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Application of directional boreholes for gas drainage of adjacent seams

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A R T I C L E I N F O

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1. Introduction

Coal gas is a serious hazard in coal mines around the world.[1,2] Additionally, methane-bearing coal gas emissions contribute greatly to the greenhouse effect.[3] If captured and processed properly, methane released during mining can also be used to generate energy.[4] Because methane must be isolated for these reasons of mine safety, greenhouse gas reduction, and energy production, there exists a need for enhanced coal gas drainage technology.[5]

Currently, ventilation and gas drainage are the main techniques for gas control. Ventilation air methane accounts for 65–70% of the total coal mine methane emissions in China because most coal mines are located underground.[3] However, the use of methane from coalmines is highly difficult, because ventilation air methane contains low concentrations of methane. In contrast, coal gas produced from drainage is transported through gas drainage pipes and yields gases with high concentrations of methane. The demands and requirements for gas drainage are currently under review as issues of public policy and coal mining itself in China. Therefore, research into coal gas drainage technology is a promising area that should be continued.

Current methods of gas drainage include surface wells, boreholes and underground roadways.[6] Underground borehole drainage encompasses both cross-measure boreholes and in-seam boreholes; of these two methods, in-seam boreholes have the advantages of requiring less work and producing higher utilization rates. Relatively new long-directional borehole drilling technology has also improved borehole drainage; this new directional drilling technology can measure and control the trajectory of a borehole, reducing the need for conventional drilling in a straight line. A long directional borehole can cross a seam, be in-seam, or be a combination of the two. This directional borehole drilling technology has many advantages over conventional drilling methods, including a larger single borehole depth and higher proportion of in-seam boreholes,[7] and it has improved over time.[8] Directional borehole drilling technology has been used successfully throughout the USA and Australia; in China, in-seam longhole directional drilling technology was implemented successfully in several mines with suitable geological conditions.[7]

Mining of gassy coal seams is common in China. During their excavation, adjacent coal seams are depressurized, and the coal gas contained inside them flows towards the working face, causing gas problems. Directional drilling technology is becoming increasingly popular for draining gas from adjacent seams,[9–11] as an alternative to conventional cross-measure boreholes[6] and roadway drainage,[12] due to its high utilization rate and low project cost relative to roadway excavation. Although the application of directional boreholes and its drilling rig has been developed in China over the past few years, this technology is still too new to be widely applied. Further research is needed before directional boreholes can be used more extensively for the gas drainage of adjacent seams.

The goal of this research was to design a suitable method for gas drainage of adjacent seams by directional boreholes, even when allowing for the immediately caving of adjacent seams during mining.

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Due to the difference in positions of adjacent seams, two types of directional boreholes were introduced and investigated in the test. Besides, directional boreholes for adjacent seams in the fractured zone were compared to conventional boreholes. These studies were undertaken in order to broaden the application range of directional drilling technology as well as to provide a feasible means of gas control under similar conditions.

2. Conditions and gas management in Xingwu Coal Mine

2.1. Geology conditions

The research was conducted in the coal seam groups of the Xingwu Coal Mine. The Xingwu Coal Mine is located in the Hedong Coal Field, one of six major coal fields in the Shanxi Province; it is located on the north–south trending tectonic belt spanning from east of the Yellow River to the western slope of Lvliang Mountain. Generally, this coal field is a west-dipping monocline located on the west wing of the Lvliang anticlinorium. The direction of strata in the Xingwu Mine Field is roughly north-northwest to northwest, with a dip angle of approximately 2–8° to the southwest. The geological structure of the Xingwu Mine Field is simple: it contains no faults and large folds, with only one minor fold occurring in the middle of the mine field.

The major coal-bearing strata in the mine field are the Shanxi Formation and the Taiyuan Formation. The Shanxi Formation has five coal seams: from top to bottom, they are coal seams #2, #3, #4, $\#4_{up}$ and #5, as shown in Fig. 1. Coal seams #4 and #5 are the main mineable seams and have stable occurrence, unlike the other coal seams. The total thickness of the coal seams in Shanxi Formation is 7.27 m, and the coal-bearing ratio is 11.99%.

Above the primary mineable coal seam #4 is the adjacent coal seam $\#4_{up}$, named extremely closely adjacent seam, which immediately caves when coal seam 4# is mined. The coal seam $\#4_{up}$ is thin and its occurrence is unstable, which makes it difficult to pre-drain coal gas. Additionally, because the coal gas will desorb from the caving coal in goaf, it is hard to control gas at the working face. The adjacent seams #3 and #2 enter the fractured zone with the mining of coal seam #4, and are called closely adjacent seams to distinguish them. Similar drainage methods for adjacent seams could be used for them.

2.2. Characteristics of gas reservoir and gas management

The production capacity of Xingwu Coal Mine is 1.75 million tons per year; it is also a highly gassy mine. Due to the simplicity of the geological structure, the monocline exerts the strongest control on the distribution of coal gas, with its faults and folds having little effect. The coal gas is vertically distributed and increases with depth. At working face 42207, the average depth of coal seam #4 is approximately 270 m, the gas content is between 7 and 11 m^3/t, the initial gas pressure near the stop mining line is 0.97 MPa, and the permeability is approximately 0.003 mD.

At the working faces in coal seam #4, gases are mostly emitted from the recovery seam and adjacent seams. Therefore, the gas drainage is focused on coal gas from the recovery seam and adjacent seams,

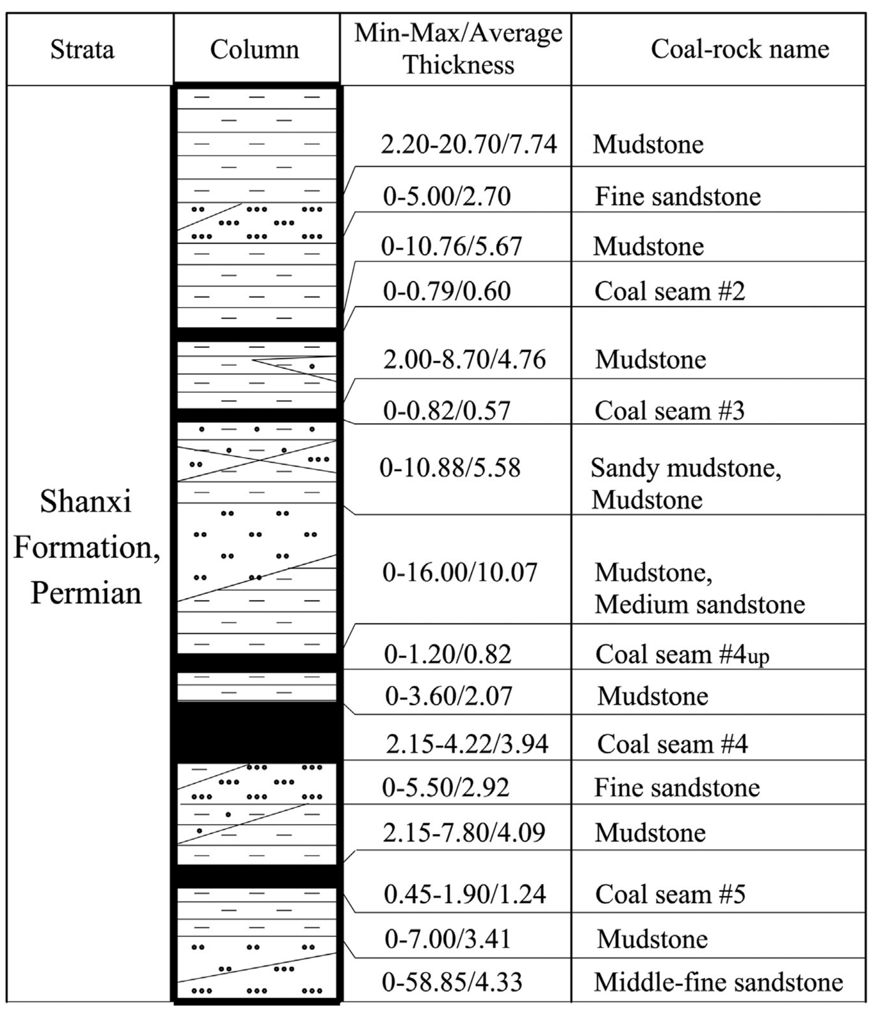

Fig. 1. Combined geological column of coal seams.