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The use of equant grain particles to validate analytical sample size in gold deposits – A case study

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ABSTRACT

The quest to sample and quantify a gold deposit depends on the ability to collect a representative sample and then maintain the lot's constitution throughout all sampling steps. Differences in ore type, grade, gold size, distribution, liberation and association are some variables which implies differences in procedures from one deposit to another. In a low-grade nugget environment, the final analysis depends more on the chance occurrence of a particle in the analytical aliquot rather than the actual concentration in the ore. A commonly used 30 g fire assay could result in bad exploration decisions and create a highly skewed database. The concept of equant grains simplifies particle size and distribution, and works with a uniform particle that represents the total content divided by the number of grains necessary to attain a certain precision. In this paper, we test this hypothesis in which 20 and 10 equant grains are used to simulate the grade values of six different analytical samples sizes, representing the smoky quartz of Lamego Mine. The results confirm that a 30 g final aliquot does not represent the rock and a 500 or 1000 g analytical sample is required to be assayed.

1. Introduction

Lode-gold deposits are known for having a strongly skewed grade distribution and a high nugget effect [1]. The nature of these deposits reflects the unique settings for the origin of a rich fluid, precipitation or remobilization [2]. Beyond the intrinsic complexity, gold sampling introduces new sources of variance, which can create misunderstanding and misinterpretation of the data [3].

By definition, a sample should represent the batch composition as closely as possible, by maintaining a constant ratio of the particles of interest in the parent throughout the entire sampling and sub-sampling process [4]. This task becomes challenging when the content of the mineral of interest drops under 1%, as is the case for gold.

A Poisson distribution is a limiting case for a binomial distribution, where the constituent of interest resides in low-frequency grains [5]. Its probability function can be described as:

$$P_n = \frac{e^{-Z} \cdot Z^n}{n!} \tag{1}$$

where Z is the average number of grains in a w-gram sample and P_n is the probability that n grains will appear in the sample. For a lot of known constitution, where in every 1000 g ($w = 1000\ g$) is one grain of interest, $Z = 1$. However, for the same lot, if $w = 250\ g$, $Z = 250/1000 = 0.25$. The probability value is rooted in the ability to represent the lot in the final stage of sampling. A shift from a Poisson to normal distribution is possible by increasing the number of gold particles to at least six in the sample. This is often implemented by using a larger analyte mass [3,6].

A larger analyte mass, collected using good sampling practices, improves probabilities of occurrence of particles and reduces variability. The limiting case is where everything is sampled and the unknown value is defined, as shown in Fig. 1.

For each sample, not only does the mass have an impact on grade variability, so does a series of other sampling errors, first discussed by Pierre Gy [4]. It is advisable to understand the mitigation of these errors and definition of optimum sample mass, which are beyond the scope of this paper. Papers by Gy [4], Pitard [7] and François-Bongarçon [8], are some literature in which the reader is referred for additional information.

Gold can be found in different sizes, forms and association through nature. A specific and challenging type of gold deposit is with free nuggetty gold. As noted by Pitard [7], any free gold deposit can be divided into two categories: a low grade, also called background, where gold is ultra-fine and sub-microscopic, and a high grade, associated with coarser grains, which accounts for most of the metal content. On this setting,

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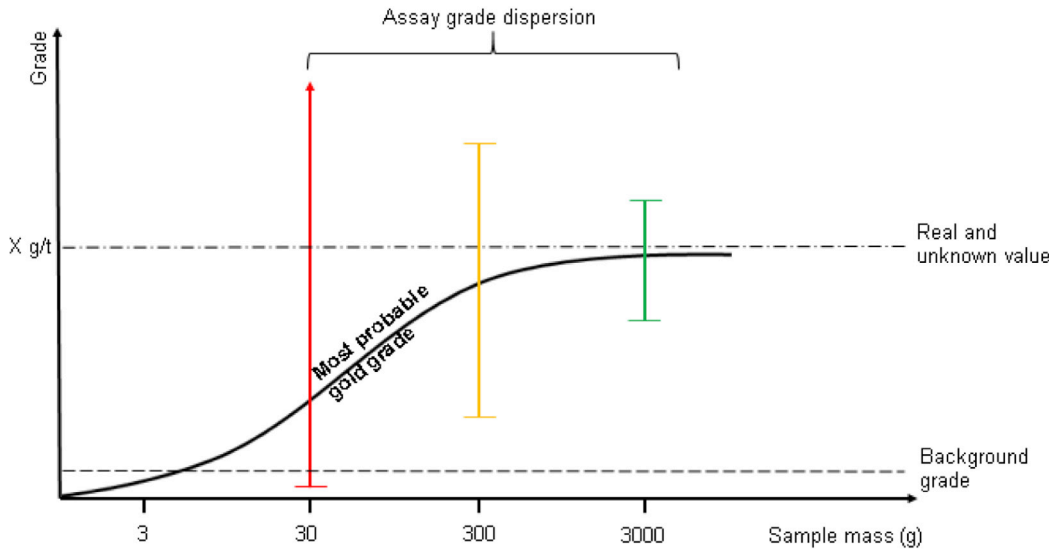

Font – modified Pitard [3]

Fig. 1. Grade distribution and most probable grade based on analytical mass.

studies based on Gy's Sampling Theory will focus on this coarser fraction. In addition, the controversy liberation factor is calculated disregarding the fine fraction of gold [7].

1.1. Equant grains

The concept of 'equant grains' is broadly used to correlate skewed data to nugget effects and sampling error [5,6,9]. Its use is effective to provide guidelines for sampling, although several important assumptions are made to simplify calculations. These assumption take part on interpretation, therefore they will be thoroughly explained for the reader's complete understanding.

The first assumption is that gold variability is random with no systematic variation across the ore body. This ideal is unreal to a certain extent, since gold is concentrated in specific geological features (distinct layers, hinge zones of folds, veins or faults). By dividing the deposit or domaining it in similar styles or mineralizations, this risk could be reduced [9].

Second, the sample is treated as a binary composition of two mineral, gold and gangue. Gold can be found associated or in contact with many minerals and rarely it would be in a setting with only one gangue mineral. Sulphides, silicates, micas and carbonates are a few common ones, with a diverse spectrum of specific gravity and concentrations [10]. A realistic assumption is to use a composition of gold and the most abundant gangue mineral, quartz.

Third, gold particles are assumed to be of uniform mass, not necessarily the same shape and gangue minerals have uniform mass, but not the same as gold particles. This ground rule cascade through different steps: definition of precision of the assays, directly associated with the number of particles; sample weight requirement to guarantee the defined number of particles; and estimation of the equant grain size [9].

The statistical analysis is simplified by a couple assumptions. If the number of particles in the sample is greater than 10^3 (i.e. a lot of 1000 particles of quartz with 800 μm in diameter, yields approximately 0.7 g) and deposit's grade is below 0.001, as usual for gold deposits, the following equation based on a binomial distribution can be resumed to:

$$E_C^{\pm} = X^{-1/2}\left[\frac{Z_{1-1/2\alpha}^2}{2}\cdot X^{-1/2} \pm Z_{1-1/2\alpha}\right] \tag{2}$$

Where E_C^- and E_C^+ are the negative and positive errors at a confidence limit, $-Z_{1-1/2\alpha}$ and $+Z_{1-1/2\alpha}$, which are read from a table of cumulative normal distribution and X is the number of gold particles. Being the expected relative error `at a given percent confidence a function of only one variable, the number of gold particles in a sample, independent of grade. As the example given by Clifton [9], for 20 particles in the sample, with a 95% confidence level, the expected relative errors are:

$$E_{95}^- = 20^{-1/2}\left[1.921\cdot 20^{-1/2} - 1.960\right] = -0.34 \tag{3}$$

$$E_{95}^+ = 20^{-1/2}\left[1.921\cdot 20^{-1/2} + 1.960\right] = 0.54 \tag{4}$$

As noted, a higher precision will require more gold grains in the sample. Based on the number of gold particles, the following step is to determine the mass in which is more likely to contain it.

The number of gold particles per weight depends on the grade, grain size and its size distribution. The later is a source of error, especially because gold particles are not restricted to a narrow range of size. This issue is diminished by assuming that gold particles have uniform mass larger than the average mass per gold particle in the sample. By definition, average mass per gold particle means the total mass of gold in the sample divided by the number of gold particles on it [9].

On Fig. 2, the relationship between gold grain size and distribution is highlighted using an example of four different hypothetical deposits yielding the same grade.

After all simplifications and assumptions, the equant grain size will be chosen from the total mass of gold in the sample, a direct correlation between sample mass and average grade, and the number of gold particles necessary for the required precision. For example, a sample with one kilogram and gold grade of 7.18 g/t, has a total gold mass of 0.00718 grams. This gold mass can be represented by a diverse range of particle sizes related to the required precision (Table 1).

The equant grain approach, assuming that gold is in a unique size as large or larger than the coarsest, and the sum of all particles yields the total gold content in the sample, can be used as a safe guide to obtain adequate sample size and a representative sample [9]. Thus, it allows one to test the effects of nuggets in final aliquots of diverse masses.

The foundation of the equant grains approach relies on a binomial distribution, where the number of gold particles is more than 5 ($Z = 5$). Since this fact is directly associated with sample mass, it cannot represent low mass samples where there is not enough particles, especially low-grade deposits with coarse grains. However, based on a deposit's historical data, average grade and particle characteristics, one could