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# Estimation of correction coefficients for measured coal bed methane contents

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ABSTRACT

Improving the accuracy and precision of coal bed methane (CBM) estimates requires correction of older data from older coal exploration surveys to newer standards. Three methods, the depth gradient method, the contour aerial weight method, and the well-point aerial weight method, were used to estimate the correction coefficient required to predict CBM gas content from coal exploration data. The data from the Nos. 3 and 15 coal seams provided the coal exploration data while the CBM exploration stages within the X1 well block located in the southern part of the Qinshui Basin provided the data obtained using newer standards. The results show the correction coefficients obtained from the two aerial weight methods are similar in value but lower than the one obtained from the depth gradient method. The three methods provide similar results for the Nos. 3 and 15 seams in that the correction factor is lower for the former seam. The results from the depth gradient method taken together with the coal seam burial depth and the coal rank suggest that variations in the correction factor increase linearly along with coal seam burial depth and coal rank. The correlation obtained can be applied to exploration and the evaluation of coal bed gas resources located in coalfields.


## 1. Introduction

Coal bed methane (CBM) is an economically viable energy source for use in the future that has attracted interest both at home and abroad for years [1]. There are two important research fields that involve the assessment the CBM reservoir and the servicing of the CBM production. Research has focused on the geological characteristics of the CBM reservoirs, including the gas content, the tectonic setting, and the hydrological features of the deposit and attempts to calculate the size of the resource have been made [2–13]. Studies of the coal reservoir permeability, the gas adsorption capacity, and coal bed factors such as pore characteristics, structure, fractures, and coal rank, have also been done [14–18]. Studies for CBM production are also available [3,19].

The CBM exploration field uses the national standards GB/T 19559-2004 and GB/T 19559-2008 to measure gas content. These are similar to the methods proposed by the United States Bureau of Mines (USBM) and include lost gas, desorbed gas, and residual gas [20,21]. However, during previous coal exploration three methods were used to measure gas content at different times. These methods include the vacuum tank, the gas gathering, and the gas desorption methods. The gas desorption method differs from the USBM direct gas content measurement and consists of free gas, desorbed gas after 2 h, the amount gas after vacuum heating degassing, and the crushed coal degassing values [21]. This method was mainly used from 1980 to 1990 with the corresponding industry standard MT 77-84. The difference in time and temperature during the desorption stage causes the gas content measured to usually be lower than that measured following national standards GB/T 19559-2004 and GB/T 19559-2008 [22].

Today, large-scale coal geological exploration in China has made it increasingly needed to have a correction coefficient relating the desorption method to the direct gas measurement of the USBM [23]. This is required to accurately evaluate CBM resources from the previously determined gas content data. In this paper, we present a comprehensive study of three correction coefficient methods to allow better estimates of CBM resources.

## 2. Geological background

The X1 block is one part of the Pangzhuang coalfield, located in the Qinshui Basin, Shanxi province, China. It was the most active CBM exploration zone where the economic model for CBM extraction was established. The structure of the X1 block is simple (Fig. 1) and there were north south trends observed during exploration.

The total thickness of the coal bearing strata of the X1 block is about 1200 m and the strata are made up of the Taiyuan formation of the Upper Carboniferous, the Shanxi, Xiashihezi formation of the Lower Permian, and the Shangshihezi formation of the Middle

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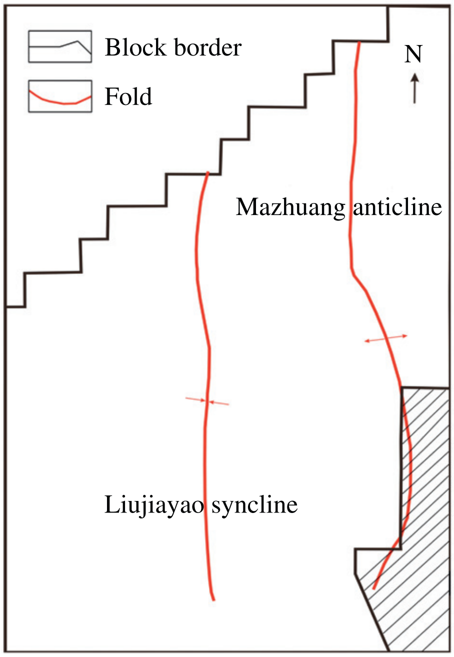


**Fig. 1.** Structure of the X1 block in Shanxi province.

Permian. The coal seam in the Xiashihezi and Shangshihezi formations is poorly developed and thinner in thickness. The Taiyuan and Shanxi formations contain many coal seams, which are much thicker and more stable. The thickness of the coal seams in these formations is approximately 18 m total and includes several main seams: The Nos. 3 and 15 coal seams. The thickness of these is about 6.0 m for the No. 3 and 3.0 m for the No. 15 and they are characterized as having moderate ash content, poor conductivity, and low density.

## 3. Methods

Three methods to obtain the correction factors were employed: the depth gradient method, the contour aerial weight method, and the well-point aerial weight method.

### 3.1. Depth gradient method

The depth gradient method is based on the theory that the CBM gas content is mainly controlled by the coal seam depth, which displays a positive liner relationship. The correction factor here is a gas content ratio. The gas content measured during CBM exploration and the gas content measured during coal geological exploration at the same coal seam depth are compared:

$$C_1 = a_1 h + b_1 \tag{1}$$

$$C_2 = a_2 h + b_2 \tag{2}$$

$$k_1 = C_2 / C_1 \tag{3}$$

where $C_1$ is the gas content from coal exploration, m$^3$/t; $C_2$ the gas content from CBM exploration, m$^3$/t; $h$ the coal seam depth, m; $a_1$ and $a_2$, respectively, the gas content gradients found during coal and CBM explorations, m$^3$/(t·m); $b_1$ and $b_2$, respectively, the compensation factors for fitting equations used during coal and CBM explorations; and $k_1$ the desired correction coefficient.

### 3.2. Contour aerial weight method

The contour aerial weight method (as shown in Fig. 2a) is based on the gas content contour maps from the different explorations. These explorations include geological coal exploration and CBM exploration. The average gas content is obtained from Eq. (4) and the correction coefficient is obtained from Eq. (5).

$$C' = \frac{\sum_{i=1}^{n} \left(\frac{C_i + C_{i+1}}{2}\right) A_i}{\sum_{i=1}^{n} A_i} \tag{4}$$

$$k_2 = C'_2 / C'_1 \tag{5}$$

where $C'$ is the average gas content, m$^3$/t; $C_i$ and $C_{i+1}$ the gas content values at the $i$ and $i+1$ contours on the map, m$^3$/t; $A_i$ the area between contours $i$ and $i+1$, m$^2$; $n$ the contour interval; $C'_1$ the average calculated from the contour map drawn using gas data measured during geological exploration studies, m$^3$/t; $C'_2$ the average gas content calculated from data measured during the CBM exploration, m$^3$/t; and $k_2$ the correction coefficient for the contour aerial weight method.

### 3.3. Well-points aerial weight method

The well-points aerial weight method was usually used to assess oil resources [24]. Assuming a uniform distribution of gas during the coal or CBM explorations, the probabilities that gas will be in the wells drilled during exploration and in those locations representing undrilled wells will be equal. The calculation range of a well is related to the intersection of a perpendicular bisector of a triangle. If the wells nearby are connected as vertices of a triangle and the intersection is inside then the area of a single well is the intersection area of the connections. Otherwise, the controlled area is determined by the intersecting area of the triangle midpoints. This is shown in Fig. 2b. So here

$$C'' = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i} \tag{6}$$

$$k_3 = C''_2 / C''_1 \tag{7}$$

where $C''$ is the average gas content, m$^3$/t; $C_i$ the gas content of well $i$, m$^3$/t; $A_i$ the controlling area of the $i$'th well, m$^3$/t; $n$ the numerical index of the well controlling area; $C''_1$ the average gas content based on the coal geological exploration data, m$^3$/t; $C''_2$ the average gas content calculated from the CBM exploration data, m$^3$/t; and $k_3$ the estimated correction coefficient for the well-points aerial weight method.

As a result of differences in these three methods the adaptability, advantages, and disadvantages of the correction coefficients vary depending upon the application. The depth gradient method is easy to calculate and could be used in simply structured areas where the CBM content is mainly affected by coal seam depth (Table 1).

Eleven coal exploration wells located within the folded region were chosen that included gas content data from the Nos. 3 and 15 seams. These data were determined following industry standard MT 77-84. Four sets of gas content data in each coal seam were measured following the GB/T 19559-2008 standard.

## 4. Results and discussion

The three correction methods were applied to the Nos. 3 and 15 coal seam data. The relationship between gas content and depth was established by the depth gradient method (Fig. 3). The gas content tended to increase as the coal seam burial depth increased in a positive linear relationship.

The correction coefficients needed to adjust the older data to the new standard varied from 1.18 to 1.47, with an average of 1.35 in the No. 3 seam, while they ranged from 1.22 to 2.20 in the No. 15 seam, with the average of 1.77. Comparing the data from Nos. 3 and 15 shows that the correction coefficient is lower in the former coal seam, see Table 2.