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麻黄山西区块延安组河道砂体反射模式 分析及应用

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摘 要: 麻黄山西区块西部断裂复杂区以构造圈闭为主, 东部稳定区以构造~岩性圈闭为主, 由于延安组储层砂体薄, 横向变化快, 且二维地震资料品质差, 储层预测较困难。为此运用地震地层学中储集体的地震反射结构原理, 以二维模型分析为手段, 通过对已知钻井地震反射结构的分析, 总结出延安组河道砂体的反射模式, 为该区延安组砂岩储层的综合预测奠定了地震技术基础。该成果在本区油气勘探开发井位建议中, 发挥了重要的作用。

关键词: 麻黄山西区块; 延安组; 地震地层学; 反射结构; 油气勘探开发

中图分类号: TE 122. 2⁺3 **文献标识码:** A

0 前言

麻黄山西区块, 位于一级构造区划天环向斜西部向西缘断折带的过渡部位。在西部断裂复杂区, 以构造圈闭为主, 由断裂牵引作用产生的背斜、断背斜及断块, 是最有利的油气储集场所。在东部稳定区, 以构造~岩性圈闭为主, 其中低幅度构造圈闭与河道砂体发育相匹配的部位, 是油气储集的有利场所。

前期的研究主要以构造为主, 处理思路是以解决构造问题为主要目的, 因而在资料品质较差和断裂区, 增加了非保幅处理手段来实现成像效果, 这给后期储层预测带来困难。而延安组储层砂体薄, 横向变化快, 单砂体厚度在几米至十四米, 对 35 Hz 左右的主频而言为薄层。由于探井较少和井位分布不均, 给利用反演大距离外推造成了困难。

针对上述难点, 作者在本文主要利用地震地层学解释的方法, 以二维模型分析为手段, 在分析该区目的层段地质特征的基础上, 对地震层序的划分与解释, 并对已知含油气井和不含油气井地震反射结构的详细分析, 总结出该区延安组河道砂体的地震反射模式, 为该区延安组砂岩储层的综合预测奠

定了地震技术基础。

1 地质特征

麻黄山西区块位于鄂尔多斯盆地天环向斜西部向西缘断折带的过渡部位, 侏罗纪延安期主要发育了一套河流~三角洲沉积体系, 烃源岩不甚发育, 油源主要来自延长组, 各期河道砂体是主要储层类型。①延 10 期主要为河流沉积; ②延 9 期整个鄂尔多斯盆地构造开始沉降, 进入三角洲平原发育阶段, 沉积了一套三角洲平原亚相的含煤岩系; ③延 8 期盆地经历局部构造抬升, 开始填平补齐, 物源供应相对充足, 三角洲平原沉积继续扩大。

因而延 8、延 9 和延 10 储集层类型主要有河道、河道砂坝和边滩微相砂体。岩性以块状为含砾粗砂岩和块状中砂岩为主, 砂岩产状为顶平底凸的透镜体, 平面呈长条状的树枝状分布, 长条的延伸方向与流向一致。粒度有自下而上变细的趋势, 粒度韵律明显, 与底部泥岩突变接触, 并见冲刷现象。

2 层序划分与解释

依据地震反射层序划分结果, T₅、T₄、T₄' 波

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组构成的第Ⅲ地震层序属燕山期侏罗系沉积,可细分为三个亚层序,从下而上 T5 波组对应延安组,即Ⅲ1 亚层序,T4 波组对应直罗组。T4'波组对应安定组。目的层延 8—9 属于延安组,属于Ⅲ1 亚层序内部的一套反射。T5 波组的反射为Ⅲ1 亚层序,该亚层序对应的是侏罗系延安组地层,延安组地层属于河流和湖沼相地层,为一套煤系地层,该套地层的顶面和底面与上、下覆地层都呈不整合接触,因此总体为一套能量强、连续性好的平行亚平行反射,特征在剖面上最为明显,由 5 个~7 个相位组成,其顶 T4 波呈中频强振幅,底 T5 波中高频中强振幅,中上部的三个波比较稳定,呈低频强振幅,连续性好。T5 波附近有充填型反射,波间出现强弱转换,与下覆地层有削蚀现象,有下切反射现象(见图 1)。

3 地震反射结构分析

3.1 地质物理模型

为进一步研究区内储集层的反射及分布特征,根据上述储层的沉积特点,作者对该区河道砂体可能的形态进行了地质模型分析。在模型的制作中,子波选用与地震剖面提取的子波相近的 30 Hz 雷克子波,不同岩性的地球物理参数参考测井资料,储层与围岩的速度、密度依据区内测井解释成果。

见下页图 2,左边的下切模型在储层反射特征模型中,反射波时差大小及波的胖瘦(频率)变化,是地层或砂体厚度变化的直接反映。这种模型的地震响应,在常规地震剖面上 T5 波附近可以看到,当砂体厚度横向变化很大时,可利用反射波内

部呈“空白”底部下凹的组合特征进行砂体有利区的预测。

见下页图 2,右边的楔状模型在储层反射特征模型中,储层厚度的变化表现较为清晰,在厚度大于 50 m 时,内部多出一个波峰,储层的形态依然存在。因此,仍可根据这种反射特征进行砂体有利区的预测。

根据延安组地层组合特点,设计由泥、煤、砂组成的透镜状地质模型,在地层下凹处充填有砂层,砂层最厚处有三十多米,向两边减薄,在储层反射特征模型中,T5 反射波的上方出现一个反射波,以充填的形式超覆在该波的上方,与下波形成透镜状,呈弱振幅(见下页图 3)。这说明在砂岩较厚处仍可根据这种反射特征进行砂体有利区的预测。

3.2 延安组早期河道砂体剖面特征

对于延安组早期河道砂体地震反射结构的分析:依据正演模型分析结果,从已知钻井在地震剖面反射特征入手,通过对砂体发育井和不发育井地震反射特征对比,总结砂体发育井的地震反射特征,以此来确立河道沉积微相的有利地震相模式,然后在地震剖面上解释河道和河口坝的位置,以此预测麻黄山西区块延安组延 8、延 9 段有利油气区带。

首先分析延 8、延 9 和延 10 段砂体发育且分布于稳定区的钻井在地震剖面上反射结构,YA2 井为延 8 的主要产油层位,延 9 的产油井 YA1 井、YA3 井,把这三口井作为延 8、延 9 的砂体发育井。

(1)从过 YA2 井的东西向地震剖面上发现(见后面图 4),位于 YA2 井东侧 YA4 井处,T5 下方有下切现象,呈强振幅反射,下切上方以弱~空

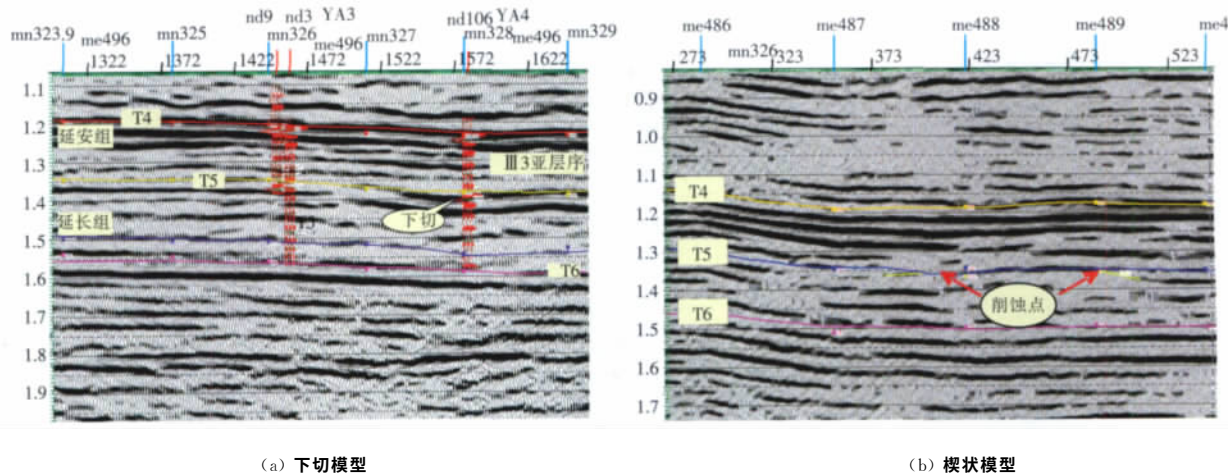


图 1 延安组地震剖面反射特征

Fig. 1 Seismic profiles reflection characteristics of the J1Y formation

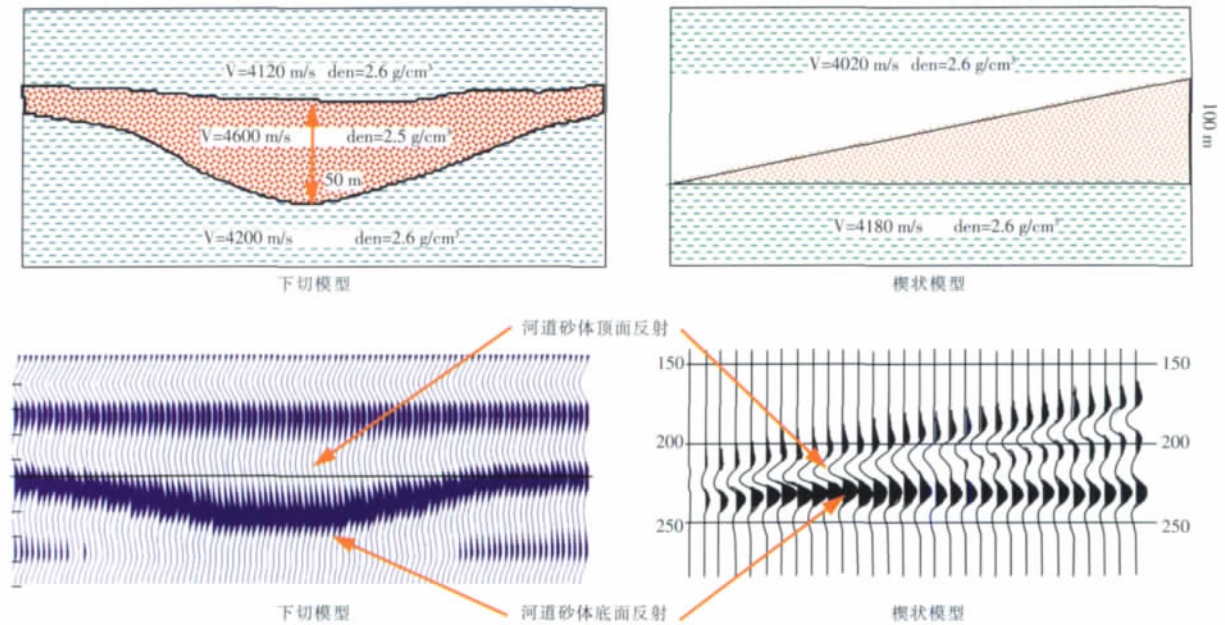


图2 河道相下切、楔状储层模型

Fig.2 Channel facies incised, wedge-shaped reservoir models

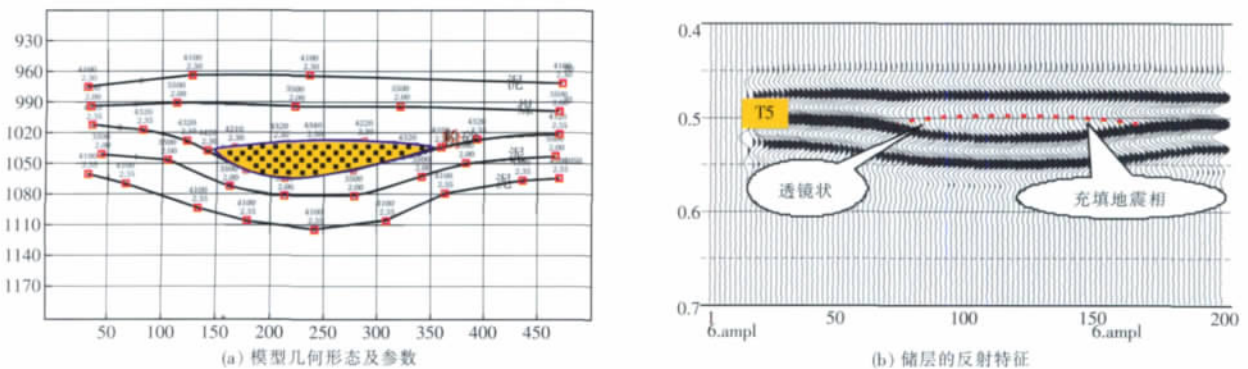


图3 河道相透镜状储层模型

Fig.3 Channel facies lenticular reservoir models

白反射为主,T5 波呈弱~中振幅,T5 上面的波振幅中强,钻井揭示 YA4 井延 10 有 10 m 厚的含水砂。同样,在 YA1(见下页图 5)、YA3(见后面图 6)侧翼也能看到这种下切现象,岩心剖面表明在延安组底部,砂岩与底部泥岩呈突变接触,并见冲刷现象。因此这些下切现象多是延 10 期下切河道的反映。

(2)在 YA1(见下页图 5)井南北向剖面上,T5 波和延 8 顶地震波间形成透镜状。在 YA3(见后面图 6)井的南侧有断层,北侧延 8 顶部波向下复合。地质成果表明,延安期这三口井处河流呈近东西向,在垂直于河流方向的南北向剖面,T5 波和延 8 顶地震波间形成透镜状、楔状反射的特征。这些区域多是延 8、延 9 河道发育区。这些透镜状、楔

状反射特征多出现在延 10 下切河道的侧翼,这也正是河道侧向迁移的结果。

(3)对砂体不发育井反射结构的分析,以 YA5、YA6 为代表(见后面图 7 及图 8)。这两口井的延 8、延 9 砂体都不发育。从这两口井的地震剖面看:T5 波组反射呈平行状,顶底界面呈强~中强振幅。

通过以上对已知井反射结构的分析,可以得出延 8、延 9 砂体发育井的反射结构具有以下二个特点:①在 T5 下方出现有下切现象,下切上方以弱~空白反射为主,T5 波呈弱~中振幅,T5 波上面的波振幅中弱;②在下切的上倾方向,T5 波附近的波呈楔状或透镜状。

同时,作者也对延安组延 8、延 9 和延 10 段控

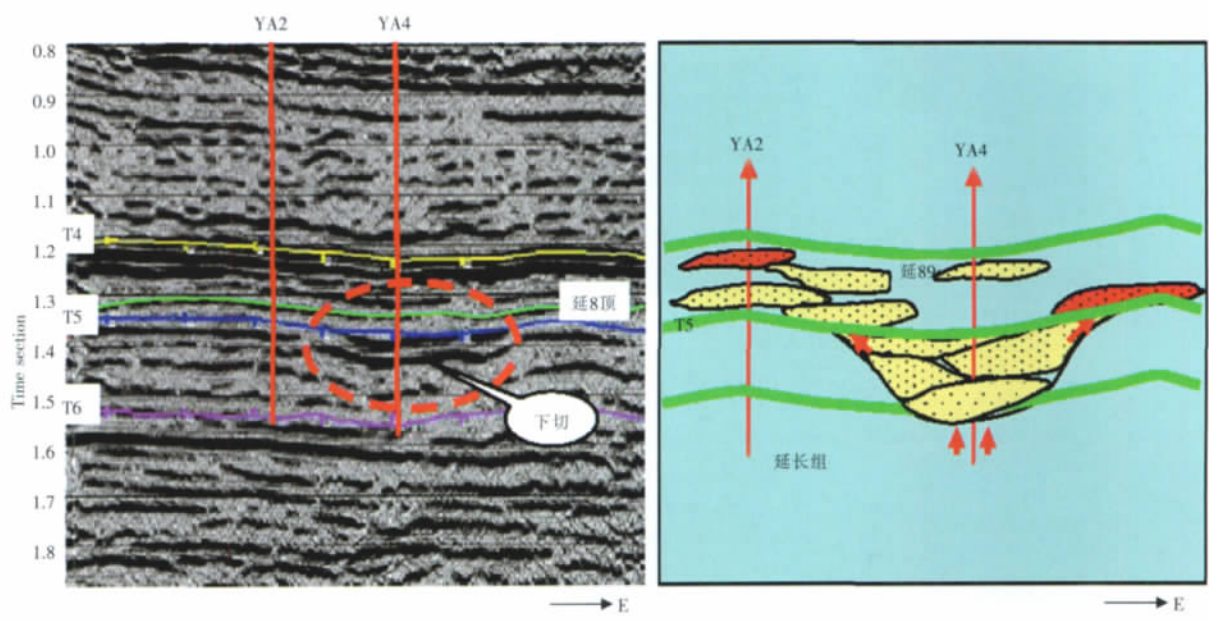


图4 YA2井延安组早期河道相反射特征

Fig. 4 Reflection characteristics of early channel facies in J1y formation of YA2 wells

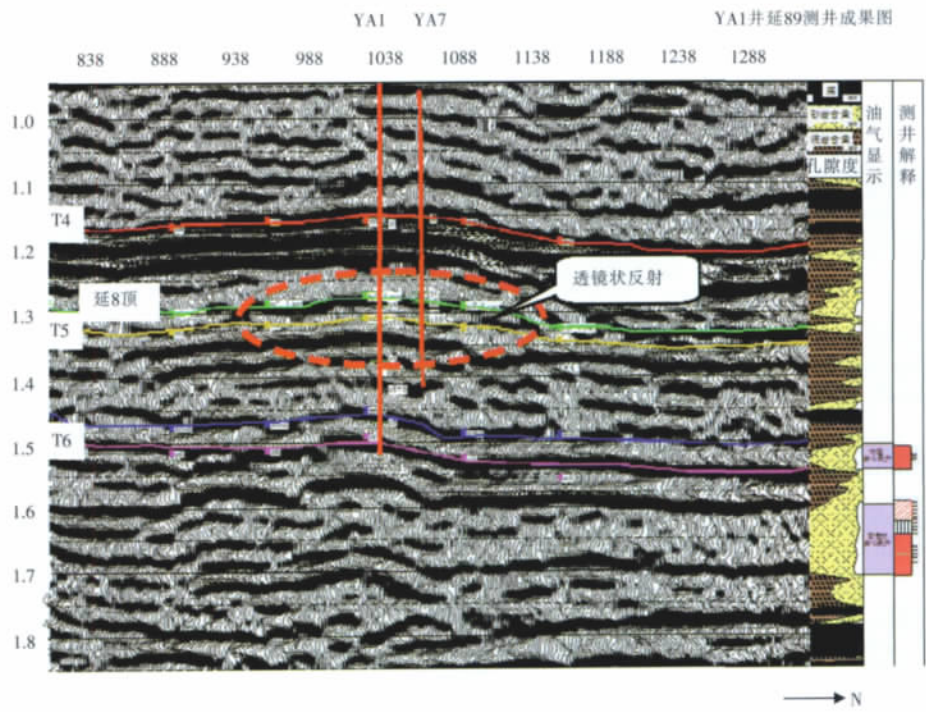


图5 YA1井延安组早期河道相反射特征

Fig. 5 Reflection characteristics of early channel facies in J1y formation of YA1 wells

油因素的成藏条件有了一些启示：①河道的下切对沟通延长组油源起到一定作用；②油气向高处运移并聚集，延10的下切河道砂体虽较发育，但往往位于较低处，随着河道的侧向迁移、分支、分叉，往往会在延10砂体发育的侧翼形成延8、延9的河道砂体，这时油气会沿延10的砂体通过侧向运移到延8、延9的砂体内成藏；③形成侧向封堵，要通过岩性的变

化或断层的存在，形成一个独立的体系，从而形成了延安组以下生上储式为主的生储盖组合。
因此通过下切反射特征，先找出延安组延10期河道的位置，再在该河道的侧翼寻找延8、延9的透镜状、楔状反射结构河道砂岩发育区，从而对麻黄山西区块延安组延8、延9段有利油气区带进行有效的预测。

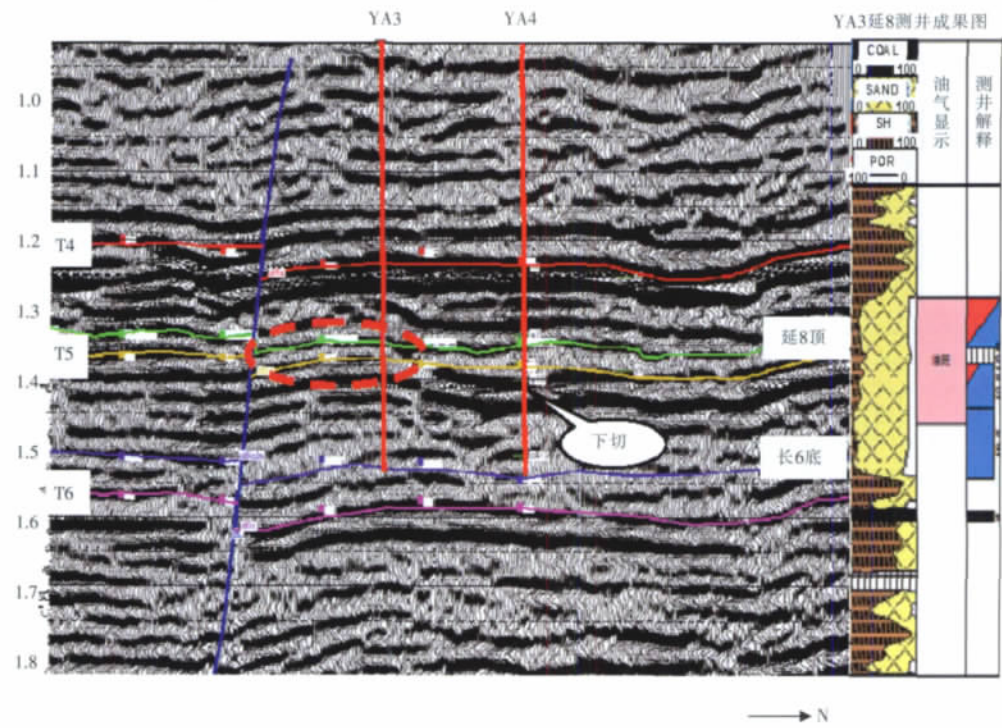


图 6 YA3 井延安组早期河道相反射特征

Fig. 6 Reflection characteristics of early channel facies in Yan'an formation of YA3 wells

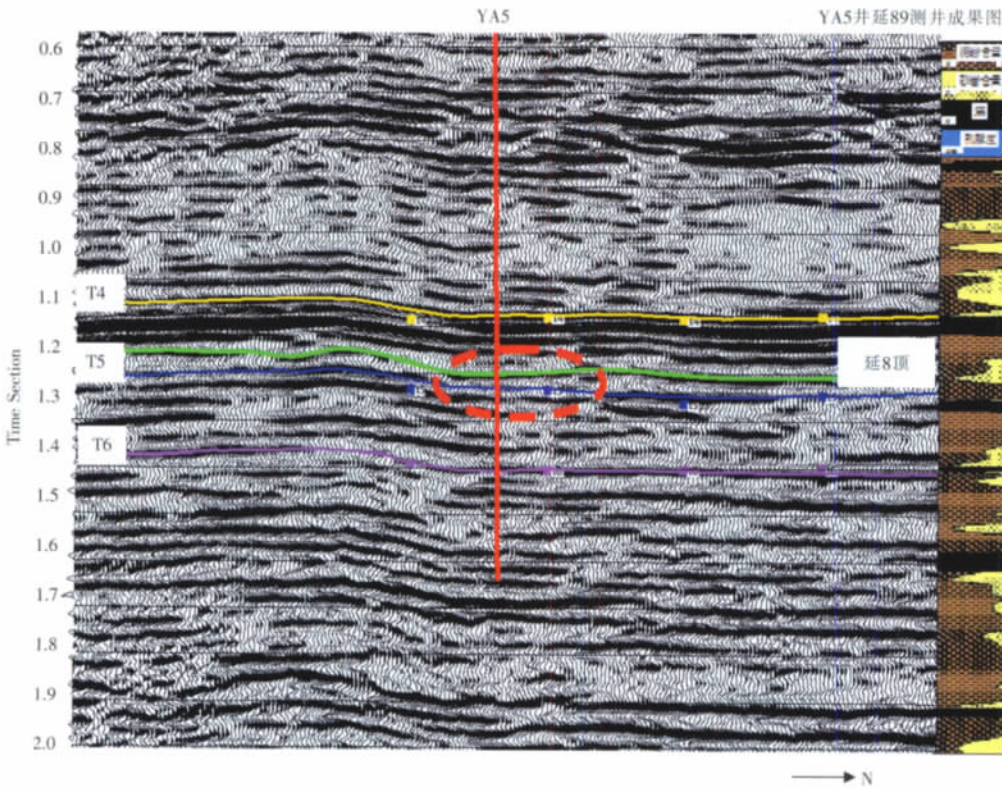


图 7 YA5 井延8、延9 砂体不发育井剖面反射特征

Fig. 7 Reflection characteristics of non-development well profiles in 8,9 sand body of YA5 wells

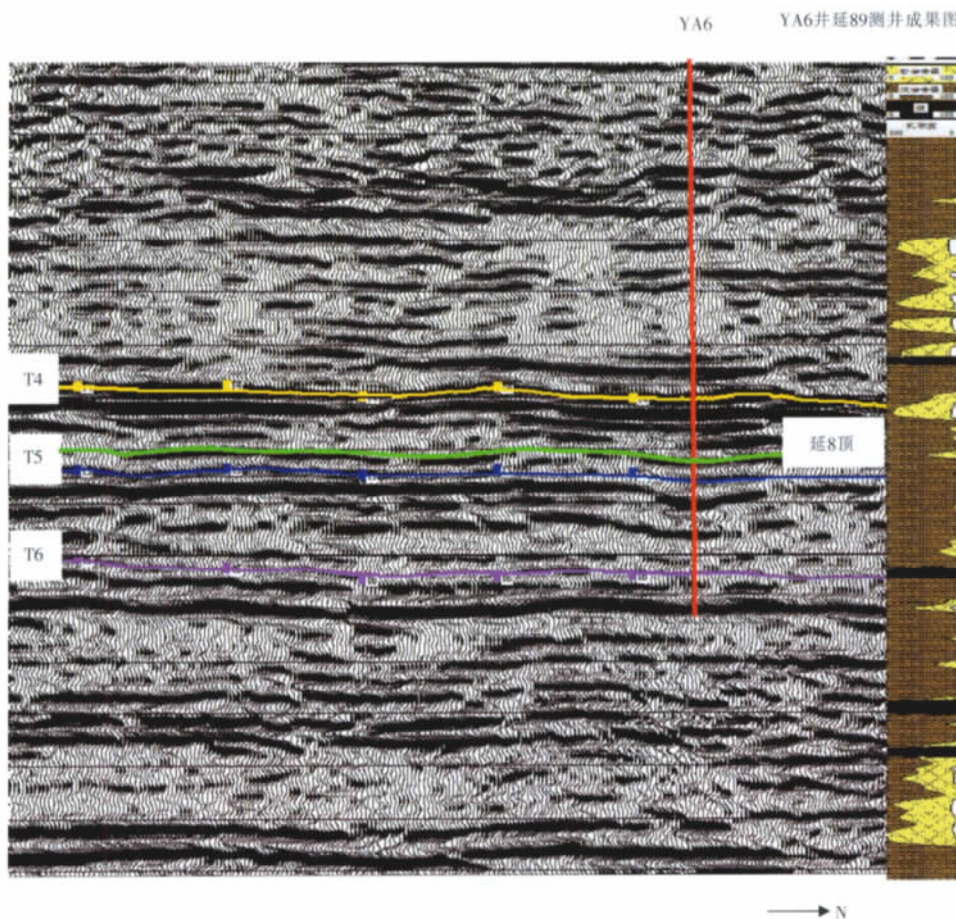


图8 YA6井延8、延9砂体不发育井剖面反射特征

Fig 8 Reflection characteristics of non-development well profiles in 8,9 sand body of YA6 wells

4 平面展布及效果分析

4.1 延安组延10河道平面展布特征

根据延安组延10期河道砂发育井的地震剖面特征,对延10期河道进行剖面特征对比,形成延安组早期河道平面展布(见下页图9)。延10期的河道主要分为二条,①呈近东西向展布,位于工区北部,在剖面上有下切的特征;②呈北西南东向展布。这与延10期的沉积微相图(见下页图10)有较好的一致性。图9河道的范围小于图10,因为图9主要反映延10期下切河道在地震剖面上能分辨出来的区域。

4.2 效果分析

从以上的分析可知,在延10河道的侧翼是延8、延9河道较发育区,A井和B井位于延10河道的侧翼:A井在延9有12 m油浸~富含油粗砂岩,平均日产原油5.93 m³,经五个月生产,产油量仍稳产在1.3 m³/d左右;B井有9.5 m的砂,中上部油

浸中砂岩下部油斑中砂岩,平均日产原油23.23 m³,基本不产水,经五个月生产,产油量仍稳产在22.5 m³/d。

从以上看,延安组属于下生上储型油藏,断层和延10下切河道对油源沟通起到了重要的作用。目前,已在该区延安组延8、延9油层提交上百万吨原油探明储量。

5 结论

通过对上述延安组地震反射特征解剖和分析,可以认为延安组的有利地震反射模式具有以下几个特点:

(1)在T5下方出现有下切现象,下切上方以弱~空白反射为主,T5波呈弱~中振幅,T5波上面的波振幅中弱。

(2)在下切的上倾方向,T5波附近的波呈透镜状或楔状。

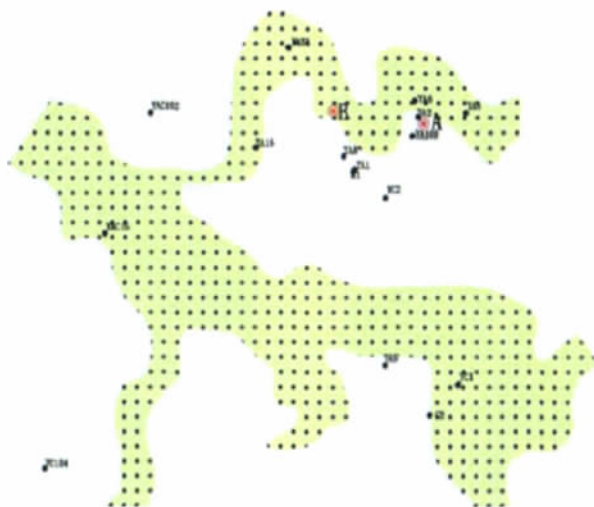


图9 延10期河道发育区平面展布图

Fig. 9 Plane distribution of YAN10 period development zone of incised channel

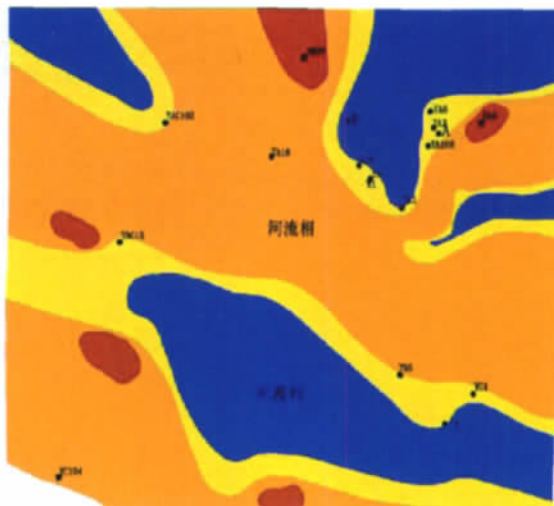


图10 延10期沉积微相图

Fig. 10 YAN10 period sedimentary microfacies map

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ABSTRACTS

THE METHOD RESEARCH FOR VELOCITY FIELD ESTABLISHING IN THE COMPLEX DEEPWATER AREA

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In the deepwater exploration, it is difficult to get the accurate velocity as there is varying water-depth (most over several kilometers), fewer wells and complex geologic condition in the continental slope area. Depth conversion of the direct use of stack velocity will lead to distortion of sedimentary layer structure. Only use drilling speed for the depth prediction of deepwater area will also lead to large errors. Based on the analysis of velocity structure characteristics and influencing factors, authors select the best velocity-inversion method due to the research of forward modeling. Then build up the depth conversion method suitable for the deepwater area of Baiyun sag, by use of the mutual restraint of drilling speed, velocity of coherent inversion and seismic stacking speed. This method resolves tectonic distortion owing to rough subsea preferably, and improves depth-prediction accuracy consumedly.

Key words: forward modeling; coherent velocity; inversion of pre-stack; lateral velocity picking; time-depth conversion; velocity field

ROCK VELOCITY REVERSE CAUSE ANALYSIS BASED ON GASSMANN EQUATION

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Gassmann effective medium theory is the most classic and most basic rock physics model. On this basis, the other equivalent model established greatly enriched media saturated rock elastic wave propagation theory. Gassmann theory is mainly used for dealing with the issue of fluid substitution, but fluid substitution always appear "reverse phenomena" under certain conditions. Interpreted as the porosity under a certain, fully gas-saturated rock velocity more than water-saturated, which is contrary to the result of physics rock laboratory test. Therefore, graphic analysis the cause of saturated rock speed reverse for different rock sample and well log data, found that the density difference of saturated rock is too large causes leading to reverse. At the same time, the saturation of carbonate reservoir rocks were replaced by numerical simulation, the simulation results was consistent with the laboratory test data, only carbonate rocks of different porosity size. Therefore emphasizes on the importance of fluid substitution forward modeling, the actual value of fluid substitutions only under certain physical meaning.

Key words: gassmann effective medium theory; fluid substitution; cause analysis; reverse phenomenon

ANALYSIS AND APPLICATION OF THE SEISMIC REFLECTION MODE OF CHANNEL SANDS FOR J1Y FORMATION IN MAHUANGSHAN WESTERN BLOCK

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Mahuangshan western block includes complex fault zone in western and stable region of formation in eastern, the main traps of the former are the structural traps and the main traps of the latter are the structural-lithological traps, but the sand body of J1y formation is thin and changes

quickly in lateral, and the quality of two-dimensional seismic data is poor, thus reservoir prediction of J1y formation is very difficult. Analyzing seismic reflection structure of the known well with seismic reflection structure principle of reservoir and two-dimensional model in seismic stratigraphy, and the reflection mode of channel sands for J1y formation is summarized, which is the seismic technology basis of comprehensive prediction for channel sands of J1y formation. Such achievements play the important role in exploration, development and well location suggestion of the block

Key words: western mahuangshan block; J1y formation; seismic stratigraphy; reflection structure; exploration and development

SHADOW AND SOURCE OVERPRINT EFFECTS IN 3D CSAMT

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Shadow and source overprint effects will lead to errors in geological structure, and some economic loss in practical work. In this paper, these effects are simulated through finite element method. By analysing numerical simulation results of different models of abnormal body between the source and line in homogeneous half-space, the influence law of shadow effect is obtained, also this paper comes to the conclusion that the area of shadow effect is much more larger than abnormal body and passes the centre of abnormal body, from which to both sides, the shadow falls off gradually. With the changes of the resistivity and size of abnormal body, shadow and source overprint effects are different.

Key words: CSAMT; shadow effect; source overprint effect

EFFECTS OF GRID SIZE AND BOUNDARY ON MT FORWARD MODELING USING FINITE ELEMENT METHOD

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The accuracy of the magnetotelluric (MT) forward modeling takes an important part in the inversion. The main factors that determine the accuracy of MT forward modeling using finite element method (FEM) are interpolation function, error of solving linear equations and grid size. However, that grid size is appropriate or not provides a prerequisite for fem simulating. According to its borders and horizontal and vertical grid length, it was discussed their effects to MT modeling. The results shows that the left, right and the lower boundary are not necessary to place at infinity and the horizontal grid has little effect on accuracy for one-dimensional or good symmetric two-dimensional media and that vertical grid is closely related to the smallest skin depth and it can not larger than 1/4 skin depth on the earth surface.

Key words: MT; grid; boundary; accuracy

PSEUDO-2D INVERSION INTERPRETATION FOR MAGNETOTELLURIC DATA USING 1D REGULARIZATION INVERSION METHOD

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The MT inversion problem is ill-posed and the inversion results are unstable and non-unique. A stable solution of the ill-posed inverse problem can be obtained by utilizing the regularization methods in the objective function. In order to improve the processing efficiency and precision of primary interpretation for MT data, 1D regularization inversion method was put forward for MT data pseudo-2D inversion interpretation, which is different from the previous interpretation. Firstly, we control layer parameters through the depth of bostick inversion and the regularization inversion calculation of model parameters exists only