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Numerical simulation of stress distributions and displacements around an entry roadway with igneous intrusion and potential sources of seam gas emission of the Barapukuria coal mine, NW Bangladesh

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ABSTRACT

This paper uses two-dimensional boundary element method (BEM) numerical modeling to analyze the deformation and failure behavior of a coal seam and to understand the nature of gas flow into a roadway entering the Barapukuria coal mine in Bangladesh. The Barapukuria basin contains Permian-aged Gondwana coals with high volatile B bituminous rank. Three models (A, B, and C) are presented here. Model A assumes horseshoe-shaped geometry, model B assumes trapezoid-shaped geometry, and model C assumes horseshoe-shaped geometry coupled with a roof fall-induced cave generated by the break-up of rock materials along the vertical dimension of an igneous dyke. The simulation results show that there is little difference in strata deformation between models A and B. In model A, there is no horizontal tensional stress and the overall horizontal stress patterns are compressive, while the distribution and magnitude of vertical stress show higher tensional stresses on the immediate rib sides and floor. In model B, both horizontal and vertical stress distributions indicate low to medium tensional stresses on the immediate roof, floor, and rib sides, but compressive stresses are prominent toward the interior of the coal seam. Deformation vectors indicate that failure extends laterally to about 7.5 m around the excavation geometry.

On the contrary, for model C, the distributions and magnitudes of horizontal and vertical stress show higher tensional stresses in both rib sides of the roof fall zone. The deformation around the dyke-induced perturbation zone affects a large volume of coal. The deformation vectors with high magnitudes are nearly horizontal and propagate laterally up to 30 m; whereas, low-magnitude deformation vectors extend about 25 m toward the roof and 20 m toward the floor. The vertical tensional displacement, which is concentrated in the floor and the left and right hand sides of the roof, propagates about 30 m on both sides and about 22 m in the floor. From these simulation results, it is thought that the extension of the dyke-induced perturbation zone toward the roof, floor, and rib sides of the entry roadway initially creates small tensional cracks that gradually grow into large-scale tensional features. These features could also be responsible for high concentrations of gas, which are emitted into the mine from fractured coals due to insufficient mine ventilation and low atmospheric pressure.

1. Introduction

Gas emission from coal seams is a major safety hazard in underground coal mines (Karacan et al., 2008). Up to 90% of the methane gas that enters longwall mining may come from adjacent seams. If the coal seam is influenced by mining activities, the seam gas, which is mostly methane, can be emitted into the coal mine. When an underground roadway is excavated into tectonically-stressed coal deposits, the natural stress in the vicinity of the new opening is redistributed. Due to the redistribution of mining-induced stresses, the gas permeability of the coal strata is substantially increased by the development and dilation of joints, bedding planes, fractures, and faults. Various aspects of mine-related stresses, gases and geologic structures have been examined in a worldwide review of the problem of gas emission in coal mines (e.g., Shepherd et al., 1981; Zhang, 1986; Shen and Stephansson, 1994; Lunarzewski et al., 1996; Clayton, 1998; Lunarzewski, 1998; Noack, 1998; Bibler et al., 1998; Zhi et al., 2007; Jia et al., 2007; Karacan et al., 2008; Islam et al., 2009). Based on recent geologic studies of gas emission sites, geologic structures have been identified as a major factor in the occurrence of gas emission (Saghafi et al., 2008). Thrusts, strike-slip faults, normal faults, igneous intrusions, and recumbent fold hinges, which are referred to as 'tectonic disturbances,' are related to highly-fractured coal and thought to cause gas emission hazards (Shepherd et al., 1981; Saghafi et al., 2008). Anomalous stress and gas conditions seem to exist in and around these geologic structures. At such sites, mining-induced fracture systems and abnormally high gas emissions have been recorded (Shepherd et al., 1981).

The process of mining has two main impacts on the production of gas. The first is the internal disruption of coal within the coal seam by extensive fracturing. The second is the opening of pathways through

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the strata that enable the gas to leave the confines of the seam (Jackson and Kershaw, 1996). The generation and propagation of fracture sets and systems depend on the fabric configuration and composition of the coals and surrounding rocks involved in the deformation events. The influence of the strata deformation processes on the rock mass is quite distinct and occurs in the micro- and mesoscopic states. Existing and mining-induced fractures open and develop, maintaining characteristic fracture zones. Mining processes

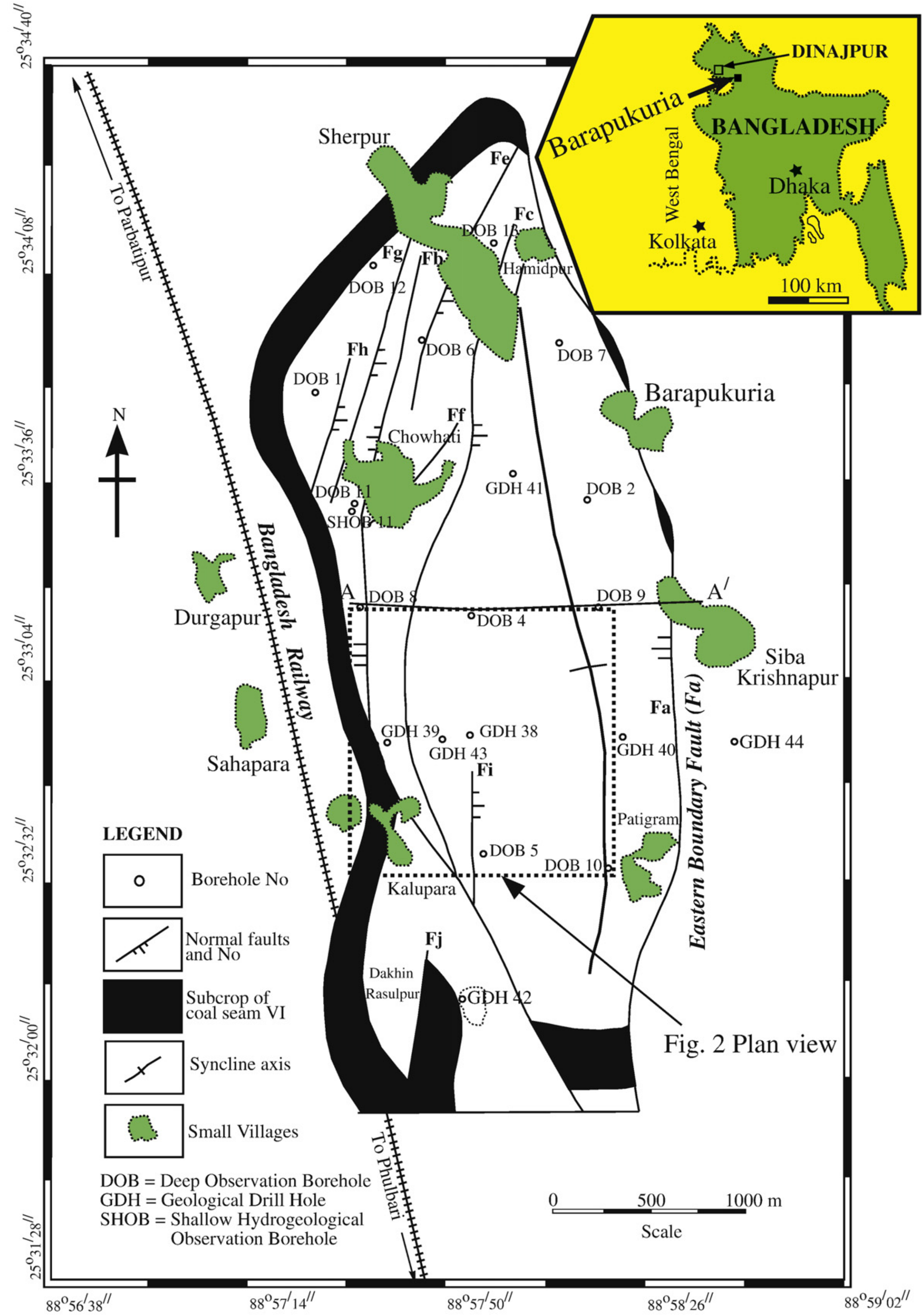

Fig. 1. Location of the boreholes, major faults, and structural pattern of the Barapukuria Coal Basin, Northwestern Bangladesh. Abbreviations: DOB = deep observation borehole; GDH = geological drill hole; SHOB = shallow hydrogeological observation borehole (after Wardell Armstrong, 1991; Bakr et al., 1996; Islam and Hayashi, 2008; Islam et al., 2009).