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Research Paper

Outlining High Gas-Bearing Sub-Panels in Parvadeh I Coal Mine Using Regression and Geostatistical Simulation

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Abstract: High gas volume is the main reason of explosion, rock burst and fatal coal mining disasters. In a coal mining project, it is necessary to model the gas volume at all parts of the target seam. Amoung coal resources of Iran, Parvadeh I has high gas bearing seams with an average of 14 m3/t of gas. C1 coal seam is the main mining target in Parvadeh I and it was explored by 134 core drilling boreholes. Gas study has been carried out for 35 boreholes, in only central and eastern parts of the deposit. Gas volume is not measured at the deep western parts. In this study, fractured zones are identified and their gas data removed from the gas modelling procedure. It is found that gas volume and seam depth are highly correlated and also, two separated populations are evident in the gas vol. – depth cross plot. The first population is related to oxidized shallow, and the second one is interpreted as deep methane bearing zones of the seam. Using the regression kriging method with the seam depth as the auxiliary variable, the gas volume is estimated for the whole mining blocks of the C1 seam. The validity of the estimations is evaluated as 94% by the Jackknife method. In order to avoid the smoothing effect of kriging, the probability of critical gas zones (> 20 m3/t) is modelled by the conditional indicator cosimulation. Results demonstrated that 1.43 million m2 of the C1 seam with the probability of 75%, and 0.38 million m2 with the probability of 100% fell into the critical category. These critical gas zones are located in central, southern and western Parvadeh I. These zones are considered to be the main targets for the future gas drainage studies.

Keywords: Coal gas volume, Geostatistics, Parvadeh I tabas, Regression kriging, Conditional indicator cosimulation.

INTRODUCTION

Numerous coal mining disasters happens due to high amounts of trapped gas in the coal seams [1-3]. It is previously found that gas volume is related to burial depth, temperature, moisture and petrological properties of the coal [4,5]. Obviously, this relationship is unique for every coal deposit and it needs to be studied accurately [6]. The first step of a gas risk reduction study is to model the in-situ gas volume for the target coal seams. The success of gas drainage plans fully depends on the accuracy and validity of gas volume estimation [7,8].

The present study, discusses about gas volume of the C_1 coal seam at the Parvadeh I Tabas coal mine in Central Iran. Parvadeh Tabas is the main source of coking coal production and also, is known for high gas volume. Core drilling data of 134 exploratory boreholes and 35 gas data is used to estimate the gas volume at all parts of the C_1 seam. Regression analysis, ordinary kriging and conditional indicator cosimulation are used to jointly build a reliable and generalizable model for unknown western parts of the deposit.

METHODS

Regression Kriging (RK) is a geostatistical method for separate modelling of deterministic and probabilistic parts of the target variable [9]. Kriging with external drift and universal kriging are similar methods which estimation carries out entirely after modelling the trend. In contrast, RK models the deterministic part by regression analysis of an auxiliary variable and then, the residuals are estimated as the probabilistic part [10]. In the end, the target variable can be calculated by summing up the regression and kriging results.

A superiority of RK over kriging with external drift is when the auxiliary variable changes drastically in the estimation domain. In such cases, the covariance matrix will be inhomogeneous and estimation error could be huge near the points with extremely distinct values [11]. Alternatively, RK can be used to model the harsh changes with regression models of arbitrary complexity. In addition, the regression models can be observed and interpreted by the researcher.

FINDINGS AND ARGUMENT

As the first step, the Whisker test showed no outlier for the gas volume values. Amoung 12 qualitative and quantitative coal variables, only seam depth forms a two-member statistical cluster with the gas volume. Although the Whisker test showed no gas vol. Outlier, it is mandatory to study the location of the gas boreholes to investiage wheter they are located in the low pressure zones or not. It is important because the trapped gas can escape from the coal seam through fractures and the entire modelling procedure will be falsified by under-estimation. Faulted and/or folded zones are studied in this research and 6 boreholes identified on the fractured zones and consequently, removed from the modelling (Figure 1).

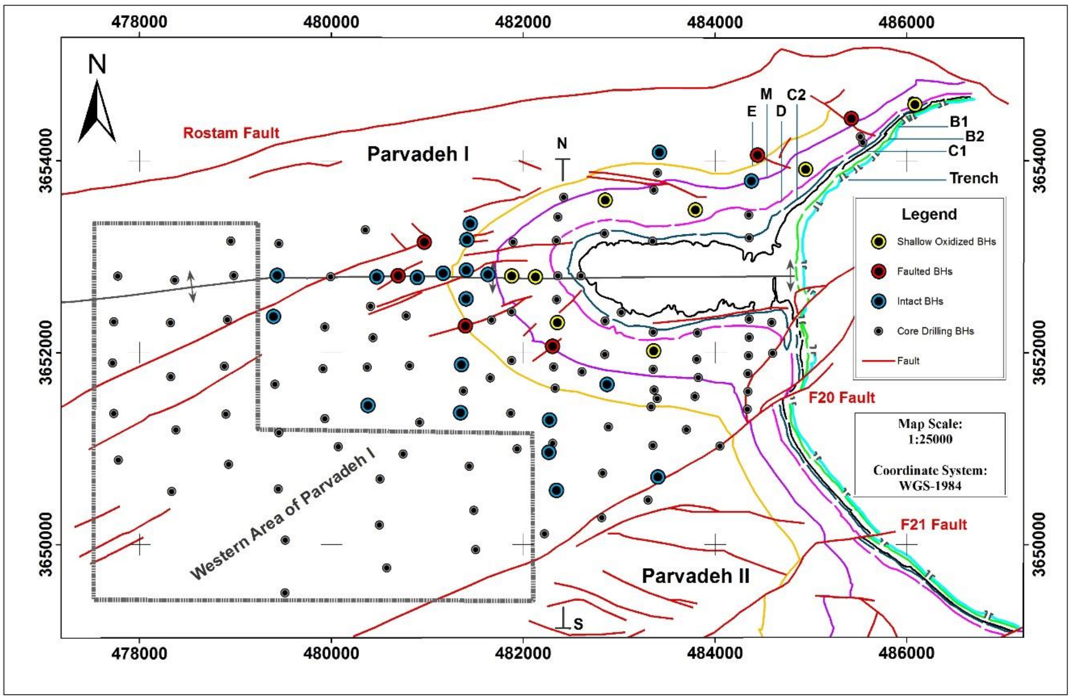

Figure 1. Summerized structural map of the Parvadeh I deposit. Boreholes near the faults are drawn in red

In the second step, the highly correlated depth variable is selected as the auxiliary variable and to perform regression analysis. The gas vol. – depth cross-plot revealed that there are two gas populations versus depth: 1- the shallow oxidized zone and 2- the deep methane bearing zone (Figure 2). As a result, these two populations were analyzed separetly to estimate the gas volume at the whole mining blocks, especially at the western deep and not-studied part of the C_1 coal seam (Figure 3).

As expeted, low gas volume estimated values are located at the shallow eastern borders, near the C_1 outcrop. A high gas area (HGZ1) is estimted to be located at the central part. This zone contains critical values upto of 21 m^3/t of gas. Moreover, a bigger zone is expected to be at the southern parts and to be extended to the western borders.

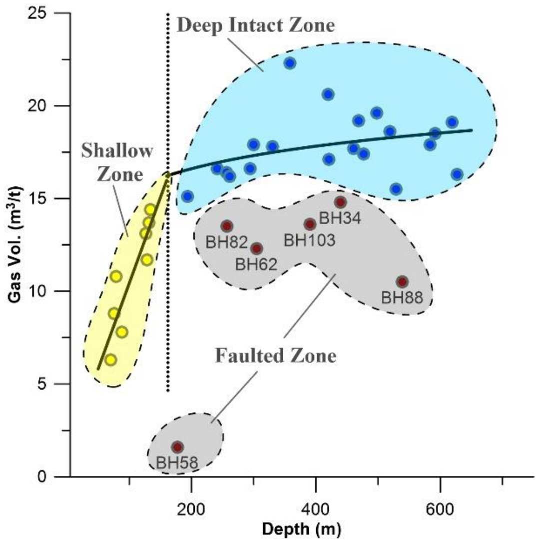

Figure 2. Gas Vol. – depth cross plot showing two populations: 1- yellow: the shallow oxidized zone and 2- blue: the deep methane bearing zone. The faulted zone is illustrated by the grey color

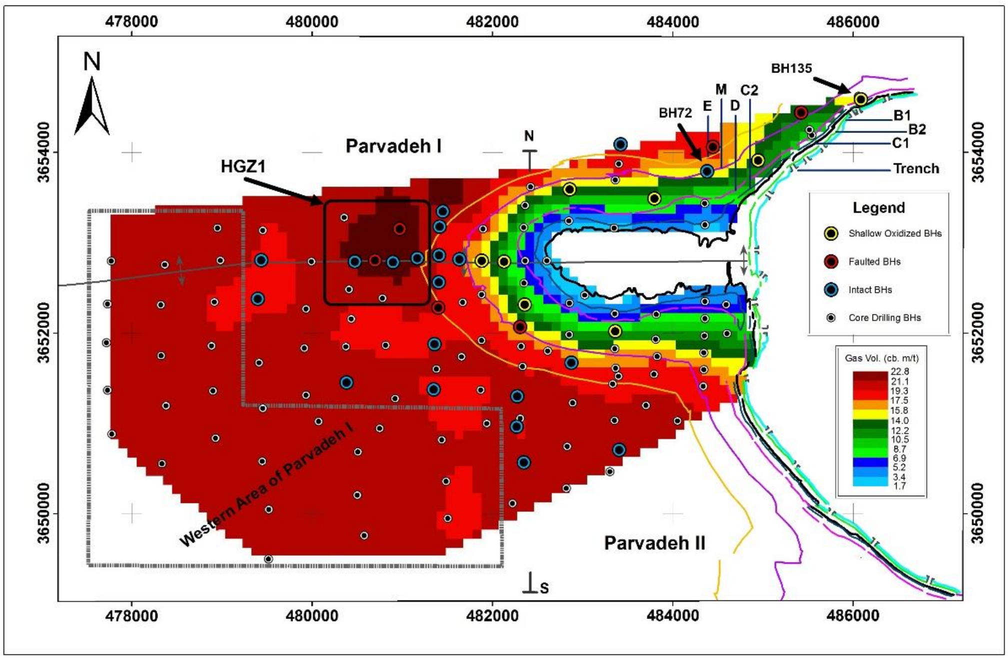

Figure 3. Distribution of the gas volume in the deposit, Estimated by the regression kriging method

The validation of RK is measured by the Jackknife method. It is calculated as 94%, which shows a high level of validity. Altough it is a high rate, the results are still exposed to the kriging smoothing effect. In order to solve this problem, a geostatistical simulation approach is followed. The critical gas vol. threshold is set to 20 m^3/t and then, 250 realizations are simulated using the conditional indicator cosimulation method. A probability study for the whole domain was carried out. It is found that the probability of critical gas volume at the estern part is zero. The probability increases by moving toward deeper western parts. In total, 0.38 million m^2 of the C_1 seam is critical with the probability of 100%. This probability is 75% for 1.43 million m^2 of the seam. Related to the RK and simulation results, two locations are proposed for gas drainage studies.

CONCLUSIONS

In this study, a joint application of statistical, geostatistical and simulation methods was used to model the gas volume in the Parvadeh I Tabas coal mine. This is important to consider the structural specifications of the target seam, such as depth, faulting and folding. Even though the regression kriging delivered acceptable results, conditional indicator cosimulation was employed to stay away from the smoothing of kriging. It is concluded that the mathematical findings of this research, conforms to the geological facts such as: 1- Separation of gas zones at the depth of 133 meters. This depth is reported as 140 m, based on a previous gas chemistry study; 2- Experimental variograms fitted by the Gaussian models are a mathematical expression of smooth changes at small distances. This is an evidence of sedimentary nature of the coal (Figure 4); 3- The major axis of the anisotropy ellipse is along the azimuth 105˚, which is concordant with the forming direction of the Parvadeh paleo-swamp. These findings are proofs for the validity and reliability of the presented models.

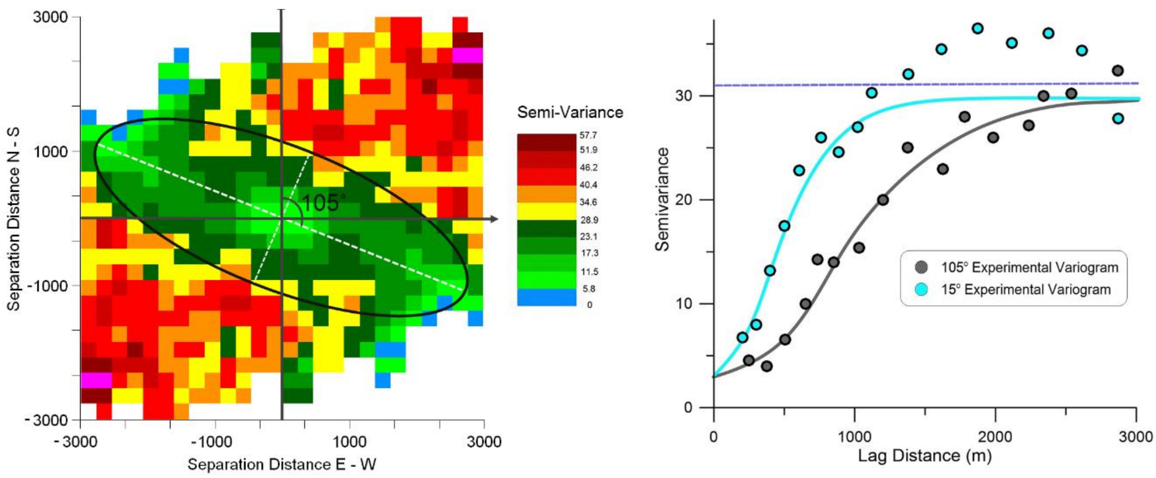

Figure 4. Left: The anisotropy map of the gas volume, with the most continuity along the azimuth 105˚. Right: Experimental variogram and Gaussian fitted models on the major and minor axis of gas volume anisotropy ellipse

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