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彰武断陷九佛堂组页岩油气潜力分析

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摘 要：松辽盆地南部彰武断陷九佛堂组发育大套半深湖—深湖相暗色泥页岩夹油页岩层. 在岩心观察、薄片鉴定和扫描电镜分析基础上，结合泥页岩的分布、电性和地化特征、含油气性、储集和保存条件等，研究九佛堂组富有机质的暗色泥页岩的页岩油气资源潜力. 结果表明：九佛堂组暗色泥页岩在测井曲线上具有“三高一低”的响应特征，纵向上厚度大，可识别上、下两段泥页岩层系，横向上展布较广；有机质丰度高，达到好的烃源岩标准，干酪根以Ⅰ型和$Ⅱ_1$型为主，镜质体反射率(R_o)为0.54%～1.10%；泥页岩含油气性较好，晶间、粒间微孔隙和微裂缝较发育；脆性矿物平均质量分数高达51.4%，易于储层压裂改造. 九佛堂组沉积后期构造活动较弱，有利于页岩油气的保存. 运用概率体积法估算页岩油资源量为12 442.0×10^4 t.

关 键 词：彰武断陷；九佛堂组；泥页岩；页岩油气；有机质丰度；测井评价模型

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0 引言

页岩油是指以游离、吸附态或溶解态等多种方式赋存于富有机质且以纳米级孔隙为主的有效生烃泥页岩层系，具有勘探开发意义的连续或准连续型非气态烃类[1-2]，为典型的自生自储成藏[2-5]. 页岩油赋存的主体是生烃泥页岩，也包括泥页岩层系中的致密砂岩、碳酸盐岩等薄夹层. 由于泥页岩矿物组分、结构和构造存在特殊性，页岩油多沿片状层理面或与其平行的微裂缝分布[2,6]. 在地下高温高压的环境下，处于游离态的凝析油或轻质油更易在泥页岩的纳米级孔喉系统中流动，也是实现工业开采的主要类型[2,7].

我国页岩油资源较为丰富，广泛分布于松辽盆地白垩系、三塘湖盆地二叠系、四川盆地侏罗系、鄂尔多斯盆地三叠系、渤海湾盆地古近系等层系[6,8]. 沉积环境以陆相富有机质页岩的湖侵—水体分层模式为主，有机质主要顺层富集[6]. 目前，在鄂尔多斯、渤海湾和南襄等中新生代陆相盆地中，已不同程度地获得页岩油流[1,9-12]，如泌阳凹陷泌页HF-1水平井分段压裂后获日产油为23.6 m^3[1]，辽河坳陷曙古165井沙三段泥页岩压裂后原油日产能为24.0 m^3[6].

在松辽盆地南部彰武断陷实钻的多口探井中，九佛堂组暗色泥页岩显示良好的气测异常，并获得工业油流[13]. 笔者根据彰武断陷九佛堂组暗色泥页岩分布、测录井特征、地球化学特征、储集和保存条件等，探讨彰武断陷页岩油气的资源潜力.

1 区域地质概况

彰武断陷位于松辽盆地南部断陷群的彰武—东胜断裂带，是以早白垩世沉积为主的陆相断陷，区域上位于大冷断陷以南、彰东断陷以西、姚堡断陷以北，整体呈北北东向展布，轴长为20 km，宽为3～5 km，面积为150 km^2(见图1). 由图1可知，结构上为东断西超的单断式箕状，断陷东北高、西南低. 基底主要为太

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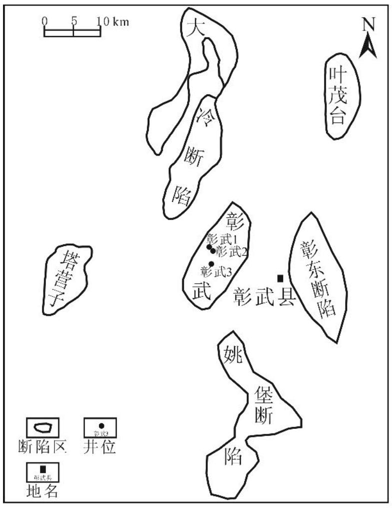
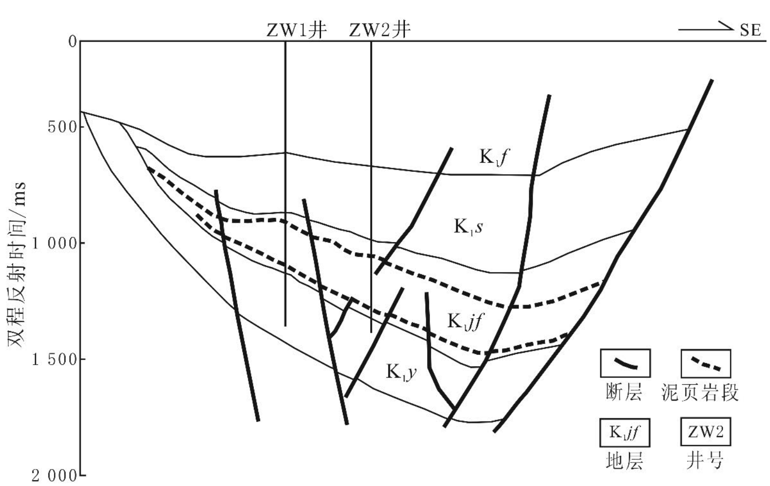
古界和早中元古界的变质砂岩、片麻岩等深变质岩系,属于华北板块和松嫩地块的结合部位[14]. 断陷主物源区来自于西北方向,至东南方向湖盆沉积中心粒度逐渐变细. 研究区沉积地层主要为断陷期地层,由下至上依次为义县组(K_1y)、九佛堂组(K_1jf)、沙海组(K_1sh)和阜新组(K_1f)(见图1). 义县期为盆地初始裂陷期,断裂活动强烈;九佛堂—沙海—阜新期早期为盆地断陷期,可划分为快速沉降、稳定沉降和抬升剥蚀3个阶段;阜新末期后区域性抬升背景下地层遭受剥蚀,盆地进入坳陷期;第四系直接覆盖在阜新组之上. 缺失坳陷期地层.



(a) 构造位置



(b) 地层分布

图1　彰武断陷构造位置和地层分布

Fig. 1 Geographical location and strata distribution of Zhangwu fault depression

2　沉积特征

研究区九佛堂组沉积时期为深断陷湖盆,具有典型的水进退积型沉积序列,以半深湖—深湖亚相的欠补偿沉积为主. 九佛堂组沉积末期达到最大湖泛面,发育大套富含有机质的湖相泥页岩层系. 岩性特征主要为深灰色—黑色的泥岩、页岩、油页岩和粉砂质泥岩,以及灰色泥质粉砂岩与粉砂岩的薄夹层. 在暗色泥页岩中发育大量的轮藻、双壳类、腹足类等生物碎屑,表明九佛堂组泥页岩具有较丰富的有机质来源.

九佛堂组富有机质暗色泥页岩沉积模式为典型的湖侵模式. 相对湖平面的上升使得深水区形成大面积的缺氧环境,丰富的有机质供给及区内有利的保存、聚集和转化条件,使有机质得以埋藏和富集,从而形成优质的暗色泥页岩与油页岩. 在断陷沉积中心周围,水体最深,沉积物供应速率慢,为欠补偿沉积,是有机质赋存最为有利的密集段,剖面上有机碳质量分数 w(TOC)往往最大[15];相反,在断陷沉积层序的边界,有机碳质量分数往往较低.

3　生烃条件

3.1　模型建立与应用

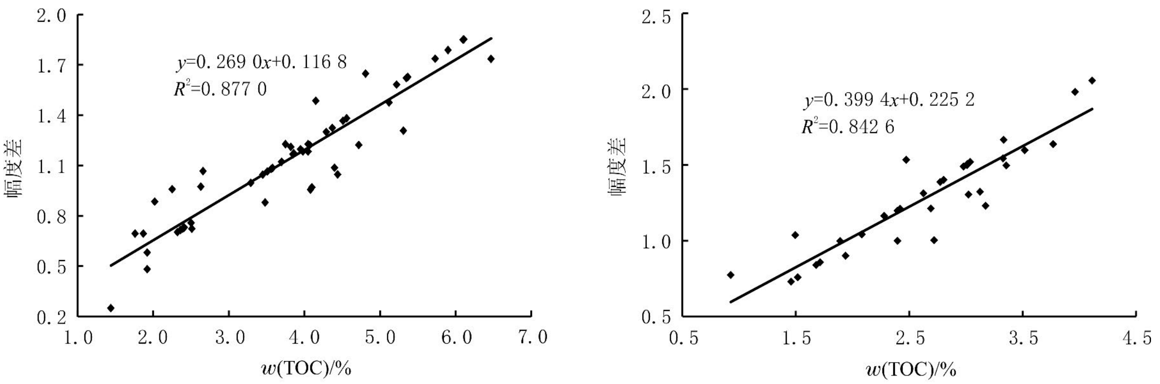
九佛堂组富含有机质泥页岩具有典型的"三高一低"的测井响应特征,即较高的电阻率、伽马值和声波时差,较低的体积密度[16],如彰武3井1 272.5～1 436.0 m井段的泥页岩实测表明,高阻泥页岩层 w(TOC)明显高于低阻泥页岩的 w(TOC). w(TOC)高值区(3%～5%)多分布在电阻率高值区,岩性以黑色泥岩、页岩和油页岩为主;w(TOC)低值区(1%～2%)多对应电阻率低值区,岩性以灰色—深灰色泥岩和粉砂质泥岩为主. 因此,结合富有机质泥页岩的测井曲线响应特征,可以对九佛堂组泥页岩层段进行纵向识别和横向对比,并分析空间展布.

综合彰武1(ZW1)、彰武2(ZW2)、彰武3(ZW3)、彰武2-1(ZW2-1)、彰武2-2(ZW2-2)、彰武3-1(ZW3-1)等钻井的九佛堂组泥页岩的实测 w(TOC)、电性特征、气测显示及岩性分布,初步划分上、下两段具有

生油气潜力的泥页岩层段，其各自的顶、底板均为泥岩层，内部无明显的水层．若要厘定泥页岩层段的评价单元，则需分析泥页岩的地化指标是否符合相关既定标准[6,17]，即 w(TOC)＞0.5%，暗色泥页岩厚度大于 30 m．故需要根据实测深度点的 w(TOC)，结合测井曲线推测其他无实测深度点泥页岩的 w(TOC)，即计算的 w(TOC)[17]．

目前，利用测井曲线计算烃源岩 w(TOC)的 $\Delta \lg R$ 法已经成熟[16,18-20]．文中采用 $\Delta \lg R$ 的改进模型，即选用声波时差(AC)和电阻率(R_t)参数进行模拟计算．基于 $\Delta \lg R$ 幅度差与 w(TOC)的线性相关关系，结合实测烃源岩的 w(TOC)，补充该地区的 Δw(TOC)非生油层的 w(TOC)背景值．$\Delta \lg R$ 法的改进模型为：$w(\mathrm{TOC})=a\Delta \lg R+b$，其中，$a$ 为相关因数，b 为 Δw(TOC)，且均为常数项．

选取资料齐全的重点预探井 ZW3 井作为建模井，运用 $\Delta \lg R$ 法建立测井评价有机质非均质性模型，利用稳健的最小二乘法分别对 $\Delta \lg R$ 幅度差和实测 w(TOC)进行数值拟合，确定模型参数 a 和 b(见图 2)．其中，九佛堂组上、下段实测 w(TOC)与 $\Delta \lg R$ 幅度差相关性均较好，相关因数分别为 0.877 0 和 0.842 6，且 a 和 b 值分别为 0.269 0、0.116 8 和 0.399 4、0.225 2．根据所建立模型得到的叠合系数，反演出 ZW3 井九佛堂组上、下段泥页岩层连续的 w(TOC)，实测 w(TOC)与计算值吻合度较好(见图 3，其中，CAL 为井径，SP 为自然电位，GR 为自然伽马，CNL 为补偿中子，DEN 为密度，AC 为声波时差，LLD 为深侧向电阻率)．



(a)上段　　　　(b)下段

图 2　九佛堂组泥页岩实测 w(TOC)与幅度差关系

Fig. 2 Correlation between measured w(TOC) and magnitude differences of mudshale in Jiufotang formation

利用 ZW3 井九佛堂组上、下段泥页岩层 w(TOC)的测井有机质非均质性模型，选取 ZW2 等井进行验证(见图 4)，并应用于其他预探井和开发井，验证和应用效果较好．因此，在获得各井的九佛堂组上、下段泥页岩层 w(TOC)值的连续分布后，再结合泥页岩评价单元需满足的条件(w(TOC)＞0.5%)，即可进一步筛选出九佛堂组上、下段泥页岩层有效评价单元的累积厚度，并外推至平面分布．

3.2　单元分布

彰武断陷九佛堂组发育上、下段富含有机质的泥页岩夹油页岩层，埋藏深度小于 2 km，主体分布在 1.0～1.5 km 之间．根据测井有机质非均质性模型和泥页岩有效评价单元，可以厘定各井在纵向上有效泥页岩的累积厚度，并在横向上进行对比(见图 5)．由图 5 可知，九佛堂组上、下段泥页岩评价单元的有效累积厚度较大，最大厚度可达 250 m．泥岩单层连续最大厚度可达 67 m，评价单元的泥岩厚度占总厚度的 64.5%～99.2%；其他为少量粉砂质泥岩和粉砂岩薄夹层，且夹层粉砂岩单层厚度均小于 1 m．研究区九佛堂组下段灰黑色—黑色油页岩夹层较上段多，单层厚度一般为 2～4 m，局部单层最大厚度可达10 m．

3.3　地球化学特征

3.3.1　高有机质丰度

有机碳质量分数与页岩油气的生烃率具有较好的正相关性，并且直接影响页岩油气的资源前景[6,21-22]．九佛堂组实测暗色泥页岩岩心样品 157 件，w(TOC)分布于 0.15%～8.63%之间，平均为 2.38%；热解 S_1 为(0.02～16.96)×10^{-3}，平均为 0.96×10^{-3}；生烃潜力(S_1+S_2)为(0.03～61.46)×

10^{-3},平均为 17.86×10^{-3}. 总体上,九佛堂组暗色泥页岩应为好的烃源岩. 由研究区九佛堂组上、下段有效泥页岩评价单元的 w(TOC)平面分布可知,断陷沉积中心是有机质赋存的密集段,其上、下段 w(TOC)分别高达4.50%和 3.00%,在靠近断陷沉积中心处的 ZW3、ZW2-1、ZW2-2、ZW3-1 等井中实测有机质丰度较高,向断陷边缘方向有机质丰度降低(见图 6).

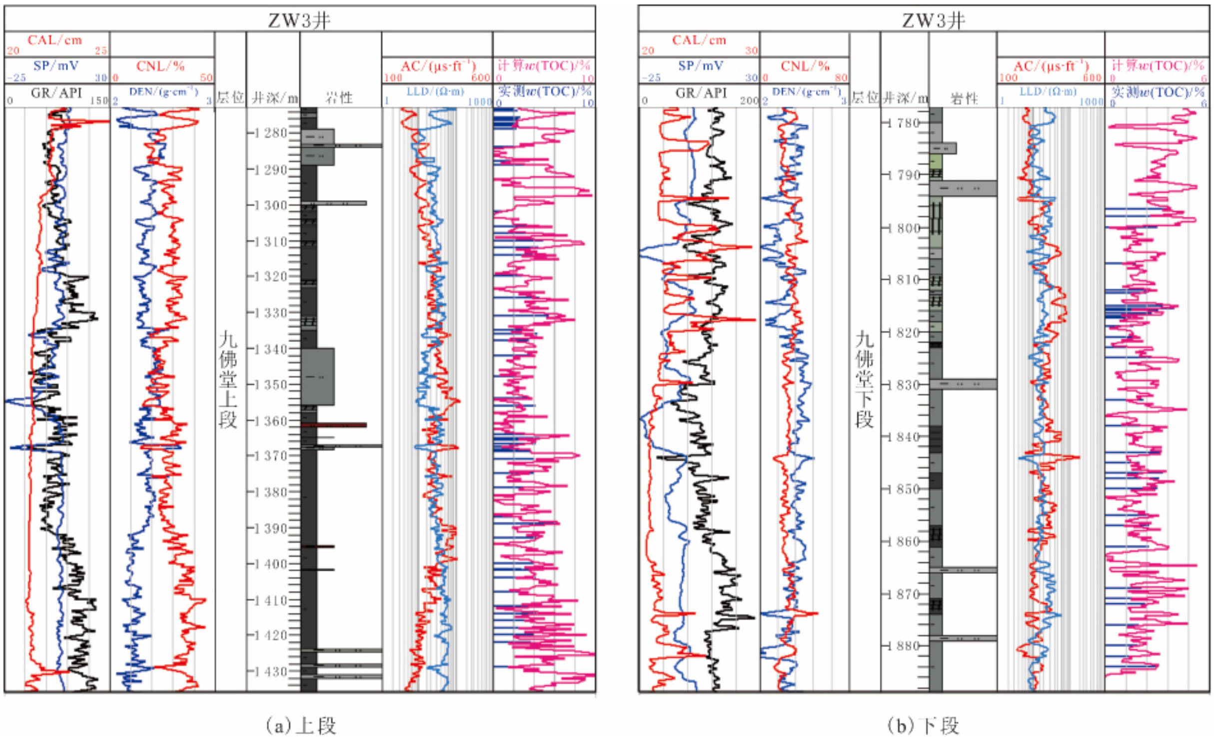


图 3　ZW3 井九佛堂组泥页岩 w(TOC)测井模型效果

Fig. 3 Logging model effective diagrams of TOC of mudshale in Jiufotang formation of well ZW3

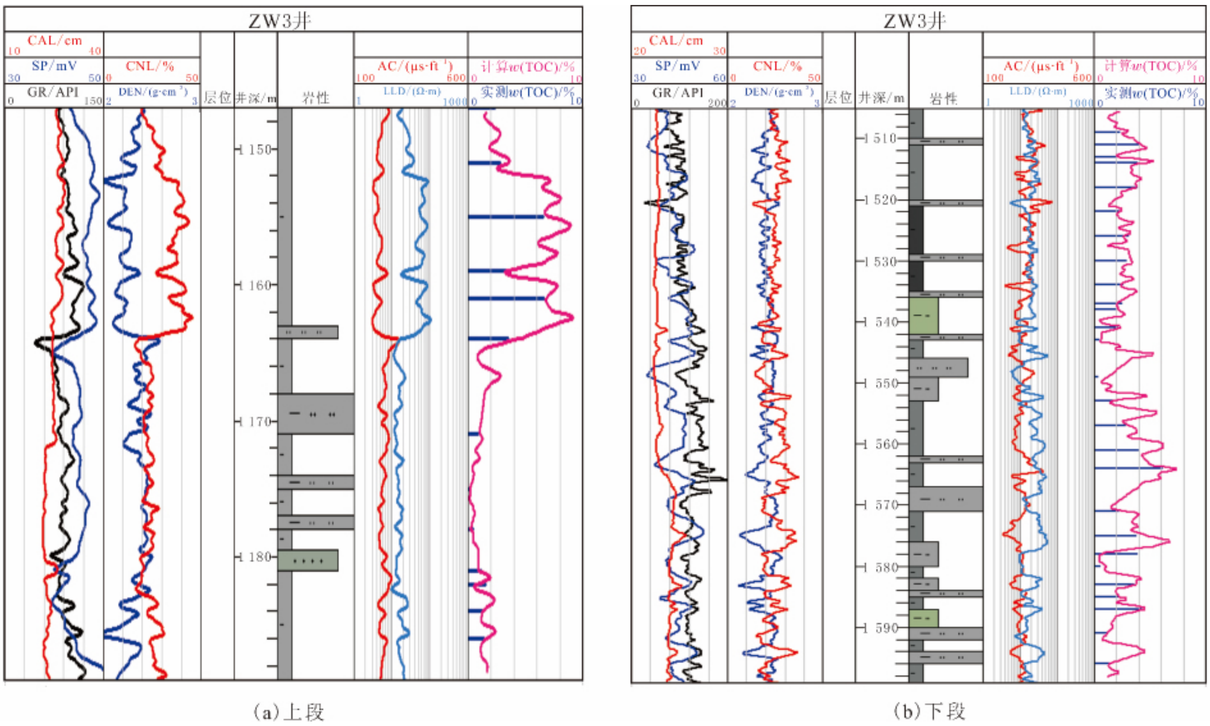
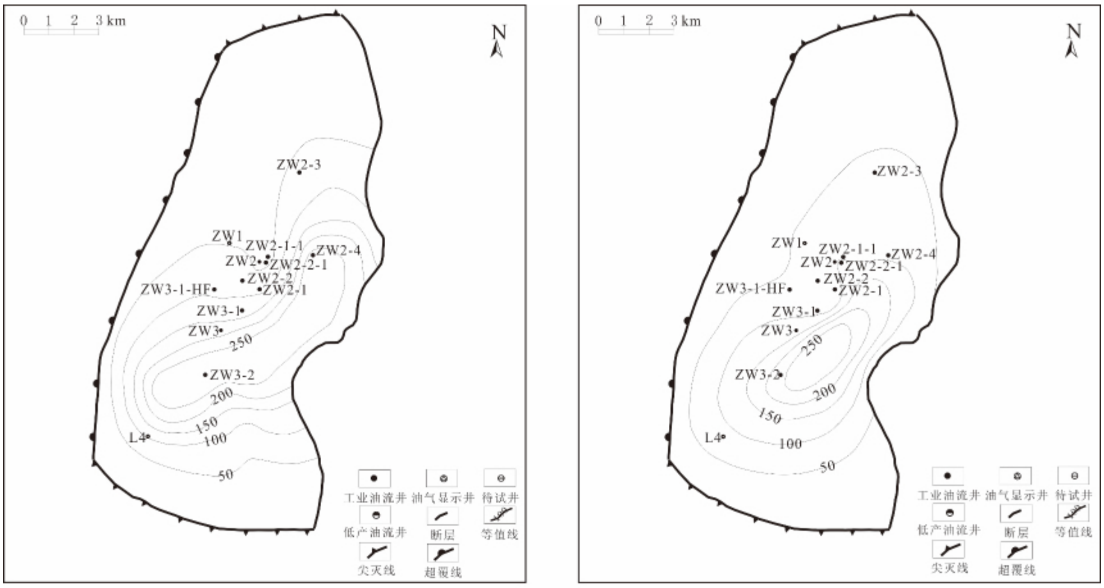


图 4　ZW2 井九佛堂组泥页岩 w(TOC)测井模型验证效果

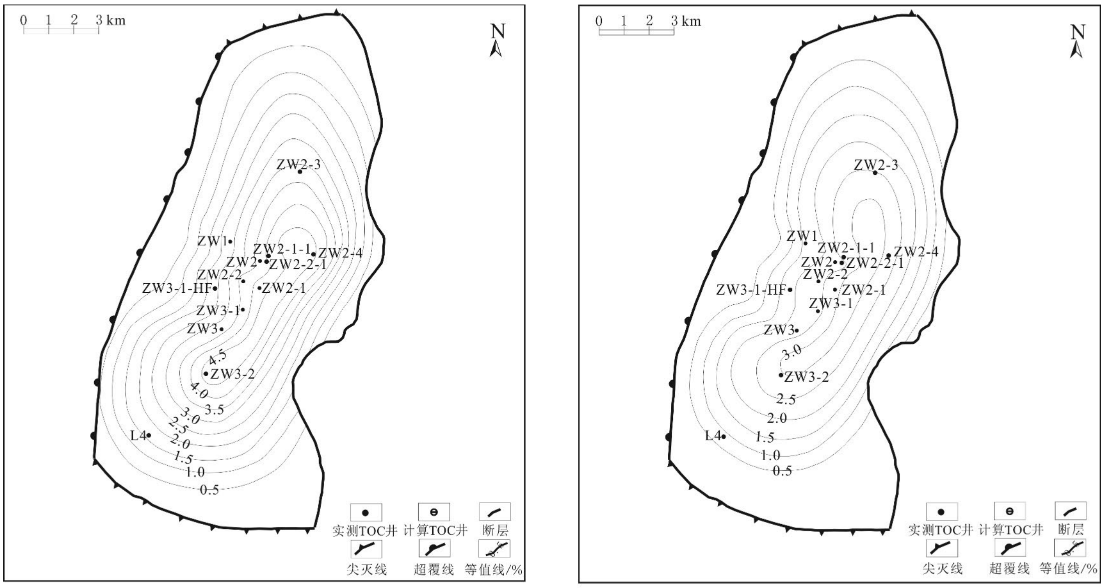
Fig. 4 Logging model verificative diagrams of TOC of mudshale in Jiufotang formation of well ZW2



(a) 上段　　(b) 下段

图 5　九佛堂组泥页岩厚度(单位:m)

Fig. 5 Isopach maps of mudshale in Jiufotang formation



(a) 上段　　(b) 下段

图 6　九佛堂组泥页岩 w(TOC)等值线分布

Fig. 6 w(TOC) isograms of mudshale in Jiufotang formation

3.3.2　母质类型

九佛堂组暗色泥页岩的母质来源以低等浮游生物和藻类为主,并混有少量陆生高等植物.泥页岩干酪根显微组分以壳质组(无定形)和镜质组为主,分别为 62%～88% 和 7%～38%,腐泥组较少,显示为Ⅱ型干酪根;而 H/C 与 O/C 关系显示出干酪根为Ⅰ型和$Ⅱ_1$型;干酪根 $\delta^{13}C$ 为 −25.1‰～−30.2‰,表明以Ⅰ型和$Ⅱ_1$型为主.因此,九佛堂组泥页岩母质类型主要为Ⅰ型和$Ⅱ_1$型.

3.3.3　热演化程度

九佛堂组暗色泥页岩岩心样品实测镜质体反射率(R_o)为 0.54%～1.10%,表明已过生烃门限(见图7),最大热解峰温 T_{max} 为 435～460 ℃,处于低成熟—成熟的热演化阶段,即大量生油期.

九佛堂组上、下段暗色泥页岩评价单元的厚度较大,埋深小于 2 km,平面展布较广,有机质丰度高,以Ⅰ型和$Ⅱ_1$型干酪根为主且成熟度适中,作为好的烃源岩为页岩油气藏的形成提供充足的油气来源.

4　含油气显示

气测录井特征能较好地反映储层的含油气性，在页岩油气的识别评价中,有重要的参考和借鉴价值.美国 Barnett 页岩的油气勘探经验也强调,在对泥页岩进行勘探时,大量的天然气显示是必须的[23].在研究区的多口钻井中,九佛堂组上、下段泥页岩层显示明显的气测异常,且粉砂岩薄夹层中也有明显的油气显示,横向上连续性较好,并在部分泥页岩岩心中见黑褐色油斑.如 ZW3 井九佛堂组上、下段泥页岩气测全烃体积分数分别达5.06%和 2.79%,甲烷体积分数分别达 2.28%和1.70%,其中气测组分主要为C_1~C_4,少量的为 H_2 和 CO_2 等,反映油型气的典型特征.整体上,向断陷东南部的沉积中心方向,气测异常值增大.另外,在 ZW2 井和 ZW3 井钻遇的泥页岩、油页岩夹粉砂质泥岩层中获得工业油流,气测全烃体积分数达 2.80%.因此,研究区九佛堂组上、下段泥页岩层评价单元的气测异常与电性特征表明,湖相泥页岩具有较好的含油气性.

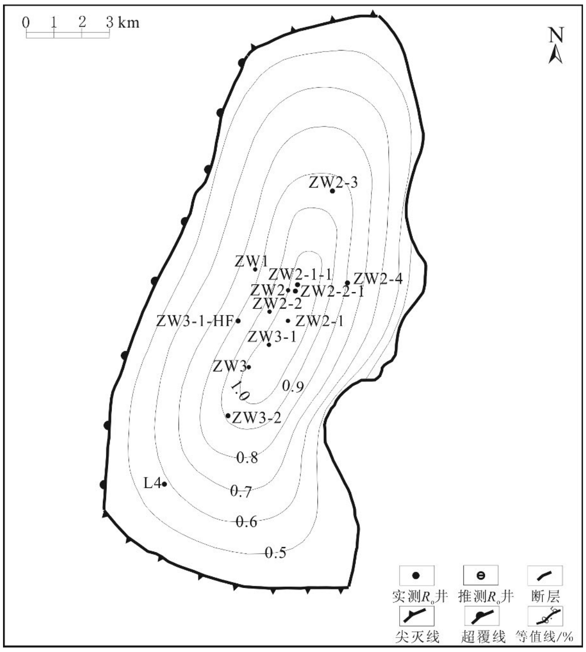


图7　九佛堂组泥页岩 R_o 等值线分布

Fig. 7 R_o isogram of mudshale in Jiufotang formation

5　储集和赋存条件

5.1　全岩矿物分析

九佛堂组暗色泥页岩岩心样品 X 线衍射全岩矿物分析结果见图 8.由图 8 可知,脆性矿物质量分数占 33.2%~62.3%(平均为 51.4%),包括石英、钾长石和钠长石,以及少量方解石和黄铁矿;黏土矿物质量分数占 37.7%~66.8%(平均为 45.5%).不同钻井岩心的黏土矿物成分差异较大,如靠近断陷沉积中心的 ZW3 井伊利石和蒙脱石质量分数居多,分别为 11.5%~21.0%和 7.0%~31.0%,其次为绿泥石(质量分数为 9.6%~23.0%),仅个别样品含有高岭石(质量分数为 8.7%).

5.2　微孔隙和微裂缝

根据岩心观察、岩石薄片和扫描电镜分析,九佛堂组泥页岩中发育的孔隙类型主要包括矿物粒间孔隙、晶间孔隙、层间孔隙和有机质孔隙,以及少量微裂缝(见图 9),孔径在几纳米至几十微米.由图 9 可知,伊蒙混层、伊利石或绿泥石等黏土矿物组成晶间孔隙(见图 9(a—e))和层间微孔隙(见图 9(b));石英或长石等脆性矿物组成层间微孔(见图 9(f))和粒间孔隙(见图 9(c、g));泥页岩中无定形有机质发育,形成有机质孔隙(见图 9(d)),孔隙载体为有机质本身或有机质与矿物接触的边缘;在泥页岩中,石英和长石等脆性矿物常呈纹层状,与黏土矿物及有机质相互叠合形成水平纹层或平行层理,还可见方解石充填的缝隙(见图 9(h));泥页岩纹层间水平缝或微斜缝使岩心沿层理面或微裂缝断裂呈饼状(见图9(i)).

实测结果表明,泥页岩岩心孔隙度为 0.24%~4.37%,平均为 3.46%;渗透率为(0.045~0.247)× 10^{-3} μm^2,平均为 0.091× 10^{-3} μm^2.九佛堂组暗色泥页岩发育的微孔隙和微裂缝为页岩油气提供储集和渗流通道.

不同类型的黏土矿物对于液态石油分子的吸附强度不同.伊利石或伊蒙混层质量分数的增加,使样品的比孔容增大,从而使吸附态油气含量增加[24-25].九佛堂组泥页岩中较高的伊利石和蒙脱石等黏土矿物质量分数及较高的有机质质量分数,有利于生成的液态石油吸附于其表面.另外,纹层状的页岩或泥岩也为油气的储集提供大量空间[26].泥页岩中脆性矿物的质量分数对于基质孔隙和微裂缝的发育程度及压裂改造方式至关重要[21-27].九佛堂组较高的脆性矿物质量分数使该地区泥页岩具有一定的可压性和形成网

状缝的条件.

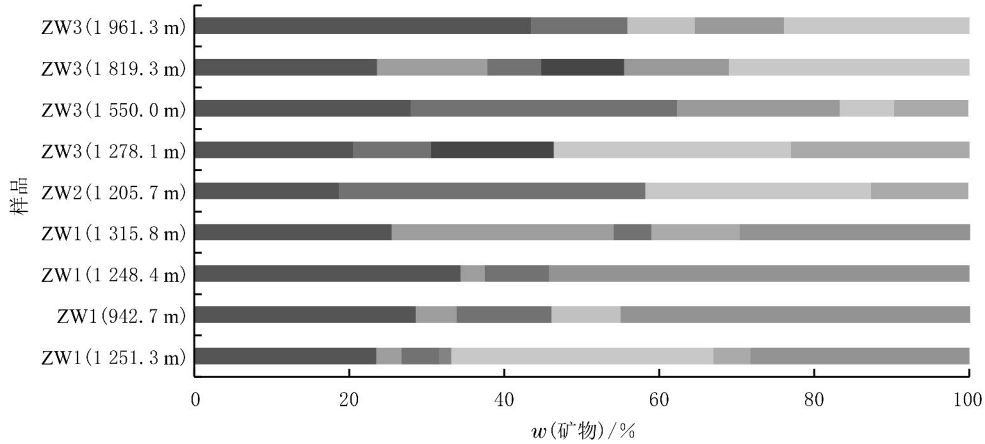
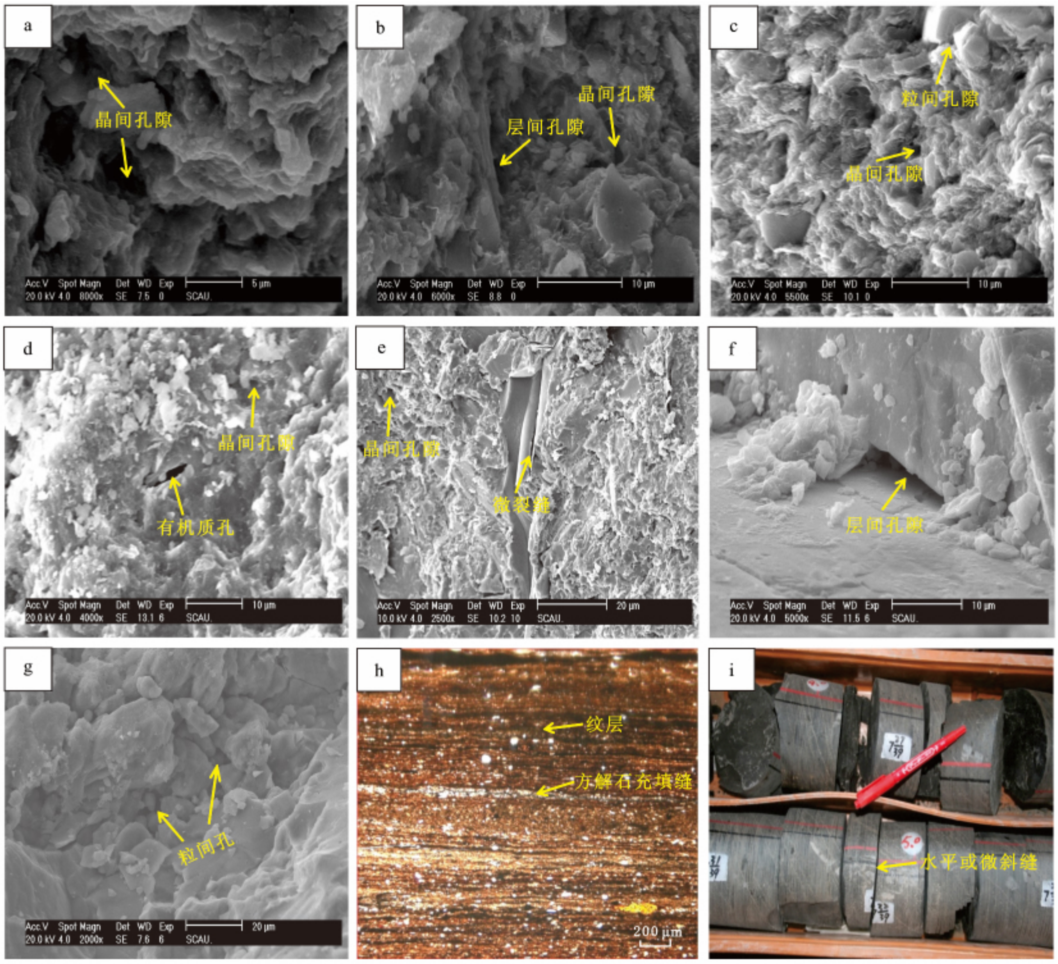


图 8　九佛堂组暗色泥页岩矿物质量分数

Fig. 8 Mineral percentage compositions of dark mudshale in Jiufotang formation



(a) ZW1 井，1 316.10 m，灰色泥岩，晶间孔隙；(b) ZW3 井，1 368.50 m，灰黑色泥岩，晶间孔隙和层间微缝；(c) ZW3 井，1 819.30 m，炭质泥岩，伊蒙混层的晶间孔隙和粒间孔隙；(d) ZW3 井，1 961.30 m，深灰色泥岩，伊蒙混层的晶间孔隙和有机质孔；(e) ZW3 井，1 819.30 m，炭质泥岩，晶间孔隙和微裂缝；(f) ZW2 井，1 205.70 m，深灰色泥岩，层间微孔；(g) ZW1 井，1 251.80 m，灰色泥岩，粒间孔隙；(h) ZW1 井，1 251.30 m，深灰色泥岩，水平纹层结构，见方解石充填微裂缝；(i) ZW1，灰黑色泥岩，水平或微斜缝

图 9　九佛堂组泥页岩微孔隙和微裂缝

Fig. 9 Micropores and microfractures of mudshale in Jiufotang formation

6 油气保存条件

泥页岩作为烃源岩既是储层又是盖层,相对于常规油气藏,它对盖层的要求较宽松,热成因型页岩油气藏主要依靠微裂缝运聚,而大断层和宏观裂缝起破坏作用,因此强烈的构造活动不利于页岩油气藏的保存[27].彰武断陷九佛堂组沉积时期为断陷快速沉降期,水体加深;沙海期断陷整体处于稳定沉降阶段,断裂活动逐渐减弱;阜新期为断陷抬升剥蚀阶段,断裂活动较弱,沉积速度大于沉降速度,整个断陷表现为充填式沉积,随后整个盆地下沉,在断陷基础上叠覆沉陷.总体上,九佛堂组泥页岩在埋藏及热演化过程中,构造破坏及深大断裂作用相对较弱,对宏观裂缝的贡献较小,有利于页岩油气的保存.

7 资源量估算与勘探潜力

页岩油资源量是根据一定的地质依据计算当前具有潜在利用价值的页岩油数量.与页岩气相似,页岩油资源计算参数难以准确把握,故仍需使用概率体积法.含油率作为体积法计算页岩油资源量的核心参数,可通过地球化学法中的氯仿沥青"A"法获取[6,28].计算结果表明,彰武断陷九佛堂组页岩油潜在资源量为 $12\,442.0\times10^4$ t,结合断陷烃源岩分布及其地化等特征,初步预测九佛堂组页岩油有利勘探区主要集中在断陷沉积中心周围.

8 结论

(1)彰武断陷九佛堂组发育半深湖—深湖相暗色泥页岩层,具有典型的"三高一低"的测井曲线响应特征,在纵向上可识别、对比.

(2)九佛堂组泥页岩测井有机质非均质性模型的建立与应用,促使九佛堂组划分出上、下段有效泥页岩评价单元,横向上分布广.

(3)九佛堂组暗色泥页岩母质类型以Ⅰ和$Ⅱ_1$型为主,有机质丰度高,处于低熟—成熟的热演化阶段,生油能力较强,具有形成页岩油气的良好物质基础;泥页岩气测显示明显,脆性矿物平均质量分数高达51.4%,具有一定的可压性;有机质和黏土矿物表面及微孔隙和微裂缝的发育,为页岩油气的储集与赋存提供有利的空间;九佛堂组沉积后期断裂改造活动较弱,有利于页岩油气的保存.

(4)运用概率体积法初步计算九佛堂组页岩油潜在资源量为 $12\,442.0\times10^4$ t,有利勘探区主要集中在断陷沉积中心周围.

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low; The organic matter abundance of the argillaceous dolomite in the Jianghan basin is good, and organic maceral of that are rich in sapropelinite, mainly at less mature-mature stage. The shale oil enrichment in Xingouzui formation is under the control of the richness of organic matter and porosity of the argillaceous dolomite reservoirs. The relationship between oil content and porosity of the argillaceous dolomite shows two-segment, namely the linear increase and stability of high value. The argillaceous dolomite reservoir, whose porosity is greater than 12%, possesses the higher oil content. The oil content of the argillaceous dolomite reservoirs enriched oil should be more than 75 mg/g.

Key words: shale oil; oil-bearing property; Xingouzui formation; argillaceous dolomite; Jianghan basin

Basic characteristic of shale of Wufeng-Longmaxi formation in Shilin, southeast of Sichuan basin/2015,39(3):83-93

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Abstract: Depending on the observation of outfield section, microscopic section, chemical analysis on the sample from Shilin area, this paper explored the sedimentary characteristics of black shale at Wufeng-Longmaxi formation in Shilin, southeast of Sichuan basin, which is the key stratum in Sichuan shale gas exploration. In conclusion, the sedimentary environment of Longmaxi formation is mainly shelf with black shale, siliceous shale, silty mudstone sediment. In this area, it is rich in graptolite and framboidal pyrite at the bottom. Shilin has high hydrocarbon potential with type Ⅱ kerogen mainly, organic matter content reach 2.0%, hermal maturity is about 2.0%. The brittle mineral content is greater than 50%, which is good for artificial joints. Nanoscale pores and micro-cracks are the main reservoir space of black shale of Wufeng-Longmaxi formation in Shilin area. There are different pore types: Intergranular pore, intragranular pore, fracture and organic pore, providing abundant surface area for shale gas, tests show porosity of 2.5%. When compared with Jiaoshiba area, it shows that southeast of Sichuan basin has organic-rich black shale with thick sediment, high organic matter content and maturity, good brittleness, high hydrocarbon potential, conducive to the development and enrichment of shale gas.

Key words: shale; sedimentary characteristic; southeast of Sichuan basin; Shilin area; Wufeng formation; Longmaxi formation

Shale oil and gas potential analysis of Jiufotang formation in Zhangwu fault depression/2015,39(3):94-103

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Abstract: Jiufotang formation deposited a group of dark mudshale with intercalation of oil shale in semi-deep and deep lacustrine facies in Zhangwu fault depression, southern Songliao basin. On the basis of core observations, thin section identification and SEM analysis, combined with the mudshale distribution, electrical characteristics and geochemical characteristics, oil and gas bearing possibility, reservoir and sealing features to preliminarily studied the shale oil and gas potential resources of Jiufotang formation. The research showed that the dark and large thickness mudshale in Jiufotang formation had a "three-high point and one-low point" logging response characteristics in logging curves, which can be used to distinguish out the upper and lower group of mudshale. Besides, the dark mudshale had a broad transverse distribution range; high abundance of organic matter which reached good hydrocarbon source rocks standard, the kerogen were type Ⅰ and $Ⅱ_1$, the vitrinite reflectance(R_o) ranged from 0.54% to 1.10%; the mudshale had good oil and gas bearing possibility, intercrystalline micropores, intergranular micropores and microfractures were developed. Moreover, the average brittle mineral content was 51.4%, which had a favorable trend for fracturing. There were rarely tectonic movements in the post sedimentary of Jiufotang formation, which created an advantageous preservation condition. Consequently, the shale oil potential resources was 12 442.0$\times 10^4$ t using the probability volumetric method, which indicated a great exploration potential.

Key words: Zhangwu fault depression; Jiufotang formation; mudshale; shale oil and gas; organic matter abundance; logging evaluation model

Productivity model of the fractured horizontal wells in shale gas reservoirs/2015,39(3):104－110

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Abstract: Based on the research of geological features of shale gas reservoir, considering of desorption, slippage, diffusion and seepage of shale gas, a productivity model of fractured horizontal well in shale gas reservoir has been established to describe all aspects of shale gas seepage mechanism. Laplace transform and Stehfest numerical inversion algorithm in combination with Matlab program are used to solve the model. Production decline curves of fractured horizontal well in shale gas reservoir are plotted. The impacts of slippage effect, desorption, storativity ratio, interporosity parameter and gas reservoir size on production are analyzed. Slippage effect, desorption, gas reservoir size and interporosity parameter mainly affect transition and middle stages of production. Storativity ratio has a major influence on initial and transition production. Slippage effect and desorption make production higher. Slippage effect makes production time shorten. Unlike slippage effect, desorption prolongs production time and makes production more stable. With gas reservoir size and interporosity parameter increasing, production becomes higher. With storativity ratio decreasing, production becomes lower.

Key words: shale gas reservoir; fractured horizontal well; desorption; slippage effect; productivity model

Performance and application of betaine type surfactant TCJ-5 in high temperature and high salinity reservoir/2015,39(3):111－117

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