Stockpile sampling: In your dreams only?

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Although Gy's numerical models in Theory of Sampling (TOS) explicitly include a demonstration of the segregation term in the overall sample variance, it was never used much, as segregation was considered transient. Separately and independently, Visman was faced with the obligation to work out that term and offer experimental procedures in the case of a lot that could not be altered much, such as the contents of a shipping boat or a large ore stockpile. But a general use of it raises issues: what are the limitations of the method, and how to handle the often impracticably large optimised increment size and sample mass in the presence of extremely large granulometries? It is shown how merging Gy's TOS, Visman's theory and size fraction assays can resolve these issues quite well.

INTRODUCTION

In the 1950s, in North Africa a French chemical engineer Pierre Gy was given the task of finding out how to sample a very large stockpile (nowadays a 3-D pile) for grading. Because he could not find a standard method in the technical literature and realising that there was no complete and directly applicable theory of sampling, he single-handedly devised what we now call Theory of Sampling (TOS) (Gy, 1982). Once the theory was developed, the answer came: a 3-D stockpile cannot be sampled in a representative manner.

VISMAN TO THE RESCUE

Concurrently, a Dutch statistician who immigrated to Canada, Jan Visman, played a key role in building a bridge between sampling theory with its homogeneous populations and sampling practice with its heterogeneous sampling units and sample spaces. Independently from Gy's TOS, but as a particular case of it as was later demonstrated, he built an elegant theory of only a few pages, that formed the basis of the Canadian sampling standards for shiploads of ore (Visman, 1962, 1969). Unlike the most usual applications of TOS, which assume absence - or cancellation - of the effects of segregation, his method, known as Visman's method, takes segregation into account. Indeed when sampling a shipload of ore with no possibility of altering it in any way, a method had to be found for controlling its sampling precision, or at least the accessible part of it. Visman provided the method and the sampling total relative variance formula to do so:

$$S_R^2 = A / M_S + B / N_G \qquad (1)$$

where A and B are constants for a given pile, M_S is the total mass of the complete sample collected in the form of N_G random increments. The first term, A/M_S is the one calculated by TOS assuming no segregation, while the second one, B/N_G, includes the effects of whatever segregation is present. For reference, note that these two terms could be calculated by geostatistics, should the increments be given coordinates (which is not our case). The first term would then come from the 'nugget' part of the variogram - which measures randomness, while the second term would come from the non-nugget component - which measures correlations, i.e. in this case, the unknown geometry of segregation.

As a result, when faced with the problem of sampling a potentially segregated stockpile of ore, Visman's method can be used efficiently, but the control is only valid for the accessible part of the pile.

VISMAN'S METHOD IMPLEMENTATION

To control the sampling of the accessible pile material (or of the entire pile if one accepts the assumption the inner part segregation is of the same nature), it suffices to calibrate sampling constants A and B in Equation (1). Constant A can be separately derived from a heterogeneity study if available, and in any case B, or A and B, can be derived from one, or respectively two, series of samples by solving a linear system of at most two equations based on (1).

After calibration, at the optimum the two terms of (1) are equal, which defines the optimal increment mass M_S/N_G as A/B. The number of increments N_G can then be chosen to achieve the desired total sampling variance $S_R^2 = 2B/N_G$.

Simple, isn't it? Or is it?

A REMAINING SERIOUS ISSUE

In an example of gold treated recently by the author (as well as in several before), underground mined material was brought to the surface in piles of 20-25t and grab sampled. 12 kg were collected in various increments. The procedure consisted of a (questionable) visual estimation of the proportions of coarse (C, >30cm), fine (F, <5cm), and medium (M) in between. Then each of these 'size classes' was grab sampled (using an electrical hammer where needed to break large blocks) and assembled into a unique ~12 kg primary pile sample with respect to these estimated proportions. The division process that then followed was complicated and even more time-consuming. Duplicates of these samples showed an unacceptable average precision of 41% – measured as one relative standard deviation (RSD). The only redeeming grace was that the samples were later found not to be likely biased.

The optimisation using the Visman method resulted in the need to take 12 increments for a total mass of 16 kg to get to a much better precision of 20% (one RSD validated on actual duplicate samples). However it was clear that the ~1.3kg increments could not represent the actual size distribution in the piles, which included blocks of more than 30 cm and up to 1 m in diameter. In other treated cases, the optimal increment mass was simply too large to be practical. So a serious issue remains, even after the Visman optimisation, for the actual sample collection.

SIZE FRACTION ASSAYING SOLUTION

Searching for a possible solution to this situation, a useful complement to pile sampling procedures was found in size fraction assaying and in a simple theoretical observation.

Indeed, if we consider a continuous function on an interval and its average value over that interval (the curve and horizontal line on Figure 1), the curve will necessarily cut the average value line in at least one point (on the particular figure, two). Around every such point, an infinity of intervals can be defined over which the function will have an average value equal to its overall average value. Each of these intervals represents a very particular truncation of the entire interval. A few are shown on the figure.

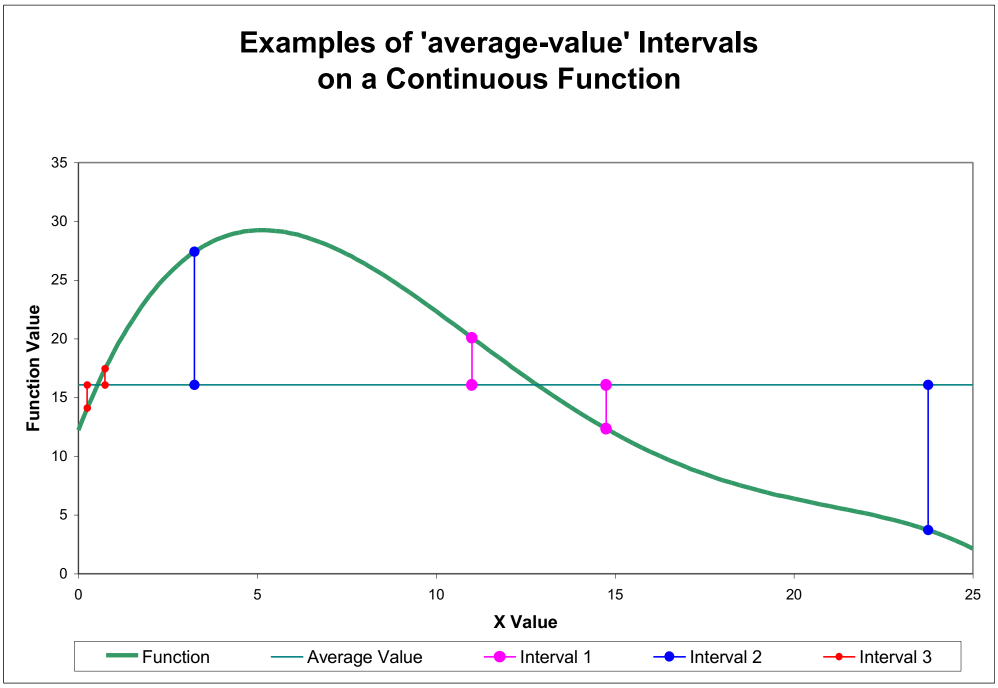

Figure 1. Theoretical principle.

If we now consider as a function the size fraction assays of a given pile to be sampled, the above theoretical consideration suggests that there may exist one or more truncations of the size range over which the average material grade would reasonably approach the overall grade of the pile. There is no guarantee this will always happen, but so far, a reasonable truncation was always found that would allow for a good estimation of the entire pile grade, tested on 25 to 40 test piles, or one with a reasonably constant bias that could be corrected using regression techniques. Figure 2 shows a summary over 27 piles for the treated example introduced above (an enormous piece of experimental work). Every single pile gave similar individual results.

In that particular case, 12 kg grab samples of minus 10 cm material collected in 12 increments around the pile gave a much simpler and fast, demonstrably unbiased sampling with an improved experimental precision of 21% (one RSD). The minus 10 cm samples harboured a very small experimental bias while the strict 0.5 cm-10 cm truncation did not (Figure 3). In practise, taking the sample with no particular effort to representatively collect fine material worked in the same way as the theoretical 0.5 cm-10 cm truncation.

CONCLUSION

The precision and time-consuming benefits of optimising this interesting pile sampling problem largely paid back for the tedious, enormous task of obtaining size fraction assays for 27 22-tonne piles with up to 1 m blocks.

Over the last 20 years, the author had previously obtained similarly beneficial results using all these methods together in cases ranging from the control of ore screen-upgrading experiments to large stockpiles or underground draw-points sampling optimisation.

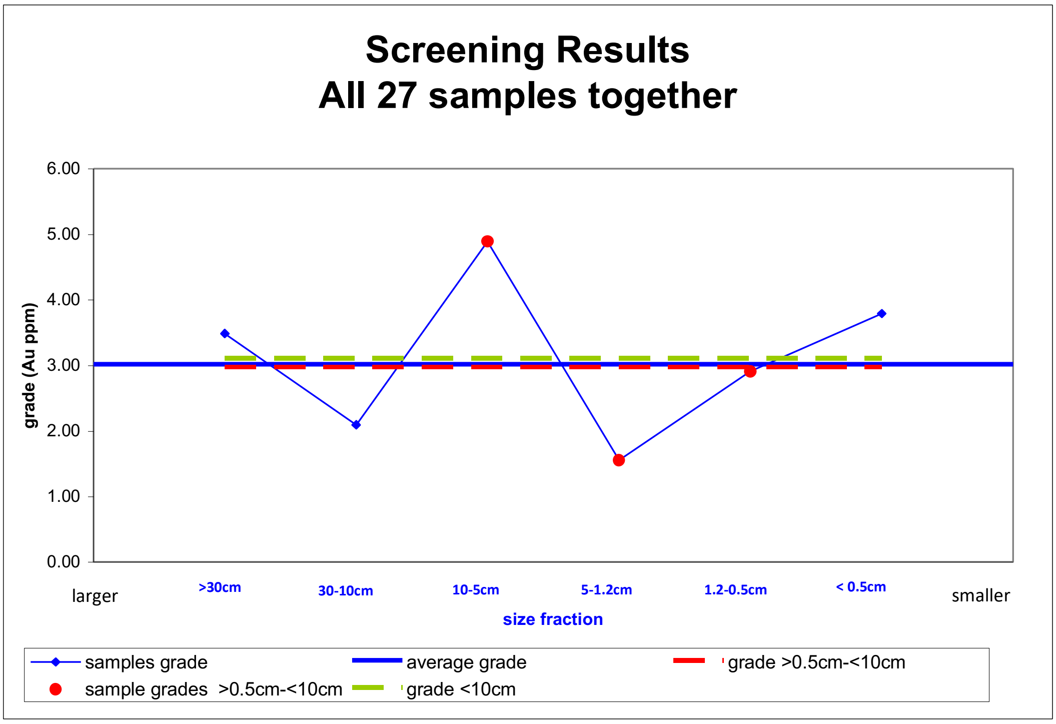

Figure 2. Truncated size fraction assaying.

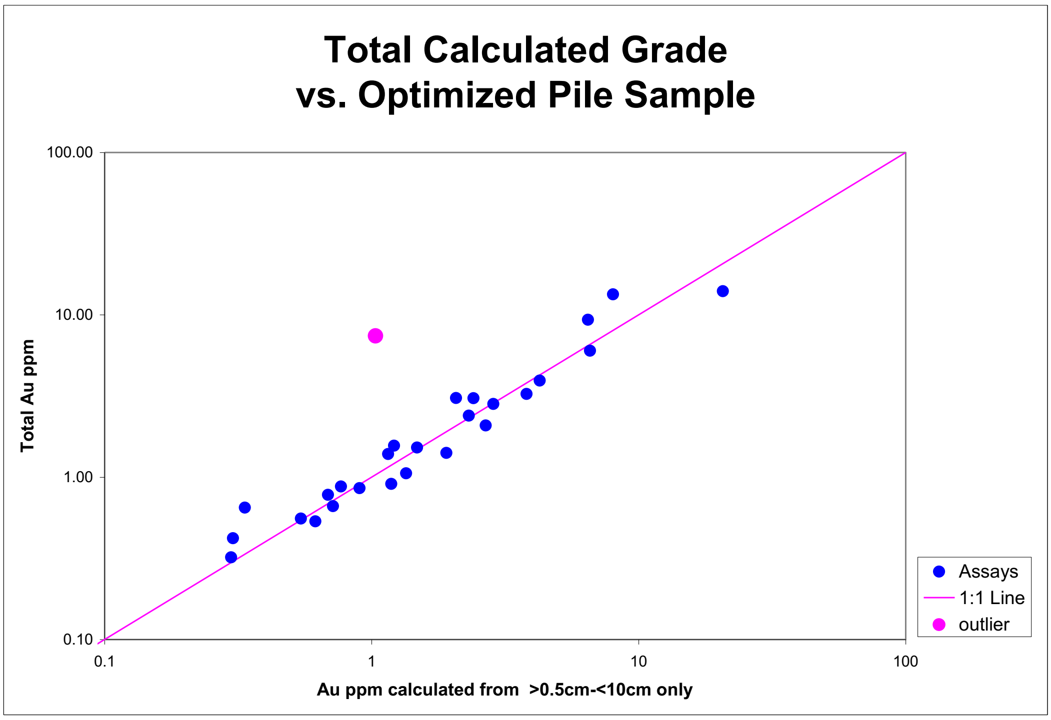

Figure 3. Strict Truncation Results

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In 1992, embarked on a career long research in Gy's theory of sampling, and worked with Pierre Gy as a consultant and on training courses. He then contributed to the onset of the WCSB cycle of conferences and in 2009, he was the recipient