A comparison between geostatistical analyses and sedimentological studies at the Hartebeestfontein gold mine

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SYNOPSIS

For life-of-mine planning, as well as for short- and-medium-term planning of grades and mine layouts, it is extremely important to have a clear understanding of the patterns followed by the distribution of gold and uranium within the mining area. This study is an attempt to reconcile the geostatistical approach to the determination of ore-shoot directions, via an analysis of the spatial distribution of gold and uranium values, with the sedimentological approach, which is based on the direct measurement of geological features.

For the routine geostatistical estimation of ore reserves, the Hartebeestfontein gold mine was divided into 11 sections. In each of these sections, the ore-shoot directions were calculated for gold and uranium from the anisotropies disclosed by geostatistical variogram analyses. This study presents a comparison of these results with those obtained from direct geological measurements of paleo-current directions.

The results suggest that geological and geostatistical studies could be of significant mutual benefit.

SAMEVATTING

Dit is met die oog op die beplanning van die lewensduur van 'n myn asook die kort- en mediumtermynbeplanning van ertsgrade en mynuitleg, uiters belangrik om 'n duidelike begrip te hê van die patrone wat die verspreiding van goud en uraan binne die myngebied volg. Hierdie studie is 'n poging om die geostatistiese benadering om die rigting van die ryk ertsstroke deur 'n ontleding van die ruimtelike verspreiding van goud- en uraanwaardes te bepaal, met die sedimentologiese benadering wat op die regstreekse meting van geologiese gesteldhede gebaseer is, te versoen.

Die Hartebeestfontein-goudmyn is met die oog op die gereelde geostatistiese beraming van die ertsreserwes in 11 seksies verdeel. In elkeen van hierdie seksies is die rigting van die ryk ertsstroke vir goud en uraan bereken aan die hand van die anisotropieë wat aan die lig gekom het deur die ontleding van geostatistiese variogramme. Hierdie studie vergelyk hierdie resultate met dié wat deur middel van regstreekse geologiese metings van paleostroomrigtings verkry is.

Die resultate toon dat geologiese en geostatistiese studies tot groot onderlinge voordeel kan strek.

Introduction

The data-base system at the Hartebeestfontein gold mine was introduced before metrication, and it records the average gold, uranium, and channel-width values for 25 ft^2 blocks on a 25 ft by 25 ft grid. On average, a block of this size contains about 2 sections of chip samples. These data are divided into mine sections, and are stored in a computer data base. The outlines of the Hartebeestfontein gold-mine sections are shown in Fig. 1. So that the statistical analyses could be based on a reasonable amount of data, the averages for the 25 ft^2 blocks were condensed into 50 ft^2 or 100 ft^2 averages, depending on the size of the section.

The geostatistical techniques used in the determination of the ore-shoot directions are based directly on the observed gold or uranium values, and have been described in detail by Krige[1].

The sedimentological approach involves the measurement, among other features, of the directions of paleo-currents within the channels that form the ore deposit. The work reported here was based on a detailed geological study of the Klerksdorp goldfield by Dr W. R. L. Minter, and on the paleo-current directions applicable to the Vaal Reef reported by Minter[2] for the Hartebeestfontein mine and adjacent areas.

Comparison of Directions

Table I gives a comparison between the paleo-current directions and the ore-shoot directions, which were obtained from the geostatistical analyses for each mine section.

The relationship between the sedimentological features and the results of the statistical analyses is shown in Figs. 2 and 3, which give the paleo-current directions, as well as the direction of the ore shoots as obtained from the semi-variogram analyses.

Gold

In Fig. 2, the paleo-current and ore-shoot directions are superimposed on a value contour plan, which was obtained by contouring (without smoothing) the average grades (in cm. g/t) of all the stoping and development sampling within 200 ft^2 blocks on a 200 ft by 200 ft grid.

West Portion of the Mine

It is clear from plan 1 that, in sections 1, 2, 3, 4, and 6, there is good agreement between the paleo-current observations, the geostatistical directions, and the directions of ore shoots indicated by the gold contours. Furthermore, it can be seen from the contours that the ore shoots are quite distinct, and this is reflected in Table I by the higher eccentricities of the ellipses fitted to the variogram anisotropies in this area.

East Portion of the Mine

Sections 11, 13, and 14 show a fairly good agreement between the geological characteristics and the statistical results. In this portion, the ore shoots are not as clearly defined as in the western part of the mine, and this is reflected by the lower eccentricities of variogram ellipses (see Table I).

Sections 12 and 19 show good agreement between the

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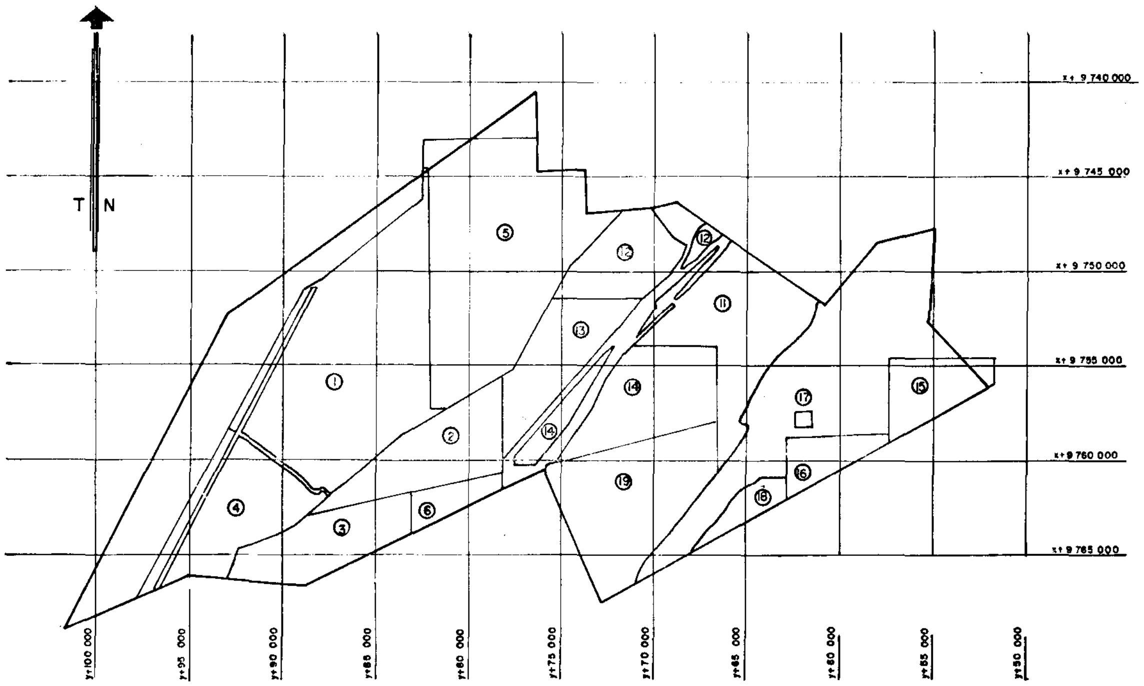


Fig. 1—Ore-reserve sections in the Hartebeestfontein gold mine

TABLE 1

A COMPARISON BETWEEN PALEO-CURRENT AND ORE-SHOOT DIRECTIONS

Section no.	Paleo-current measurements			Variogram analysis				
					Gold		Uranium	
	No. of observations	Mean direction*	Standard deviation of mean	No. of samples	Direction*	Eccentricity†	Direction*	Eccentricity†
1	1	171	—	877	157	0,57	100	0,57
2	7	161	68	4 185	202	0,67	191	0,67
3	8	144	71	7 600	188	0,67	177	0,67
4	—	—	—	1 202	180	0,67	169	0,67
6	4	191	92	657	201	0,57	231	0,84
11	4	211	57	3 757	180	0,51	—	0,00
12	5	150	57	4 330	88	0,57	151	0,57
13	6	95	17	3 159	129	0,57	80	0,67
14	8	105	26	8 732	74	0,57	94	0,63
19	2	119	6	3 365	69	0,67	120	0,57

*Direction measured in degrees clockwise from true north
†Eccentricity of ellipse fitted to the variogram anisotropy

Fig. 2—Gold contours, and paleo-current and ore-shoot directions

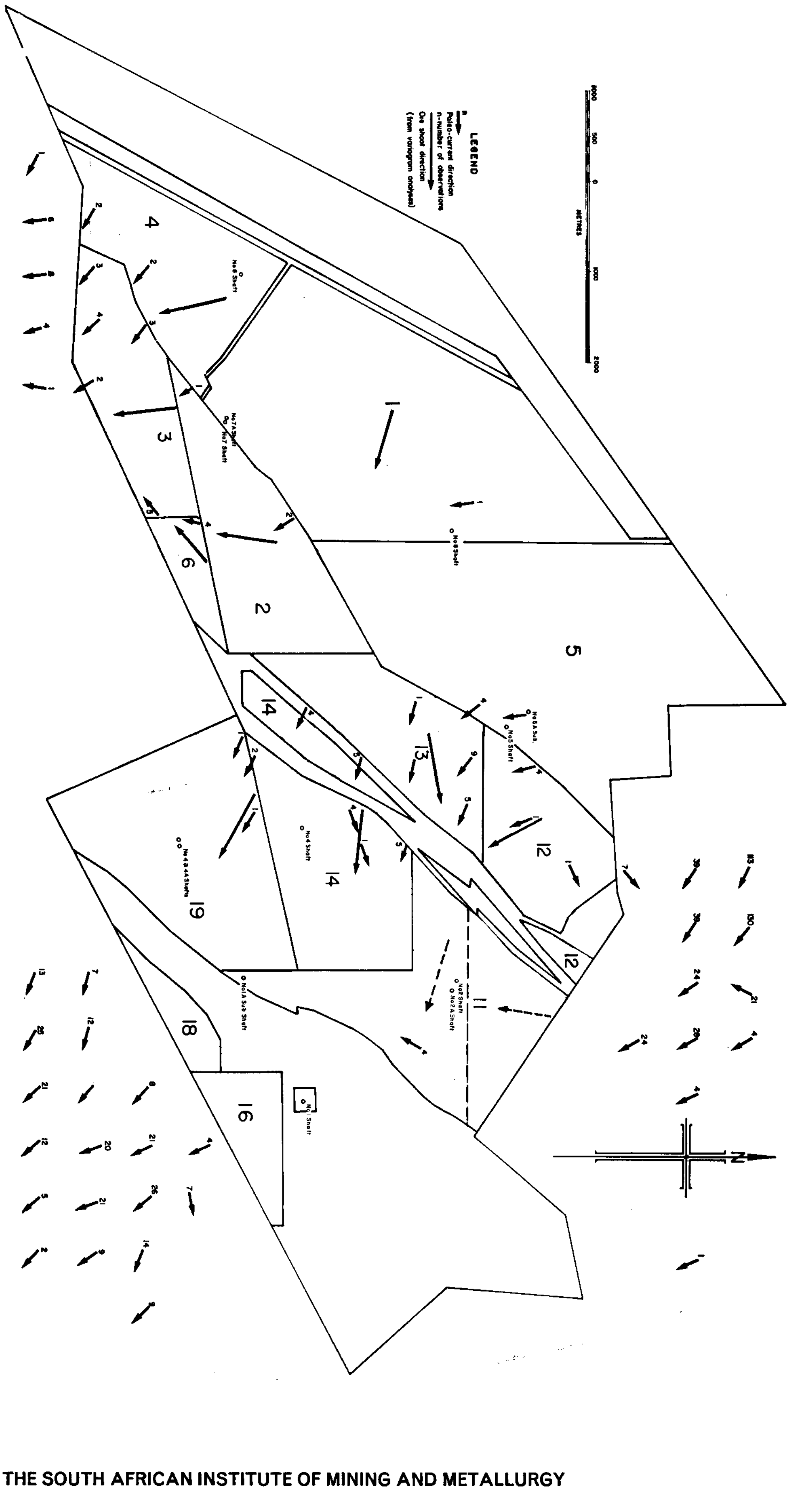


Fig. 3—Uranium contours, and paleo-current and ore-shoot directions

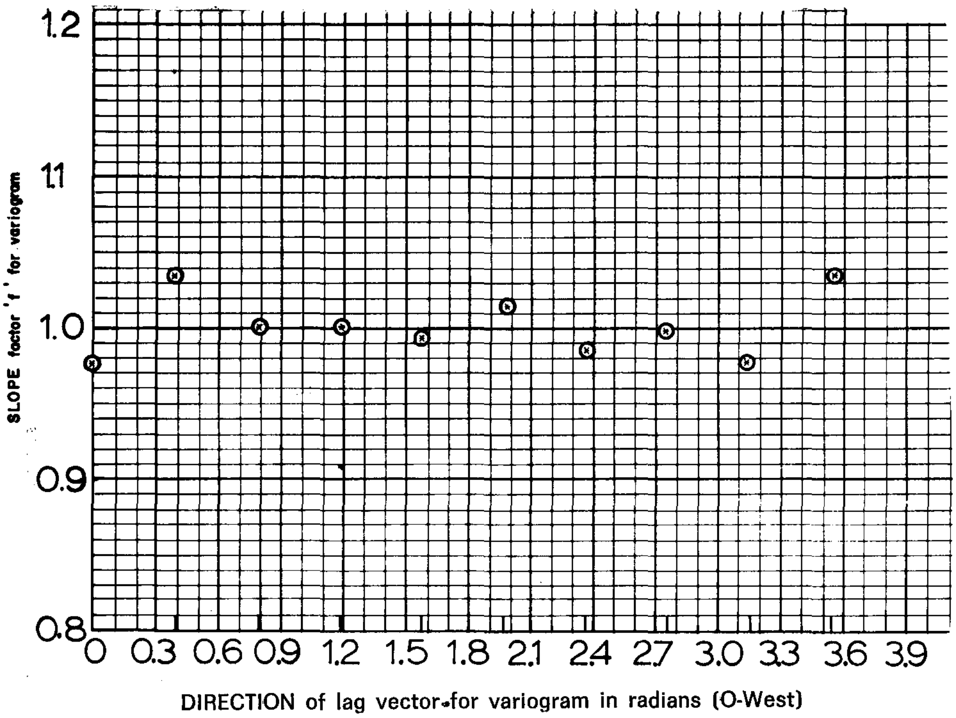


Fig. 4—U_3O_8 lag categories 1-11 in section II

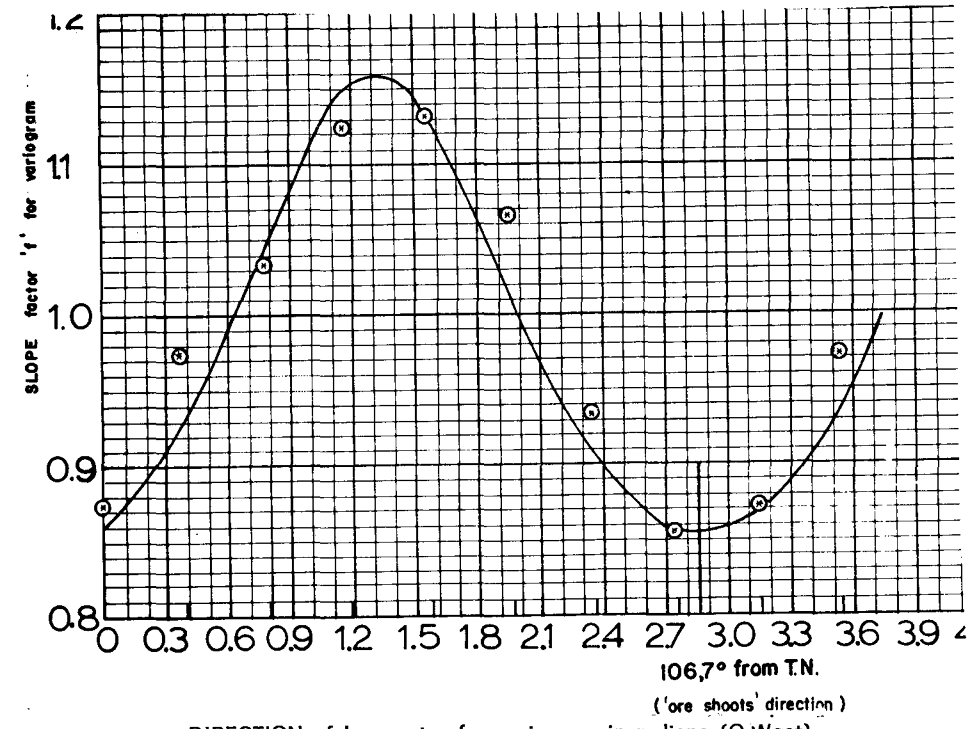
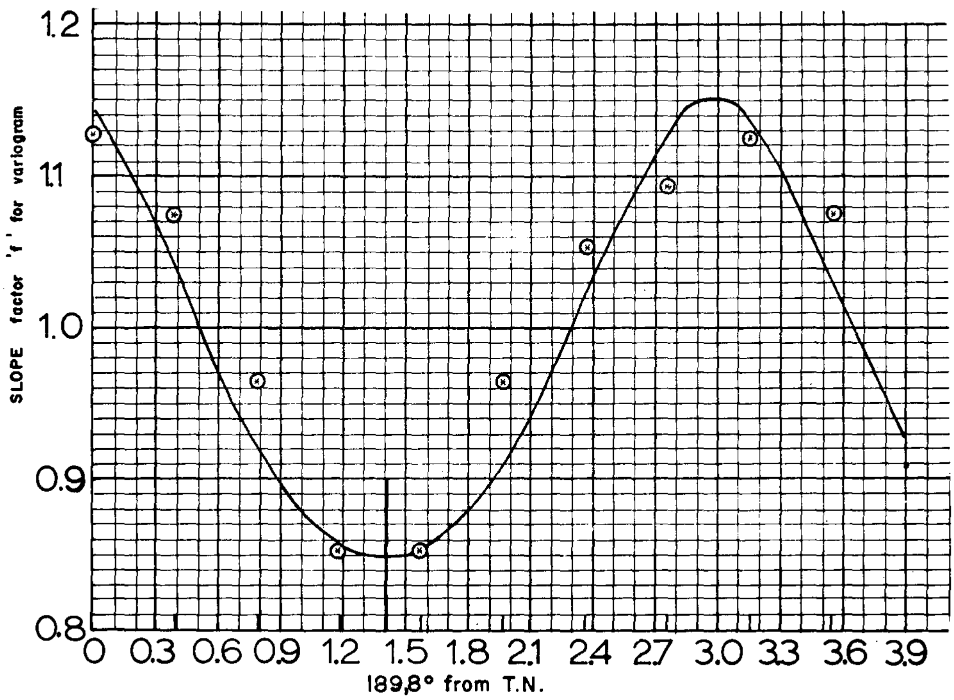


Fig. 5—U_3O_8 lag categories 1-15 in section II (south part)



DIRECTION of lag vector for variogram in radians (O-West)

Fig. 6—U_3O_8 lag categories 1-5 in section 11 (north part)

paleo-current directions and the directions of the ore shoots revealed by the contours; however, the geostatistical directions show poor agreement with these two directions. This can be attributed to the somewhat arbitrary way in which these portions of the mine were divided into sections.

Uranium

For the mine as a whole, good agreements can be seen on Fig. 3 between the geological features and the statistical analyses, with the exception of section 11, for which the variogram analysis did not show any preferential direction owing to the fact that this section contains a mixture of trends (the northern part has an approximately N–S trend while the southern portion shows an E–W trend).

This was confirmed by the subdivision of this section into a northern and a southern portion. Fig. 4, which covers the variogram fit before the section was subdivided, shows no preferential direction. Figs. 5 and 6 give the variogram fit after the subdivision, showing clearly the E–W and N–S directions of the southern and northern portions respectively, as shown by the dotted arrows in Fig. 3.

Agreement

In general, fairly good agreement was found between gold and uranium ore-shoot directions as determined by the geostatistical analyses. The discrepancy in some areas can be due to the fact that most of the gold occurs in the Vaal Reef proper, while significant concentrations of uranium can occur in the hangingwall of this reef; consequently, in such areas part of the hangingwall is mined together with the Vaal Reef, and, as pointed out by Minter[2], the hangingwall rocks have a different provenance from that of the Vaal Reef.

This effect has been studied by Krige *et al.*[3]

Conclusion

Further improvements could be obtained in the evaluation of ore reserves and the definition of ore-shoot directions through the application of geostatistical techniques if the mine were first divided into sections of more homogeneous sedimentological characteristics that were established independently in advance by paleo-current measurements. This methodology, when applied on a larger scale, could also be useful for the extrapolation of major gold and uranium trends for use in life-of-mine planning and estimates.

Acknowledgements

Grateful acknowledgement is made to the following: Dr D. G. Krige for his constant encouragement and constructive ideas, Dr W. E. L. Minter for his friendly advice and comments, Mr G. Knox for all the computer work involved in this study, and the management of the Anglo-Transvaal Consolidated Investment Company for their permission to publish this work.

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