平湖组、花港组断层封闭性的评价标准（表 1）。

根据平湖油气田 0 号断层 *SGR* 计算结果（图 2）分析：0 号断层的平湖组 P_4—P_{12} 砂层组 *SGR* 值较高，为 68% ~90%，且横向上变化较小，*CSP* 值也较高，为 4.2 ~6；P_1—P_3 砂层组 *SGR* 值较低，为 50% ~68%，*CSP* 值也较低，为 2 ~4.2。花港组 H_1—H_8 砂层组 *SGR* 值为 50% ~62%，且横向上变化较小，*CSP* 值整体较小，为 2 ~3.5。

表 1　平湖油气田断层封闭性评价标准

层位	*SGR*,%				*CSP*			
	差	中等	较好	好	差	中等	较好	好
花港组	<50	50 ~60	60 ~75	>75	<3	3 ~4	4 ~5	>5
平湖组	<60	60 ~70	70 ~80	>80	<3	3 ~4	4 ~5	>5

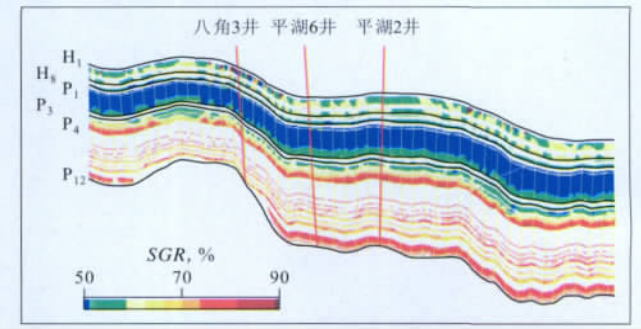

图 2　平湖油气田 0 号断层断层泥比率

利用构造应力场分析法评价了 5 条主要断层的应力机制（图 3）。0 号断层在八角亭地区挤压应力大于拉张应力，在放鹤亭地区以拉张应力为主，至中山亭地区为挤压应力与拉张应力共同作用，二者强度相差不大；1 号断层整体表现为挤压应力大于拉张应力；2 号断层拉张应力与挤压应力强度相当；4 号断层和 11 号断层以拉张应力为主。

对断层泥比率、泥岩涂抹潜力及构造应力场的综合评价表明，平湖油气田 0 号断层在平湖组 P_4—P_{12} 砂层组沉积时期封闭性好，在平湖组 P_1—P_3 砂层组沉积时期封闭性差；在花港组沉积时期断层封闭性中等。1 号断层在平湖组沉积时期封闭性较好，在花港组沉积时期封闭性差。2 号断层在平湖组沉积时期封闭性较好，在花港组沉积时期封闭性好。4 号断层和 11 号断层在平湖组、花港组沉积时期封闭性均差（图 3，表 2）。

实际钻探表明，在平湖油气田已钻的 11 口探井中，平湖 7 井和八角 3 井钻探失利，其原因为平湖 7 井东侧的 1 号断层封闭，阻挡了来自放鹤亭地区的油气运移至此，而 11 号断层封闭性差，未能封堵由东北部八角亭地区运移来的油气。八角 3 井失利原因主要为 0 号断层在该井附近封闭性差，导致油气散失。而平湖 2 井和八角 2 井等在平湖组 P_4—P_{12}

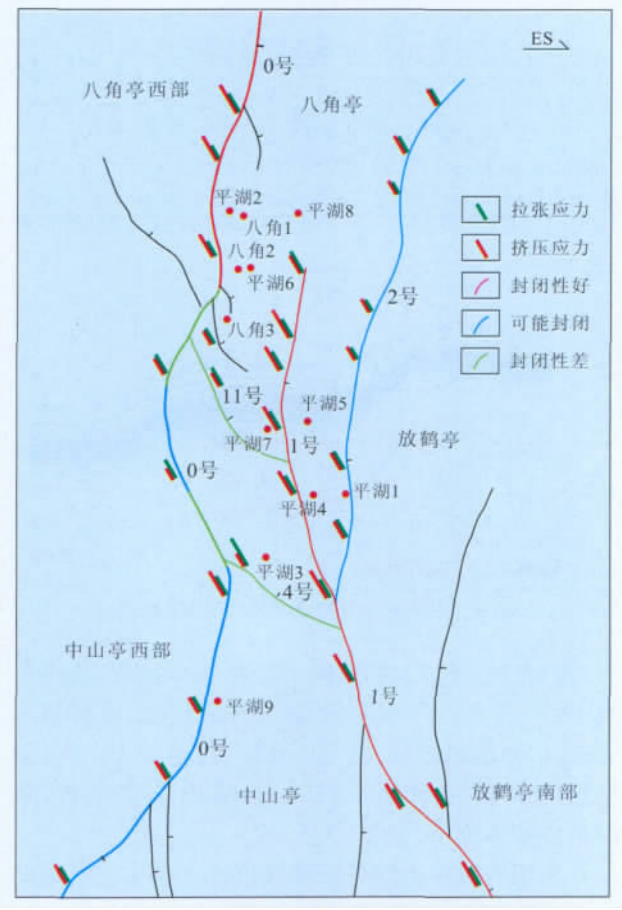

图 3　平湖油气田构造应力及断层封闭性综合评价

表 2　平湖油气田断层 *SGR* 和 *CSP* 值综合评价

断层	层位	砂层组	*SGR*,%	*CSP*	评价
0 号	花港组	H_1—H_8	57	2.6	中等
	平湖组	P_1—P_3	52	2.6	差
		P_4—P_{12}	79	4.6	好
1 号	花港组	H_1—H_8	45	1.9	差
	平湖组	P_1—P_{12}	80	5	较好
2 号	花港组	H_1—H_8	82	5.5	好
	平湖组	P_1—P_{12}	76	5.1	较好
4 号	花港组	H_1—H_8	40	1.9	差
	平湖组	P_1—P_{12}	45	1.86	差
11 号	花港组	H_1—H_8	42	1.92	差
	平湖组	P_1—P_{12}	46	2.0	差

砂层组均获得较好的油气显示，说明由于断层封闭性较好，有效封挡了油气。

3　结论

应用属性参数法并结合构造应力场分析法评价断层的封闭性，在平湖油气田取得了较好的效果。

当断层泥比率大于 60% 且泥岩涂抹潜力大于 4 时，基本达到断层侧向封闭条件。断层封闭性与构造应力相关，拉张应力期，断层开启；挤压应力期，断层封闭。断层在平湖组沉积时期封闭能力较强，在花港组沉积时期封闭能力较弱。但断层封闭性评价始终是以油气运移、成藏为核心，单纯考虑断层封闭还是开启是比较片面的，因此，需要将其与生烃强度、生油期次结合起来动态地指导油气勘探才能取得更好的效果。

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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.