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Analysis of gob gas venthole production performances for strata gas control in longwall mining

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ABSTRACT

Longwall mining of coal seams affects a large area of overburden by deforming it and creating stress-relief fractures, as well as bedding plane separations, as the mining face progresses. Stress-relief fractures and bedding plane separations are recognized as major pathways for gas migration from gas-bearing strata into sealed and active areas of the mines. In order for strata gas not to enter and inundate the ventilation system of a mine, gob gas ventholes (GGVs) can be used as a methane control measure. The aim of this paper is to analyze production performances of GGVs drilled over a longwall panel. These boreholes were drilled to control methane emissions from the Pratt group of coals due to stress-relief fracturing and bedding plane separations into a longwall mine operating in the Mary Lee/Blue Creek coal seam of the Upper Pottsville Formation in the Black Warrior Basin, Alabama. During the course of the study, Pratt coal's reservoir properties were integrated with production data of the GGVs. These data were analyzed by using material balance techniques to estimate radius of influence of GGVs, gas-in-place and coal pressures, as well as their variations during mining.

The results show that the GGVs drilled to extract gas from the stress-relief zone of the Pratt coal interval is highly effective in removing gas from the Upper Pottsville Formation. The radii of influence of the GGVs were in the order of 330–380 m, exceeding the widths of the panels, due to bedding plane separations and stress relieved by fracturing. Material balance analyses indicated that the initial pressure of the Pratt coals, which was around 648 KPa when longwall mining started, decreased to approximately 150 KPa as the result of strata fracturing and production of released gas. Approximately 70% of the initial gas-in-place within the area of influence of the GGVs was captured during a period of one year.

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1. Introduction

Longwall mining induces deformation, fracturing, and bedding plane separations within a large volume in the overburden strata. These effects can release a significant amount of gas from overburden strata, which may find its way into sealed and active areas of the mine if not controlled. Therefore, strata gas control, especially in geologies with high gas amount, is an important consideration in support of ventilation to ensure mine safety in addition to its benefits as an unconventional energy source.[1–3]

In the U.S and elsewhere, gob gas ventholes (GGVs) are the most common borehole type used to control gas from the fractured strata by capturing it before it can enter the mine environment.[4–8] Despite the importance of these boreholes in controlling gob gas, it may be hard to predict their performance due to stability issues,[9,10] relative importance of different operational parameters on their performance,[11] and the effect of surface elevation (overburden thickness) on the rate-decline properties.[12] A schematic representation of the various zones of deformation in longwall overburden and a GGV placed to control strata gas is shown in Fig. 1.

While some of the operational constraints, such as suction pressure, casing depth, proximity to tailgate of the longwall panel, can be addressed for optimum performance of GGVs,[11] one of the most important aspects of gob gas venthole performance is dynamic subsidence and the geology of the overburden strata that is affected by it. Dynamic subsidence, or surface movement, of a particular location begins as mining face approaches, and continues until maximum displacement occurs after longwall face passes that location to some distance. The magnitude of the displacement and how it progresses are controlled primarily by the thickness of the extraction, the width of the panel, the overburden thickness and the properties of the strata. The properties of the strata not only affect the subsidence and the stress distribution,[13] but also where emission potential from the strata surrounding the coal mine can develop and how GGV designs can be optimized to

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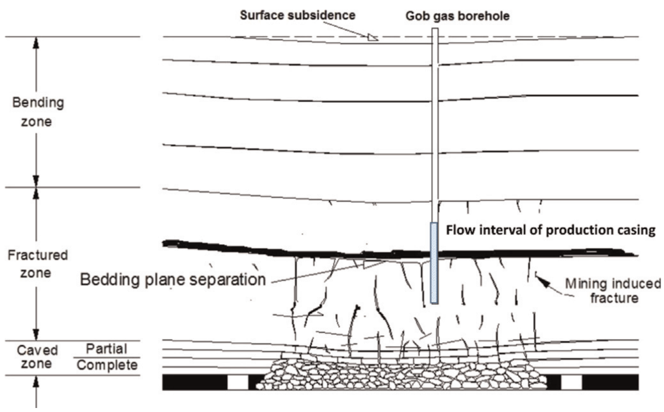

Fig. 1. A schematic representation of deformed overburden as a response to longwall mining, and location of GGV to control strata gas.

control emissions. Without well-developed permeable paths, GGVs may not be effective at all. Therefore, the location of GGVs and completion intervals are decided in relation to gas sources and mining-induced fractures and bedding plane separations to be able to control strata gas. For instance, with these considerations, in the Southwestern Pennsylvania section of the Northern Appalachian basin, the GGVs of supercritical panels are traditionally located near the tailgate, or headgate, margins of the longwall panels to take advantage of tensional fractures at the panel margins to capture the methane.[3]

Stress-relief fractures and bedding plane separations (Fig. 1) created as the result of mining-induced deformations are the major pathways for gas migration from gas-bearing strata. Thus, in order to be able to take full advantage of the benefits of GGVs for controlling gas, zones of strata deformations should be known. Extensive effort has been made to locate fracture and strata separation intervals. An empirical method proposed by Palchik[14,15] is based on correlation of the presence and absence of estimated horizontal fractures with uniaxial compressive strength and thickness of rock layers, distances from the extracted coal seam to the rock layer interfaces, and the thicknesses of extracted coal. He predicted that the probability of fracturing increased with the compressive strength difference between neighboring rock layers, i.e. weak-strong layer transitions. However, this does not mean that every single weak-strong layer interface is prone to separations. Whittles et al.[16] conducted studies on the effect of different geotechnical factors on characteristics of fracturing, gas sources, and gas flow paths for longwall operations in the United Kingdom. More recently, Karacan and Olea[17] predicted the potential intervals of strata separations using continuous wavelet transform (CWT) and generalized quadratic variations of well logs. The CWT matrix of coefficients was analyzed to locate the frequency and space parameters of singularities, which are precursors for discontinuities and weaknesses in the strata that are precursors for separation. Singularities were then isolated at their corresponding depth locations and modeled to determine their continuity and spatial correlation using single normal equation simulation (SNESIM). Results showed that the predicted intervals of strata separations were consistent with the expected locations of strata separations and data in the literature.

The productivity of GGVs and their rate decline behavior can be a function of complexity of the gob at the production interval, but more importantly can be a function of the magnitudes of fracture conductivity therein. Guo et al.[18] reported with a detailed study that in the fractured zone, vertical or sub-vertical and horizontal fractures are both well-developed and interconnected through the layers. In the deformation zone above the fractured zone, whose thickness is suggested to be between 80 m and 135 m, permeability development through strata separations is more prominent. These separations generally have very high conductivity for fluid flow, as demonstrated by Karacan and Goodman,[19] who determined by using well test techniques that a strata separation with a fracture thickness of 0.16 m can have a permeability of ~80 Darcy, while the effective average of the rest of the fractured gob interval could have permeability values varying between 1 and 15 Darcy,[20] although lesser values were observed too.[21,22] These are significant values for potential gas flow within the gob and between active and sealed portions of the mine, if strata separations and fractures intercept gas sources within the zone affected from the mining stresses. Strata separations and the values of fluid conductivity are not restricted only to panel areas. Gale[23] simulated rock fracture, caving, stress redistribution, and induced hydraulic conductivity enhancements around longwall panels, and concluded that horizontal conductivity can be significantly enhanced along bedding planes within and outside the panel area, thereby increasing the potential of methane migration from affected regions. These results are consistent with the drainage radius estimates, which go beyond the physical widths of the longwall panels, obtained using well test techniques reported in the literature herein.

Despite the advances in understanding strata geomechanics and production behavior of GGVs, some of the barriers toward effective management of methane in mines through the use of gob gas ventholes still exist due to the complexity of the gob environment, the involvement and interdependence of multiple influential factors, and the lack of knowledge on interactions of the GGV with the gob reservoir. Improvements in GGV production performance evaluation capabilities for site-specific mining conditions and circumstances can address a variety of longwall gas emission issues, resulting in improvements in GGV design and gas capture from overburden strata.

In this paper, we analyze production performances of the GGVs drilled over a longwall panel operating in the Mary Lee/Blue Creek seam of the Black Warrior basin in Alabama, to control methane emissions from the Pratt group of coals due to stress-relief fracturing and bedding plane separations. During the course of the study, Pratt coal's reservoir properties were integrated with production data of the GGVs. Then, material balance techniques were used to estimate the radius of influence of GGVs, gas-in-place, and coal pressures, as well as their variations during mining.

2. Background information on the location of the study area, its geology, and methane control activities

2.1. Site description and analyses conducted on vertical and Horizontal degasification boreholes of the area

The study area, which is approximately 50 km^2, is located between Brookwood and Oak Grove fields in the Alabama section of the Black Warrior basin and is nearly 3 km from the main thrust fault (Figs. 2 and 5). There are multiple faults and fractures within the study area and in the basin, in general. This structural deformation have significant effect on the performance of coalbed methane wells, mining emissions, the hydrodynamics in the area, and on the pressure gradients within the coal reservoirs with varying distance to these deformations.[24–26]

The majority of the coal-bearing strata of economic value in the Black Warrior basin are in the Pennsylvanian age Upper Pottsville Formation. In the Upper Pottsville Formation, the Pratt, Mary Lee, and Black Creek coal groups are probably the most important ones due to mining and coal gas production activities (Fig. 3). All of these coal groups have multiple coal seams of varying thicknesses. However, the Mary Lee coal group, which covers an interval of