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Technical Note

Time-dependent methane emission from vertical prospecting boreholes drilled to abandoned mine workings at a shallow depth

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1. Introduction

Methane emission contributes to the growing background concentration of ozone. Wuebbles and Hayhoe [1] have examined past trends in the concentration of methane in atmosphere. It was shown that methane is a greenhouse gas that remains in the atmosphere about 100 years and is 20 times more effective in trapping heat in the atmosphere than carbon dioxide. One of main sources of methane is coal mines. Methane is a dangerous explosive gas, and pollutes air, which impacts on the air quality in mines and on the ground surface and, hence, human health. A number of researchers, such as [2–12] and many others have investigated gas emission and formation of fractured zones in overburden during active longwall mining at intermediate and greater depths. Palchik [4,5] showed that the extents of fractured zones induced by coal excavation can be determined based on the change in natural methane emission from these zones. Karacan [7] and Karacan et al. [9] studied different aspects of methane emission of US longwall coal mines: modeling and prediction of gas emission process, and capture and utilization practices in order to provide mining safety and greenhouse gas reduction. Sang et al. [8] summarized the status of engineering practice, technology and research related to stress relief coalbed methane drainage using surface wells in China. Guo et al. [10] presented key findings from a recent comprehensive study of longwall mining-induced strata movement, stress changes, fractures, and gas flow dynamics in a deep underground coal mine in China. Majdi et al. [11] described the mechanism of development of the height of distressed zone above the mined panel roof and presented the simple mathematical approaches to estimate this height. Zhou [12] performed numerical simulation study that demonstrates history matching and production prediction for an actual horizontal coalbed methane well located in Australia.

A lot of research [e.g. [13–20]] are focused on the study of gas emission from abandoned underground working at shallow depths and from boreholes, shifts, faults or through weathering-induced fractures in surface and subsurface rock layers. Judd et al. [16] described gas seeps occurring on tidal flats on the northern shore of the inner Firth of Forth (Scotland). The principal gas is methane, which is considered to come from the coal-bearing rocks or from abandoned coal workings. Leifer and Wilson [18] measured oil and gas seepage at a repeatedly abandoned well, on the seabed from a caisson located along the historical location of the Treadwell Wharf, where the world's first off-shore oil wells were drilled at the end of the 19th century. Etiope [19] confirmed that geological emissions of methane are an important greenhouse-gas source, and remarkable amounts of methane are naturally released into the atmosphere from the Earth's crust through faults and fractured rocks. Palchik [20] studied the natural methane emission from coal pillars to the atmosphere through weathering-induced fractures in surface rock layer.

In Donetsk city (Ukraine) voids in old mine workings trap and accumulate methane from coal pillars. The methane accumulated in shallow abandoned workings finds a way to leak into the atmosphere. There are accidents (explosions and fires) associated with the emission and then accumulation of methane within confined spaces in surface constructions. The location of voids in old workings at a depth up to 80 m has been generally carried out by exploratory drilling (Palchik [21]). The natural methane emission from the void to the ground surface occurs through such vertical prospecting boreholes.

The prospecting boreholes drilled from ground surface to underground abandoned workings represent potential pathways of gas leakage from voids to ground surface. The knowledge of gas emission from these vertical boreholes is important to evaluating the risk of

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methane rising to ground surface through such potential pathways as vertical or close-to-vertical faults, shafts, improperly plugged vertical boreholes drilled for industrial goals, abandoned wells, and through-going vertical fractures formed after collapse of rock mass overlying the abandoned workings. Since rock mass above shallow old mines in Donetsk area is very weathered and mine working roof material is weak [22], there is high degree of probability that through-going vertical fractures will reach ground surface if the collapse occurs.

The goal of this paper is to study the time and quantitative characteristics of natural gas emission process from vertical prospecting boreholes (drilled to voids in old workings at shallow depths (<80 m)) in order to (1) define potential hazard for humans in case of methane migration from voids into surface constructions through potential migration pathways in rock and to (2) evaluate gas productivity of prospecting boreholes for gas utilization.

Experimental dependencies of gas flow volumetric rate and volume of gas from studied boreholes on time are statistically analyzed. The exponential decline analysis (DCA) for estimation of gas flow rates parameters and cumulative gas production was performed. The gas concentration and possibility of explosion in surface buildings in case of gas penetration into buildings through potential migration pathways in rocks are evaluated.

In this study, conditions and parameters of abandoned shallow workings are not studied, and presented in detail elsewhere [21,22].

2. In situ measurements and their results

2.1. Description of old openings

In 1917–1951 in Donetsk city (Ukraine) dozens coal mines used to operate at depths up to 80 m [21]. The rock mass overlying the working in coal seams consists of beds of sandstones, argillites and sandy shale layers dipping at approximately 10° or less (Fig. 1(a)). The alluvium (sands and clays) overlies sandstones, argillites and sandy shale layers. The dipping of coal seams is between 5° and 10°. The

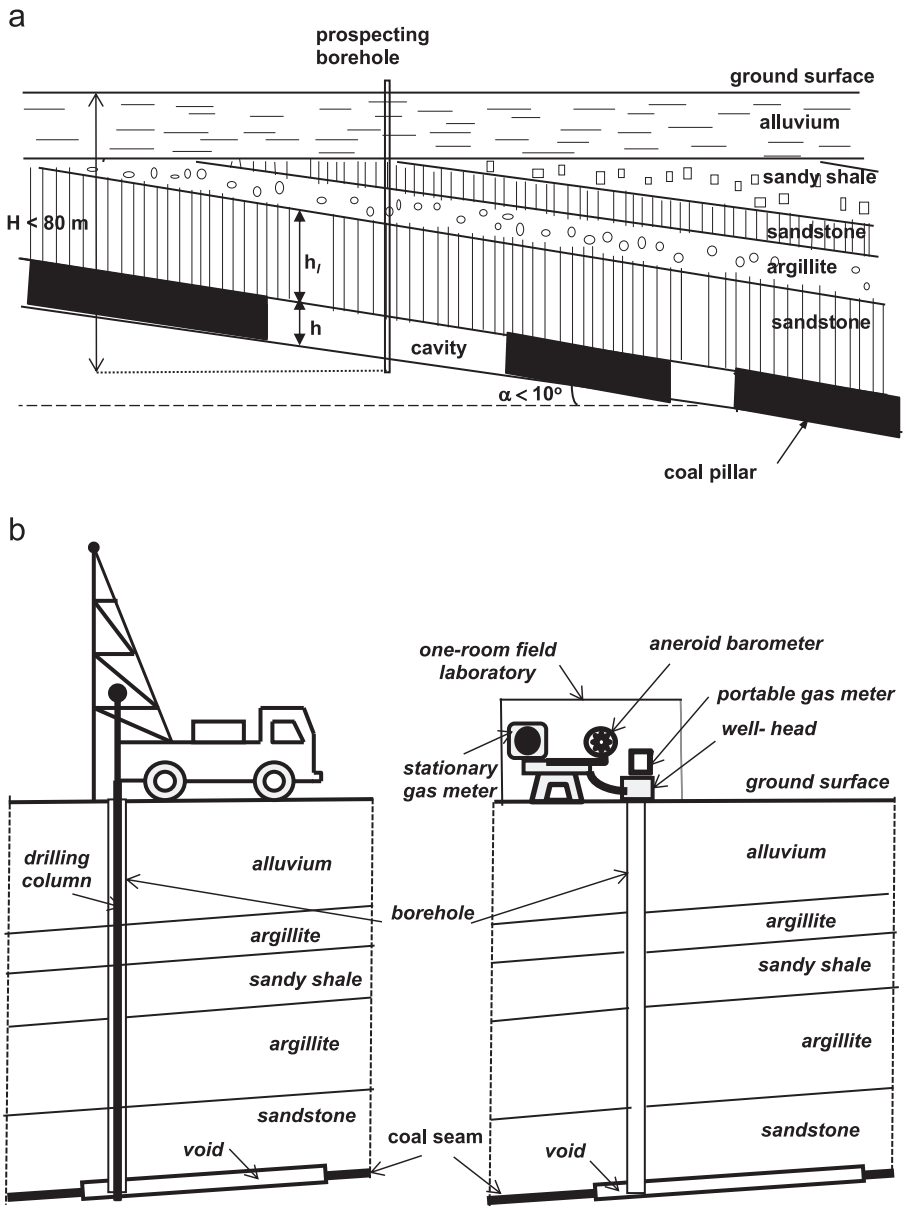

Fig. 1. The prospecting borehole and apparatus used for study of process of gas emission from voids in old workings: (a) borehole and schematic geological profile of rock layers overlying the voids in old workings (modified after [21]). $H<80$ m is depth of prospecting borehole, h_l is thickness of immediate roof, h is thickness of extracted coal seam (or height of the abandoned workings); (b) schema of apparatus used for measurements of gas emission parameters.