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A new method to determine the depth of the de-stressed gas-emitting zone in the underburden of a longwall coal mine

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ABSTRACT

Underground coal mining induces de-stressing and fracturing of strata above and below the targeted seams. This creates a gas-emission zone, which contains gas-bearing coal seams and strata in the roof and floor of the mined (working) seam. In longwall mining, most of the gas released from the emission zone escapes into the coal face and the goaf (caved-in area) behind the coal face, where it presents a safety issue. Depending on the extent and shape of the emission zone, various gas drainage strategies could be applied to maximise capture of the gas from the emitting seams. We developed and trialled a new method to identify the gas emission zone in the underburden of an underground mine in the Sydney Basin, Australia. In this operation, all coal seams are located below the major targeted seam for mining. By measuring the isotopic and molecular composition of gas desorbed from coal cores from exploration drilling and gas collected from the goaf, we identified the source of gas and quantified the limit of the emission zone in the underburden of the working coal seam. This has allowed drainage to be focused and limited to the required depth. Our study will assist others to plan the required depth of gas drainage drilling below the floor of mined seams.

1. Introduction

During underground coal mining large volumes of gas are released from coal seams and gas-bearing strata above and below the mined seam within the mining-affected emission zone (fractured and de-stressed zone), in addition to the gas released from the mined (working) seam. Depending on geological and geomechanical conditions, as well as mining methods, the emission zone can establish different geometries. Gas is emitted from both the mined seam and the influenced zones in the roof and floor of the mined seam. Hence, the volume of emitted gas is generally much larger than the gas contained in the mined seam. This can be demonstrated by comparing the volume of gas emitted into the coal mine with the pre-mining volume of gas trapped in the working seam. For example, Saghafi et al. (1997) found that in Australian gassy underground mines, methane (CH_4) emissions into the coal mine were four times that of pre-mining CH_4 trapped in the mined seam. Similarly, Kissell et al. (1973) found that in United States underground coal mines, CH_4 emissions into the coal mine were seven times greater than that trapped in the mined seam. These data and experience of mine operators around the world show that most gas emitted into an underground mine is generally sourced from coal seams and strata above and below the working seam.

To reduce gas emissions into mine workings, gas is drained from satellite coal seams in the roof and floor of the working seam. Various drainage strategies and patterns are used that aim to optimise gas drainage by maximising gas capture and reducing the cost of drilling. Delineating and predicting the mining-influenced emission zone in the overlying and underlying strata should assist in concentrating drainage efforts in the zone from which most gas is emitted. Gas drainage patterns (up and down-cross measure drilling) can then be designed to maximise gas capture by placing gas boreholes at suitable locations and optimal angles.

Over the history of coal mining, empirical models have often been used to estimate gas emissions into the coal face. Many of these were developed during the 20th century, mostly by European researchers for deep coal mining conditions in Europe (see Firedamp Drainage, Handbook for the Coalmining Industry (1980)). Among these empirical models are those suggested by Winter (1958), Schulz (1959), Gunther (1965a, 1965b), Lidin (1965), Airey (1971), Flügge (1971), and Jeger (1978). All of these assume that underground mining operations create a fractured volume (mining-influenced emission zone) above and below the working seam, and that all or part of the gas initially trapped in this zone is then liberated during mining. Using these models, mine operators could predict the shape and extent of the fractured zone and the degree of emissions. Therefore, specific emission, or volume of gas emitted per tonne of coal extracted, could be estimated and used to design suitable ventilation and gas drainage.

The empirical models were generally based on the experience of mining in the country of the researcher, and included geology, depth,

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geometry of mining and rate of advance. Jeger (1978) suggests a rectangular-shaped emission zone (mining-influenced zone) based on French mining conditions. The model assumes that the mining-influenced zone covers a volume of strata that expands vertically up to ~165 m in the overburden and ~55 m in the underburden strata. The degree of emissions from unmined coal seams within the mining -influenced zone depends on the distance of these seams from the mined seam. However, gas release is not complete, and some residual gas would still remain in coal post-mining (at least 10% of the pre-mining gas content). Jeger also suggests that emissions are also sourced from interburden materials. Emissions from non-coal strata are approximated by emissions from equivalent coal thickness (e.g. one metre of sandstone strata is equated with a 10-cm coal seam). In Germany, Flügge (1971) suggests a prism-shaped emission zone, expanding from 100 to 160 m in the overburden and 40 m down in the underburden. These methods were used in Australia – specifically in the deeper mines of the Sydney Basin – to estimate specific emissions in longwall mining (see e.g. Battino et al. (1988); Meyer (2006)).

A variation of the empirical model for delineating the mining-influenced zone injects a tracer gas that differs from the CSG into the satellite coal seam before mining begins. Tracer gas has most often been used in coal mining for increasing the efficiency of ventilation systems. For example, Thimons et al. (1974) and Vinson et al. (1980) used sulphur hexafluoride (SF_6) gas as a tracer to follow the paths of gas migration, and built more efficient systems for ventilating the coal face. However, the use of SF_6 is problematic, because it has the highest global warming potential of all greenhouse gases (~23,900 times that of CO_2) according to the Intergovernmental Panel on Climate Change (IPCC) (2007). Moreover, SF_6 is five times heavier than air, and moves slowly from its injection site to the collection site for analysis. Other gases have also been used as tracers to study the fracturing and conductivity of mine strata. For example, in the Sydney Basin, where our study was conducted, other researchers (Heritage and Gale, 2009) used helium (He) to investigate whether a surface-to-goaf connection existed in an underground longwall mine. An alternative method is the use of a rare component of coal seam gas (CSG) such as ethane (C_2H_6), which occurs at low concentrations in some coal seams.

In the current study, we used geochemical properties (molecular and carbon isotopic compositions) of the main components of CSG to identify the gas-emitting coal seams adjacent to the mined seam in the mining-influenced zone. We analysed CO_2 and CH_4 as components of CSG, which are often present in Australian coal seams. Our method was applied to an underground coal mine in the Southern Coalfield of the Sydney Basin in New South Wales, Australia, where longwall mining is used to extract coal from the depth of approximately 500 m. Coal in this mine is extracted from the top seam in the Illawarra Coal Measures. Fig. 1 shows the geographic locations of the Sydney Basin, Southern Coalfield and coal mine studied. All coal seams studied are located in the floor of the mined seam. The aim of our study was to identify the depth of the mining-influenced zone in the underburden and thereby optimise gas drainage of seams in the floor of mining, to focus gas drainage on the coal seams contributing to gas emissions into the goaf and coal face areas.

2. The Sydney Basin, Southern Coalfield and Illawarra Coal Measures

The Sydney Basin consists of Permian and Triassic rocks and extends along the coast of New South Wales, Australia, from near Batemans Bay in the south to the north of Newcastle where coal was first discovered in Australia (see e.g. Handbook of Australian Black Coals: Geology, Resources, Seam Properties, and Product Specifications (1991)). The basin contains most of the black coal resources of Australia, hosted in four main coalfields: the Hunter, Newcastle, Western and Southern coalfields (Fig. 1). The highest producing coalfields are the Hunter Coalfield in the north and northwest of the basin, where coal is mostly mined using open cut methods; and the Southern Coalfield in the south of the basin, where coal is mined exclusively underground from coal seams of the Sydney subgroup of the late Permian Illawarra Coal Measures (Fig. 1). The Illawarra Coal Measures (Fig. 2) are dipping

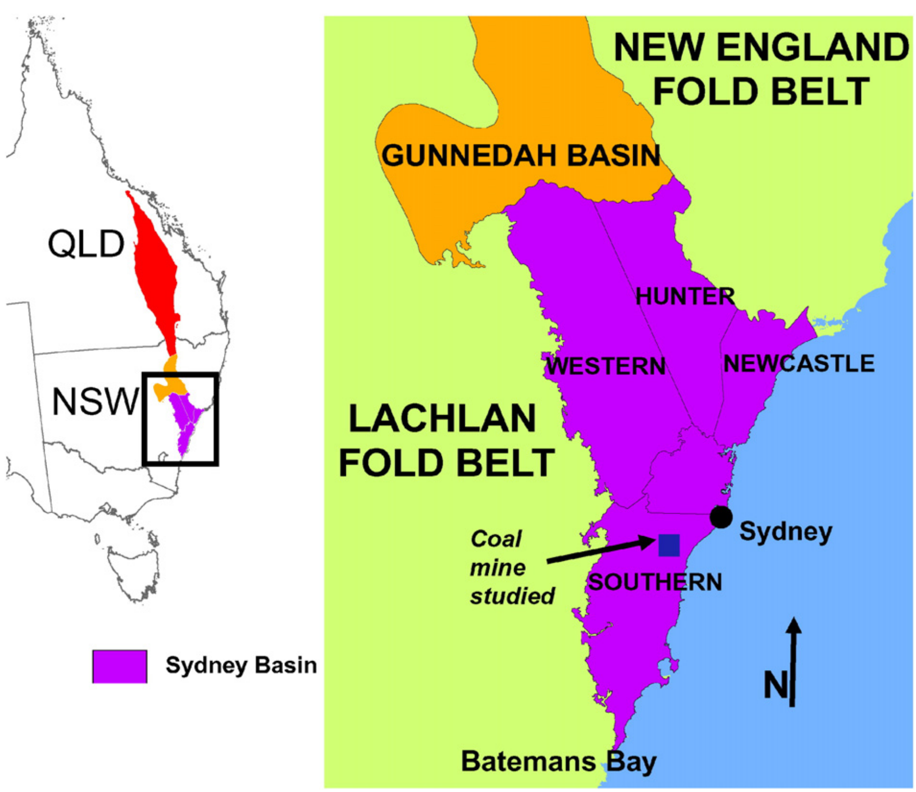

Fig. 1. Geographic location of the Sydney Basin and the coal mine studied. NSW = New South Wales; QLD = Queensland.