Photon Assay: A New, Revolutionary Technique Everybody Wants to See Succeed – An Independent Evaluation Part 1: Experimental Bias Detection and Synthetic Sample Simulations

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ABSTRACT

Photon Assay (CPA), a gamma-ray excitation technique marketed by Chrysos for rapid, non-destructive gold determination on ~450 g samples, has attracted strong interest in the mining industry for its speed and grade-control potential. Early, anonymous reports and comparative tests at nine anonymous gold deposits suggested systematic biases: crushed-material CPA readings were frequently lower than paired pulverized readings and differed from fire assays to extinction by 4–8%, though experimental designs were not always optimal.

To isolate effects attributable to sample preparation, controlled synthetic samples were prepared by spiking barren rock with ≥99.99% pure gold fragments of known mass and size. Four combinations of coarse/fine gold and coarse/fine barren matrix were tested under the standard PAAU02 service, with ten replicate analyses per jar. Student's t-tests (95% confidence) revealed statistically significant negative biases in three of the four cases, except for fine gold in a finely pulverized matrix. Coarse-gold samples also showed unexpectedly higher measurement variance, consistent with positional redistribution within the jar.

These findings confirm the importance of full pulverization prior to CPA and demonstrate the need for rigorous, site-specific validation before adoption. Further mechanistic studies are recommended.

1. Introduction and Marketing Overview

In the times of the gold rushes, the classical preparation for gold assays was as follows: jaw crushing; splitting of 500g; pulverizing; assaying 30g by fire assaying. The reason for the (small) 500g split after crushing was that the ring and puck pulverizers existing on the market would not pulverize more than 500g. A poor reason, but that was a time the economics of gold deposits were a lot less marginal than today and gold operations could commit gross errors and still make money. This protocol (which is still part of the South-African standards) lasted until maybe 40 years ago, when people finally realized that today's gold mines cannot afford such lousy splits. In parallel, similar economics for coarse gold mines was calling for larger assay charges. These classically went from 30g to 50g, then 100g. Multiple fire assays became routine, as well as more massive assaying techniques such as bottle roll leaching and screen fire assays.

The calls clearly were for both larger pulverization masses and for larger assaying charges. Larger pulverizers were constructed that were able to accommodate 1.5kg then 3.5kg samples, then continuous ringmills appear that did not have a mass limit. The continuous ringmill had its detractors on the basis of possible sample to sample contamination and alleged difficulty of cleaning (which was largely exaggerated). A first abuse was witnessed when the large pulverizers of the LM5 type, able to pulverize 3.5kg were seen by not-knowledgeable decision-makers as a license to reduce the collected field sample size from 10kg or more down to 3.5kg at the rig. It was easy, but devastating in terms of sampling variances, most of the time.

That was the point at which the massive assaying techniques also appeared.

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Starting with bottle roll leaching, that could easily accommodate several kilograms of pulverized sample but had a large footprint in the laboratory and was time consuming. Next to appear was the PAL (pulverize and leach) system that had a reduced footprint and was faster. The sample (500g or 1kg) was leached in a rotating steel container with Leachwell catalyst, and was pulverized and smashed by small steel balls, not unlike a mini-ballmill. A new abuse appeared. The sales pitch for the PAL was that you did not need to spend money pulverizing before assaying as the sample was pulverized anyway under the effect of the steel balls during the agitated leaching in the container. As a result, samples as small as 500g were (again in history!) split directly from the crushed material under the bad judgment of not-knowledgeable decision makers, going back in history, with the same potentially devastating effect, since not all gold deposits are forgiving. In the meantime, screen fire assays (SFAs) were also used at times on samples of up to 1kg, to handle coarse gold situations. This was often done without realizing that not all coarse gold situations equate high sampling variances, and that SFAs came with their own realms of practical problems and were in no ways close to a panacea.

Then most recently a new technique marketed by Chrysos, the Photon Assay (CPA), has appeared. It subjects a ~450g sample jar to high energy gamma ray excitation and detects gold's only natural isotope by the decay of its resulting metastable nuclear isomer. The method is non-destructive, so that samples can be recovered and re-assayed any other way desired, and the assay turn around time offered is at a record low, making it extremely desirable for grade control samples.

Allegedly, the penetration is total and the material assayed can be rock, crushed ore or pulverized ore, with no difference, for total contained gold determination. Of course this suggests a same marketing danger is present, in which non-knowledgeable decision-makers may see an (unjustified and dangerous) opportunity to skip the pulverizing step before final sampling of the jar contents. But this not the sole issue.

2. CPA Bias Issues

Indeed, from the onset of the CPA method, there were undocumented rumors on the streets that CPA readings on crushed material could differ from the reading of the pulps. A number of large mining groups and laboratories that were considering adopting the CPA for their assaying therefore engaged in some assaying tests.
One of the authors was asked to review the results of these tests statistically (mostly without being involved in the experimental design except in one case) at 9 anonymous fine and coarse gold deposits around the world, in Africa (5), Canada (1), South-America (1) and Australia (2). In each case but one, the data available consisted of crushed and pulverized CPA readings on the very same material, and of fire assaying of the samples to extinction. For some deposits the samples were from RC rigs while the other were from crushed core. Comparisons between paired data were made in a classical manner using simple t-tests applied using a 95% confidence level.

Results were concerning at best. In general, large biases between crushed and pulverized readings were present in all crushed cases, with statistical significance, and relative amplitudes of 7%-10% for hard rock and 1%-2.3% for RC samples, pulp readings being always higher in all cases but one. For the crushed RC (almost pulverized already by the drill bit), the differences to pulp readings were of course quite small (1%-2%) but significant in most cases. Differences between CPA pulp readings and FA to extinction were often of the 4%-8% order, FA being higher whenever significance was reached. In one RC case, however, the reverse was true with a relative bias of 2.6% and in 3 cases, no significance was attached to the observed differences.

At this point it is clearly paramount to fully test the method first before adopting it in any particular situation. In addition to the sampling considerations expressed above, it seems very unsafe to use CPA on material that has not been pulverized first. The experimental design is important so that if biases are indeed detected they cannot be unduly blamed on imperfections of the experiments. It should be noted also the CPA method demand special characteristics for the samples, as they must fill the sample jar completely well packed and tamped. Results are not adequate if the jar is not full. It is important to realize this certainly is a huge limitation about the routine use of the method.

3. Bias Testing

3.1 Denial Considerations and Issues

Several points are worth noting:

1. The marketers of CPA have been keen to deny there were any issues with biases in cases they had studied themselves.
2. When confronted with different test outcomes that differed from their, experimental design was usually blamed.
3. It is true most of the experiments above were not necessarily optimally designed. The only one for which design was fully controlled from the onset showed a statistically significant bias between crushed and pulverized reading on RC samples, of around 1% in relative terms (crushed reading higher). But it showed no significance for the difference of the same amplitude that was found between pulverized readings and FA to extinction. A slight doubt remained that needed to be verified.

3.2 T-test and Unequal Variances

The test to try and demonstrate statistical significance in this case is Student's t-test for the means of paired data. It is a very robust, hypothesis statistical test which applies well and usefully even if the two variables have different variances, provided the ratio of variances is less than 4 (a ratio which is far from being reached in all these cases). When run at a 95% confidence level to a calculated difference between pairs in a data set, if it shows statistical significance, it means there is a probability of at least 95% the experimental difference observed is due to an operational bias. In the contrary case, the test is simply inconclusive and it never means there is no bias.

Modifications of the test by Cochran, Cox and/or Welch exist to be applied when the variances are appreciably unequal. These modified tests are less stringent and will tend to be inconclusive more easily. As a matter of scientific logic, it is clear an inconclusive test cannot be used to deny the significance previously demonstrated by another test, even though this flawed logic was indeed used by the marketers when needed.

3.3 Experimental Take-away

More tests needed to be run, with fully controlled experimental designs, to assess the reliability of the CPA method as it stands today. But there was ample preliminary evidence the CPA method may present some accuracy problems, at least under certain circumstances. As a result, it was decided to run tests on synthetic samples, to confirm these observations and try to explain the bias mechanisms.

3.4 Synthetic Samples

To make a controlled, empirical measurement of biases arising directly from the physical form of the sample, an experimental procedure was carried out on synthetic samples of barren rock spiked with ≥99.99% gold fragments. The gold content of the barren rock material was established as below the detection limit of the instrument by ten repeat CPA measurements. Synthetic materials were created with both fine and coarse barren rock, as well as fine and coarse gold fragments and are summarized in Table 1.

Table 1: Summary of synthetic materials created from barren rock and ≥99.99% gold fragments.

Sample	Au P100 (µm)	Barren P_{80} (µm)	Au Grade (g/t calculated)
Coarse-Coarse	<850	2000	255.5
Fine-Coarse	<45	2000	287.2
Coarse-Fine	<850	75	2.655
Fine-Fine	<45	75	2.801

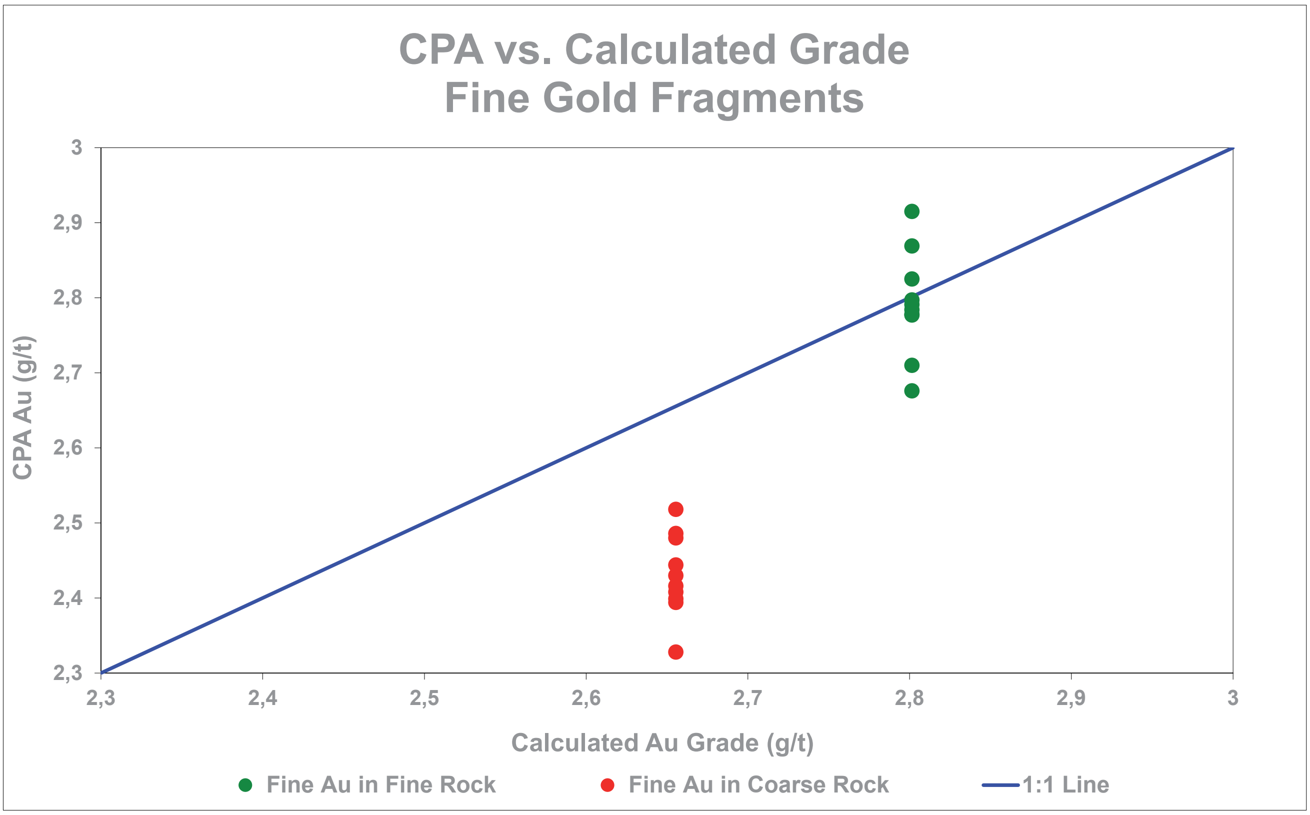

Figure 1: Measured CPA Au grades vs the grades calculated from the known mass of fine Au fragments and barren rock used to produce the material.

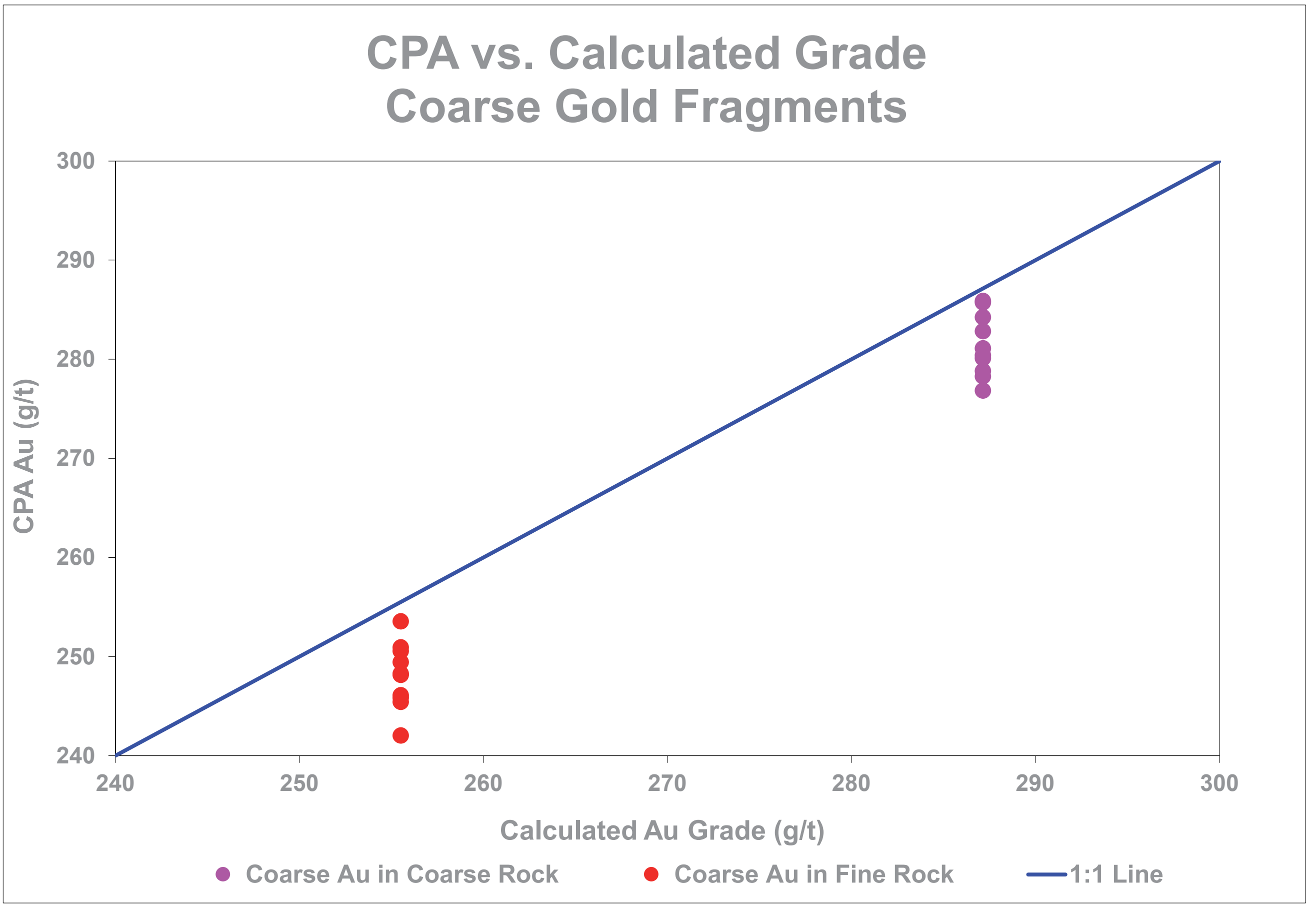

Figure 2: Measured CPA Au grades vs the grades calculated from the known mass of coarse Au fragments and barren rock used to produce the material.

Table 2: Summary of synthetic material gold grades as measured by PhotonAssay and the associated t-statistics.

Sample	Calculated Au Grade (g/t)	Avg PA Au Grade (g/t)	PA Au Grade Variance	Difference	t-statistic
Coarse-Coarse	255.5	248.024	4.41%	-2.93%	7.159
Fine-Coarse	287.2	281.406	3.51%	-2.00%	5.784
Coarse-Fine	2.655	2.430	0.12%	-8.48%	13.021
Fine-Fine	2.801	2.792	0.17%	-0.33%	0.424

The synthetic materials were placed into CPA jars and ran under the PAAU02 service (standard 2-cycle gold only service) and 10 replicate analyses were conducted on each jar (Figure 1 & Figure 2). Each jar was briefly shaken by the operator between measurements to induce reorganization of the fragments.

Student's t-test was carried out on the results to test the null hypothesis that there was no statistically significant difference between the average measured gold grade and the known true gold grade (Table 2).

The bias for CPA results of all material types was negative and met the threshold for statistical significance in all cases except for fine gold fragments in finely pulverized barren rock matrix. The larger variance associated with the coarse gold fragments was somewhat unexpected as the technique is expected to deliver tighter repeat precision with increasing grade.

This may be the result of changes in the fragments' positional distribution through the jar between measurements. The effect of positional distribution changes would be expected to be more pronounced for coarser particles, as was observed. The impact of this effect deserves further investigation.

4. Concluding Remarks

The authors invite the reader to discover the inner mechanism of the biases in the second part in this two part series of articles. They are sincerely hoping their work will help Chrysos turn this innovative technique into a new standard in the industry by addressing and resolving the issues described in this series.