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渤海海域L油田砂质辫状河储层构型特征

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摘要:随着油田开发进入中后期,油水关系更加复杂,剩余油挖潜难度随之增大,基于储层构型的精细地质研究成为油田剩余油挖潜的关键。综合利用露头、岩心、现代沉积和密井网等资料,应用层次界面分析法,深入解剖渤海海域L油田4区砂质辫状河储层构型特征。以构型倒序分级方案为基础,参考构型正序分级方案,将研究区辫状河储层构型界面分为6—12个级次。依据砂质辫状河储层经验公式、现代沉积和密井网井间对比,分级次对砂质辫状河单一辫流带、心滩坝和辫状河道及心滩坝内部夹层进行定量表征,形成一套适用于砂质辫状河储层不同级次构型单元的定量表征方法;明确单一辫流带级次、心滩坝和辫状河道级次及心滩坝内部夹层级次3个层次的构型特征。提出辫状河道具有砂质充填、半泥质充填、泥质充填和残存泥质充填4种充填模式,并分析不同充填模式的成因。

关键词:辫状河 储层构型特征 层次界面分析法 落淤层 渤海海域
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Internal architecture characteristics of sandy braided-river reservoirs in L Oilfield, Bohai Bay Basin

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Abstract: As the oilfield development entered the middle and late stage, difficulty of tapping residual oil increases when the relationship between oil and water becomes more and more complex. Fine geological research based on reservoir architecture becomes the key to tap residual oil. The hierarchy interface analytical method was applied in the article to analyze the internal architecture characteristics of sandy braided-river in the 4th area of L Oilfield in Bohai Bay Basin based on outcrop, core, modern deposits and dense well logging data. On the basis of architecture reverse classification scheme, the architecture interface of braided-river in the study area was divided into 6-12 levels considering positive sequence classification. Based on the experience formula for sandy braided-river reservoir, modern deposits constraints and stratigraphic correlation between closely spaced wells, single braided channel belt, braided bar and braided channels and interlayers within braided bar were quantitatively characterized by grade. A set of methods for quantitatively characterizing different levels of sandy braided-river were developed, and the characteristics of single braided channel belt, braided bar and braided channels and interlayers within braided bar were determined as the three levels of the architecture. There are four filling patterns for the braided channels, including sand filling, half-mud filling, mud filling and remaining mud filling, and then the genesis of different filling patterns was analyzed.

Key words: braided river; architecture characterization of reservoirs; hierarchy interface analytical method; silting layer; Bohai Bay Basin

辫状河沉积作为陆相河流—三角洲沉积体系 的重要构成单元,是中国已发现油田的主要储层类

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型之一。自20世纪80年代Miall提出构型要素分析法[1]以来,中外学者对辫状河储层构型的研究主要针对野外露头与现代沉积[2-5],对地下储层构型的研究主要以构型模式为主,对心滩坝和辫状河道的分布特征、发育样式及内部结构的研究较少,而心滩坝和辫状河道砂体作为辫状河沉积最重要的油气储集体,对其剩余油预测及油田二次开发具有重要意义。为此,笔者以渤海海域L油田4区L70小层为研究对象,以层次界面分析法为指导,按单一辫流带、心滩坝和辫状河道及心滩坝内部夹层逐级进行精细解剖,以明确不同级次砂体的几何形态和内部构型特征。

1　区域地质概况

L油田处于渤海海域中南部,位于郯庐断裂带中段,发育在渤南低凸起基底隆起背景上,是受2组近南北向走滑断层控制的背斜构造。L油田自下而上钻遇的地层有中生界白垩系,新生界古近系孔店组、沙河街组、东营组和新近系馆陶组、明化镇组,第四系平原组,其中馆陶组为其主力含油层系,以砂质辫状河储层为主,油藏埋深为900~1 400 m,储层孔隙度平均为18.9%~32.6%,渗透率平均为15.0~5 900.0 mD,属于中高孔、中高渗透储层。其中4区自2008年投产以来,已有近十年的开发历程,为密井网布井,其井距为40~300 m,岩心、测井、生产动态及测试资料丰富。目前,4区综合含水率为78%,采出程度仅为18%,剩余油仍具有巨大挖掘潜力。

2　沉积微相特征

渤海海域L油田4区L70小层馆陶组为辫状河沉积,是其主力产层之一。岩性主要发育细砂岩、中砂岩、中—粗砂岩和泥岩,少量含砾砂岩;矿物成分以石英和长石为主,碎屑颗粒分选差,磨圆较差,以次棱角状和次圆状为主,胶结疏松;砂岩内部主要发育低角度交错层理、槽状交错层理、波痕、不连续层理、平行层理、透镜状层理和递变层理等,冲刷面也较发育,厚层砂岩内可见水平状薄层泥岩夹层,砂岩顶、底界面以岩相突变为主,河道底部发育河床滞留沉积,测井曲线形态以箱形和钟形为主。由图1可知,碎屑颗粒以跳跃和悬浮组分为主,跳跃组分含量较高,达70%,悬浮组分和跳跃组分的交截点中值为1.5~2 ϕ,说明研究区水动力条件较强。此外,根据Leclair等提出的经验公式[6-7],由交错层理系平均厚度计算其辫状河古水深为5~8 m。综合分析认为,研究区L70小层河流相砂体类型属于远源砂质辫状河沉积,主要发育心滩坝、辫状河道、溢岸和泛滥平原4种沉积微相。

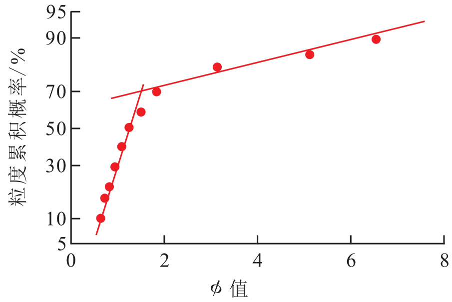

图1　L70小层岩心粒度累积概率

Fig.1　Grain size probability curves of core in L70 layer

2.1　心滩坝微相

心滩坝是辫流带内主要沉积微相类型,砂体厚度大,分布范围广。岩性以中砂岩和细砂岩为主,底部可见冲刷面,局部发育含砾砂岩;沉积构造以槽状交错层理和低角度交错层理为主;沉积韵律性不明显,以均质为主;自然伽马曲线以箱形为主。

2.2　辫状河道微相

辫状河道与心滩坝均为辫流带内主要沉积微相类型,砂体厚度大,分布范围广。岩性以中砂岩和细砂岩为主,常见交错层理和平行层理,底部可见明显的冲刷面。受物源供给和河流改道的影响,辫状河道发育砂质充填、半泥质充填、泥质充填和残存泥质充填4种充填模式。砂质充填主要是由于河道分流等原因造成水流速度突然降低,导致河道内携带的沉积物超过其负载能力,使其携带的砂质沉积物卸载,形成砂岩储集体;自然伽马曲线呈钟形(图2a)。半泥质充填主要是由于物源供给不充足,水流速度突然降低后,河道内携带的砂质和泥质沉积物按粒度大小先后沉积下来,使得河道下部发育砂岩,上部发育粉砂质泥岩和泥岩;自然伽马曲线呈钟形(图2b)。泥质充填主要是辫状河改道造成在一段时间内保持隔离的静水环境,最终,河道中细粒悬浮物质自然沉积下来形成泥质充填(图2c);自然伽马曲线位于泥岩基线附近,由于河道底部发育低自然伽马泥岩,与泥岩基线之间存在明显幅度差,反映河道早期冲刷沉积物的痕迹[8]。残存泥质充填主要是由于河道复活使得前期废弃的河道再次被激活,河道下切作用使得前期沉积下来的泥质沉积物被部分冲刷掉,形成河道下部发育泥岩、上部发育砂岩的沉积组合;自然伽马曲线特征为河道下部位于泥岩基线附近,河道上部呈钟形(图2d)。

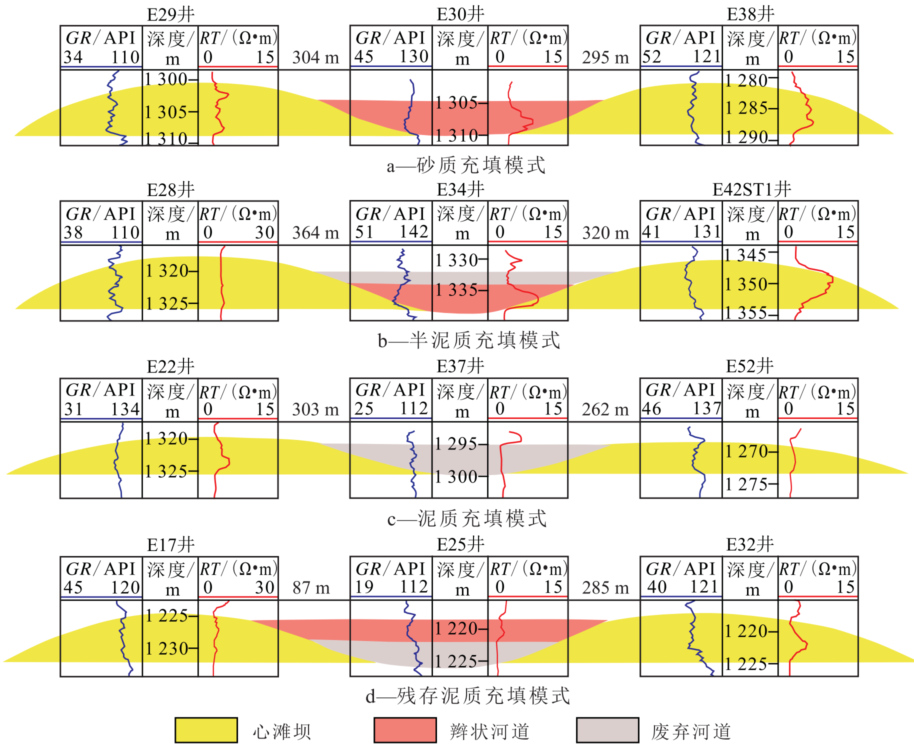

图2 L70小层辫状河道微相充填模式

Fig.2 Filling patterns of braided channels of L70 layer

2.3 溢岸微相

溢岸微相主要分布在辫流带的两侧及泛滥平原内，岩性以粉砂岩和中—细砂岩为主，局部可见粉砂岩和泥质粉砂岩互层沉积，可见透镜状层理；砂体厚度较薄，一般韵律性不明显；自然伽马曲线呈指状。

2.4 泛滥平原微相

泛滥平原微相主要分布在辫流带两侧，横向分布稳定，岩性以粉砂岩和泥岩为主，发育水平层理和块状层理；自然伽马曲线较平直，位于泥岩基线附近。

3 储层构型级次划分与特征

3.1 辫状河储层构型级次划分

Miall的构型分级方案属于正序分级方案，适用于地面地质研究，而吴胜和等构型分级方案属于倒序方案，适用于地下地质研究，因此，以吴胜和等构型分级方案[9]为基础，参考Miall的构型分级方案，将研究区辫状河储层构型界面分为6—12个级次。6级界面为单层界面，是一套分布稳定、连续性较好的泛滥平原沉积面，代表一次洪泛事件的开始或结束，界面内多个单一辫流带侧向叠置形成复合辫流带。7级界面为辫状河道砂体底界面，如单一辫流带的底界面，以河道底部滞留沉积底界面为代表，该界面所限定的构型单元为单一辫流带。8级界面为大型底形界面，如单期心滩坝或辫状河道的沉积间断面或冲刷面，或心滩坝与辫状河道之间的接触面，该界面所限定的构型单元为心滩坝和辫状河道。9级界面为大型底形内大规模再作用面或增生面，主要是受不同水动力条件影响而形成的界面，如心滩坝内部不同增生体间的界面，该界面所限定的构型单元为增生体和落淤层。10级界面为交错层系组界面。11级界面为交错层系界面。12级界面为纹层界面。充分利用岩心和测井资料，进行辫状河储层构型特征研究，以录井较易识别的7—9级界面为研究重点。

3.2 储层构型特征

3.2.1 7级构型特征

7级构型单元为单一辫流带，是指同一沉积时期多个微相单元的组合体；平面上，辫流带与辫流带间发育泛滥平原和溢岸沉积微相；垂向上，可能有高程差或者规模差。根据研究区辫状河道的古水深和L70小层内发育的稳定夹层，将L70小层细分为L70A，L70B和L70C共3个单层。通常利用井间对比、三维地震资料和经验公式3种方法进行辫流带的预测。受研究区三维地震资料分辨率的限制，采用经验公式[10]与井间对比相结合的方法，确

定目的层辫流带的规模。

L70C单层平均单河道满岸深度为5~8 m，利用经验公式计算辫流带宽度为1 000~3 300 m。由图3可知，研究区辫流带最大宽度为2 000 m，且仅在边部发育大规模泛滥平原沉积，据此确定L70C单层在一个辫流带内，这为单一辫流带内心滩坝和辫状河道储层构型表征奠定基础。

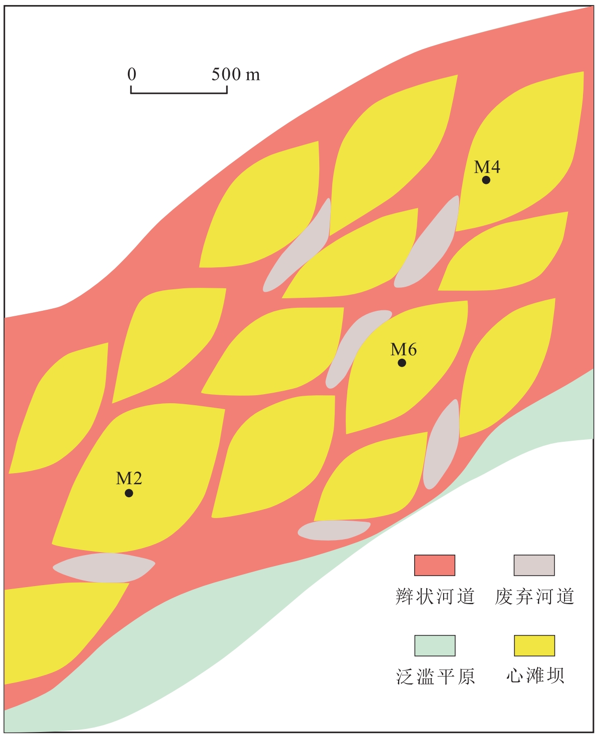

图3　L70C单层构型平面分布

Fig.3　Planar distribution of the architecture of L70C single layer

3.2.2　8级构型特征

8级构型单元为心滩坝和辫状河道，是辫流带内发育的主要沉积微相类型，进行心滩坝级次的构型表征，就是在单一辫流带内识别出心滩坝和辫状河道。野外露头和现代沉积研究表明：心滩坝与辫状河道之间的岩相界面清晰可见；剖面上，心滩坝呈底平顶凸状，辫状河道呈底凸顶平状，心滩坝的厚度略大于辫状河道的厚度；平面上，辫状河道呈“条带状”环绕心滩坝[11-18]。

心滩坝和辫状河道的规模主要是在单井相识别的基础上，通过连井剖面的井间对比来确定。然而井间对比受井间距的限制，加之井间微相边界的确定存在多解性，从而造成井间对比确定的沉积微相规模不准确。研究证实，现代沉积的辫流带宽度与心滩坝宽度之间具有一定相关性，心滩坝宽度与长度之间也具有一定相关性。因此，应用Google卫星照片，选定与研究区沉积背景相似的Sagavanirktok River和Waimakariri River等典型辫状河段作为研究对象，选取其中15段辫流带宽度、心滩坝宽度和长度建立构型要素之间的定量关系，分析发现辫流带宽度与心滩坝宽度、心滩坝宽度与长度之间均呈现较好正相关性(图4)。利用经验公式计算心滩坝宽度为250~750 m，心滩坝长度为600~1 750 m。根据Kelly等经验公式[19]，计算辫状河道宽度为100~250 m。

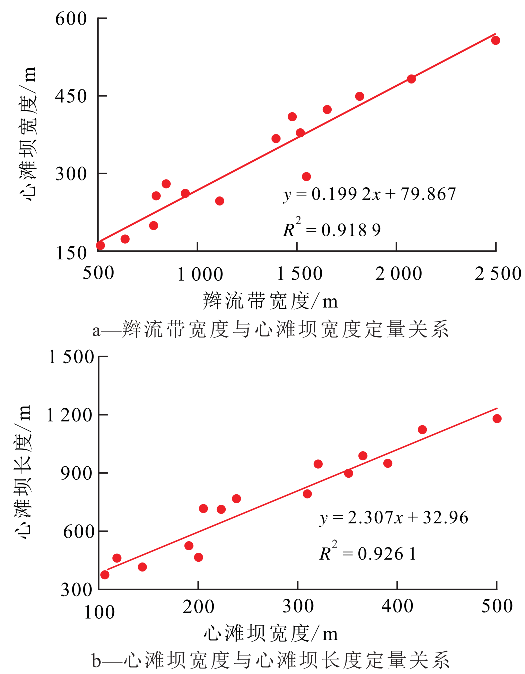

图4　现代沉积中辫流带宽度与心滩坝规模相互关系

Fig.4　Crossplots showing relationship between width of braided belt and scale of braided bar in modern sedimentation

3.2.3　9级构型特征

9级构型单元为心滩坝内部增生体和落淤层。在辫状河洪泛期，由于水动力能量较高，形成砂质增生体沉积；在洪泛事件末期，随着水动力能量快速减弱，由于沉积分异作用，在心滩坝顶部大范围沉积细粒悬浮物[20]，即落淤层沉积，心滩坝内部级次构型表征主要是对心滩坝内部的落淤层进行表征。落淤层岩性为泥岩、粉砂质泥岩或泥质粉砂岩，厚度为0.3~1.0 m，通过取心井岩电标定，利用测井曲线对非取心井心滩坝内部落淤层进行识别，然后利用密井网井间对比，计算落淤层的倾角和规模。将底部标志层拉平，做心滩坝短轴方向的连井剖面(图5)，根据三角函数计算短轴方向上落淤层倾角为0.5°，长轴方向上落淤层倾角为0.7°。远源砂质辫状河河水能量相对较小，心滩坝以垂向加积为主，落淤层倾角较小。根据三角函数公式、落淤层角度、落淤层厚度以及密井网约束得到落淤层宽

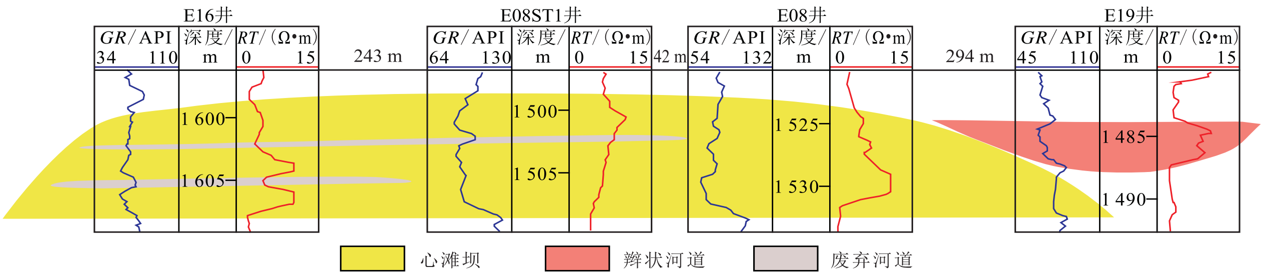

图5 L70C单层心滩坝短轴方向落淤层连井剖面

Fig.5 Connecting-well sections of silting layer along the short axis of the braided bar of L70C single layer

度为100~300 m,落淤层长度为200~600 m。

4 结论

渤海海域L油田4区L70小层为远源砂质辫状河沉积,对砂质辫状河储层构型界面分为6—12个级次,并重点分析了录井较易识别的7—9级界面的储层构型特征。依据砂质辫状河储层的经验公式、现代沉积和密井网井间对比,对砂质辫状河7级构型单元的辫流带级次、8级构型单元的心滩坝和辫状河道级次及9级构型单元的心滩坝内部落淤层级次进行定量表征。结果表明,研究区辫流带宽度约为2 000 m,心滩坝宽度为250~750 m,心滩坝长度为600~1 750 m,辫状河道宽度为100~250 m,心滩坝内部的落淤层宽度为100~300 m,落淤层长度为200~600 m。针对辫状河河道提出了砂质充填、半泥质充填、泥质充填和残存泥质充填4种充填模式,并分析不同充填模式的成因。

参考文献:

[1] Miall A D.Architectural-element analysis:A new method of facies analysis applied to fluvial deposits[J].Earth Science Reviews,1985,22(4):261-308.

[2] 辛仁臣,柳成志,雷顺.粗粒曲流河体系河道沉积的沉积构形分析——以籍家岭泉头组露头为例[J].大庆石油学院学报,1997,21(3):16-19.

Xin Renchen,Liu Chengzhi,Lei Shun,et al.Depositional architecture analysis of coarse meandering rivers system-a case study of Jijialing outcrop[J].Journal of Daqing Petroleum Institute,1997,21(3):16-19.

[3] 廖保方,张为民,李列,等.辫状河现代沉积研究与相模式——中国永定河剖析[J].沉积学报,1998,16(1):34-39,50.

Liao Baofang,Zhang Weimin,Li Lie,et al.Study on modern deposit of a braided stream and facies model-Taking the Yongding River as an example[J].Acta Sedimentologica Sinica,1998,16(1):34-39,50.

[4] 陈彬滔,于兴河,王天奇,等.砂质辫状河岩相与构型特征——以山西大同盆地中侏罗统云冈组露头为例[J].石油与天然气地质,2015,36(1):111-117.

Chen Bintao,Yu Xinghe,Wang Tianqi,et al.Lithofacies and architectural characteristics of sandy braided river deposits:a case from outcrops of the Middle Jurassic Yungang Formation in the Datong Basin,Shanxi province[J].Oil & Gas Geology,2015,36(1):111-117.

[5] 杨丽莎,陈彬滔,李顺利,等.基于成因类型的砂质辫状河泥岩分布模式——以山西大同侏罗系砂质辫状河露头为例[J].天然气地球科学,2013,24(1):93-98.

Yang Lisha,Chen Bintao,Li Shunli,et al.Pattern of genesis-based mudstone distribution for sandy braided river:a case study of sandy braided-river outcrop,Datong,Shanxi Province,China[J].Natural Gas Geoscience,2013,24(1):93-98.

[6] Leclair S F,Bridge J S.Interpreting the height of dunes and paleochannel depths from the thickness of medium scale sets of cross strata[C].AAPG:AAPG Annual Meeting Expended Abstracts,1999:80.

[7] Best J L,Roden J,Ashworth P J,et al.Three-dimensional sedimentary architecture of a large,mid-channel sand braid bar,Jamuna River,Bangladesh[J].Journal of Sedimentary Research,2003,73(4):516-530.

[8] 陈玉琨,吴胜和,毛平,等.砂质辫状河储集层构型表征——以大港油区羊三木油田馆陶组为例[J].新疆石油地质,2012,33(5):523-526.

Chen Yukun,Wu Shenghe,Mao Ping,et al.Characterization of sandy braided river reservoir configuration- an example from Guantao formation in Yangsanmu oilfield,Dagang oil region[J].Xinjiang Petroleum Geology,2012,33(5):523-526.

[9] 吴胜和,纪友亮,岳大力,等.碎屑沉积地质体构型分级方案探讨[J].高校地质学报,2013,19(1):12-22.

Wu Shenghe,Ji Youliang,Yue Dali,et al.Discussion on hierarchical scheme of architectural units in clastic deposits[J].Geological Journal of China Universities,2013,19(1):12-22.

[10] Leclair S F,Bridge J S.Quantitative interpretation of sedimentary structures formed by river dunes[J].Journal of Sedimentary Research,2001,71(5):713-716.

[11] 孙天建,穆龙新,吴向红,等.砂质辫状河储层构型表征方法——以苏丹穆格莱特盆地Hegli油田为例[J].石油学报,2014,35(4):715-724.

Sun Tianjian,Mu Longxin,Wu Xianghong,et al.A quantitative method for architectural characterization of sandy braided-river reservoirs:taking Hegli oilfield of Muglad Basin in Sudan as an example[J].Acta Petrolei Sinica,2014,35(4):715-724.

[12] 于欢.辫状河储层内部构型精细描述及剩余油分布[J].大庆石

油地质与开发,2015,34(4):73-77.
Yu Huan.Fine characterization of the internal configurations for the braided river reservoirs and remained oil[J].Petroleum Geology & Oilfield Development in Daqing,2015,34(4):73-77.
[13] 乔雨朋,邵先杰,接敬涛,等.远源砂质辫状河储层构型及控制因素——以秦皇岛32-6油田为例[J].油气地质与采收率,2016,23(1):46-52.
Qiao Yupeng,Shao Xianjie,Jie Jingtao,et al.Architecture analysis and controlling factor on far source sandy braided river reservoir:A case study of Qinhuangdao32-6 oilfield[J].Petroleum Geology and Recovery Efficiency,2016,23(1):46-52.
[14] 刘卫,路智勇,牛栓文.东辛油田营13断块辫状河储层构型模式[J].油气地质与采收率,2015,22(4):33-37.
Liu Wei,Lu Zhiyong,Niu Shuanwen.An architecture model of braided river reservoir in Ying-13 fault block of Dongxin oilfield[J].Petroleum Geology and Recovery Efficiency,2015,22(4):33-37.
[15] 王敏,赵国良,冯敏,等.砂质辫状河储层隔夹层分布模式及其对边底水运移的影响——以南苏丹P油田Fal块为例[J].油气地质与采收率,2017,24(2):8-14.
Wang Min,Zhao Guoliang,Feng Min,et al.Distribution pattern of intercalations and its impact on migration of edge and bottom water in sandy braided-river reservoirs-A case study of Fal structure in P Oilfield,South Sudan[J].Petroleum Geology and Recovery Efficiency,2017,24(2):8-14.
[16] 党胜国,赵春明,侯东梅,等.海上辫状河弱边水油藏差异化开发模式[J].特种油气藏,2017,24(1):128-132.
Dang Shengguo,Zhao Chunming,Hou Dongmei,et al.Different development modes for offshore braided river reservoirs with weak edge-water[J].Special Oil & Gas Reservoirs,2017,24(1):128-132.
[17] 王锐.辫状河厚砂体内部夹层的识别及分布特征[J].大庆石油地质与开发,2016,35(3):83-87.
Wang Rui.Identification and distribution characteristics of the internal interbeds in the thick sandbodies of the braided river[J].Petroleum Geology & Oilfield Development in Daqing,2016,35(3):83-87.
[18] 吴吉元,冯琳,刘树平,等.鄂尔多斯盆地宜君地区长3油层组沉积体系及砂体展布[J].石油实验地质,2015,37(5):575-581.
Wu Jiyuan,Feng Lin,Liu Shuping,et al.Depositional system and sand body distribution in the third member of the Yanchang Formation in the Yijun area in the southern Ordos Basin[J].Petroleum Geology & Experiment,2015,37(5):575-581.
[19] Kelly S.Scaling and hierarchy in braided rivers and their deposits:Examples and implications for reservoir modeling[M]//Sambrook Smith G H,Bristow C S.Braided rivers:Process,deposits,ecology and management.Oxford,UK:Blackwell Publishing,2006:75-106.
[20] 陈玉琨,吴胜和,王延杰,等.常年流水型砂质辫状河心滩坝内部落淤层展布样式探讨[J].沉积与特提斯地质,2015,5(1):96-101.
Chen Yukun,Wu Shenghe,Wang Yanjie,et al.Distribution patterns of the fall-siltseams in the channel bar of the perennial sandy braided river:an approach[J].Sedimentary Geology and Tethyan Geology,2015,5(1):96-101.

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(上接第47页)

Wang Xiangzeng,Fan Bojiang,Zhang Lixia,et al.Reservoir space characteristics and charging process of Lacustrine shale gas—a case study of the Chang7 member in Yanchang Block in Shanbei slope of Erdos Basin[J].Oil & Gas Geology,2015,36(4):651-658.
[15] 杨友运,刘喜强,孙睿.深埋砂岩储层长石溶孔率定量计算的新方法及应用:以鄂尔多斯盆地陇东地区长8_1储层为例[J].石油实验地质,2016,38(3):395-401.
Yang Youyun,Liu Xiqiang,Sun Rui.A new method for the calculation of secondary porosity originating from the dissolution of feldspars in deeply buried formations and its application:A case study of the Chang8_1 Formation in Longdong area,Ordos Basin[J].Petroleum Geology & Experiment,2016,38(3):395-401.
[16] 梁承春,郭景祥.鄂尔多斯盆地红河油田延长组长8_1小层致密砂岩成岩作用与储层特征[J].油气地质与采收率,2017,24(1):57-63.
Liang Chengchun,Guo Jingxiang.Diagenesis and reservoir characteristics of tight sandstones of Chang8_1 member of Yanchang Formation in Honghe oilfield,Ordos Basin[J].Petroleum Geology and Recovery Efficiency,2017,24(1):57-63.
[17] 王香增,任来义,贺永红,等.鄂尔多斯盆地致密油的定义[J].油气地质与采收率,2016,23(1):1-7.
Wang Xiangzeng,Ren Laiyi,He Yonghong,et al.Definition of tight oil in Ordos Basin[J].Petroleum Geology and Recovery Efficiency,2016,23(1):1-7.
[18] 王禹诺,曹青,刘宝宪,等.鄂尔多斯盆地西南部致密砂岩气成藏主控因素[J].特种油气藏,2016,23(4):81-84.
Wang Yunuo,Cao Qing,Liu Baoxian,et al.Key controlling-factors of tight sandstone gas accumulation in the Southwestern Ordos Basin[J].Special Oil & Gas Reservoirs,2016,23(4):81-84.
[19] 杨华,付金华,刘新社,等.鄂尔多斯盆地上古生界致密气成藏条件与勘探开发[J].石油勘探与开发,2012,39(3):295-303.
Yang Hua,Fu Jinhua,Liu Xinshe,et al.Accumulation conditions and exploration and development of tight gas in the Upper Paleozoic of the Ordos Basin[J].Petroleum Exploration and Development,2012,39(3):295-303.

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