沁水盆地煤层气勘探及地质分析

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摘　要　沁水盆地是我国重要的煤层气勘探地区,盆地内蕴藏着丰富的煤炭资源和煤层气资源。该盆地面积约 2.4×10^4 km^2,预计煤层气资源量约 6.85×10^{12} m^3。到目前为止,整个沁水盆地共有煤层气井 48 口。经过原煤炭部、中联煤层气有限责任公司、CNPC 等单位近年的勘探,相继在该盆地南部获得高产煤层气流。初步查明沁水盆地南部为一个煤成气高渗富集区,具有良好的勘探开发前景。分析了该盆地南部聚煤条件与生气潜力,研究了煤储层特征及含气性,结果发现自盆地中部向南具有煤层气勘探井成功率增高的趋势。因此,该区勘探的战略方向应尽量向南。

主题词　沁水盆地　南　煤成气　高渗透油气藏　勘探方针　开发研究

沁水盆地是我国重要的煤层气勘探地区,盆地内蕴藏着丰富的煤炭资源和煤层气资源。该盆地位于晋东南地区,是一个在古生界基底的基础上形成的构造盆地,其现今面貌为一近南北向的大型复式向斜,面积约 2.4×10^4km^2,预计煤层气资源量约 6.85×10^{12} m^3。到目前为止,整个盆地有专门的煤层气井 48 口。

盆地内部次级褶皱发育,盆地南部以近南北向为主,北部则以北北东向和北东向为主;断裂主要以北东向、北北东向和北东东向的高角度正断层为主。沁水盆地的特点是:内部褶皱发育,断裂不太发育,煤系地层广泛稳定发育,长期抬升,主煤层埋藏浅(小于 1 000 m)。它不同于其西侧的鄂尔多斯盆地,也有别于太行山以东华北东部的断块含煤区,因为鄂尔多斯盆地在煤系地层沉积之后,长期稳定沉降,上覆地层厚,构造简单,而华北东部断块含煤区在煤系地层沉积后又经历了强烈断块作用的改造。

沁水盆地自下而上钻遇的主要地层有峰峰组(O_2f)、本溪组(C_2b)、太原组(C_3t)、山西组(P_1s)、下石盒子组(P_1x)、上石河子组(P_2s)、石千峰组(P_2sh)和第四系(Q)等,其中山西组和太原组为主要含煤层系,3 号和 15 号煤层为煤层气勘探的主要目的层,9 号煤层为局部勘探目的层。

经过原煤炭部、中联煤层气有限责任公司、CNPC 等单位近些年的勘探,相继在潘庄井组、晋城井组、TL-003 井、TL-006 井和 TL-007 井获得了高产煤层气流,最高达 16 000 m^3/d,平均稳产可达 2 000～3 000 m^3/d。初步查明沁水盆地南部为一个煤层气高渗富集区,展示出良好的勘探开发前景。

沁水盆地南部的聚煤条件与生气潜力

1. 聚煤条件

前人的研究表明,中奥陶世后,除山西省西北部靠近阴山古陆地区及南部古隆起较高外,其境内广大地区均准平原化。中石炭世后,经过本溪期海湖相沉积对古侵蚀面的填平补齐,进入晚石炭世和早二叠世,地形更趋平坦,总趋势是北高南低,均匀沉降和补给。这种古地形条件有利于大范围形成沼泽,也给海水从东南方向进泛创造了有利条件,泥炭沼泽成煤后得以保存。而且经古地磁研究,石炭纪时期山西靠近赤道,气候温暖潮湿多雨,有利于植物生长,成煤物质鳞木属大量繁殖,这种古气候条件易形成泥炭。

晚石炭世太原期,南部地区总体上处于三角洲前缘亚相,早二叠世山西期总体上处于上三角洲平原亚相;其中 C_3t 早期主要为大范围的分流间湾相环境,P_1s 早期主要为湖泊—沼泽相环境,有利于两套主煤层的形成。在这种环境条件下形成了北起安泽县南至沁水县,西起浮山东到长子县的大范围 3 号和 15 号煤的厚煤分布带。

2. 煤层分布特征

表 1 为部分钻井煤层厚度一览表,从中可看出,

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沁水盆地南部 3 号煤层全区稳定,平均厚 6 m,埋深 300～500 m; 15 号煤层属于较稳定煤层,平均厚约 3 m,埋深 500～600 m。煤层气井一般合采煤层厚度 6～10 m,平均厚 8 m。埋藏浅、厚度大且分布稳定的煤层对勘探开发煤层气非常有利。

表 1　部分钻井煤层厚度一览表

井　号	煤层厚度(m)		合　计	备　　注
	3 号	15 号	(m)	
QD-2	4.4	4.5	9.9	煤层气勘探井
QD-3	6.45	1	7.45	煤层气勘探井
QD-4	6.2	3.1	9.3	煤层气勘探井
QD-7	5.2	4.4	9.6	煤层气勘探井
QD-9	7.0	4.9	11.9	煤层气勘探井
ZY-2	6.3	3.25	9.55	煤层气生产试验井
0002	5.84	3.35	9.19	煤田勘探孔
0402	7.16	1.4	8.56	煤田勘探孔
1205	5.14	2.79	7.93	煤田勘探孔
6-1	5.89	3.13	9.02	煤田勘探孔
1103	6.8	2.82	9.6	煤田勘探孔
127	5.67	2.23	7.9	煤田勘探孔
P2	6	2.8	8.8	煤层气勘探井

3. 煤的有机组成与生气潜力

(1) 显微组成特征与生气能力

从沁水盆地南部煤岩显微组成特征资料可知,3 号煤层镜质组含量平均为 77.99 %,灰分含量平均为 13.51 %;15 号煤层镜质组含量平均为 79.21 %,灰分含量平均为 12.56 %;两层煤的壳质组含量甚微。均属于高镜质组、低灰分煤。这种低灰分含量、高镜质组含量、低壳质组含量的显微组成特征表明其原始有机质主要来源于陆源高等植物。具有这种特点的煤层有利于形成原生割理裂隙,保证了煤层气的解吸通道和导流能力,同时镜质体中的大量微孔也为煤层气提供了储存空间;无机物含量低使煤层有巨大的基质颗粒表面吸附煤层气,从而使煤层能够赋存大量的煤层气。

(2) 煤岩煤质特征

资料表明,3 号煤和 15 号煤的宏观煤岩类型主要为半亮煤和半暗煤,夹亮煤和暗煤条带,而且总体上表现出 15 号煤层比 3 号煤层煤岩类型好的特点。宏观煤岩类型越好,其产气能力就越高。该区煤的显微组成和宏观煤岩类型与其原始沉积环境的变迁相关。

(3) 煤的元素分析

元素分析表明(图 1),该区煤的 H/C 原子比和 O/C 原子比都很低,前者平均 0.46,后者平均 0.02,样品点全部落在左下角,反映煤层的高演化特征。

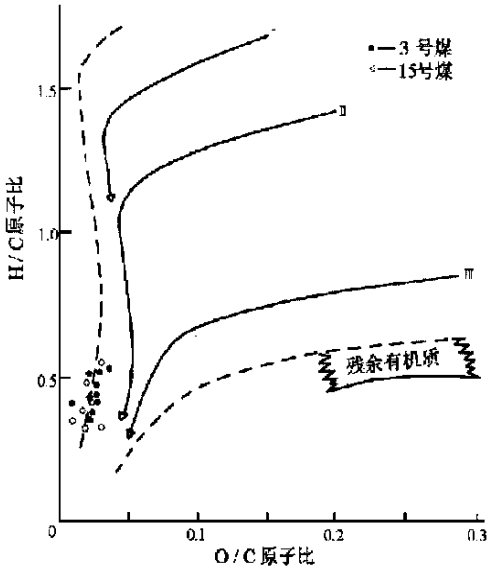

图 1　沁水盆地南部煤干酪根类型图

(4) 煤的热演化程度与生气作用

该区煤的 R_o 在 2.3 %～3.99 %之间,自北向南由贫煤演变为无烟煤,具有较高的生气能力。煤变质程度高,以及高煤阶煤分布面积广是本区最明显的特征。另外,挥发分含量与镜质体反射率呈现良好的负相关,随着煤的演化程度增高,挥发分减小,其回归系数在 0.9 以上。

沁水盆地南部煤储层特征及含气性

1. 煤层渗透率及其影响因素

该区煤的演化是深成变质作用和区域性岩浆热变质共同作用的结果。燕山期以前,煤变质主要受控于深成变质作用,据 TTI 指数推算,三叠纪末,区内煤层 R_o 为 0.57 %～1.04 %,属于气、肥煤。进入燕山期,强烈的构造运动使本区抬升、褶皱,石炭—二叠纪煤系及上覆地层遭受剥蚀,同时莫霍面抬升和局部岩浆侵入,形成区域性高地温场,使煤的演化加快,由气、肥煤快速变为焦煤—无烟煤。也就是说,该区的高变质煤是在上覆压力不断减小,而地温场又异常高的条件下快速演化而成,它不同于单纯有深成变质作用形成的无烟煤,因此煤层能够保持相对较高的渗透性。

渗透率与煤层埋深有直接关系。这是因为埋深增大,煤层承受的静压力越大,有效应力也就越大,导致煤层渗透率降低。国内外的资料均表明,煤层埋深与渗透率有着良好的负相关性。可见埋深仍然是影响该区煤层渗透率的主要因素之一。目前因为

样本较少,尚不能定量确定其最终开采深度,但总的来说开采浅层比深层有利。

2. 储层压力系统

从实际勘探情况来看,该区具有储层压力偏低的特点,3 号煤储层压力为 2.35～3.7 MPa,15 号储层压力为 2.67～6.105 MPa,压力系数均小于 0.8,属于欠压储层。欠压储层对煤层气排采不利。

3. 含气性与封盖条件

沁水盆地南部煤层含气量较高,一般在 13～20 $m^3/t_{原煤}$之间,且全区基本稳定,这一点对在该区开发煤层气有利。煤层含气量高与煤层的高演化程度有关。贫煤—无烟煤具有很强的生气能力和吸附能力。因此,尽管后期抬升时间很长(图 2),煤层气大量逸散,但是仍有相当数量的吸附气体被保存至今。

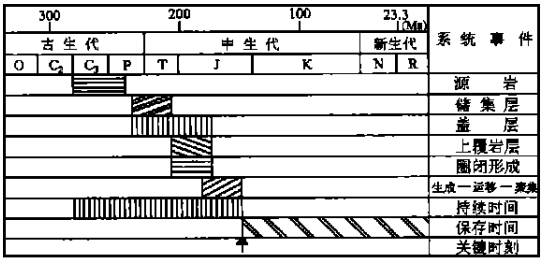

图 2　沁水盆地南部浅层含煤层气系统事件示意图

含气量除了与演化程度有关外,还与煤层埋深和封盖条件有关。从本区的煤层含气量与埋深关系资料可以看出,含气量与埋深呈良好的反比关系,与以往的认识有差别,以往认为含气量随埋深增大而增大。其原因可能与煤层气在漫长的地质历史时期向浅部运移聚集有关,因为煤层气毕竟也是气体,应该符合气体的一般规律。由这一点可知,勘探浅部比深部有利一些。

煤层的封盖条件对其含气性起着不可忽视的作用。我国许多以泥岩为盖层的煤田,煤层甲烷含量都比较高,并且大都是瓦斯突出矿井,如丰城、淮南、淮北、北票等。图 3 为沁水盆地南部生储盖综合图,从中可看出,该区 3 号煤层含气量高的煤层顶板主要为泥岩,具良好的封盖性,处于泥岩顶板区的井煤层含气饱和度也较高(图 4)。15 号煤层含气量高,其顶板为石灰岩,局部缝洞发育,一定程度上影响了煤层含气性,但这种缝洞发育规律目前无法准确预测。如果把 15 号煤层与有缝洞的石灰岩作为一个勘探目标考虑,就可以降低因缝洞而造成的影响。

4. 煤体结构及可改造性

煤心观察表明,沁水盆地南部各主煤层都表现

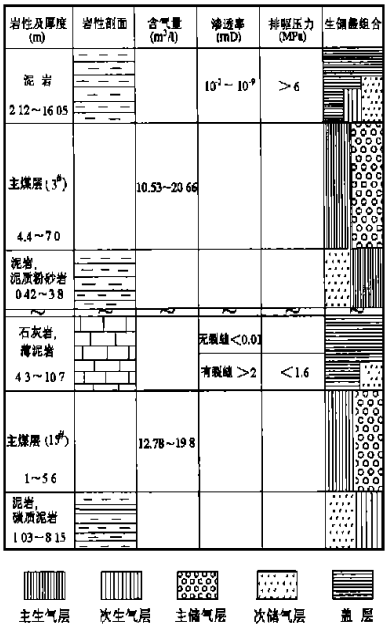

图 3　沁水盆地南部生储盖综合图

注:mD 是非法定计量单位,1mD≈$10^{-3}\mu m^2$。

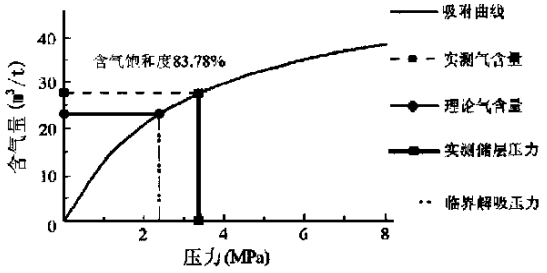

图 4　QD-3 井等温吸附曲线

为原生结构,这种煤体结构对煤层的割理和裂隙的形成和保存有利。由于煤层保留了较好的煤体结构,加之煤层区域热变质过程中形成的大量“气胀节理”和岩体的“拱劈作用”共同作用的结果,使该区煤层总体上具备了较好的渗透性和导流能力;而且无烟煤本身硬度大,比较适合于进行压裂改造,从而更好地提高煤层的导流能力。

结论及建议

沁水盆地南部是我国目前发现的煤层气高渗富集区之一,而且也是煤层气勘探程度最高的地区。该区煤层气勘探开发条件优、劣并存,但总体上仍然是具有良好的煤层气开发前景。

目前的勘探情况表明,自盆地中部向南具有煤层气勘探井成功率增高的趋势。因此,该区勘探的战略方向应尽量向南。

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shown as follows: ①according to the requirements of both clean energy resources and environmental protection the government departments in China have attached great importance to the development and utilization of coal-bed gas and a series of preferential policies are making up one after another; ②the development and utilization of coal-bed gas in China have become the focal point concerned by the world coal-bed gas industry; ③the self-operating exploration for coal-bed gas in China is vigorously carrying out with significant achievements; and ④the standardized management of coal-bed gas in China has been led onto the correct path. At present the competitions faced by developing the coal-bed gas industry in China and the countermeasures which should be adopted are: ①the capital construction of gas line network in China is very weak and the long-distance transmission pipeline network of coak-bed gas should be brought into the state middle- and long-term development planning; ②although the marjor engineering of developing coal-bed gas has been basically grasped in China, it is far inferior to perfection and its key techniques should be overcome in coordination under the support and organization by relevant government departments; ③certainly, the exploration risk inicreases for lack of the effective methods and means to survey high-permeability accumulation regions in China, so that a systematic research work should be carried out as quickly as possible; ④because the occurrence condition of coal-bed gas in China is much different from that in U. S. A., it is suggested that relevant ministries and commissions should organize the basically theoretical research on the coal-bed gas of low- and high-rank coals as quickly as possible; and ⑤it is suggested that relevant government departments should give the development and utilization of coal-bed gas much more preferential policies.

SUBJECT HEADINGS: Coal-formed gas, Reserve, Producing, Production forecast, Forming, Developing strategy

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COAL-BED GAS EXPLORATION IN QINSHUI BASIN AND ITS GEOLOGICAL ANALYSIS

Li Mingzhai (China National Union Coal-bed Gas Corporation Ltd.). *NATUR. GAS IND.* v. 20, no. 4, pp. 24～26, 7/25/2000. (ISSN 1000-0976; **In Chinese)**

ABSTRACT: Qinshui Basin is a major coal-bed gas exploration region, being rich in coal resources and coal-bed gas resources. This basin occupies an area of about 2.4×10^4 km^2 and possesses coal-bed gas resource extent of about 6.85×10^{12} m^3 (predicted). Up to now, there are 48 coal-bed gas wells all over the basin. Through exploration in recent years by the former Ministry of Coal, the China National Union Coal-bed Gas Corporation Ltd. and CNPC, a great number of high-production coal-bed gas wells have been drilled in the south part of the basin successively. It is primarily proved that the south part of the basin is a coal-bed gas accumulation region with high-permeability, being of fair exploration and development potential. Through analyzing the coal-accumulated conditions and gas-generating potential in the south of the basin and studying the coal reservoir properties and hydrocarbon potential, it is found that the success ratio of caok-bed gas exploration well increased from the middle part of the basin to its south. Therefore the strategic deployment of surveying for coal-bed gas should be to put he exploration wells to the south of the basin as far as possible.

SUBJECT HEADINGS: Qinshui Basin, South, Coal-formed gas, High permeability pool, Exploration policy, Development research

Li Mingzhai's introduction: See v. 18, no. 4, 1998.

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EVALUATION METHOD OF CLEATS IN COAL RESERVOIR BED

Liu Honglin, Wang Hongyan and Zhang Jianbo (Natural Gas Department, Langfang Branch of Research Institute of Petroleum Exploration and Development, PCL). *NATUR. GAS IND.* v. 20, no. 4, pp. 27～29, 7/25/2000. (ISSN 1000-0976; **In Chinese)**

ABSTRACT: Cleats are the endogenetic fracture systems which are widely distributed in the coal bed and are of great significance for the coal-bed gas to be produced, being the natural fractures formed by desiccation, coalification, lithification and tectonic force. Because, in coal-bed gas exploration, the formation and preservation of cleats and cleat permeabilities have great significance for predicting coal-bed gas high-production accumulation zones, it is very important for geological region selection evaluation to understand the genesis and classification of cleats and their research methods. The main conclusions are as follows: ①the formation of cleats results from both exogenic and endogenetic effects and they are the result of the coaction of internal and external geological agents such as desiccation, coalification, lithification and palaeotectonic stress, etc., so that a dual-genesis hypothesis is much more appropriate; ②a set of methods