A STATISTICAL APPROACH TO SOME BASIC MINE VALUATION PROBLEMS ON THE WITWATERSRAND

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INTRODUCTION BY THE AUTHOR

I am glad that the Society has found it possible to set aside to-night's meeting for a full discussion on mine valuation, a subject which does not always attract the attention it deserves. I would like to regard the attendance to-night as a sign that the importance of mine valuation is fully realized by our Mining Industry, and that there is a general and earnest desire to discuss and investigate any new suggestions which are aimed at improving the standard and effectiveness of our valuation procedures.

My paper has now been available in printed form for some time and I will, therefore, not delay you by discussing it in detail, but will rather confine my remarks to certain of the more important aspects raised.

To anyone who appreciates the far reaching effects of decisions constantly being based on mine sampling results, it will be evident that the major requirement in this subject is sound judgment based not only on experience but also on the best available procedures. Unfortunately, procedures differ considerably from mine to mine and too often reflect a variety of personal interpretations placed on sampling data. No wonder that Mine Valuation is generally acknowledged as a highly contentious subject.

The need for greater uniformity in valuation procedures, and for the limitation as far as possible of the personal element, cannot be disputed. The solution to this problem lies, in my opinion, in the extensive application of the powerful tool of statistics. I do not wish to imply, however, that statistics is a miracle tool with rigid procedures which can be applied indiscriminately on any mine without a proper appreciation of local conditions. On the contrary, a clear concept of the problems involved is essential, and this can emanate only from practical experience. Once the necessary spade work has been done, however, the routine application of statistics on any mine will involve only simple arithmetical calculations well within the scope of the average surveyor and sampler.

The concept, which is fundamental to the application of statistics to mine valuation, is that the arithmetic average of the sample values available round the periphery of an ore block or along a stope face, does *not* represent the actual mean gold content of the block or face, even should it be found possible to take perfect samples underground. Such an arithmetic average, in fact, only represents an estimate of the actual average gold content concerned, and at that, an estimate which, under average conditions, is subject to considerable error. The accuracy of a block or face valuation will, however, naturally increase as the number of individual sample values on which the estimate is based, becomes larger.

This aspect is of such vital consequence that I wish, even at the risk of overstressing the point, to enlarge on it by quoting the results of a sampling experiment conducted on a certain mine. A 20-foot length of reef face was sampled five times in succession at 1 foot intervals in an identical manner and without any intermediate blasting. The arithmetical averages of the 5 sets of 20 values each were 4·4, 4·9, 5·9, 6·2 and 6·3 dwts/ton over the stoping width, respectively. To illustrate the extent to which the number of available values affect the position, I have divided these 5 sets into 10 sets of 10 values each at 2 foot intervals along the 20 foot face, and these yielded the following arithmetical averages over the stoping width: 3·5, 4·4, 5·4, 5·4, 5·5, 5·7, 6·1, 6·2, 6·6 and 6·8 dwts/ton, respectively.

This striking variation in the valuation of this 20 foot face, if based on 10 individual section values only, and even where the number of available values is increased to 20, will, I hope, convince everyone present to-night that under such conditions decisions affecting grade control and the starting and stopping of stope faces, should be based only on a sufficient number of available sample sections.

It is for this reason that stope valuations based on the usual small number of sample sections, will in general be unreliable and why I was led to suggest for serious consideration, the possible curtailment of stope sampling and the placing of more reliance on block valuations, where these are to be based in each case on a sufficient number of sample sections.

How large this number of sections should be under average conditions in order to confine block valuation errors to within any specified limits, is indicated in the paper on the basis of current procedures and on random sampling theory. The extent to which the position is improved on account of the fact that the underground sampling is done systemmatically and not in a random fashion, presents a problem for further research, but the overall position is not expected to be materially different from that indicated in the paper.

There is, however, a further and even more important contribution which statistics can make towards mine valuation, that is, the development of more efficient procedures for estimating the true average block values from the available individual values.

In the case of most engineering measurements the customary arithmetic average of the observations provides a suitable and relatively accurate estimate. In mine valuation, however, the extent of the variation between individual values is very large and accounts for the inaccuracy of a valuation if based on a small number of individual values. But apart from the large variation between individual gold values, we find that they form a distinctly skew type of frequency distribution. It is largely due to this fact that in the case of gold values, the arithmetical mean does not present the most efficient and accurate estimate which can be obtained from the available data.

The statistical procedures recommended in my paper will, however, yield estimates subject to considerably reduced errors as compared with the customary estimates made from the arithmetic mean, and are rendered possible by the fact that the lognormal curve provides a suitable model for representing the skew frequency distributions of gold values. This type of curve has so far been found to fit the distributions of gold values from several reefs on a number of Witwatersrand mines. Departures from this pattern have, however, been observed; for example, on the East Rand where marked shoot conditions often give rise to a bimodal type of distribution, that is, a curve with two peaks instead of the customary one. I feel that it will be possible, even in such a case, to observe the suggested procedures by regarding the bimodal distribution as a combination of two separate lognormal distributions corresponding geographically to the ore shoots and the more or less barren areas, respectively.

The suggested statistical estimation procedures make better use of the available data as compared with current methods, do away with the undesirable practice of cutting high values, and are *not* as complicated as they may appear at first glance. These procedures, therefore, commend themselves and should not be dismissed as impracticable merely on general grounds.

In conclusion, I wish to draw attention to a few minor errors which unfortunately escaped notice during the preparations for publication. These will be published with to-night's discussion.

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ERRATA.

Page 126 : Footnote :—σ should read σ^2.

Page 129: Footnote:—σ_b should read $\sigma_b{}^2$.
σ_i should read $\sigma_i{}^2$.

Page 137 : Table between formulae (13) and (14) :—σ should read σ^2.

Page 138 : Formula (17) :—Delete σ^2 in second factor and add after the formula ' the unbiased estimator being

$$\exp\left[\bar{x} - \frac{\sigma^2}{2n}\right]\text{'}$$

Line above formula (18) :—Delete (17) and substitute $\left[\exp\left(\frac{\sigma^2}{n}\right)-1\right]\left[\exp(2\xi+\sigma^2)\right]$

2nd line below formula (18a) :—σ should read σ^2.

Formula (19) :—σ_p, σ_s and σ_m should read $\sigma_p{}^2$, $\sigma_s{}^2$ and $\sigma_m{}^2$, respectively.

Page 139 : 1st line :—x should read $\bar{x}$.