International Journal of Coal Geology 78 (2009) 47–64

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/ijcoalgeo

Reservoir rock properties of coal measure strata of the Lower Monongahela Group, Greene County (Southwestern Pennsylvania), from methane control and production perspectives

C.Özgen Karacan *

CDC/NIOSH Pittsburgh Research Laboratory, Disaster Prevention and Response Branch, 626 Cochrans Mill Road, PO Box 18070, Pittsburgh PA, 15236, United States

ARTICLE INFO

Article history:
Received 4 September 2008
Received in revised form 16 October 2008
Accepted 20 October 2008
Available online 29 October 2008

Keywords:
Reservoir characterization
Monongahela Group
Greene County
Appalachian basin
Wellbore logs
Geomechanical properties
Permeability

ABSTRACT

The methane emission rate into an underground mine environment from overburden strata during longwall mining is impacted by reservoir and geomechanical characteristics of the coal measure rocks in the overlying strata, as well as the presence of any coal seam. The reservoir characteristics and how they change during mining potentially affect the performance of gob gas ventholes, which consequently impacts the efficiency of methane control in the mining environment.

This study presents reservoir and elastic properties of coal measure rocks in the Lower Monongahela Group in Greene County, southwestern Pennsylvania, of the Northern Appalachian Basin. Since the source of methane in this region from underground mining is located between the Sewickley coal and the Pittsburgh coal, a specific emphasis was given to this interval. Core analyses were performed in the laboratory to determine rock porosity and permeability. Geophysical logging data (gamma, density, sonic) obtained from two exploration boreholes were used for evaluating formation boundaries, shale contents, log porosities, and geomechanical properties of formations. Permeability was also calculated using density-log data and empirical equations and compared with laboratory measurements and slug tests performed in isolated intervals of boreholes. The results presented in this study can be used as data sources for reservoir studies related to the production and control of methane.

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1. Introduction

Methane inflow into mines from overburden strata during longwall mining and the production potentials of the surface methane degasification systems, mainly gob gas ventholes (GGV), are impacted by reservoir and geomechanical characteristics of the overlying strata. Core analyses and geophysical logging techniques are two of the important data sources for characterizing the geological formations. Determinations of reservoir and strength properties of the formations are important since they affect fluid flow and storage in the overburden before and after coal extraction as the stress and strain states change as a result of longwall operations.

Available coalbed methane (CBM) production literature often provides more detail on the reservoir and mechanical properties of the coal bed than on the properties of the adjacent coal measure rocks. For instance, Vaziri et al. (1997) discuss a back analysis method for strength properties of the coal seam from field measurements of wellbore cavitations and methane production. Deisman et al. (2008) give results of some unconventional geomechanical testing for coal bed reservoir well design for the Alberta foothills and plains. Beamish and Crosdale (1998) describe the relationship between coal strength and coal composition and their effects on outburst potential. Simulation studies for CBM production and coal seam degasification also are concerned mainly with the properties of the coal bed (King et al., 1986; Remner et al., 1986; Diamond et al., 1989; King and Ertekin, 1994).

Despite their lack of attention in the literature, the reservoir and strength properties of coal measure rocks are as important as the mined coal seam itself, since their properties determine gas flow paths. Lunarzewski (1998) and Noack (1998) emphasized that the influence of the deformation processes on the mechanical properties of the rock mass occurs in a micro to macro scale. During mining-induced deformations, existing and mining-induced fractures may open further. The generation and propagation of the fractures depend on the type and composition of the rocks overlying the seam. Mining processes can thus create sudden and unstable gas releases leading to potentially dangerous underground conditions which must be prevented by using a properly designed ventilation system or by employing gob gas ventholes effectively. For instance, Whittles et al. (2006) reported the results of a simulation study to predict the source and flow path of methane emissions in a UK longwall. They concluded that the geology of coal measure strata is important to determine the caving and control of methane. Palchik (2003) conducted a series of field measurements in gob gas ventholes in Torezko-Snezhnyanskaya (Ukraine) longwall mines to determine the formation of fractured zones during mining. His study showed that the location of

* Tel.: +1 412 386 4008; fax: +1 412 386 6595.
E-mail address: cok6@cdc.gov.

0166-5162/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.coal.2008.10.005

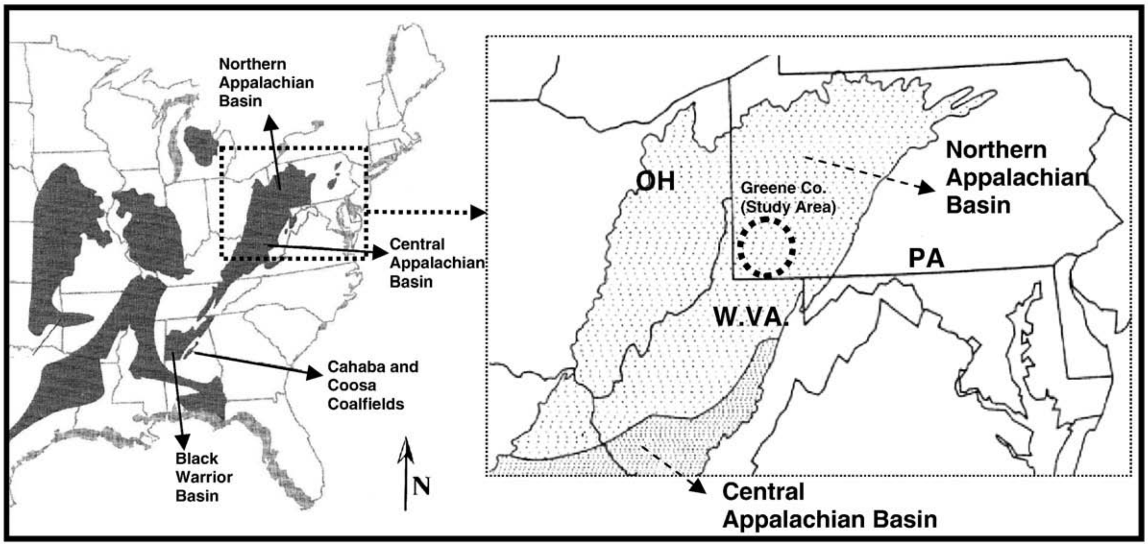

Fig. 1. Appalachian Basin and location of study area in Greene County.

fractures and gas emissions are closely related to the geology of coal measure rocks and their distances from mining activity.

In addition to the overall reservoir and strength properties, the types and thicknesses of coal measure rocks at the roof of a mined coal seam cause borehole stability problems during mining. Whittles et al. (2007) described the application of a computational model (FLAC2D) to simulate the geomechanical disturbances created due to the mining of a longwall panel at the Thoresby mine, Nottinghamshire, UK. The roof geology was considered a significant feature because it was known from previous experience that the amount of roof movement within the roadway in the region behind the coal face greatly influenced the stability and hence the gas drainage efficiency of the boreholes. An analysis of the simulation results provided a method of quantifying the effects of the geological conditions on determination of the optimum borehole spacing for the different regions of the panel.

Gas emissions and the design and stability of gob gas ventholes depend on the reservoir rock properties, the types and thickness of different layers, and the degree of their deformation dictated by their rock-strength properties. The knowledge of these rock properties is important for predicting gas emissions, sudden gas releases and changes in emission rates, as well as designing surface methane control systems. Thus, laboratory analyses of available core materials from boreholes and accurate borehole logs of coal measure rocks are important for any emission prediction and gob gas venthole design method.

This paper presents analyses on coal measure rocks recovered from the Lower Monongahela Group from exploration boreholes drilled in Greene County, Southwestern Pennsylvania (Fig. 1). Gamma ray, density, and sonic log analyses are presented to determine formation boundaries, in-situ porosities, existing fractures, and geomechanical properties (shear, Young's, and bulk moduli, and Poisson's ratio). Permeabilities calculated using log data and empirical relationships are also presented and compared with laboratory measurements and slug test permeabilities. The results of this paper are intended to serve as basic properties of coal measure rocks for site evaluations, gob gas venthole designs, and for development of numerical models for reservoir or geomechanical simulations.

2. Southwestern Pennsylvania section of the Northern Appalachian Basin

2.1. Methane sources and production potentials

The Appalachian Basin is one of the most important coal basins in the U.S. and the world's second largest coal bed methane (CBM) producing basin (Lyons, 1998). The northern part of this basin, trending in the northeast–southwest direction and occupying portions of five states (Pennsylvania, West Virginia, Ohio, Kentucky, and Maryland), is called the Northern Appalachian Basin (Fig. 1). The basin is bounded by a graben structure at the southern margins.

The Northern Appalachian Basin in southwestern Pennsylvania is a very important area for coal mining, for CBM production from coal bed degasification boreholes, and for mining-related methane (from gob and from ventilation system) emission and capture. Markowski (1998) reported that there are 24 coalbed methane pools in Pennsylvania and 11 of these 24 are located in Greene County, Pennsylvania. The main coal beds in this area are the Pittsburgh, Sewickley, and Waynesburg. Pre-mining degasification wells in this area have penetrated the Washington, Waynesburg, Uniontown, and Pittsburgh coal beds, as well as others in the Conemaugh Group (Markowski, 1998). Flows from these wells vary up to 2.8 Mm^3/day, mainly after hydraulic fracture treatment of the Pittsburgh coal seam interval. Coal mining companies are also becoming interested in converting GGVs into methane production boreholes, a practice not previously economical due to air contamination of the gob gas by the mine's ventilation system. However, with optimum drilling designed for the overlying strata and using pressure swing adsorption or a molecular gate system, gob gas can be converted economically to pipeline quality gas.

For a detailed analysis and discussion on coalbed and coal mine methane resource and production potential of the Northern Appalachian Basin, please refer to Kelafant et al. (1988), Lyons (1998), and Markowski (1998).

2.2. Coal measures of the Monongahela Group in Greene County

Greene County, located at the southwest corner of Pennsylvania (Fig. 2), is remarkable for having many productive underground coal mines. A great flat-to-dome shape of this county between two major rivers (Monongahela and Ohio) is underlain by almost perfectly flat coal seams and coal measure rocks, most of which are located in the Monongahela Group.

The Monongahela Group is located within the Pennsylvanian age sediments and includes the interval from the base of the Pittsburgh coal to the top of the Waynesburg coal. Deposition of the Monongahela Group was primarily in lacustrine and swamp environments. The Monongahela Group has a maximum thickness of about 122 m and a minimum thickness of about 76 m along the Ohio River at the southwestern edge of the basin.

Fig. 3 shows lithological logs obtained from a series of boreholes (I–VII) located along the *X*–*Y* section shown in Fig. 2. This figure also