煤储层割理评价方法

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摘　要　割理是广泛存在于煤层中对煤层气的产出具有重要意义的内生裂隙系统, 是煤层经过干缩作用、煤化作用、岩化作用和构造压力等各种过程形成的天然裂隙。由于在煤层气勘探中, 割理及割理渗透率形成与保存对煤层气高产富集区预测有着重要意义, 所以了解割理的成因和分类及相应的研究方法对煤层气地质选区评价至关重要。本次研究结论如下: ¹ 割理形成既有外生成因, 也有内生成因。煤层割理是干缩作用、煤化作用、成岩作用及古构造应力等内外地质作用共同作用的结果, 双重成因假说更为贴切。º 提出了一套研究煤层割理及割理系统的方法, 并完善了用割理评价渗透率的方法。» 通过对影响割理发育的内在因素的分析, 认为割理是外在地质作用(煤化作用、构造应力等)通过煤层内在属性(煤厚、煤岩组成、灰分等)形成的, 是各种地质作用在煤储层中的综合反映。煤层内在属性和外在地质作用缺一不可, 这两者都是形成割理、改善煤层渗透性的必要条件。

主题词　煤　储集层　裂缝(岩石)　评价　方法

割理是广泛存在于煤层中对煤层气的产出具有重要意义的内生裂隙系统, 是煤层经过干缩作用、煤化作用、岩化作用和构造压力等各种过程形成的天然裂隙。目前, 有关割理成因的假说有三种, 即内生成因、外生成因和双重成因。割理通常被划分为相互垂直的两组: 连续性好的面割理和连续性不太好的终止于面割理的端割理, 这两组割理通常垂直于或接近垂直于煤层层理面, 共同组成了煤层的割理系统。

割理系统具有割理的间距和高度、连通性、充填度和闭合度等重要属性, 这些重要性质受到诸如煤阶、煤岩组分、灰分等多种储层因素的影响。例如割理间距主要受亮煤条带高度的限制, 割理间距和高度随煤岩组分厚度的变薄而分别变窄和降低[1,12]。而在一些煤层中, 割理间距与煤阶有关, 由中挥发分到低挥发分烟煤而变窄, 而后又随煤阶的升高而变宽[1,22]。

在煤层气藏的开采过程中, 煤储层割理系统是水和气产出过程中的主要渗流路径, 是影响煤渗透率的主要因素。因此研究煤层气割理的评价方法对煤层高渗透性选区评价具有重要地质意义。

割理的研究方法

11 割理的识别

煤层中一般有两种裂缝系统, 一是由地质构造作用造成的, 其力学性质可以是压性、张性或剪性的; 二是在煤化作用过程中, 煤中凝胶化物质受温度和压力等因素影响, 体积均匀收缩产生内张力而形成的, 力学性质是张性的。按成因分类, 前者为外生裂隙, 后者为割理。因此, 在实际工作中, 如果不把这两种裂隙加以区别对待, 则煤层高渗区带的评价预测将难以进行。

由于割理和外生裂隙的成因不同, 它们的地质特征和分布规律的地质控制因素也不完全相同。由于成因上的差别, 割理和外生裂隙在产出特征上表现出如下重要区别: ¹ 割理面垂直或近似垂直于层理面, 而外生裂隙面与层理面间的夹角变化大, 可以是平行的、垂直的或斜交的。º 割理在纵向上或横向上均不穿过不同的煤岩类型界面或界线, 而外生裂隙则穿过这些界面或界线, 有的还延伸到煤层的顶、底板之中。» 割理面上无擦痕, 而外生裂隙面上有时可见擦痕或磨光面。上述 3 条重要的区分标志适用于煤岩手标本上、煤层地面露头和煤矿人工露

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头上的煤层割理和外生裂隙的区分。

21 割理描述要素

用以下要素来描述煤层割理的表现特征(表1)。

表1　煤层割理描述要素分类表

割理分类	描述要素	
面割理	割理组数、组合类型	面割理走向、面割理长度、面割理密度、割理面形态、面割理壁距、割理的面密度、充填程度、充填物
端割理	割理组数、组合类型	端割理走向、端割理密度、割理面形态、端割理壁距、端割理长度、割理高度、充填程度、充填物

不论在野外还是在室内,割理的观察都要在分别平行于面割理、端割理和层面或煤岩类型界面的3个断面上进行。常用的割理要素涵义阐述如下。

割理长度是在平行于层面的断面或煤岩类型界面上割理的横向连续延伸长度,而割理高度指的是垂向上割理的连续延伸长度。割理密度是在平行于层面的断面或煤岩类型界面上,与一条垂直于割理延伸方向的一定长度的直线相交的割理的条数,该直线的长短视割理的疏密而定,一般以5 cm较合适。割理的面密度是在平行于层面或煤岩类型界面上,一定平面面积内的面割理和端割理的总条数,一般使用两边分别与面割理和端割理平行的四边形来进行统计。割理面形态是指煤岩沿割理裂开后,割理的两壁是光滑平整的,还是参差不齐的。由于割理为张性裂隙,所以,参差不齐的割理面形态并非少见。割理壁距是同一条割理的两壁之间的距离。最有意义的是那些矿井内或钻井岩心上被充填的割理,充填物的厚度代表某一地质时期内地下状态下的割理壁距。

由于不同煤岩类型的割理特征差别很大,同一样品或同一煤岩剖面上常存在两种或两种以上的煤岩类型,因此在实际工作中应分别采集各种煤岩类型的割理特征数据,进行对比,以准确评价煤储层割理系统。

3. 割理平面组合类型划分

割理的平面组合形态可以大致划分为网状、孤立)网状和孤立状三种类型(表2)。在其它条件,如现今地应力、地层压力、煤体结构、外生裂隙特征和充填程度相近时,网状割理的煤层渗透性好,具孤立)网状的渗透性各向异性不明显。就开发井的布置而言,要使开发区在短期内达到峰值产量,具孤立)网状或孤立状割理的煤层的生产井井距应比网状割理的小一些。由于不同割理组合类型的渗透性各向异性程度的差异,所以为了扩大排泄面积,提高气田产量,网状割理的煤层可布置等间距井网,但对孤立)网状或孤立状割理的煤层,沿端割理方向的井距应比沿面割理的方向的井距小。

表2　煤层割理平面组合划分表

组合类型	形态特征	渗透性
网状	任何两条相邻的面割理之间的任何一条端割理均与这两条面割理相交	好
孤立)网状	仅部分面割理之间存在与之相交的端割理	较好
	大部分端割理仅一端与面割理相交	中等
孤立状	仅发育面割理	差

注:据樊明珠,1995,有修改。

41 利用割理描述要素来评价储层渗透性

割理系统是影响煤储层渗透性的主要因素,其中又以割理密度、割理壁距、割理走向和平面组合特征对煤层的渗透性影响最为明显。一般割理密度越大,煤层渗透性越好,反之则越低。

割理壁距是影响煤层渗透性的又一重要因素。据休伊特)帕森斯的研究结果,理想的裂缝)基质系统,其水平方向的渗透率与裂缝各种要素间存在如下关系[132]:即煤层的水平渗透率与割理壁距的三次方呈正比,与割理密度的一次方呈正比,说明割理壁距在提高煤层渗透性方面起着很重要的作用。由于割理壁距受现今地应力影响,在地层压力一定时,地应力越高,割理壁距愈小,渗透性越差,反之,渗透性越好。所以,在煤层高渗带预测中,低应力区的识别具有重要意义。

割理走向,尤其是面割理走向可用来识别潜在的流体流动通道,有助于煤层气开发方案的设计。割理长度是实现煤层气井井间干扰的必要条件。割理面形态的不规则性有利于高应力环境下的割理仍部分地保持着开启状态。

在安阳和柳林煤层气勘探开发试验区中,割理特征对煤层渗透性的控制作用十分明显。钻井煤心观察统计结果表明,安阳试验区的割理组合类型为孤立)网状,以孤立状为主,而柳林试验区为网状,其它特征的比较见表3。这两个地区在割理特征上的这些明显差别,使它们地层测试的煤层渗透率差别很大,安阳试验区为0.01~0.3 mD(注:mD为非法定计量单位,换算关系为1 mD=0.987@10^{-3}

Lm^2, 下同), 而柳林试验区 10 个渗透率数据中有 8 个变化在 0112~ 1212 mD 之间, 比安阳高出 1 或 2 个数量级。

表 3　安阳、柳林煤层气试验区煤层割理密度对比表

试验区	割理面密度 (条/ 25 cm^2)	面割理密度 (条/ 5 cm)	端割理密度 (条/ 5 cm)
安阳	2~ 10	2~ 8	0~ 4
柳林	12~ 30	8~ 18	4~ 14

注: 据樊明珠, 1995。

5.1 影响割理发育程度的煤储层因素分析

煤层割理的发育程度受很多煤层因素影响, 包括煤阶、类型(显微组分和岩石力学性质)、宏观煤岩组分组合模式和煤层厚度等方面。

1) 煤阶是影响割理发育的主要因素。通常低煤阶煤的割理不甚发育, 演化到烟煤时割理发育, 割理面最密集的主要发生在低挥发分烟煤煤阶附近, 高于低挥发分烟煤煤阶, 割理反而变得不发育, 在手标本或露头上表现为割理封闭。B. E. Law(1993) 等曾研究过割理间距和割理频率, 认为割理频率(割理数/线性单元) 与煤阶存在确定的函数关系。割理频率从褐煤到中等挥发分烟煤随煤阶升高而增大, 然后到无烟煤时随煤阶上升而下降, 形成一条钟形曲线[142]。

2) 一般煤层厚度越小, 割理密集度越大。在大多数情况下, 割理间隔煤岩厚度相等或略小。

3) 割理通常存在于富含镜质显微组分的光亮型镜煤条带中, 极少出现在暗煤(丝质组及惰性组) 中。割理高度一般是在垂直煤岩分界面上沿割理面测量, 这种测量结果显然受煤岩成分控制。例如, 水果地组在露头上的光亮煤条带中割理的高度在 1 至数十厘米之间, 而其煤心中镜煤条带的割理高度小至肉眼无法观察, 大至 60 cm, 平均长度为 2.8 cm。镜质条带上下一般以丝质组、惰性组及非煤岩层界面为限, 使得割理的发育也局限于镜煤条带之间[152]。

4) 大量的观察和实验数据显示: 割理通常开始于煤层灰分显著变化的地方。

5) 通过对晋城矿区无烟煤中割理的研究发现, 割理发育也可能起始于煤岩的微裂缝处。所谓微裂缝就是延伸范围极小, 宽度与岩石孔径在同一数量级, 所提供的补充渗透率也在同一数量级的裂缝, 有时也称潜在裂缝, 随着应力加大它可以发育成显裂隙、小断层、大断层。这些观察结果与压应力场中张性裂缝发育于岩石中微小裂缝处的观点是一致的。

结　论

在煤层气勘探中, 割理及割理渗透率形成与保存对煤层气高产富集区的预测有着重要意义。本次研究主要结论如下。

1) 割理形成既有外生成因, 也有内生成因。煤层割理是干缩作用、煤化作用, 成岩作用及古构造应力等内外地质作用共同作用的结果, 双重成因假说更为贴切。

2) 提出了一套详细研究煤割理及割理系统的方法, 并完善了用割理评价渗透率的方法。

3) 通过对影响割理发育的内在因素的分析, 认为割理是外在地质作用(煤化作用、构造应力等) 通过煤层内在属性(煤厚、煤岩组成、灰分等) 形成的, 是各种地质作用在煤储层中综合反映。煤层内在属性和外在地质作用缺一不可, 这两者都是形成割理、改善煤层渗透性的必要条件。

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shown as follows: ¹ according 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 coal2bed gas and a series of preferential policies are making up one after another; º the development and utilization of coal2bed gas in China have become the focal point concerned by the world coal2bed gas industry; » the self2operating exploration for coal2bed gas in China is vigorously carrying out with significant achievements; and ¼ the standardized management of coal2bed gas in China has been led onto the correct path. At present the competitions faced by developing the coal2bed gas industry in China and the countermeasures which should be adopted are: ¹ the capital construction of gas line network in China is very weak and the long2distance transmission pipeline network of coak2bed gas should be brought into the state middle2 and long2term development planning; º although the marjor engineering of developing coal2bed 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; » certainly, the exploration risk inicreases for lack of the effective methods and means to survey high2permeability accumulation regions in China, so that a systematic research work should be carried out as quickly as possible; ¼ because the occurrence condition of coal2bed 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 coal2bed gas of low2 and high2rank coals as quickly as possible; and ½ it is suggested that relevant government departments should give the development and utilization of coal2bed gas much more preferential policies.

SUBJECT HEADINGS: Coal2formed gas, Reserve, Producing, Production forecast, Forming, Developing strategy

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COAL2BED GAS EXPLORATION IN QINSHUI BASIN AND ITS GEOLOGICAL ANALYSIS

Li Mingzhai(China National Union Coal2bed Gas Corporation Ltd.). NAT UR. GAS IND. v. 20, no. 4, pp. 24~ 26, 7/ 25/ 2000. (ISSN 100020976; In Chinese)

ABSTRACT: Qinshui Basin is a major coal2bed gas exploration region, being rich in coal resources and coal2bed gas resources. This basin occupies an area of about 2. 4@10^4 km^2 and possesses coal2bed gas resource extent of about 6. 85@10^{12} m^3 (predicted). Up to now, there are 48 coal2bed gas wells all over the basin. Through exploration in recent years by the former Ministry of Coal, the China National Union Coal2bed Gas Corporation Ltd. and CNPC, a great number of high2production coal2bed 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 coal2bed gas accumulation region with high2permeability, being of fair exploration and development potential. Through analyzing the coal2accumulated conditions and gas2generating potential in the south of the basin and studying the coal reservoir properties and hydrocarbon potential, it is found that the success ratio of caok2bed gas exploration well increased from the middle part of the basin to its south. Therefore the strategic deployment of surveying for coal2bed gas should be to put he exploration wells to the south of the basin as far as possible.

SUBJECT HEADINGS: Qinshui Basin, South, Coal2formed gas, High permeability pool, Exploration policy, Development research

Li Mingzhaics 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). NAT UR. GAS IND. v. 20, no. 4, pp. 27~ 29, 7/ 25/ 2000. (ISSN 100020976; In Chinese)

ABSTRACT: Cleats are the endogenetic fracture systems which are widely distributed in the coal bed and are of great significance for the coal2bed gas to be produced, being the natural fractures formed by desiccation, coalification, lithification and tectonic force. Because, in coal2bed gas exploration, the formation and preservation of cleats and cleat permeabilities have great significance for predicting coal2bed gas high2production 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: ¹ the 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 dual2genesis hypothesis is much more appropriate; º a set of methods

of studying cleats and cleat systems in coal2bed in detail are pro2 posed and the method of evaluating permeability by cleats is per2 fected; » through analyzing the internal factors influencing the growth of cleats, it is thought that the cleats are formed by the external geological agents (coalification and tectonic stress, etc.) in combination with the internal attribution of coal2bed (coal thickness, coal petrologic composition and ash content, etc.) , being a comprehensive reflection of various geological a2 gents in coal reservoir bed. Not a single one of both the internal attribution of coal2bed and the external geological agent can be dispensed with and they are the necessary conditions of forming cleats and improving the permeability of coal2bed.

SUBJECT HEADINGS: Coal, Reservoir, Fracture(rock) , Evaluation, Method

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APPLICATION OF FUZZY PATTERN RECOGNI2 TION METHOD TO GAS LOGGING DATA INTER2 PRETATION

Wu Zhengping(Jianghan Petroleum Institute) . NATUR. GAS IND. v. 20, no. 4, pp. 30~ 32, 7/ 25/ 2000. (ISSN 100020976; In Chinese)

ABSTRACT: The major purpose of compound logging is to prove the hydrocarbon potential of stratigraphic profile drilled and to reasonably interpret and evaluate the hydrocarbon2bear2 ing layers found in accordance with display strength and compo2 nental composition data. In gas logging there are many factors influencing gas logging display, such as the physical property of hydrocarbons in formation, gas loss in mud outlet pipeline, mud property, the sensitivity of device to a certain component and the working effectiveness of degasser, etc. The influence of these fa2 tors on gas logging data is of randomness and fuzzyness. On the basis of introducing the general methods commonly used for gas logging data interpretation, the basic principle of fuzzy pattern recognition method and the practical steps of how to interpret gas logging data by use of fuzzy pattern recognition method and relevant software developed are emphatically introduced in the paper. Through processing the practical data from a certain oil and gas field by this method, it is proved that its recognition rate is up to 81%. Therefore this method is relatively reliable for gas logging data interpretation. .

SUBJECT HEADINGS: Fuzzy mathematics, Recognition, Integration, Logging, Drilling fluid logging, Hydrocarbon anomaly, Gas logging, Stratigraphic section

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FOLLOW2UP MONITORING AND EVALUATION OF THE FORMATION PRESSURE IN THE PRO2 CESS OF DRILLING

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ABSTRACT: In Sichuan basin, especially in East Sichuan region, the multiple pay beds and multiple pressure systems are common longitudinally and the high pressure and low one are al2 ternative, which generally causes the complexity in borehole, prolongs the drilling cycle and increases the drilling cost. For this reason, utlizing the function of logging while drilling with combination logging tool to conduct the follow2up monitoring and evaluation of the carbonate formation pressure in the process of drilling to evaluate thus the main target zone and the reser2 voirs above the target zone is of a very important practical sig2 nificance for the drilling engineering decision (making drill stem test or not, selecting the density of the drilling fluid and drilling measures for following drilling and adopting casing off or not to change casing program, etc.) and completing the drilling with safety and high quality and efficiency.

SUBJECT HEADINGS: Drilling, Formation pressure, Mon2 itoring, Evaluation, Sichuan basin, East

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WELL CEMENTING TECHNOLOGY FOR SICHUAN REGION

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ABSTRACT: The well cementing technology for Sichuan region is mainly aimed at the fractured carbonate gas reservoirs which are characterized by the multiple pressure systems, the