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# Exploration Testing Network Optimization at the Operational Stage of Coal mining

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**Abstract.** In the article the problem of the quantitative estimation of coal deposit efficient detailed prospecting and a way of its decision which is based on the three sequential problems solving is considered. The quantitative assessment of performance itself is verified on sufficiency of the studies carried out by well-drilling. The sufficiency condition is determined by comparing the existing testing density with the predictive optimal one. The forecast of the optimum density of the testing network is based on the use of summarized relative entropy value, as measures of homogeneous significant mineable coal seams and also regulations acting on the territory of the Russian Federation. The application of the technique proposed in this article is considered on the sample of the Site No. 1 of the Elga Coal Deposit. The forecast of the optimal testing density, which makes it possible to increase the efficiency of acceptable design operational decisions for this deposit field was performed for following parameters of coal quality as raw-coal ash, thickness of the plastic layer, devolatilization and moisture of analysis sample. Due to the evaluation findings of the efficient detailed prospecting at Site No. 1 of the Elga Deposit it was determined that the existing network of exploration wells in the southern part of the site should be partially condensed.

## 1. Introduction

One of the main aspects of putting into operation any type of mineral deposits in today's economic environment is the geo-hazard assessment of its development [1-4]. At the same time, the key role in the estimation of the geological hazard is played by the availability of error-free information about complexity of the deposit's geological structure and its quantitative characteristics of the conditions. As a source of this information in this case, as a rule, the results of detailed exploration work act, which precede the procedure for designing a mining enterprise. The efficiency assessment of detailed prospecting in the design of a mining enterprise more objectively determine required extra charges to update the deposit geological information, which will directly affect the level of the geo-hazard of further deposit development [1, 3]. In view of this, it is worth noting the logical problem actualization of previous detailed exploration quantitative assessment of effectiveness in designing a mining enterprise.

Thus, the indicated problem can be resulted to a phased solution of three tasks. The first one is, according to the data of the most representative deposit testing system, to mathematically assess the quantitative indices of inhomogeneity of its main characteristics taken into account in the design of a mining enterprise. The second task is to forecast the optimal network of the testing system based on data of deposit quantitative characteristics. And the last task is to make a decision of required



additional studies (the effectiveness of previously performed prospecting) based on comparison between forecasted and now existing network testing system.

## 2. Research Question

For a more detailed idea of the procedure for solving the above-mentioned problem, coal deposits are considered as the object of research in this paper. The subject of the study is the testing deposit drilling system as a main system used at the stage of detailed exploration of coal deposits [5-6]. To further facilitate the information sense outlined in the work, all proposed solutions are accompanied by a sample performed on the Site No 1 of the Elga Coal Deposit, which is scheduled to be worked out as a matter of priority (Figure 1) [7]. The sites allocation shown in Figure 1 is made concerning to the main tectonic deformations adjusted during detailed exploration [7-10].

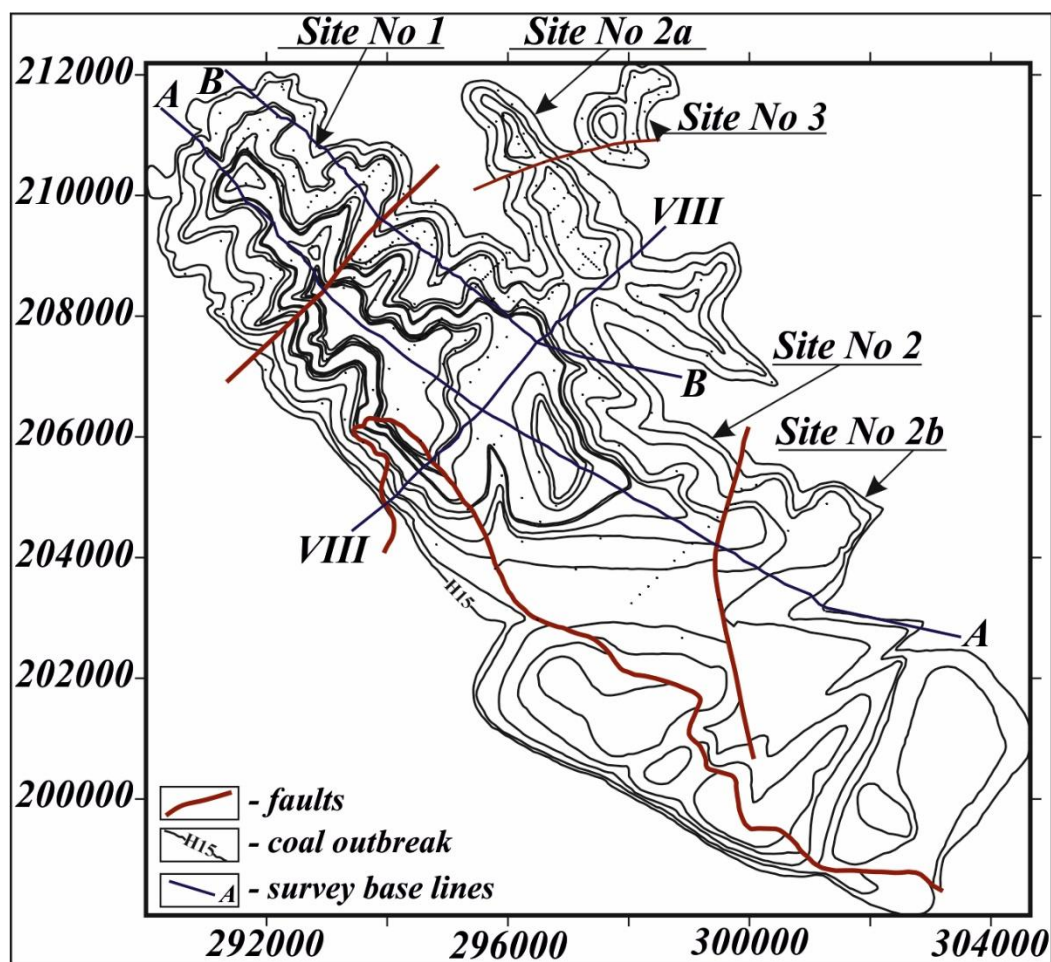


Figure 1. Sites of the Elga Coal Field.

## 3. The sample of the technique use

### 3.1. The first task is to quantify the inhomogeneity of coal quality indicators

As a quantitative assessment of the inhomogeneity of coal quality indicators authors suggest using the value of generalized relative entropy calculated by the formula:

$$H_{otn}^s = \sum_{k=1}^{k=m} H_k^{otn} \cdot K_k^{ves}, \quad (1)$$

where:  $H_{otn}^s$  – generalized relative entropy;  $H_k^{otn}$  – relative entropy calculated for the k-th coal quality index;  $K_k^{ves}$  – weight coefficient calculated for the k-th quality index of coal;  $m$  - number of coal quality indicators..

The relative entropy was proposed by C.R. Peltó. For now, this value is used quite efficiently to describe and visualize the homogeneity of the geoenvironment [11-17] and, as shown in [18-19] can be used to assess the uniformity of coal deposits quality indicators. Calculation of the relative entropy in this case should be done according to the formula:

$$H_k^{otn} = \frac{-\sum_{i=1}^n p_i \cdot \ln p_i}{\ln n} \cdot 100\% = \frac{H}{H_{max}} \cdot 100\% \quad (2)$$

where:  $H_{otn}$  – relative entropy ( inhomogeneity), %;  $H_{max} = \ln n$  – maximum entropy, nit ;  $n$  – number of analyzed geological components (characteristics), determined on the basis of the Sturges rule or by entering a fixed significant step of the interval;  $p_i$  is the fraction of the i-th component in the system.

B The weight coefficient introduced in formula 1 makes it possible to proceed to a comprehensive assessment of the uniformity of coal quality indicators and is calculated according to the formula [20]:

$$K_k^{ves} = \frac{n_i}{\sum_{i=1}^m n_i}, \quad (3)$$

where:  $n_i$  - number of indicators for the quality index of coal;  $m$  - the total number of groups of coal quality indicators accepted for calculation.

Based on the generalized relative entropy value calculations, the inhomogeneity degree of the coal quality indicators of coal-bearing solid mass is determined according to the classification developed by the authors (Table 1) presented in the papers [18-19].

**Table 1.** Classification of geological features and their characteristics according to inhomogeneity.

Types of inhomogeneity	Value of relative entropy, %	
	from	to
Highly homogeneous	0	22
Homogeneous	22,1	38
Heterogeneous	38,1	55
Highly heterogeneous	55,1	100

The values of the relative and generalized relative entropy for such coal quality indicators as moisture of analysis sample, raw-coal ash, devolatilization and thickness of the plastic layer were calculated as a sample for significant mineable coal seams of Site No. 1 of the Elga Deposit. The results of calculations based on the above formulas are presented in Table 2. Analyzing the data presented in this table, it can be noted that all significant mineable Site No. 1 coal seams of the Elga Deposit are highly heterogeneous in terms of coal quality indicators.

### 3.2. The second task is to forecast the optimal density of the testing network

The forecast of optimal testing density exploration wells network for coal quality indicators obtained as a result of testing coal at the stage of detailed exploration is carried out on a crossplot developed by the authors for coal deposits located on the territory of the Russian Federation and presented in paper [18]. The crossplot scheme is based on a comparison of the State Committee for Mineral Reserves recommendations determined the optimal network density [6] and the classification of geological features and their properties by heterogeneity (Table 1).

For the conditions of Site No. 1 of the Elga Deposit, Table 2 presents the results of determining the optimal densities of exploration wells network for significant mineable coal seams, obtained on the basis of a sequential interpretation developed by the authors of the crossplot and calculated data of the generalized relative entropy given in Table 2.

**Table 2.** Results summary table of the optimal testing exploration calculations of site No.1 of the Elga Coal Field.

Coal layers	Relative entropy, %				Generalized relative entropy, %	Spacing, m	
	$W_a$	$A_d$	$V^{daf}$	$Y$		line (profile) spacing	well spacing
H <sub>15</sub>	81,93	66,85	76,50	73,84	74,25	428	214
H <sub>15</sub> <sup>B</sup>	71,95	87,51	69,60	71,24	75,25	428	214
H <sub>16</sub>	74,62	72,07	74,34	75,19	74,08	429	214
Y <sub>4</sub>	69,01	63,72	59,17	68,69	65,69	438	219
Y <sub>5</sub> <sup>H</sup>	66,53	79,29	73,90	69,56	72,94	430	215
Y <sub>5</sub>	80,64	82,19	80,09	78,14	80,27	422	211
Y <sub>6</sub>	85,75	87,30	-	81,70	84,07	418	209
Y <sub>8</sub>	83,96	87,42	79,03	88,81	85,04	417	208
Y <sub>12</sub>	87,74	70,55	-	-	80,18	422	211
Y <sub>13</sub>	88,98	90,61	97,38	-	91,4	410	205
Y <sub>14</sub>	84,10	83,81	92,48	95,31	88,93	412	206
Y <sub>16</sub> <sup>H</sup>	-	64,78	92,33	-	80,48	422	211
Y <sub>16</sub> <sup>B</sup>	-	75,37	92,83	64,61	80,01	422	211
Y <sub>17</sub>	-	-	-	89,64	89,64	412	206

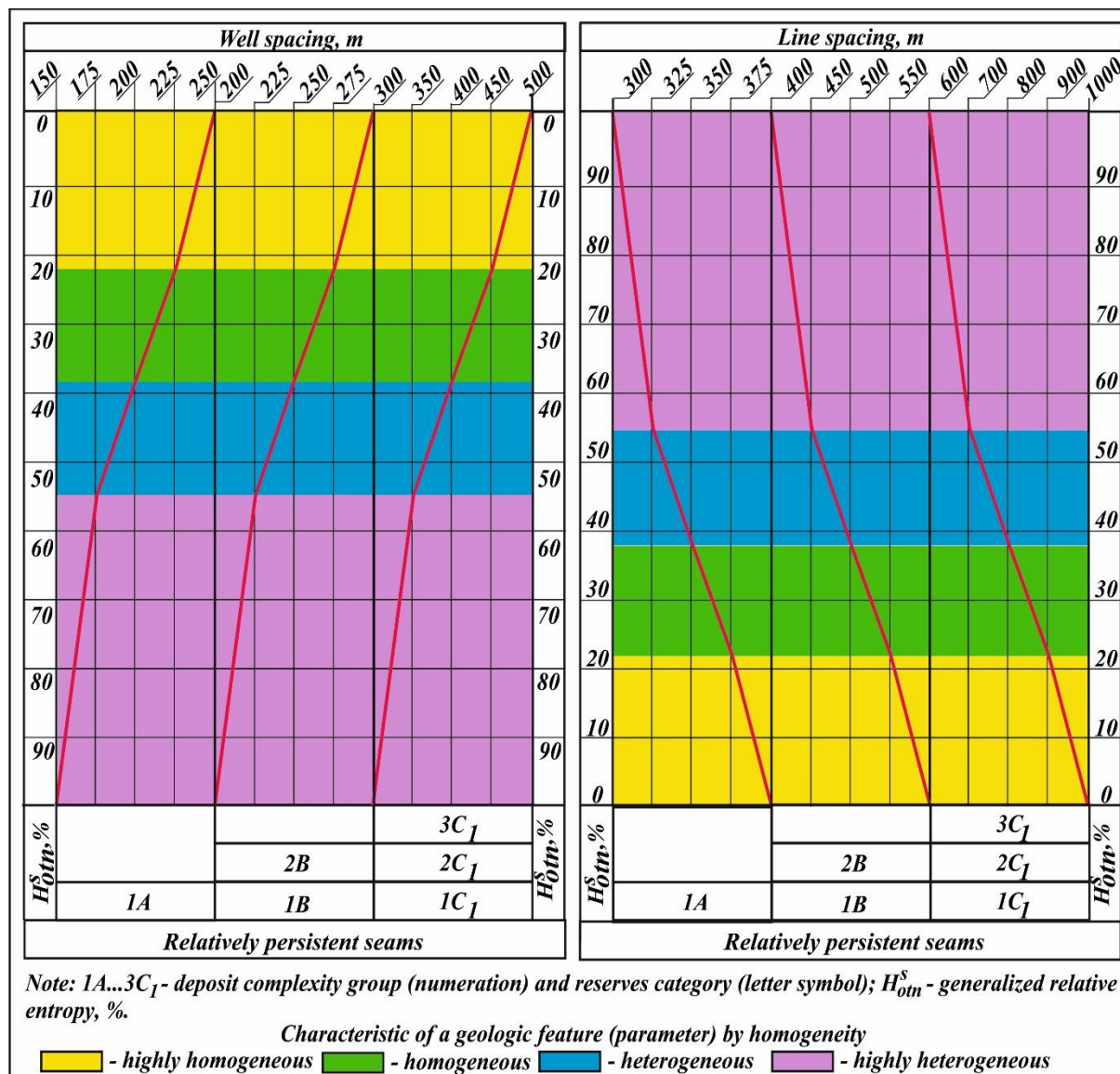
Note:  $W_a$  - moisture of analysis sample,  $A_d$  - raw-coal ash;  $V^{daf}$  - devolatilization;  $Y$  - thickness of the plastic layer.

Figure 2 shows the fragments of the crossplot used to determine the optimal density of the exploration well network taking into account the complexity of the geological structure (group 2) and the consistency of the coal beds of the Elga Deposit Field in terms of capacity (relatively persistent). Analyzing the data presented in Table 2, we can come to the conclusion that for the Site No. 1 of the Elga deposit, the optimal distances can be considered like this: survey profile spacing of 410 meters; wells spacing on profiles of 205 meters.

### 3.3. The third task is to assess the effectiveness of detailed exploration of coal deposits

The procedure for evaluating the effectiveness of detailed prospecting carried out by drilling exploration wells is realized by comparing the predicted density of wells network with the actual existing one on a coal deposit. A decision based on the results of this comparison is made on required additional geological exploration in order to increase the reliability of design works that determines the order of operation of the field as a whole.

A Analyzing the results of detailed prospecting at the Site No. 1 of the Elga Deposit [8], it was noted that the exploration network is non-uniform both in the site and in the entire field. The main exploration network of detailed prospecting has a length of 1000-1500 meters between survey profiles and 100-150 meters between exploration wells on them accordingly. In the north-west direction from the intersection of the exploration profile of the B-B with a fault, the exploration network thickens to a dimension of 250-300 meters between exploration profiles and 100-150 meters between exploration wells on them (Figure 1). Within the B-B and A-A profiles, the network is diluted to 500-550 meters of survey profiles spacing and 250-300 meters of wells spacing on them. Based on the comparison of the actual exploration network with the forecasted one and to improve the efficiency of the design work, it is recommended to thicken the exploration wells network of the of Site No. 1 in the south-west direction from the intersection point of the B-B profile and the fault with the length: survey lines (profiles) spacing of 410 meters and wells spacing of 205 meters.



**Figure 2.** Fragments of the crossplot determining the coal deposits' exploration wells optimal density [18].

#### 4. Conclusion

The article presented an approach to assessing the effectiveness of previous detailed exploration at the stage of taking design solutions for the mineral deposits operation by three sequential problems solving. This approach makes it possible to determine the optimum testing mineral network in order to improve the efficiency of taking design solutions for the mineral deposits operation, as well as required extra charges to update the field geological information, which directly has an impact on level of the geo-hazard deposit development.

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