

惠民凹陷西南缓坡带新生代构造 演化与油气成藏特征*

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摘要: 惠民凹陷西南斜坡是一长期发育的稳定斜坡, 其上发育不同产状的基底断层, 构成复杂的断块构造。早第三纪断陷阶段, 断裂强烈活动, 对沙河街组沉积有明显的控制作用。晚第三纪、第四纪, 大多数断裂均停止了活动。运用泥涂抹系数, 对夏口断层封闭性进行研究, 结果表明, 以夏口断层的沙河街组三段中亚段为界, 之上封闭性好, 之下封闭性差。这一特征决定了临南洼陷沙河街组三段中亚段以上层位的油气无法穿过夏口断层, 只能在断层上盘形成聚集; 以下层位的油气却能穿过夏口断层, 进入到西南斜坡。因此, 西南斜坡的油气勘探重点应放在沙河街组四段及以下层位。

关键词: 构造演化; 断层封闭性; 油气成藏; 夏口断层; 惠民凹陷

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惠民凹陷西南缓坡带是一个继承性发育的缓坡, 很难预测油气怎样经过夏口断层又怎样在缓坡带的哪一层位运移和聚集, 所以将断层的封闭性与构造演化结合起来研究对于揭示该地区的油气成藏机制有重要的指导作用。国内通过分析构造带的剖面演化过程来研究油气成藏已经引起许多学者的高度重视^[1~4]。本文通过构造几何学、运动学解析, 分析了西南缓坡构造带的演化并与断层的封闭性结合起来, 更准确的预测了油气藏的空间分布和成藏规律。

1 几何学特征

西南缓坡带位于惠民凹陷的西南部, 属于临南地区的一个次级构造单元(图1), 北与重要的生油洼陷临南洼陷相邻并以夏口断裂带为界, 南与鲁西隆起相接, 东接曲堤地垒和济阳地堑, 西临禹城洼陷, 面积约500 km²。

西南缓坡带是一个长期发育的稳定斜坡, 地层大致上是由东南向西北倾斜, 砂体呈楔状。它的构造特征主要表现为以下几个方面: 第一, 整体上表现为一南抬北倾的大型鼻状构造背景上的宽缓坡带, 并被多条断层切割; 第二, 断层走向以

NNE向为主, 受夏口断层的影响, 缓坡带下第三系较薄, 并发育以NNE向为主的共轭正断层; 第三, 由于夏口断层下盘的盖层较薄, 多数盆倾的调节正断层由于位移较小而没有明显的盖层滑脱正断层的变形特征(如滚动变形和次级调节断层的出现等), 而是表现为在盖层地层中尖灭; 第四, 夏口断层的活动抑制了其下盘的掀斜运动, 使得发生的地形“坡折带”及其视迁移规律变得更加复杂。

2 运动学特征

研究表明, 从烃源岩排出而进入邻近储集层的油气总是在浮力作用下寻求最短途径做垂向或侧向运移, 古构造形态和构造运动控制了油气的运移方向和聚集场所^[5]。为研究该地区新生代的构造运动学特征, 根据平衡剖面原理经过去压实校正, 做了钱斜13井-夏33井连井投影构造演化剖面图(图2), 较真实的再现了新生代构造演化过程。

2.1 早第三纪断陷阶段

孔店组-沙河街组四段沉积时期, 夏口断层就已初具规模, 但这时主要是作为临商断层上盘发育的调节性反倾断层出现。它对西南缓坡带的控制作用还不明显。

沙河街组三段-沙河街组二段沉积时期, 夏

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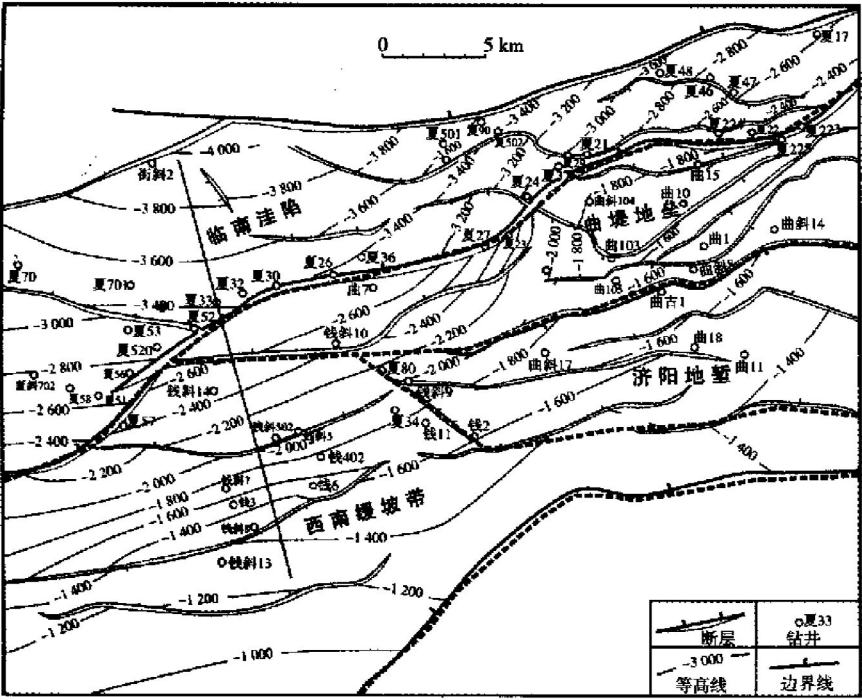


图 1 临南地区构造位置及构造单元划分图

Fig. 1 Structural units in Linan area

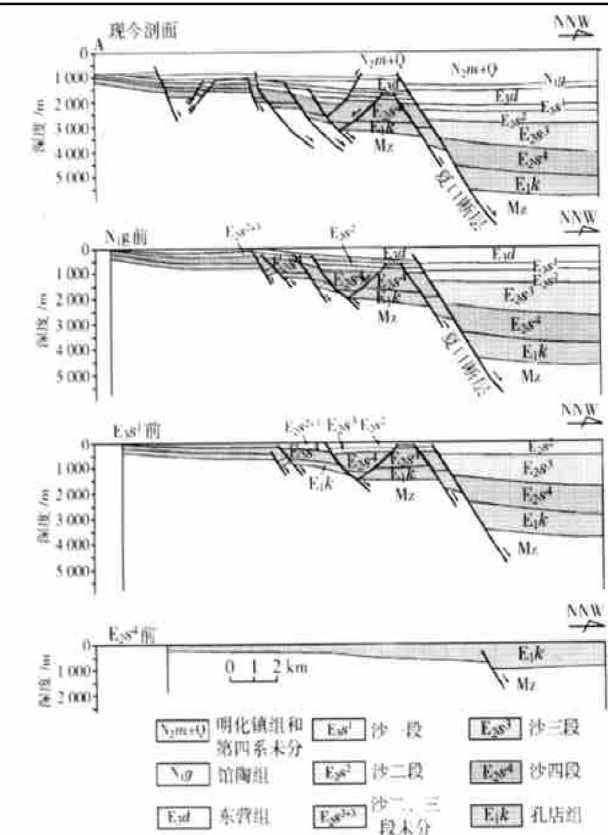


图 2 西南缓坡带钱斜 13 井- 夏 33 井连井投影构造演化剖面图

Fig. 2 Evolutionary section of structures along Qx13 well to X33 well in southwest gentle slope belt

口断层开始强烈活动,在洼陷内部沉积了一套巨厚的烃源岩沙河街组三段,为以后提供足够的油气奠定了坚实的基础。沙河街组三段沉积初期,少量的盆倾调节性正断层在钱官屯地区开始出现。这一时期缓坡带上开始了掀斜运动,造成这一时期在缓坡带的沉积地层薄,甚至有些部位缺失该地层。

沙河街组一段沉积时期,斜坡带的断裂活动达到了鼎盛时期,水体进一步扩大。随着埋深的增加,沙河街组四段的部分烃源岩已开始进入生烃门限(2 600 m),但这时的生烃还没有达到一定的规模。由于运移距离的制约,油气主要在洼陷内部运移。大约在东营组沉积后,油气开始大规模运移(馆陶期和明化镇期),缓坡带上的大多数断层基本停止活动,具有封闭性,这大大的限制了油气在缓坡带地区的纵向运移。

2.2 晚第三纪和第四纪拗陷阶段

东营组沉积末期,发生了区域升降运动,是整个渤海湾盆地由断陷转为拗陷的标志。该时期大部分的断裂活动已经停止,只有少部分的断裂在活动,这时的夏口断层活动不如沙河街组三段沉积时那么强烈了,上第三系-第四系为大套以河流相为主的红色碎屑岩建造。该时期沉积的馆陶组直接覆盖在东营组、沙河街组一段、沙河街组二段甚至沙河街组三段之上,馆陶组与下伏地层呈区域不整合接触。这一时期是馆陶组下伏不整合构造圈闭形成的主要时期,也是生烃排烃的重要时期。

3 断层封闭性及其对油气运移的影响

夏口断层是一条区域性的长期活动的同沉积大断层,长约 70 km,总体走向 NEE 向,不同地段表现出近 EW 向和 NE 向变化。它是分割惠民凹陷深陷区与南部斜坡的重要构造边界。夏口断层的断面形态以铲式和高角度平面式为主,断层局部有分支复合现象。

一般认为,油气聚集期停止活动的断层,特别是停止活动时间较长的断层,多数情况下对油气起封堵作用;而油气聚集期活动的断层常具开启

性,使油气沿断层通道由高势区向低势区运移或从深层向浅层运移^[6]。本次研究主要针对西南缓坡带的夏口断层西段,采用了泥岩涂抹系数加以定量研究。据研究,惠民凹陷断层涂抹系数的临界值为5,即当泥岩涂抹系数小于5时,断层是封闭的;大于5时,断层在侧向上不能对油气起到封闭作用^[7](表1)。

表1 夏口断层泥岩涂抹系数表
Table 1 Smearing coefficient of Xiakou fault

井号	不同层位的系数值				
	E_3d	E_3s^1	E_2s^2	$E_2s^{3上}$	$E_2s^{3下}$
夏32井处	1.52	3.31	2.63	4.49	4.87
夏36井处	1.44	2.76	7.62	2.22	3.78

由断层泥涂抹原理可知,涂抹系数值越小,反映泥岩涂抹越均匀,断层的封闭性就越强。从表1可以看出,处于临南油田的双丰砂体上的夏32井处泥岩涂抹系数基本上是随着深度的增加而逐渐变大的,表明此处夏口断层的封闭性随深度的加深而变差。在沙河街组三段中亚段以上,涂抹系数小于5,表明断层封闭性好,能对油气的侧向运

移形成遮挡;以下,封闭性开始变差,对油气的侧向运移不能起到遮挡作用。由以上分析可知,沙河街组二段、沙河街组三段上亚段和中亚段是夏32断块圈闭的油层主要分布层位;而夏口断层在沙河街组三段下亚段和四段不封闭,不能在这些储层的上翘方向形成有效的遮挡,没能形成油气藏。夏36井除了沙河街组二段外,其他层位也基本符合上述特征。事实上,断层泥涂抹的效果与断层性质、产状、活动程度等因素有关。不同埋深和不同倾角的断面受力大小不同;多次活动的断层对断层泥涂抹层有破坏作用。因此在评价夏口断层封闭性时主要从断层的产状、活动次数以及断层泥涂抹系数等方面进行综合考虑。

从夏口断层的封闭性研究可知,夏口断层西段在沙河街组三段中亚段以上有很好的封闭性,临南洼陷生成的油气无法继续穿过断层,只能在断裂上盘聚集形成临南油田;由于夏口断层在沙河街组三段中亚段以下封闭性差,上盘的沙河街组三段下亚段又与下盘的沙河街组四段上亚段对接,所以临南洼陷沙河街组三段下亚段运移来的油气穿过夏口断层而在上盘的西南缓坡带中运移,并且在适当的沙河街组四段断鼻圈闭内聚集成藏(图3)。

4 结语

考虑到西南缓坡带构造位置以及油气运移距离和断层封闭性的影响,认为由于夏口断层在缓坡带沙河街组三段中亚段以上封闭性较好,西南缓坡带发生油气纵向运移的可能性很小,而以下封闭性较差。因此,勘探目标应集中在沙河街组四段及其下伏地层的断块圈闭勘探的同时,应加大对沙河街组四段岩性圈闭、地层圈闭和复合圈闭的勘探力度,对其他层的勘探力度应适当减少。

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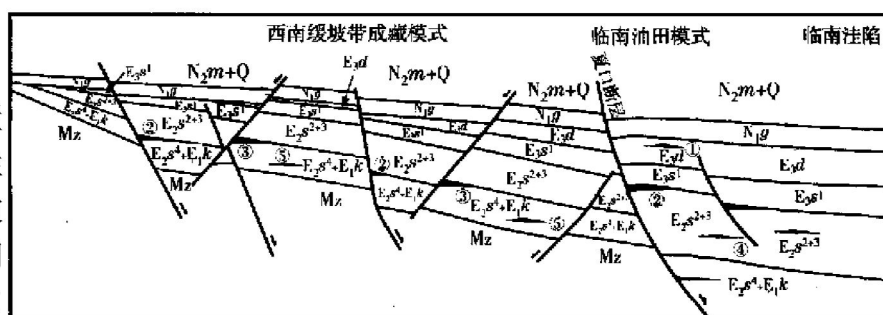


图3 西南缓坡带成藏样式图

Fig. 3 Pattern of hydrocarbon accumulation in southwest gentle slope belt

- ①—盆倾盖层滑脱正断层上盘的滚动背斜圈闭; ②—盆倾正断层上盘的构造鼻及断层圈闭; ③—反盆倾正断层下盘断块圈闭; ④—坡折带下方的岩性圈闭;
- ⑤—缓斜坡部位水进体系中的砂岩层圈闭

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STUDY OF CENOZOIC TECTONIC EVOLUTION AND HYDROCARBON ACCUMULATION IN SOUTHWEST GENTLE SLOPE BELT, HUIMIN SAG

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Abstract: The southwest gentle slope belt in Huimin sag is located in the structural slope to the south of Xiakou fault. In the north, it is adjacent to Linnan depression, an important oil kitchen, and is bounded by Xiakou fault zone; it is adjacent to Luxi uplift in the south, Qudi horst and Jiyang graben in the east, and Yucheng depression in the west. Its area is about 500 km². The Paleogene in the gentle slope belt is relatively thin. On the whole, it appears to be a wide and gentle monocline, uplifted in the south and dipping to the north. There are only a few NNE conjugated normal faults with small displacement in it. At the same time, these faults cut through the strata into the basement and pinch out upward in the Paleogene or end up beneath the unconformity. The Cenozoic tectonic evolution in that area can be divided into 4 stages: (1) During the deposition of Kongdian Fm to Es₄, Huimin sag was a simple half-graben fault depression and the southwest gentle slope belt was located on the structural slope of the half-graben. The tilting movement resulted in the whole area to be dipping to the north, and so deposited a wedge-shaped sedimentary sequence composed of Kongdian Fm-Es₄. During this stage, the displacement of Xiakou fault was small, and it could be regarded as accommodating the counter-inclined fault developed on the hanging wall of Linshang fault. (2) During the deposition of Es₃-Es₂, the activity of Xiakou fault was intensive, which became the southern boundary fault of the graben-type Linnan depression. The southwest gentle slope belt located on the footwall of Xiakou fault subsided slowly, and the tilting had apparently been restrained. There were conjugated normal faults with small displacement in the belt. The thickness of the Es₃ and Es₂ were relatively thin and uniform. (3) During the deposition of Es₁ to Dongying Fm, the faults in the southwest gentle slope belt had stronger activity. During the deposition of the Dongying Fm, the tilting made the whole belt to be dipping to the north. (4) During the deposition of the Neogene to Quaternary, Xiakou fault and the faults within the southwest gentle slope belt were basically inactive. As a result, a regional unconformity occurred between Guantao Fm and the underlying formations. In the southwest gentle slope belt near the basin margin, source rock can only be found locally in some well-developed Es₄. The sealing characteristics of Xiakou fault have an important effect on the hydrocarbon migration and accumulation in the southwest gentle slope belt. Xiakou fault is characterized by listric and high-angle plane fault. The smearing coefficient analysis of Xiakou fault indicate that the fault's sealing property becomes poorer with increasing depth. The middle Es₃ and younger formations have relatively good sealing characteristics, while the lower Es₃, Es₄ and older formation have relatively poor sealing characteristics. The Es₄ source rock in the southwest gentle slope belt reached the hydrocarbon-generating threshold (2 600 m) after Dongying Fm was deposited. The hydrocarbon generated from Es₄ source rock on the hanging wall of Xiakou fault can migrate laterally through the fault to the southwest gentle slope belt. Because of the lack of source rock in Es₃ and sequences above it, and the sealing of Xiakou fault, the hydrocarbon generated in Linnan depression have been hampered to migrate to the gentle slope belt. The characteristics of the structural evolution and the hydrocarbon accumulation model set up from the migration condition show that fault-block and stratigraphic traps might be formed in the Es₄ and older formations in the southwest gentle slope belt, but oil and gas reservoirs would hardly be formed in the Es₃ and younger formations.

Key words: structural evolution; sealing property of fault; oil and gas accumulation; Xiakou fault; Huimin sag