Illusory reconciliation: compensation of manual sampling errors

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In the mining industry, reconciliation can be defined as the practice of comparing the tonnage and average grade of ore predicted by the geological models with the tonnage and grade generated by the processing or metallurgical plant. This practice is of increasing importance, since, if correctly executed, it allows the reliability of short-term planning to be improved and the mining and processing operations to be optimised. However, the usefulness of reconciliation relies strongly on the quality of the input data, which is generated by many different sampling methods across the industry. In fact, successful reconciliation can be *illusory*—errors generated at one point of the process can be offset by errors generated at other points, resulting in *apparently* excellent reconciliation. Such a situation will in fact also hide compensating biases in the system that will, unavoidably, surface some other day. When this happens, sampling errors are masked and may lead to an erroneous appreciation of the reconciliation system as a whole, which results in serious consequences for the mine operation, especially when reaching poorer or more heterogeneous areas of the deposit. Since valid estimation is only possible with TOS-correct sampling practices, the reliability of reconciliation results depends critically on the representativeness of the samples that generated them. This contribution a summary of an analysis of the manual sampling practices carried out at a copper and gold mine in Goias, and proposes a more reliable sampling method for reconciliation purposes. Results show that the apparently excellent reconciliation between the mine and the plant was in fact illusory; here a consequence of accidental compensation of many errors due to sampling practices for short-term planning.

Methodology

Sampling at Maraca mine

The data required to perform the undertaking reported in this work was collected during an extensive sampling campaign conducted on February of 2011 at Maraca mine in Goias, central-west of Brazil.

Short-term sampling performed at Maraca is *manual* and uses particulate material (chips) from the Furukawa model HCR1500 drill rig, which generates two products: one of fine material (back discharge) and the other of medium and coarse material (front discharge). From the front discharge pile, 12 increments are taken in radial directions, and from the back pile one increment is taken, in total generating a 13 increments composite sample.

Block sampling campaign and sampling preparation procedures

The main sampling grid of the block sampling campaign had a 10×10m size and all holes in the sampling grid were drilled with 5m depth, except the central hole with 10m depth. As presented in the following, four lithological domains were studied, with a focus on the ANX (amphibole shale), the most complex and diverse in the deposit, i.e. the critical lithological domain.

The sampling campaign was performed with two different drilling rigs, Atlas Copco L8 ROC and Furukawa HCR 1500, in order to evaluate the sampling performance of each, which employs different drill diameters. The ROC L8, drilling with a larger diameter and, consequently, resulting in larger sample masses, was *a priori* expected to generate more representative samples. The ROC L8 was used to drill the central hole; the other holes were drilled by the Furukawa. The central holes had 10m depth and were sampled every 2.5m. In the ANX domain, an extra twin hole was diamond drilled next to the ROC L8 and the Furukawa holes (and the cores analysed every 2.5m) in order to evaluate the sampling error related to the two different drillers.

After selecting the area to be sampled, the survey department marked out the hole, and each hole generated two samples, A and B. The first sample (Sample A) was collected using the standard procedure of manual sampling with a shovel, Figure 1.

Figure 1. Shovel used for manual sampling.

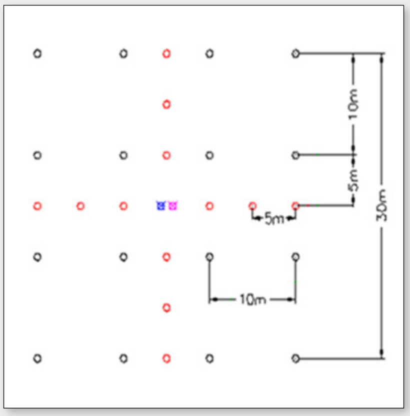

Figure 2. Sampling grid for the campaign.

After collecting Sample A (about 10 kg), *all* the remaining material (approximately 190 kg of medium, coarse and fine material) was collected, mixed well ("homogenised") and split using a proper riffle splitter to form Sample B. All samples were bagged and identified, subsequently passing through exactly the same process in the laboratory.

Sample preparation comprised crushing the 10–20 kg samples so that 95%

Figure 3. Atlas Copco ROC L8 drill rig.

passing 2 mm, then splitting and pulverising the 400 g sub-samples, 95% passing 150 # (or 105 µm). Next, 150 g of the pulverised material was selected and sent to the chemical laboratory for gold, copper, sulphur and iron analysis. To determine the gold content, the standard fire assay technique was performed.

It is important to emphasise that, in order to prevent contamination and to optimise the material recovery, before starting the drill hole, the area around each hole was cleaned, especially removing all coarse material with a hoe. In this type of sampling, the most significant problem is the loss of fines. To minimise this problem, the area around each hole was covered with a canvas big enough to collect all the material recovered by the drill rig.

Summary of results and discussion

The four lithological domains studied were: (1) GNS (gneiss): stone grey, brittle, coarse grained, schist, composed mainly of biotite and feldspar; (2) BTO (biotite schist) rock dark grey, medium to coarse, with pronounced foliation, composed of biotite, feldspar and quartz; (3) QSRT/GNS (quartz sericite schist/gneiss): rock of greyish white, medium to coarse, schist, with quartz, sericite, biotite and feldspar; (4) ANX (amphibole shale): grained rock with schistosity undeveloped comprising amphibole crystals (60%) of green, oriented in the matrix formed by quartz and feldspar. The relative errors below refer to the differences generated by collecting the 13 increment composite sample (Sample A) in relation to the more representative Sample B (reference

Figure 4. Furukawa drill rig.

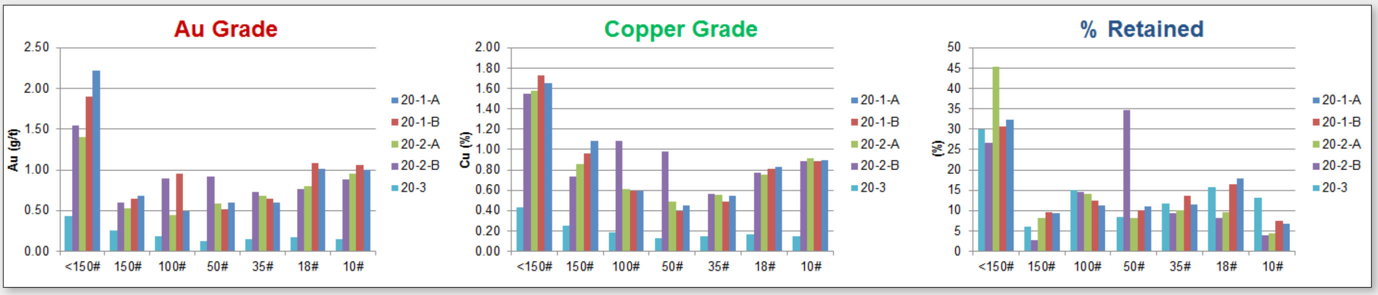

Figure 5. Gold and copper content by particle size fraction and percentage retained by particle size fraction. A and B samples as described in text. According to the Maraca Mine field sampling team, sample 20-3 originates from a part of the experimental block with distinctly lower ore grades, emphasising large fluctuations in the different regions of the block studied; sample 20-3 is therefore not immediately comparable to samples 20-1 and 20-2.

sample). Mean elative errors were: GNS—0.29%, BTO—4.71%, QSRT/GNS—3.59%, ANX—7.69%. Standard deviation (relative errors) were: GNS 43.36%, BTO 20.33%, QSRT/GNS 18.76%, ANX 10.07%.

Based on the results, the following comments can be made: (1) with the exception of the ANX domain, there is no significant systematic error (bias) between Sample A and Sample B, since the average error only varies from –0.29% to –4.71%; this means that the Samples A are practically identical to the B samples; (2) in the case of ANX domain, there is a significant bias (–7.69%) between Sample A and Sample B; this result means that, for this domain, the 13 increment *manual* samples are not accurate, presenting values 7.69% lower than the values of the reference samples; and (3) it can be noted that, for all domains, the average sampling error is negative, which means that the sample collected by the manual shovel tends to underestimate the real gold content of the material recovered by the drill rig.

The ANX domain

The ANX geological domain is comprised of weak schistose and medium grained green amphibole-quartz-feldspar rock. This domain is considered the most complex and heterogeneous of the deposit and this reason led the authors to select this domain for a special experiment using a diamond drill. Samples of 2.5 m were generated by the Furukawa, the ROC L8 and the diamond drill rig on the ANX domain. The holes were made close to each other and the drill was used as a reference to analyse the results.

Results show that both the Furukawa and the ROC L8 *overestimate* the gold and copper grades when considering the diamond drill samples as references. The Furukawa overestimates the gold grade at 75.5% and the copper grade at 32.4% (relative deviations); the ROC L8 overestimates the gold grade at 34.8% and the copper grade at 14.2%.

Conclusions

These empirical results demonstrate that a successful reconciliation can in fact be illusory. In this case study, errors introduced by manual sampling using a shovel were compensated by errors introduced by the supposedly superior drill rigs used for reference sampling. The manual 13 increments composite samples tend to *underestimate* the grades of the hole, especially in the case of gold, while the drill rig results tend to *overestimate* the grades of the hole, resulting in apparent satisfactory, but artificial reconciliations.

The manual sampling procedure in Maraca mine is therefore unsuitable for reconciliation purposes. The economic impacts of this incorrect procedure cannot be understated, because the errors inherent to the sampling process are, in this case, masked, which may well result in erroneous appreciation of the mine operation performance, especially when mining reaches poorer or more heterogeneous regions of the deposit.

It was observed that estimation errors due to the composite sampling are not as large as the errors due to the type of drill rig used. To minimise this problem, it is recommended to employ automated sampling systems with reverse circulation, which has several advantages that can far outweigh their capital outlay costs. According to Pitard,[1] some of these advantages are: (1) absence of sub-drill, avoiding the delimitation error; (2) possibility to drill several benches at the same time; (3) possibility to drill at a chosen angle; (4) minimisation of contamination and losses; (5) ability to drill into benches away from blasting; (6) sampling does not interfere in the production; (7) more precise and accurate grade control. Among the disadvantages of introducing an automated sampling system, the extra cost will always be noted by mining management and financial officers, as will the increase mine traffic involved.

Such a system was recently implemented in the Maraca mine and promptly proved to generate more precise, more accurate and, therefore, more fit-for-purpose samples, ensuring significantly increased reliability on the reconciliation results.

This study demonstrates the critical importance of sampling representativeness in all of mine the reconciliation undertakings.

Reference

1. F.F. Pitard, "Blasthole sampling for grade control—the many problems and solutions", in *Sampling 2008.* AusIMM Publication series No 4/2008, 27–29 May 2008, Perth, p. 15–22 (2008). ISBN 978-1-920806-81-1

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