

# 韩城矿区煤层含气性分布规律及地质控制因素研究

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**摘要:**为了找出韩城矿区单井之间生产特征差异性的原因,基于该区主采煤层的含气性特征,从煤岩变质程度、显微煤岩组分、构造条件、水文地质条件等4个方面探讨了影响该区主煤层含气性的地质控制因素。结果表明:该区煤层含气性具有2个典型特征,太原组11号煤层含气性好于山西组3号煤层和5号煤层,这与煤层的埋藏深度和沉积环境有关;各煤层的含气饱和度为25%~94%,平均为63%,随埋深变化较小,但总体上呈现增大的趋势,分析原因该区煤储层为欠压储层,还没达到不同煤岩吸附性能差异的临界点。同时发现,随煤岩变质程度和镜质组含量的增高,煤岩含气量和吸附性均呈升高的变化,认为这是2次煤化作用对煤层气地质条件控制效应的具体体现;煤层含气量受构造条件和水文地质条件的控制非常明显。

**关键词:**韩城矿区;煤层气;含气性;地质控制因素

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## Study on distribution laws of gas-bearing property of coal seams and geological control factors in Hancheng Mining Area

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**Abstract:** In order to find out the difference of production characteristics between single wells in Hancheng Mining Area, based on the gas-bearing property of main coal seams of Hancheng Mining Area, the geological control factors were discussed in the paper, such as coal rank, coal maceral, geologic structures, and hydrogeological conditions, which has influence on the gas-bearing property. The results showed that the gas-bearing property of main coal seams had two typical characteristics: on the one hand, the gas-bearing property of No.11 coal seam of Taiyuan Formation was better than that of No.3 and No.5 coal seam of Shanxi Formation, which was closely related with the depth of coal seam and the sedimentary environment; The gas saturation of each coal seam was 25%~94%, with an average value of 63%, with the burial depth increasing, the gas saturation of each coal seam varied little, but it showed an increasing trend in general. The reason was that the coal reservoir in this area was under pressure reservoir, and it had not reached the critical point of the difference of the adsorption behavior of different coal and rock. It was also found that with the increase of metamorphic degree of coal and rock and the increase of vitrinite content in this block, gas content and adsorption all increased, which was considered to concrete manifestation of the geological effect of coalbed methane controlled by the two coalifications; The gas content of coal bed was obviously controlled by the structural conditions and hydrogeological conditions.

**Key words:** Hancheng Mining Area; coalbed methane; gas-bearing property; geological control factors

## 0 引言

煤层含气性是评价一个区块煤岩储层的重要

因素之一,也是煤层气成藏的基本要素,是决定煤层气产能及其开发潜力的重要参数之一,包括煤层的含气量、含气饱和度、气体组成、资源丰度及

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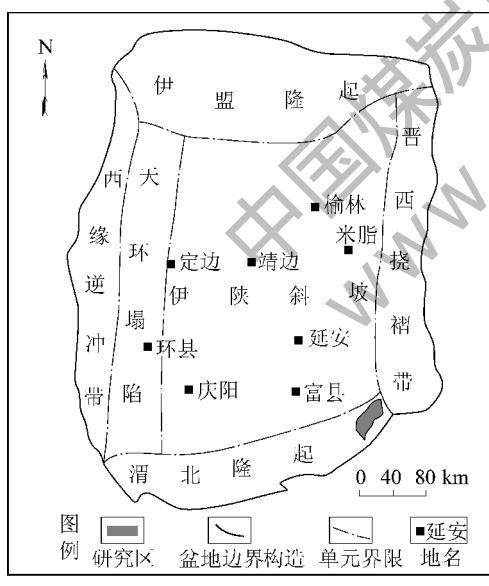
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其在平面和垂向上的分布特征<sup>[1]</sup>。影响煤层含气性的地质因素主要有生气条件、储藏条件和保存条件,主要包括区域的地质条件、煤岩煤质、煤变质程度、煤层埋深、煤层顶底板岩性和水文地质条件等控制因素<sup>[2-3]</sup>。韩城矿区是我国目前中高煤阶煤层气勘探程度较高、煤层气储气条件较稳定、开发潜力较大的煤层气田,是我国首个中高煤阶煤层气规模性开发的地区,勘探与开发资料丰富,通过生产情况来看,矿区内的产气效果差异比较大,有些井区甚至没有产气,对于这种现象很难解释清楚,因此有必要对其含气性规律和影响因素进行详细研究,找出产气差异性的原因。前人对韩城矿区的煤层气成藏条件和储层特征方面进行了很多研究<sup>[4-6]</sup>,认为该区煤岩演化程度较高,达到了大量生气的阶段,盖层条件的封闭性也较好,煤层厚度在3~8 m,为煤层气的吸附富集提供了储存条件,由此得出该区具有良好的煤层气成藏条件,但是对煤层含气性方面没有进行深入的研究,这严重制约了煤层气的进一步高效开发。目前,该区的勘探工作已基本完成,探井遍布全区,

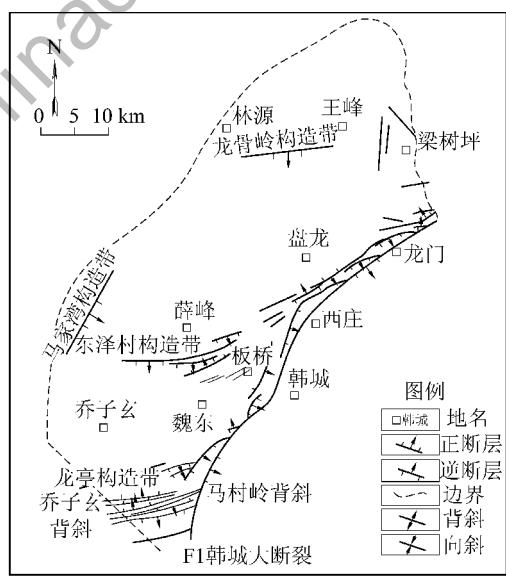
所以获取的地质资料更全面更丰富,笔者依据最新的煤层气勘探开发资料,在分析区块内主煤层的含气性分布规律的基础上,从煤岩变质程度、煤岩显微组分、构造条件、水文地质等条件入手,探讨了研究区内含气性特征的地质控制因素,以期为该区煤层气的勘探开发提供借鉴。

## 1 区域地质概况

韩城矿区位于鄂尔多斯盆地渭北隆起的东北缘(图1a),韩城矿区构造相对简单,整体为一走向北东、倾向北北西的单斜构造<sup>[7-9]</sup>(图1b)。区内含煤地层为二叠系的山西组和太原组,与下伏奥陶系呈平行不整合接触<sup>[10-11]</sup>。主煤层为山西组3号、5号煤层和太原组11号煤层<sup>[12-13]</sup>,3层煤的累积厚度为5.5~13.3 m,平均为8.6 m。煤岩镜质体反射率为1.83%~3.05%,煤阶变化较大,全区分布有瘦煤、贫煤和无烟煤,主要以贫煤为主。韩城矿区的煤主要为低含水低挥发分的低—中灰煤。矿区东南缘的浅部接受地表水补给,在深部形成滞留带,水文地质条件简单<sup>[14-15]</sup>。



(a) 韩城矿区位置



(b) 韩城矿区构造纲要

图1 韩城矿区位置及构造纲要

Fig. 1 Location and structure of Hancheng Mining Area

## 2 煤层含气性分布规律

基于韩城矿区全区26口煤层气探井的72个煤心测试数据分析,3号煤层含气量为7.46~18.73 m<sup>3</sup>/t,平均为13.75 m<sup>3</sup>/t,70%的煤样含气量为10~15 m<sup>3</sup>/t;5号煤层含气量为8.00~18.07

m<sup>3</sup>/t,60%的煤样含气量为10~14 m<sup>3</sup>/t;11号煤层含气量为4.75~19.73 m<sup>3</sup>/t,50%的煤样含气量大于10 m<sup>3</sup>/t。煤层实测含气饱和度为25%~94%,平均为63%,含气饱和度大于60%的煤样约占61%,平均74.8%,总体呈欠饱和状态,各煤层含气量分布如图2所示。

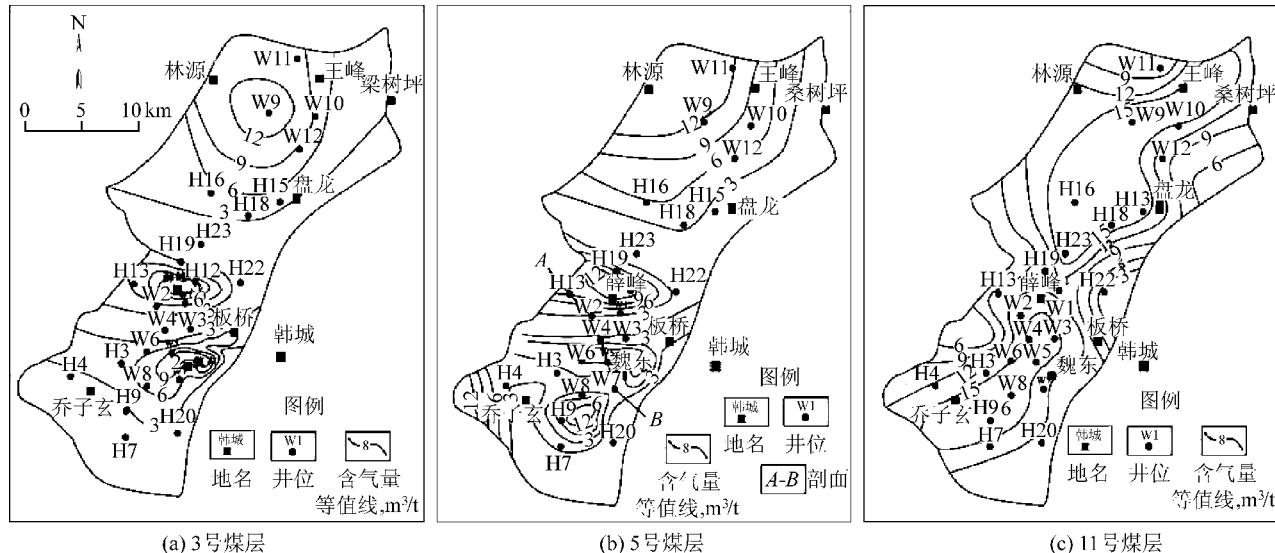


图2 韩城矿区3号、5号、11号煤层含气量等值线

Fig. 2 Isograms of gas content of No.3, No.5, No.11 coal seam in Hancheng Mining Area

韩城区块3号煤层含气量呈现“东南部低、西北部高、北部和南部均有富集中心”的总体展布格局,西北部、中部的含气量均大于9 m<sup>3</sup>/t,W9井、H12井区和W5井区大于12 m<sup>3</sup>/t(图2a);5号煤层含气量也有类似的展布规律,除乔子玄西部地区,其余地区含气量与3号煤层相差不大;11号煤层含气

量的展布格局与3号和5号煤层有差异,呈现“周边低中部高、西高东低”的展布格局,薛峰东北部、魏东西部地区含气量均大于12 m<sup>3</sup>/t,总体上11号煤层含气量大于3号和5号煤层的含气量,分析其原因,太原组沉积环境为海陆交互相,而山西组为陆相沉积<sup>[3]</sup>,此外,含气性与埋深关系如图3所示。

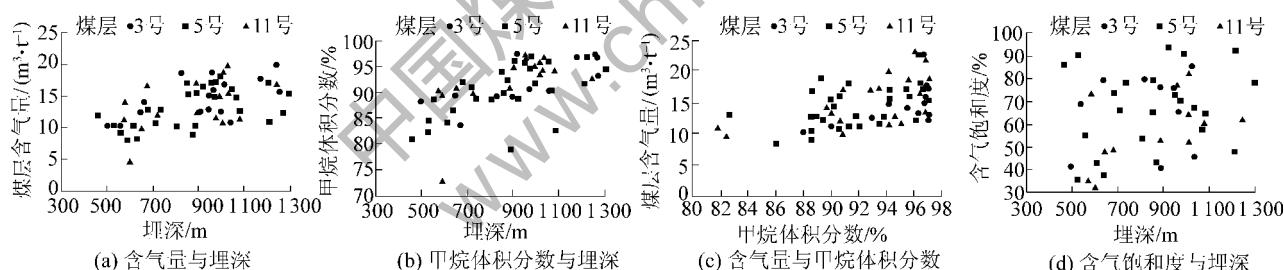


图3 煤层含气性与埋深关系

Fig. 3 Relationships between gas bearing property and buried depth of coal seam

尽管煤层含气量与埋深之间的关系较为离散,但两者总体上呈正相关关系(图3a)。甲烷浓度随埋深增大呈增大的趋势(图3b),除个别煤层气井的甲烷体积分数低于85%,其余均大于85%,最高达97.2%,平均91.6%,且与煤层含气量呈正相关关系(图3c)。总体来看,区块内的煤层气保存条件较好。含气饱和度与埋深呈离散性关系(图3d),总体来看,5号煤层的含气饱和度略高一点。

### 3 煤层含气量分布的地质控制因素

#### 3.1 煤变质程度

煤的镜质组反射率可以反映出煤岩的变质程

度,镜煤反射率不同,煤的吸附量也不同<sup>[6-17]</sup>。韩城矿区晚古生代煤层经历了印支和燕山期的变质作用,煤岩演化程度较高,镜质组反射率  $R_o = 1.81\% \sim 3.09\%$ ,普遍达到贫煤-无烟煤煤阶。该区煤岩经历了2次高温变质作用,为煤层含气量高的地质因素。随镜质组反射率的增高,煤层含气量和吸附性呈现增高的趋势(图4)。镜质组最大反射率小于3.5%煤化作用,煤物理结构和化学结构经历过2次煤化作用。煤岩随变质程度的增加,一方面煤岩的温度升高,煤化作用加强,生气能力增强,另一方面,变质作用越高,煤岩中的原生孔隙数量会更多,会增加对煤层气的吸附能力。

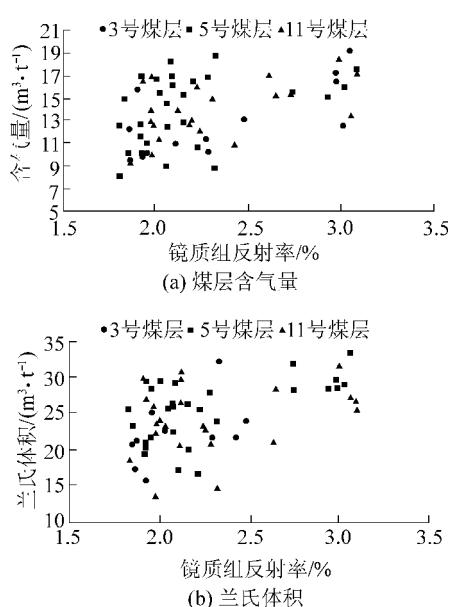


图4 韩城矿区煤层含气性与煤阶之间的关系

Fig. 4 Relationships between gas bearing features and coal rank of coal seam in Hancheng Mining Area

### 3.2 煤岩显微组分

煤岩镜质组既是生成煤层气的物质,又可以吸附煤层气,所以其含量的高低直接决定了煤岩吸附含气量的能力。韩城区块煤岩中显微组分以镜质组为主,含量为46.67%~97.01%,平均为75.77%,其次为惰质组。随镜质组含量的升高,煤的兰氏体积呈增大趋势,导致煤层含气量趋于增高(图5)。

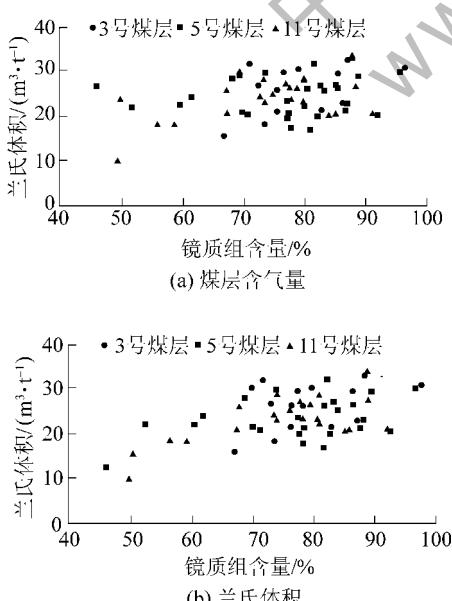


图5 韩城矿区煤层含气性与显微组分之间的关系

Fig. 5 Relationships between gas bearing and maceral of coal seam in Hancheng Mining Area

煤岩显微组分的差异,主要通过其孔隙性和吸附能力的不同而影响煤层含气量。前人研究发现,镜质组的吸附能力强于惰质组,相同煤阶富镜质组煤的吸附能力要大于富惰质组的煤<sup>[19~21]</sup>。韩城矿区的规律表明显微组分的差异对煤层含气量有着显著的影响。

### 3.3 构造条件

韩城矿区内部断裂较发育,尤其是中部和东南部均发育大规模断裂,所以断裂对煤层含气量的高低起着至关重要的作用,由图1和图2可以看出,含气量低值区主要分布在东南缘、薛峰南部和薛峰北部断裂发育的地区,含气量的高值区分布在断裂不发育的地区。大断裂的发育破坏了煤层气的保存条件,对煤层气的保存和富集起到了破坏作用,所以构造条件很大程度上影响了煤层含气量的分布特征。

在剖面上,以5号煤层为例分析变化趋势,煤层含气量变化趋势受断裂的影响非常明显,断裂内部和断裂附近的含气量明显低于断裂不发育地区,且含气量低值区均出现在断裂发育区,如W4井的含气量小于5 m<sup>3</sup>/t,而远离断裂带的H13井的含气量明显增高(图6)。

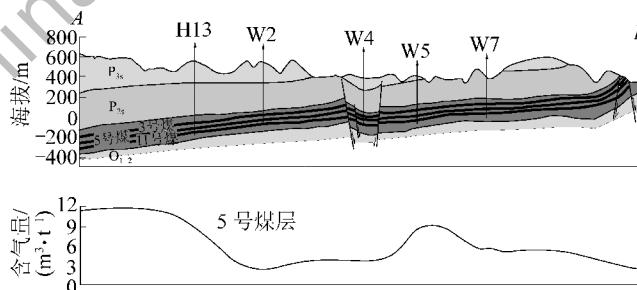


图6 构造部位与煤层含气量变化关系(剖面位置见图2b)

Fig. 6 Relationships between tectonic position and gas content in coal seam

### 3.4 水文地质条件

水文地质条件对煤层含气性的的影响主要体现在保存条件和运移条件2个方面<sup>[18]</sup>。

以太原组为例,分析该区的地下水水流场。该区地下水动力场是来自西北和西南部的高水位区的地下水和来自东南部的地表水共同形成的(图7),3个方向的水源在板桥西部地区相遇并形成一定范围的滞水地带,通过含气量等值线图可以看出,这一地区的含气量明显高于两侧地区,由地下水补给区到远离地下水补给区,煤层含气量逐渐升高,由此可以看出地下水滞流区域有利于煤层气的保存和富集。

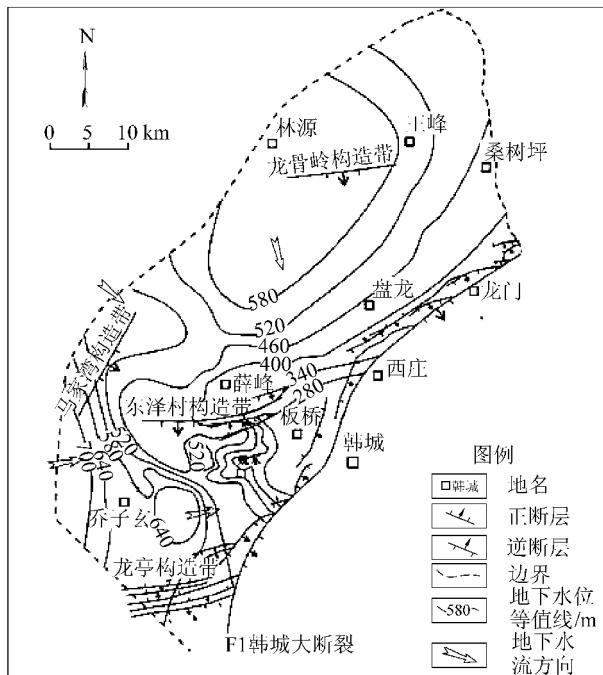


图7 韩城矿区太原组灰岩含水层地下水水流场示意

Fig. 7 Groundwater flow field of limestone aquifer in Taiyuan Formation in Hancheng Mining Area

## 4 结 论

1) 韩城矿区煤层甲烷浓度较高、含气量较高和含气饱和度较高。煤层含气性在此“三高”背景下还显现出2个特征:①太原组11号煤层含气性好于山西组3号和5号煤层;②含气饱和度受煤层埋深变化影响很小,但是呈现增大的变化趋势。研究认为,前者受控于研究区含煤地层的沉积环境;后者是地层压力与地层温度综合作用的必然结果。

2) 研究发现,韩城矿区煤层含气量、吸附性随煤岩变质程度增高均呈现先升高的变化趋势。分析认为,该区煤化作用程度是2次煤岩热演化作用的结果。进一步而言,这2次煤化作用对煤储层含气量的具体影响,值得今后进行进一步的研究。

3) 随镜质组含量的升高,韩城矿区煤层含气量和煤岩的兰氏体积均呈增大趋势,表明微组分差异对煤岩的吸附性和含气性具有显著影响。同时,构造条件和水文地质条件对煤层气的富集及分布也起到了非常关键的作用。

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