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# Earthquake-induced unusual gas emission in coalmines — A km-scale in-situ experimental investigation at Laohutai mine

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**Abstract**

In the present study, a km-scale in-situ experiment was carried out at Laohutai coalmine in Fushun city, China, to investigate the possibility of earthquake-induced unusual methane gas emission in coalmines. The motivation of this study was attributed to the observation of a series of coalmine gas explosion accidents in China and the incidental strong earthquakes that seemed to be related to these accidents. Laohutai coalmine was chosen as the experiment base because of its high methane content in the coal body and its past and current active rockburst activities. The mechanisms of rockbursts and earthquakes are the same, i.e., both are violent failure of rock masses and geological structures due to stressing or straining. Detailed microseismic event and gas content monitoring programs were carried out at the mine site and combined with field inspection by experienced engineers, a large amount of data were collected and analyzed. It is revealed that there is a good correlation between rockburst and high methane gas emission events at the mine site. High gas emissions have been observed before, during, and after rockburst events. Therefore, an analogy can be made from the findings of this study, i.e., unusual gas emission can happen in coalmines before, during, and after an earthquake. When gas content is high and all boundary conditions are met, both rockbursts and earthquakes can trigger unusual gas emission, and sometimes the gas gushes are violent enough to fit into the category of gas outbursts. On the other hand, gas gushes can also trigger rockbursts in coalmines. This type of rockburst, which is called gas outburst rockburst, is triggered by the coupling between the unloading of the porous material and the gas storage structures and the expansion due to desorption of methane gases. A fractal relationship between seismic energy and influence radius is derived. It is suggested that methane gas emission warnings could be provided to coalmines located within the influence radius when releasing earthquake risk warnings.


*Keywords:* Unusual methane gas emission; Gas outburst; Earthquake; Rockburst; Coalmine; In-situ experiment

## 1. Introduction

Coal is a porous material that contains gases such as methane ($CH_4$) and carbon dioxide ($CO_2$), nitrogen, hydrogen sulphide, and sulphur dioxide, but the major composition is $CH_4$ and $CO_2$. The amount of methane gas that can be stored in coal seams varies from 0.0003 to

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18.66 $m^3$/t, and up to 25 $m^3$/t had been reported in Lunarzewski (1998). As mining activities disturb the balanced state of stress and gas pressure in the coal body, rocks can fail and gas can emit into the opening as a result. There are two types of gas emission in coalmines, i.e., normal and unusual. Normal gas emission usually happens uniformly in the temporal and spatial spaces. The highest gas emission can be expected when coal is extracted so that the normal gas emission rate is usually proportional to production rate. Gas outburst, the extreme of unusual gas emission, is a sudden ejection of gas from a coal body. Gas outbursts, characterized by the abrupt release of high density and large volumes of gases at certain locations in a mine, have been the cause of major disasters in the coal mining industry (Beamish and Crosdale, 1998; Bo, 2002). Methane associated with a gas outburst usually cannot be diluted quickly by ventilation and can be ignited either by open lights, smoking, and sparking from mining equipments. Methane mixtures are explosive in the range of 5 to 15% in air.

The first documented coalmine gas explosions occurred in the United States in 1810 and in France in 1845 (Flores, 1998). Worldwide, most of these underground coalmine gas outbursts or explosions were caused by coalbed methane gas (Anderson, 1995; Lama and Bodziony, 1998). A gas outburst can eject tens of cubic meters to hundreds of thousands of cubic meters of gases. For example, in 1981, the largest ever underground coalmine outburst in Japan expelled 4000 $m^3$ of coal and up to 600,000 $m^3$ of gas, killing 93 miners (Deguchi et al., 1995). In 1969, at Gagarin coalmine in the Donetsk Basin in Ukraine, an outburst resulted in the ejection of 14 million kg of coal and 600,000 $m^3$ of gas (Lama and Bodziony, 1998).

There is a certain minimum gas content that must be present if a gas outburst is to occur in a coal seam (Lama and Bodziony, 1998). This critical value depends on the overall strength of the coal seam or part of the coal seam, permeability of the coal seam, and other geological conditions associated with it. In general, a gas content greater than 8 to 9 $m^3$/t is considered high enough to initiate an outburst if other conditions, such as coal and rock properties and mining-induced stress, are favorable (Lunarzewski, 1998; Lama and Bodziony, 1998).

Although the precise mechanism of gas outbursts, with respect to the gas/coal/rock system, is still unresolved, many researchers agree that the most important factors that influence the occurrence of gas outbursts are: gas content in the coal seam, tectonics or geological disturbances, properties of the coal and rock, and mining-induced stress state in the coal seam and rock. When all four factors are combined to create a critical condition, gas outbursts and/or rockbursts will result. Without a gas content that reaches a critical level, gas outbursts cannot happen. When the gas content and the ratio of in-situ stress magnitude to coal/rock strength are high, a

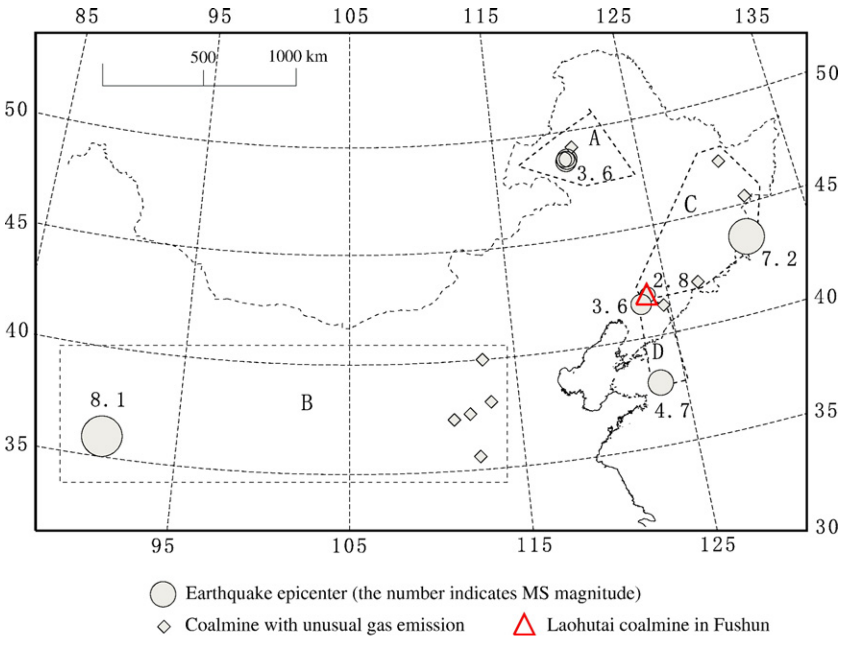


Fig. 1. Locations of earthquakes and coalmines that experienced gas outbursts following the earthquake. A: Ewenke earthquakes and Second coalmine of Dayan Coal Co.; B: Kunlun earthquake and coalmines in Shanxi Province; C: Wangqing earthquake and three gas explosions in Jilin and Heilongjiang Provinces; D: Dongling and Bohai Sea earthquakes and Mengjiagou coalmine.