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Numerical investigation of CO_2 fringe behaviour on a longwall face and its control

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ABSTRACT

Gas management at longwall faces has always been a challenging issue to mine operators. Along a longwall face of an Australian colliery where CO_2 is the dominant coal seam gas, frequent power trip off occurred due to the high goaf gas (CO_2) emission, which significantly affected the normal longwall production and brought about safety threats to the longwall crew. CO_2 fringe fluctuation changes close to tailgate (TG) was identified as a major concern. To better understand the CO_2 fringe behaviour on the longwall face and develop the corresponding effective control measures, Computational Fluid Dynamics (CFD) model was developed and validated based upon field data collected from the colliery. General gas flow characteristics on the longwall face were obtained based on which parametric studies were then carried out to investigate the impact of ventilation system and gas drainage options on goaf gas fringe behaviour. The use of a back-return ventilation system was demonstrated to be an effective approach to control the CO_2 fringe at TG; however, it was not practical due to the restriction of existing panel layout. As a compromise of the back-return system, a new gas drainage option using TG borehole which was more practical and cost effective was proposed and assessed by the CFD models. Model results indicated that goaf gas fringe at TG can be effectively controlled when a suction pressure between − 1500 Pa and − 2000 Pa was applied to the TG borehole. Therefore, it can be concluded from this study that gas drainage conducted through TG borehole can be an effective approach to solve the CO_2 accumulation at TG on a longwall face, especially when the back-return system is not applicable on site.

1. Introduction

Coal seam gas, including both methane (CH_4) and carbon dioxide (CO_2), will be liberated during coal extraction from underground coal mines, and its management has always been a major safety concern for mine operations. Historically, fatalities have occurred due to insufficient removal or dilution of the hazardous gases in the underground environment. Even in the modern times, methane explosions occur from time to time throughout the global mining industry, not only in developing countries, but also in developed countries. Therefore, it is vital to further understand the ventilation and the associated gas flow characteristics in underground workings. At longwall face, the correct position of gas monitors at tailgate (TG) is also of great significance for early detection of any abnormal gas emissions during longwall production, reducing the potential risk of explosion and allowing more time to cope with the gas issue or evacuation.

The Bulli seam, which is located in the Illawarra Coalfield with generally 2 to 3 m seam thickness, is the primary coking coal source of New South Wales, Australia. And the main production of underground coal mining in the Illawarra region is currently conducted in the Bulli seam. Fig. 1 shows a typical stratigraphical column of the mine site where the study was carried out. The virgin gas (CH_4 and CO_2) content of major gas bearing strata is also shown in Fig. 1. It can be seen that gas emission during the mining of Bulli seam will dominantly from underlying seams, in particular the Balgownie seam which is only 6 m below the Bulli seam. Meanwhile, long terms of operational practice indicated that the geological conditions of the Bulli seam varies greatly. For example, during the retreat of a longwall panel, the gas content may vary from 6 m^3/t to 15 m^3/t and the gas components may change from 95% CH_4 to 90% CO_2. Geological structure, depth and proximity of igneous intrusions are the main reason leading to the significant gas composition changes in the region as reported by Faiz et al. (1999).

Under the specific geological conditions, longwall operation in the Bulli seam at an Australian Colliery has been experiencing high goaf gas (predominantly CO_2) emission problems as a result of gas desorption and migration from both working and adjacent seams. Production

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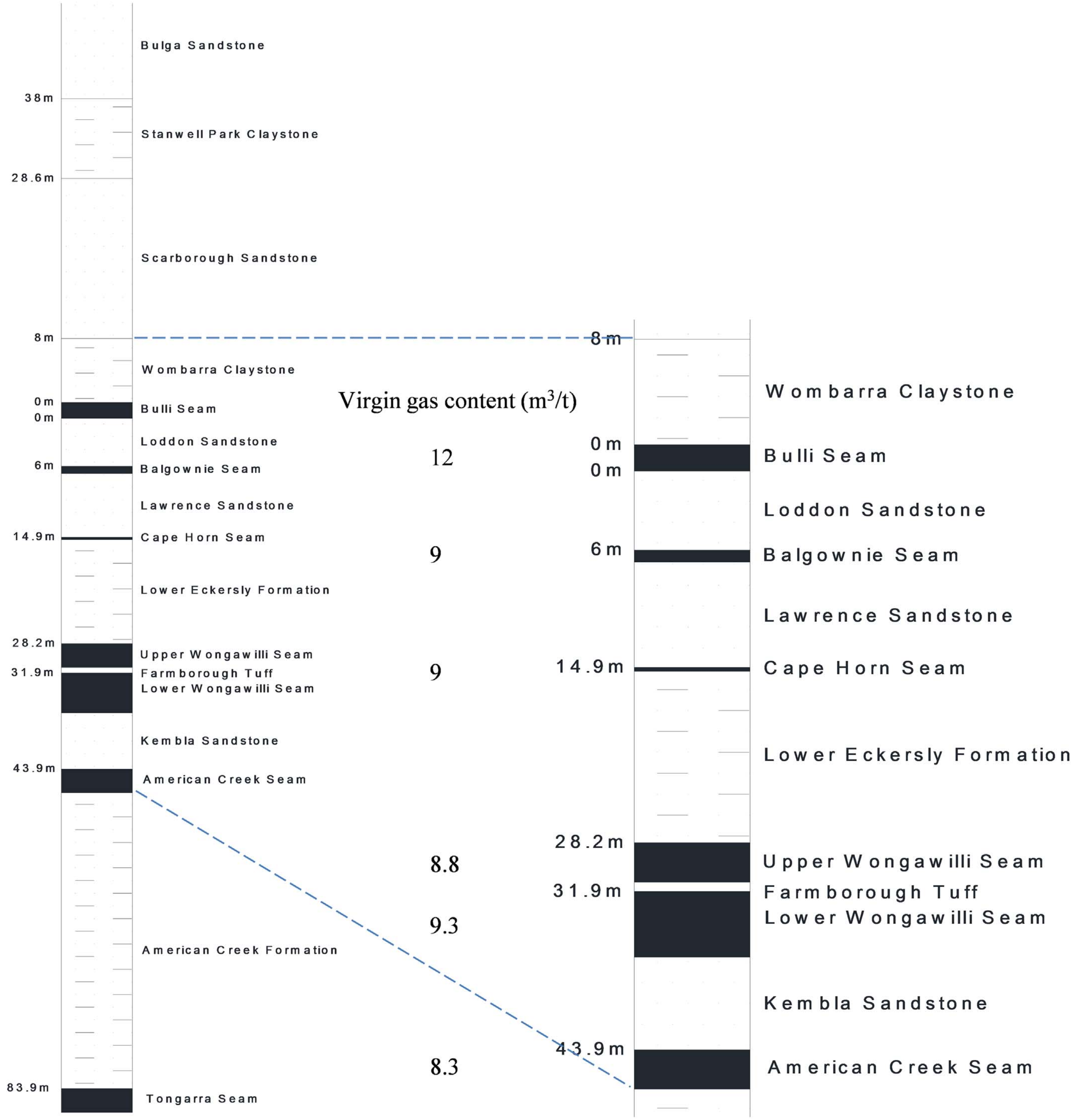

Fig. 1. Stratigraphical column of the mine site and coal seam gas content.

delays have occurred because of automatic tripping of power to the longwall machine when the CO_2 concentration is greater than the statutory level. CO_2 fringe fluctuation changes close to the TG have been identified as a major concern by monitoring results. Brattice has been used to divert fresh ventilation to dilute CO_2 accumulation in this area and this has been proved a success to certain degree. Field operational experiences indicate a need for a better understanding of the CO_2 fringe dynamics under the influence of changing longwall operation conditions and mitigation controls.

Currently, computational models have gained its popularity in mining research owing to its prominent advantages in terms of safety and low cost in operation. The use of Computational Fluid Dynamics (CFD) modelling technique in mining started at early 1990s, when Heerden and Sullivan (1993) first investigated the ventilation and gas flow patterns in a development heading. At the same time, Srinivasa (1993) modelled the air velocities distributions in a longwall face using a three dimensional CFD code. Later, a general process of conducting a CFD simulation was discussed by Edwards et al. (1995) by modelling the ventilation flow patterns within a heading, they also claimed that there was great potential for using CFD models to solve mine safety and health related problems. Then, the ventilation and gas flow at development headings were modelled by many scholars, including but not