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APPLICATION OF GEOSTATISTICS FOR ESTIMATING THE DISTRIBUTION OF ONE OF THE BAUXITE DEPOSIT RESERVE IN THE REPUBLIC OF GUINEA

To estimate the content of Al_2O_3 in the block exploring a bauxite depositsiteof Sangaredi in the Republic of Guinea (West Africa), one of geostatistics methods, discrete kriging, was applied. The use of discrete kriging in these conditions allows to ensure tightly controlled amountmore reliably, i.e., not less than 48% of Al_2O_3 content in the concentrate when shipping it from the processing plant onto bulk carriers. This problem isbecoming more and more urgent as the amount of field parts being rich is decreasing.

Key words: geostatistics, kriging, variogram, de Wijs's model, variance of increment, the distribution of reserves.

Geostatisticsin geology is used for assessing geological parameters such as the content of chemical elements in the orebody, the power of the orebody and others, between the exploration mine workings on the basis of discrete sampling of minerals in these workings. In geostatistics the concept of spatial variable [3] is usedas the object of study. Any geological parameter can be taken as such variable. When solving practical geological problemsthe random function [3] is usedas a mathematical model of the spatial variable.

Geostatistics is basedon J. Krige's assumption, a South — African geologist, [5] that there is a finiteincrement variance of the spatial variable, i.e.stationary increments exist. The assumption is true for many fields. In this case, the mathematical expectation of the spatial variable increment is equal to zero:

$$M[Z(x_i \quad h) \quad Z(x_i)] \quad \frac{1}{N(h)} \sum_{i \; 1}^{N} [X(x_i \quad h) \quad Z(x_i)] \quad 0, \tag{1}$$

where N is the number of pairs of values of the spatial variable at two locations x_i and $x_i + h$, h is the distance between two locations; Z is the value of the spatial variable in the points x_i and $x_i + h$.

Under the assumption for the incrementvariancemade

$$D[Z(x_i \quad h) \quad Z(x_i)] \quad \frac{1}{N(h)} \sum_{i \; 1}^{N} [X(x_i \quad h) \quad Z(x_i)]^2 \quad 2 \; (h), \tag{2}$$

where

$$(h) \quad \frac{1}{2N(h)} \sum_{i \; 1}^{N} [Z(x_i \quad h) \quad Z(x_i)]^2, \tag{3}$$

is called semi-variogram or variogram. In geostatistics variogram is the primary tool for structural studies and evaluation of the deposit.

One of the most effective methods of geostatistics is known as kriging.

Kriging is the method for searching for the estimationof the average value of the spatial variable (for example, the average mineral content in the ore deposit) in the block using the sampling results both inside and outside the assessed unit. The sampling results are usedwith the weights for the variance of the average useful component to be minimal.

Let an orebody is drilled for square exploration network. It is necessary to estimate the average content of the spatial component in the block, in the center of which the well is drilled A (Fig. 1). In this case, the kriging problem is to determine the weights to be assigned to the spatial variable values in central well A and wells B_1, B_2, B_3, B_4 and C_1, C_2, C_3, C_4, being equidistant from well A and surrounding it. The selected values of the weights must ensure the minimum error of the average value estimates of the spatial variable in the estimated block.

Let Z_A is the average value of the spatial variable in well A; Z_B — the average value of the spatial variable in the loop formed by wells B_1, B_2, B_3, B_4; Z_C is theaverage value of the spatial variable in the loop formed by wells C_1, C_2, C_3, C_4; $t \quad \frac{h}{d}$, where h is the mineral body power; d is the exploration networkstep, then the average value of the spatial variable in the estimated block iscalculated using the following kriging formula:

$$Z^* \quad Z_A \quad Z_B \quad Z_C, \tag{4}$$

where , , are weights, and 1.

The weight values depend on the variogram model and the spatial derivative. For the logarithmic model of

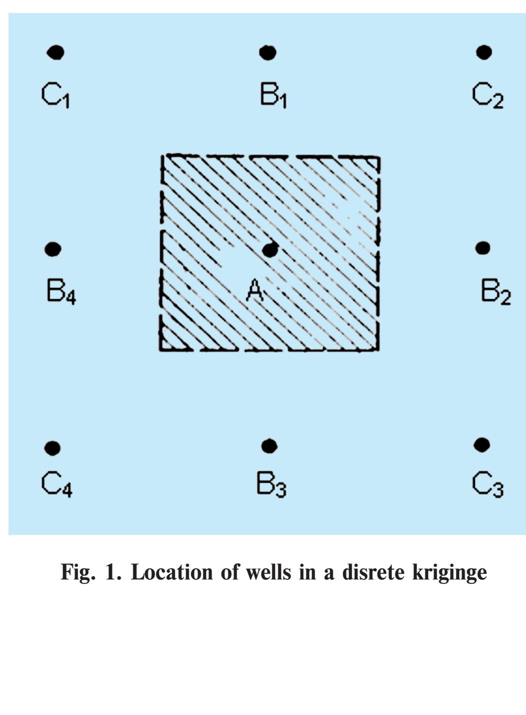

Fig. 1. Location of wells in a disrete kriginge

de Wijs's variogram, the formulas for the weights at $t < 1$ are the following [2]:

$$\frac{(0{,}4277\quad \ln(t))\ 0{,}5173\quad \frac{1}{4}\ln(t)}{0{,}9121\quad 1{,}4739\ln(t)\quad \frac{9}{16}\ln^2(t)}; \qquad (5)$$

$$\frac{(0{,}4277\quad \ln(t))\ 0{,}0841\quad \frac{1}{4}\ln(t)}{0{,}9121\quad 1{,}4739\ln(t)\quad \frac{9}{16}\ln^2(t)}. \qquad (6)$$

1 .

The assessment of reservedistribution of one of the areas of Sangaredi bauxite deposit

Polygenic bauxite deposit Sangaredi in West Africa (Guinea) was formedin the result of deep chemical erosion of the Devonian shales [7]. The quality of ores is rather high (Al_2O_3 up to 65%). The field is developed by the pit method. The bauxite cut-off grade is 42% of Al_2O_3. The exploration network is 37,5 37,5 m. The contentof Al_2O_3 and SiO_2, TiO_2, Fe_2O_3, and losses during the combustion in the block are estimated by the content of these components in the core extracted from a well drilled in the center of the block. The deposit development is realizedby the blasting method. Blast holesare drilledbetween exploratory wells under the network 6 6 m. After having been broken the ore is stored on the area at a certain place in the blocks. The Al_2O_3 content in the block and its position in the storage location are entered the database. The ore loaded into carsis sentfrom the storage sites to the processing plant. Having been enriched the ore is loaded onto bulk carriers and sent to steel mills. On board the bulk carrier, the Al_2O_3 content should be less than 48%. If the content block does not provide that number, then theore of this block is mixed with bauxites of other blocks with a higher content of Al_2O_3.

The author evaluated the Al_2O_3 content in the block using the kriging method. The conditions for its using at this bauxite depositwere favorable. Firstly, the field has clear boundaries, secondly, there are no faults; and thirdly, no abrupt changes in the Al_2O_3 content between exploratory wellsare discovered.

The area of Bundu Vaade of Sangaredi field containing 287 wells is chosen to apply the kriging method. The statistical data of sampling results of the area are presented in Table 1.

The variance of the spatial variable (in this case the content of Al_2O_3) or the variogram threshold is 35,59, which agrees well with the data of Table 1 (variance 35,49). The impactinterval of spatial variable or autocorrelation radius is 112,5 m, which allows the use of kriging to estimate the average Al_2O_3 content in the block under the exploratory network of 37.5 37.5 m.

Table 1

Statistical data of Bundu Vaade area sampling

Statistics	Sampling	Kriging
Average content, Al_2O_3, %	46,18	46,18
Maximum content, Al_2O_3, %	62,80	56,80
Minimum content, Al_2O_3, %	27,30	27,60
Average thickness of the ore layer, m	9,12	9.12
Maximum thickness of the ore layer, m	18,00	18,00
Minimum thickness of the ore layer, м	1,00	1,00
Content variance, Al_2O_3	35,49	20,45

It may be noted that the variogram model is coordinated with de Viysa's logarithmic model: $Y(h) = A + Blg(h)$. This allowsto realize kriging method using the above formulas (5 and (6) to estimate the average Al_2O_3 content in the block. Besides, it may be stressed that the maximum thickness of the ore layer (18 m) is much smaller (2-fold) compared to exploration network step (37.5 m), which also allows to use these formulas for kriging. Kriging results for the area of BunduVaadeare given in Table 2, kriging statistics in Table 1.

Excluding the anomalous value of the difference between the results of geological sampling and kriging (-13.77, -10.11 - 9.1), that may be explained by the error of chemical analysis of the core, the difference between the sampling results and kriging varies from -5.69% to 5.52%.

The obviously smoothing effect after the application of kriging can be noted. The distribution of bauxite reserves in the given area becomes calmer after the application of the discrete krigingprocedure. Certainly, the same effect can be achieved by using other methods, such as calculating the average value in the predetermined size. However, the use of kriging has the advantage of providing the minimum value of the variance Al_2O_3 content when weighting factorsareproperly

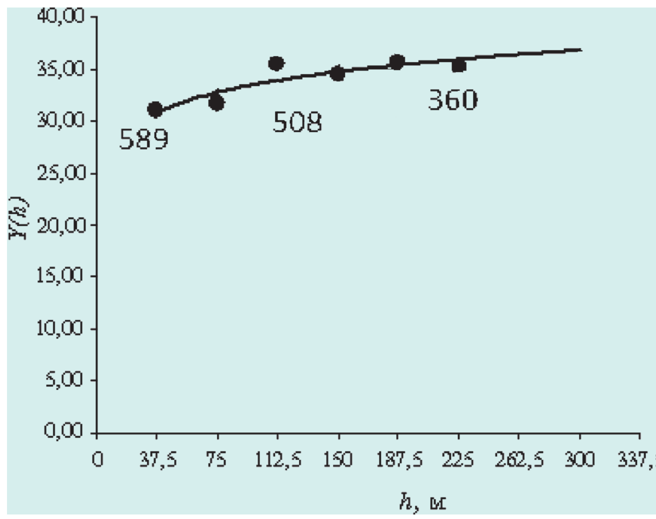

Fig. 2 shows the variogram of Al_2O_3 content on the BunduVaadearea

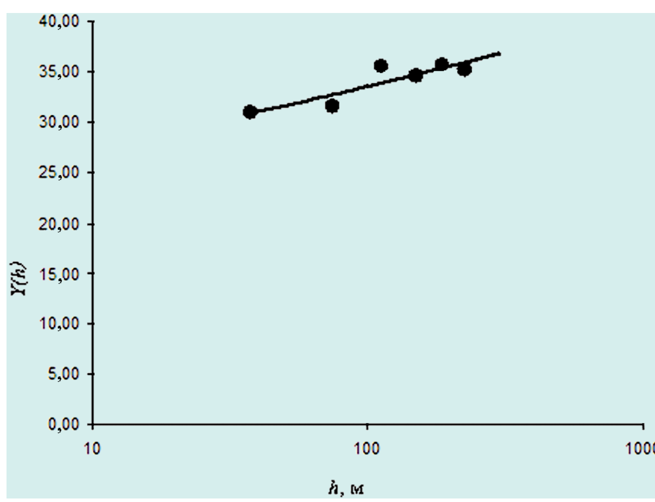

Fig. 3 shows the variogram with logarithmic horizontal scale

Table 2

Kriging results for some area of Bundu Vaade

LI NES	PROFILES								
	XV			XVI			XVII		
	1	2	3	1	2	3	1	2	3
14	48.1	50,45	-2,35	53	51,10	1,90	48,8	48,91	-0,11
13	54,7	49,35	5,35	49	47,61	1,39	34,9	45,01	-10,11
12	38,3	41,20	-2,90	45	44,07	0,93	47,9	45,38	2,52
11	38,9	38,45	0,45	39,8	40,86	-1,06	45	43,35	1,65
10	40,1	40,74	-0,64	38,6	40,86	-2,26	38,3	40,52	-2,22
9	53,3	48,99	4,31	43	45,10	-2,10	48,3	45,15	3,15
8	52	49,79	2,21	50,1	47,41	2,69	48	45,60	2,40
7	39,6	45,29	-5,69	43,8	44,66	-0,86	31,4	40,57	-9,17
6	54,8	49,28	5,52	49,7	46,21	3,49	47,6	45,59	2,01
5	52,6	48,14	4,46	29,3	43,07	-13,77	45,6	45,83	-0,23

Note. Column 1 gives the results of chemical analyzes of the core (percentage). Column 2 shows Al_2O_3 content (percentage) calculated by the method of discrete kriging, i.e. Al_2O_3 content in the given well and 8 wells closest to the given one (see Fig. 1). Column 3 shows the difference between the results of the chemical analysis of the core in the given well and kriging.

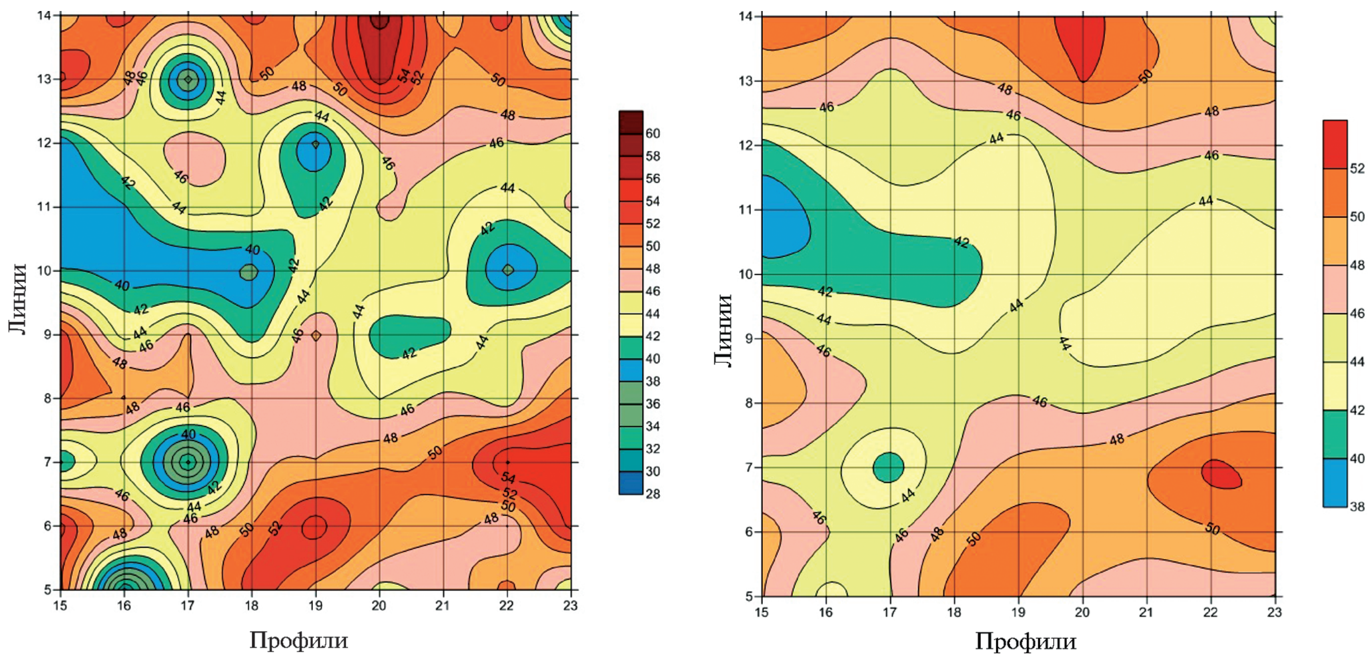

Fig. 4. 5. Presented maps of the distribution of the stocks on the BunduVaadearea
(9 profiles and lines 10—90 wells) on the results of sampling and after kriging

selected. The use of discrete kriging in these conditions allows to ensure tightly controlled amountmore reliably, i.e., not less than 48% of Al_2O_3 content in the concentrate when shipping it from the processing plant onto bulk carriers.This problem isbecoming more and more urgent as the amount of field parts being rich is decreasing.

LITERATURE

1. David M. Geostatistical methods for the evaluation of ore reserves: Trans. from English. L.: Nedra, 1980. 360 p.
2. Demyanov V.V., Saveliev E.A. Geostatistics theory and practice. M., Nauka, 2010. 327 p.
3. Kaputin Yu.E., Yezhov A.I., Henley S. Geostatistics in mining and geological practice, Apatity, Kolsky Scientific Center, 1995. 189 p.
4. Materon J. Fundamentals of geostatistics, M., Mir, 1968. 408 p.
5. Sapozhnikov D.G., Bogatyrev S.A. Types of bauxite deposits of Guinea shield // Erosion crust and hypogene mineralization. Moscow: Nauka. 1977. 188—208 p.
6. Armstrong Margaret et Carigan Jacques. Geostatistiquelineaire, Paris, 1997. 152 p.
7. Krige D.G. Geostatistics and the definition of uncertainty. Trans. Inst.Min.Metall. Vol 93, 1984. April. P. A41—A47.
8. Matheron G. Principes de la Geostatistique, Paris, 1968, 435 p.

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