CHRYSOS CORPORATION
Assays at the speed of light

Technical Note TN-003

Chrysos PhotonAssay™ Measurement Performance for Precision Gold Services

Executive Summary

A set of commercial gold analysis services are currently offered on the Chrysos PA1408X system. The standard service (PAAU02) involves running each sample for 2 cycles at 8.5 MeV with an irradiation time of 15 seconds and measurement time of 15 seconds. Other gold services extend the upper limit by reducing X-ray power, or use more cycles to increase precision and reduce the detection limit. This technical note discusses the latter, comparing the standard and precision gold services to assess the impact of number of measurement cycles on PhotonAssay^{TM} gold analysis performance, with a particular focus on detection limit and measurements at low gold grades.

The reported results are derived from a test suite of blank and certified reference materials (CRMs) run 24 times using the 8-cycle PAAU08 service on a PA1408X unit operating in Bendigo over a period of 12 days spanning 23 December 2021 to 20 January 2022. These data were also resampled to simulate running with the 4-cycle PAAU04 and 2-cycle PAAU02 services for direct comparison.

Operating at a throughput of 72 samples per hour, the PAAU02 service has a 2-sigma lower detection limit of 11±1 ppb on silica sand selected as a reagent-blank material. Increasing the number of measurement cycles to 4 with the precision gold service reduces the sample throughput to 36 samples per hour and improves the 2-sigma lower detection limit to 9±1 ppb. With the 8-cycle high precision gold service the detection limit is further improved to 6±1 ppb, with a sample throughput of 18 samples per hour. This improvement in detection limit is consistent with expectation, decreasing by approximately a factor of 1.4 each time the number of measurement cycles is doubled.

Based on measurements performed on a suite of low-grade CRMs, the lower detection limit for the PAAU02 service is found to be 10 ppb. Real-world materials can contain higher levels of uranium, thorium and barium elements, with typical ores having detection limits between 10 and 30 ppb for the standard gold service.

Determination of the true grade for a bulk sample is also impacted by sampling error associated with drawing the aliquots taken for gold assay. In cases where sampling error dominates instrument precision, it is substantially more beneficial to increase the mass of measurement material by preparing more jars for PhotonAssay^{TM} than to increase the number of measurement cycles on a single jar.

Based on this test work, we provide recommended grade ranges where the standard and precision gold services are best suited, and discuss other factors to consider in selecting a PhotonAssay^{TM} service for gold analysis. The results of this study are illustrated using a case study on plant samples from the Ravenswood Gold mine in Queensland, Australia.

Related Content

Technical Note TN-001 Chrysos PhotonAssay^{TM} Measurement Performance for Gold on Certified Reference Materials

Technical Note TN-101 Chrysos PhotonAssay^{TM} Measurement Performance for Gold on Ore Samples

Contents

Introduction

PhotonAssay^{TM} is a method for measuring gold and other elements in large mineral samples, based on the activation of nuclei using high-energy X-rays and the subsequent detection and counting of characteristic gamma-rays emitted when these nuclei decay.

For any analysis method, the instrument precision (repeatability error) describes the variation in grade that would be observed if a homogeneous sample were to be repeatedly measured. Given that most conventional assay methods are destructive, it is generally not possible to obtain an estimate of this error directly. Instead, repeat measurements are typically performed on multiple aliquots prepared from a highly uniform bulk material such as a certified reference material (CRM).

Due its non-destructive nature, the PhotonAssay^{TM} instrument precision can be experimentally verified by performing repeat measurements on the same sample. The software that PhotonAssay^{TM} uses to calculate gold grade can also provide a direct estimate of instrument error from a single measurement based on an analysis of the statistics of the gamma-ray counting process.

PhotonAssay^{TM} services run for a configurable number of measurement cycles. Consequently, by effectively extending the total measurement time, services such as the 4- and 8-cycle gold analysis services can provide higher precision gold grade measurements compared to the standard 2-cycle gold analysis service. Besides the number of measurement cycles, the PhotonAssay^{TM} instrument error also depends on the grade of the material, the presence of elements such as uranium, thorium and barium that increase gamma-ray background, and sample heterogeneity.

For determination of the average grade of a bulk sample which is larger than the 500 g aliquot mass typically measured using PhotonAssay^{TM}, sampling error is also important. The sampling error is a measure of how the true grade of an aliquot can be expected to deviate from other aliquots taken from the same bulk material. For heterogeneous materials, sampling error can significantly exceed the intrinsic PhotonAssay^{TM} instrument precision. If sampling error dominates, any improvement in PhotonAssay^{TM} instrument precision afforded by an increase in number of measurement cycles may yield little improvement in the measurement of the true sample grade, particularly compared to measurement of additional aliquots on a 2-cycle service.

In this report, we evaluate the precision of the PhotonAssay^{TM} method as a function of gold grade for both the standard (2-cycle) and precision (4- and 8-cycle) gold services using repeat measurements on CRMs. Measurements on blank materials are also performed to validate the detection limit for these services. The impact of uranium and thorium on PhotonAssay^{TM} instrument precision and detection limit is then discussed. The contributions from PhotonAssay^{TM} performance, background elements, and sampling error are then illustrated using a case study of 26 low-grade plant samples.

Methodology

A suite of blank jars and 13 CRMs were prepared and run 24 times over a period of 12 days from 23 December 2021 to 20 January 2022 using the 8-cycle high precision gold service on the PA1408X unit operating in Bendigo. For more information about sample preparation and the PhotonAssay^{TM} measurement procedure please refer to TN-001. The blank jars were silica sand with very low concentrations of U, Th and Ba. CRMs with certified grades ranging from 18.89 ppb to 46.27 ppm were also included. The table below summarises the material used, their certified fire-assay grades provided by the manufacturer, the number of PhotonAssay^{TM} aliquots (jars) prepared, the number of measurements performed on each jar and the total number of measurements.

Table 1. Summary of materials used for PhotonAssay^{TM} performance measurement

Material	Certified fire-assay Au grade	Jars	Number of repeat measurements	Total number of measurements
Geostats GLG920-5	18.89 ppb	4	24	96
Geostats GLG305-3	55.48 ppb	4	24	96
Geostats GLG310-5	82.03 ppb	4	24	96
Geostats GLG314-3	103.11 ppb	2	24	48
Geostats GLG304-1	153.91 ppb	2	24	48
Geostats GLG904-4	204.08 ppb	2	24	48
OREAS 684	0.248 ppm	2	24	48
OREAS 264	0.307 ppm	2	24	48
OREAS 230	0.337 ppm	2	24	48
Gannet ST484	7.418 ppm	1	24	24
Gannet ST588	1.658 ppm	1	24	24
Gannet ST620	46.27 ppm	1	24	24
Gannet ST643	4.94 ppm	1	24	24
BLANK	BDL	9	-	147

Two and four cycles subsets of the 8-cycle measurements were also aggregated to simulate measurements using 2-cycle and 4-cycle analysis services, allowing performance of the standard and high-precision assay services to be compared.

Results

PhotonAssay^{TM} detection limit and instrument precision

At low grades, the PhotonAssay^{TM} repeatability for homogeneous samples is dominated by the Poisson statistics associated with counting individual gamma-rays emitted by the sample, a factor that is estimated as part of the spectral analysis process. The analysis software then uses conventional error propagation to calculate the instrument precision for each reported grade value. This corresponds to the expected 1-standard deviation (SD) repeatability error if the jar were to be measured many times. The calculated precision is also used to determine the lower detection limits (LDL) for each sample.

The theoretical improvement in the PhotonAssay^{TM} lower detection limit and precision at low grades conferred by increasing the number of measurement cycles varies like $\sqrt{N}$ where N is the number of cycles. At higher grades, generally above a few ppm, non-statistical factors contribute to the instrument error and the improvement in precision is less.

The blank material used to determine the PhotonAssay™ detection limit contains very low levels of uranium, thorium, and barium. The 2-sigma gold detection limit on blank materials determined for each of the services is shown in Table 2, alongside the expected detection limit based on a $\sqrt{N}$ improvement from the quoted PAAU02 detection limit. Good agreement is observed between these different measures.

Table 2. 2-sigma detection limits and 2-sigma measurement uncertainties for PAAU02 and precision gold PhotonAssay™ services on reagent-blank material.

Service	LDL (PhotonAssay™ instrument error), ppm	LDL (SD of repeat blank measurements), ppm	Expected LDL based on PAAU02, ppm
PAAU02	0.011 ± 0.002	0.011 ± 0.002	0.010
PAAU04	0.008 ± 0.002	0.009 ± 0.002	0.007
PAAU08	0.005 ± 0.002	0.006 ± 0.002	0.005

In practice, the observed precision is also impacted by sample heterogeneity, the presence of background elements such as uranium, thorium, and barium and to a lesser extent by the uncertainty in other parameters entered into the PhotonAssay™ system such as the sample mass and jar fill. For highly heterogeneous samples, the measurement repeatability may be worse than the estimated instrument precision, due to random movement of gold particles within the jar volume between measurements. Elevated levels of uranium, thorium and barium raise the gamma-ray background beneath the gold signal and lead to an increased detection limit. Consequently, the observed 2-sigma detection limit for the PAAU02 service for typical ores can range from 0.010-0.03 ppm.

For samples with gold grades above detection limit, measurement precision varies as a function of grade. Figure 1 plots the measured PhotonAssay™ instrument precision as a function of gold grade for the CRM materials measured in the study. A trend line through the results is also shown. Directly determined 1-SD variations are shown using circles, and the estimated 1-SD instrument precision values using triangles.

The PhotonAssay™ gold instrument precision for the PAAU02 service improves from about 34% at 0.03 ppm to 14% at 0.1 ppm to 4% at 1 ppm and approaches 1.5% for grades above 20 ppm. The 4- and 8-cycle services follow a similar trend, scaled down by the square root of the number of measurement cycles. Table 3 comparing the instrument precisions for a range of grades for the 2-, 4- and 8-cycle services is shown below.

Table 3. PhotonAssay^{TM} detection limits and instrument precisions versus grade for the PAAU02 and precision gold analysis services based on measurements of CRMs. Typical equivalent values for fire-assay with various finishes are also reported.

Service	LDL	Precision at 0.1 ppm	Precision at 0.35 ppm	Precision at 1.0 ppm
2-cycle service	10 ppb	12%	6.5%	4.0%
4-cycle service	8 ppb	8.5%	4.6%	2.8%
8-cycle service	5 ppb	6.0%	3.2%	2.0%
Fire-Assay*	1 ppb (ICP) 5-10 ppb (AAS) 30 ppb (grav.)	6-9%	5-8%	3-7%

* Detection limits from (1). Precision ranges estimated from inter-laboratory standard deviation values derived from Geostats certified reference materials, available from www.geostats.com.au/crm_list_download.php.

The PhotonAssay^{TM} instrument errors provide a good estimate of the repeatability errors for most CRMs included in the study. Of the 13 CRMs analyzed, Gannet ST588 was the only one to demonstrate a significant discrepancy between the two error estimates. This CRM was found to have unusually high jar-to-jar variability. Consequently, the pooled rather than the standard deviation of all measurements is shown in Figure 1 for this CRM. Two CRMs (Geostats GLG310-5 and OREAS 264) showed elevated but consistent PhotonAssay^{TM} instrument errors and repeatability errors, which reflects the higher background element content of these materials. Table 4 summarises these findings.

Table 4. Table of CRMs with elevated PhotonAssay^{TM} instrument errors and repeatability errors (based on 8-cycle results).

CRM	Expected precision (assuming minimal background)	Observed precision (accounting for U/Th/Ba content)	Observed repeatability error	Combined U/Th grade (ppm)*	Barium grade (ppm)*
GLG310-5	8.75%	11.70%	11.94%	2.6†	170†
OREAS 264	3.97%	5.57%	5.24%	12.71*	841*

† Grades based on neutron activation analysis results from Geostats CRM certificate
* Grades based on 4-acid digestion results from OREAS CRM certificate

For real-world materials such as ore-samples, the observed precision is also impacted by sample heterogeneity. For highly heterogeneous samples, the measurement repeatability may be worse than the estimated instrument precision, due to random movement of gold particles within the jar volume between measurements.

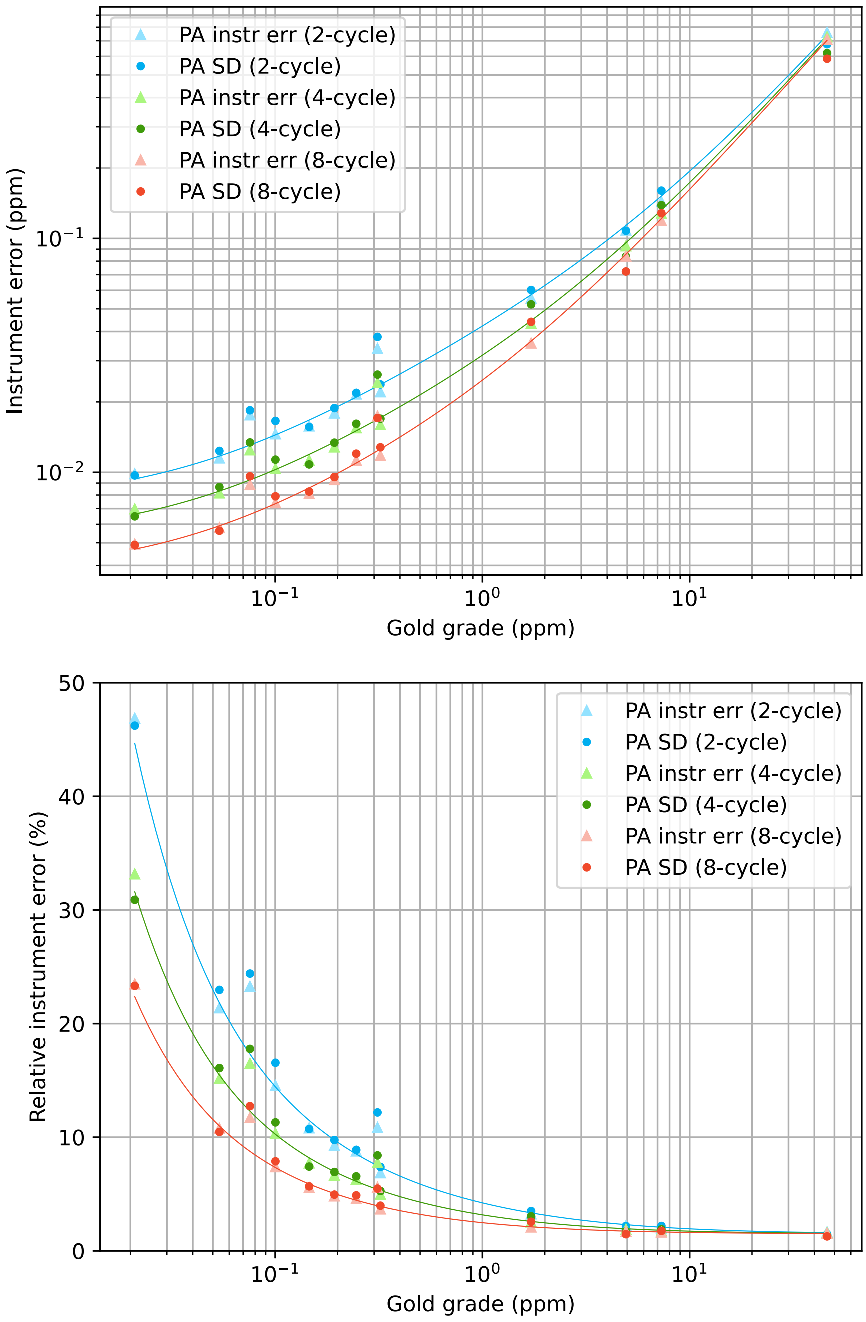

Figure 1. PhotonAssay^{TM} 1-standard deviation absolute (top) and relative (bottom) instrument errors and spread in repeat grade measurements plotted against gold grade for the CRM materials measured in the study. A trend line through the PhotonAssay^{TM} instrument errors is also shown.

Impact of background elements

The presence of certain elements in a sample in sufficient concentrations can raise the level of background counts in the emission spectra and increase the PhotonAssay™ detection limit and instrument error above normal levels, particularly for low gold grade samples. Common background elements include uranium, thorium and barium. A high-background (HB) flag is reported when the background has increased the standard deviation by 42% or more when compared with a "clean" sample of equivalent grade.

The greatest impact of uranium, thorium and barium on assay performance occurs at low gold grades. This is most evident in the increase in lower detection limit with increasing concentrations of background elements. The presence of uranium and thorium have equivalent effects on gold measurement precision. For example, a combined uranium and thorium grade of 15 ppm raises the 2-SD lower detection limit to about 30 ppb. Significantly higher concentrations of barium (about 3500 ppm) are required to have the same impact. Figure 2. shows the expected PhotonAssay™ instrument error for gold samples between 0.01 ppm and 1 ppm containing different levels of background elements.

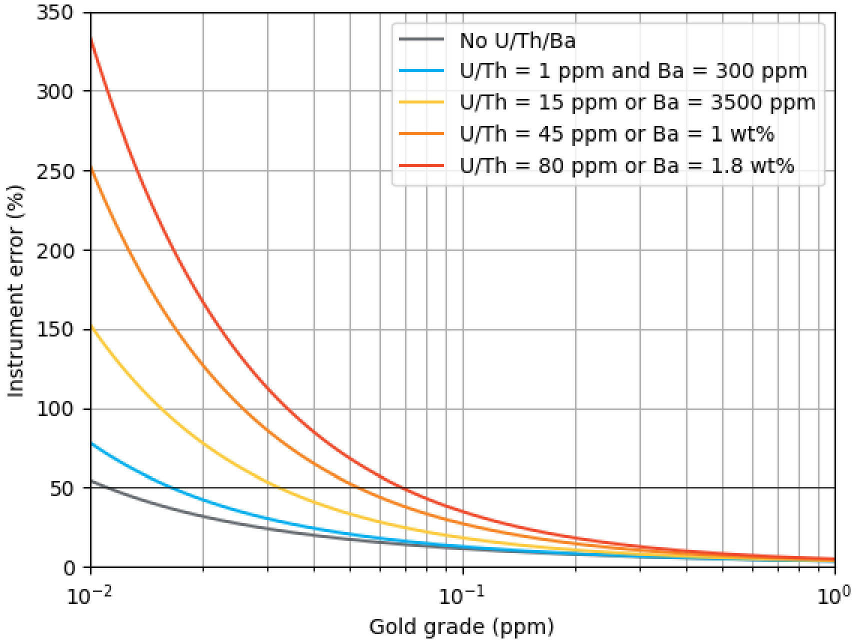

Figure 2. PhotonAssay™ 1-standard deviation relative instrument errors for samples with different levels of uranium, thorium and barium. The grey line shows the instrument error for samples with no uranium, thorium or barium content. For samples with low levels of uranium, thorium (combined < 1 ppm) and barium (< 300 ppm) the instrument error is expected to be below the blue line. For samples with a combined uranium and thorium grade of 15 ppm, or equivalently a barium grade of 300 ppm, which is common in real-world materials, the expected instrument error is shown in yellow. The orange and red lines show the expected instrument errors for samples with a combined uranium thorium grade of 45 ppm (or 1 wt% barium) or 80 ppm (or 1.8 wt% barium) respectively. The 2-sigma detection limit for each case is the grade at which the corresponding instrument error line crosses 50%.

A combined uranium and thorium level above about 80 ppm, or barium level above about 5% can interfere with the operation of the gamma-ray detector system used for PhotonAssay™. Assay of gold grades of a few ppm or less in such materials is not recommended. Analysis of higher gold grades is possible by operating the X-ray source at lower power.

Impact of sampling error

The results of the previous sections demonstrate that a predictable improvement in instrument precision can be achieved by increasing the number of measurement cycles from 2 to 4 to 8, at a cost of sample throughput.

When measuring real-world samples, the concept of total measurement error is more useful than instrument precision. We define total measurement error as the combined uncertainty resulting from instrument precision and sampling error. As such, it represents the uncertainty of the measurement of the true grade of a bulk sample (say a few kg received by a laboratory) based on the measurement of one or more aliquots sampled from that bulk.

Whilst sampling errors for well-prepared CRMs are generally negligible, sampling errors for real-world gold-bearing materials are not. From experience across more than 50 studies on gold ores and process samples from around the world, 1-SD sampling errors for 300-500 g PhotonAssay^{TM} aliquots generally range from 5-10% for highly uniform materials to 50% or higher for materials contains high levels of coarse gold. Pulverisation improves material uniformity, although often not significantly compared to ore crushed to a 2-3 mm top size. Sampling errors for the smaller 50 g aliquots used for fire-assay are correspondingly larger and often exceed 100% for coarse gold ores even after pulverisation.

To explore these effects, we consider the impact of combining various levels of sampling error (7%, 15% or 30% relative 1-SD for a single PhotonAssay^{TM} aliquot) to the base instrument precision values reported in Table 5.

Tables 6 – 8 take these instrument errors and add sampling errors in quadrature to give an estimate of the total measurement error that would be obtained for a few different scenarios: 2, 4 or 8-cycle measurements on a single jar, and 2-cycle measurements on 2 or 4 jars drawn from the same sample. As machine throughput depends on the total number of cycles, performing PAAU02 on two jars results in the same throughput as performing the PAAU04 service on one jar; PAAU02 on four jars is equivalent in throughput to PAAU08 on one jar.

The colour of each cell indicates whether the service is recommended (green), not suitable with a total measurement error greater than 50% (red) or not recommended (white). The criteria for ‘recommended’ for the various higher precision services are that they should deliver an appreciable improvement (equivalent to about a 25% relative decrease in total measurement error) in performance for the loss in throughput involved.

For samples with grades in the range 0.01 – 1 ppm and sampling errors above 7%, only modest performance gains can be obtained from running the samples above 0.05 ppm using the 4- or 8-cycle services. Below 0.05 ppm, if sampling errors are moderate (< 30%) a comparable performance improvement can be obtained from increasing the number of measurement cycles to increasing the number of jars for each sample. For samples with sampling errors above 30%, measuring additional jars is always preferrable to increasing the number of measurement cycles performed on a single jar.

Table 5. Expected PhotonAssay^{TM} instrument errors for a range of grades measured with the SGA or precision gold services (assuming low levels of background elements).

Grade	2-cycle	4-cycle	8-cycle
0.01	84.4	59.7	42.2
0.02	46.5	32.9	23.3
0.05	23.0	16.3	11.6
0.1	14.4	10.3	7.3
0.2	9.6	6.8	5.0
0.5	5.9	4.3	3.2
1	4.2	3.2	2.5

Table 6. Total measurement error (1-SD, relative %) as a function of gold grade assuming a sampling error of 7%. Recommended services are shown in green. Services that are not suitable are shown in red, and white cells indicate services that do not confer any significant benefit compared to 2-cycle analysis.

Grade (ppm)	2-cycle	4-cycle	2 jars (2-cycle)	8-cycle	4 jars (2-cycle)
0.01	84.7	60.1	59.9	42.8	42.4
0.02	47.0	33.6	33.2	24.3	23.5
0.05	24.0	17.7	17.0	13.5	12.1
0.1	16.1	12.4	11.4	10.1	8.1
0.2	11.8	9.8	8.4	8.6	6.1
0.5	9.1	8.2	6.5	7.7	4.8
1	8.2	7.7	5.9	7.4	4.3

Table 7. Total measurement error (1-SD, relative %) as a function of gold grade assuming a sampling error of 15%.

Grade (ppm)	2-cycle	4-cycle	2 jars (2-cycle)	8-cycle	4 jars (2-cycle)
0.01	85.8	61.6	60.6	44.8	42.9
0.02	48.8	36.1	34.5	27.7	24.5
0.05	27.4	22.1	19.4	18.9	13.8
0.1	20.8	18.2	14.8	16.7	10.5
0.2	17.8	16.5	12.6	15.8	9.0
0.5	16.1	15.6	11.4	15.3	8.2
1	15.6	15.3	11.1	15.2	7.9

Table 8. Total measurement error (1-SD, relative %) as a function of gold grade assuming a sampling error of 30%.

Grade (ppm)	2-cycle	4-cycle	2 jars (2-cycle)	8-cycle	4 jars (2-cycle)
0.01	89.6	66.8	63.4	51.8	44.8
0.02	55.3	44.5	39.1	38.0	27.7
0.05	37.8	34.1	26.7	32.1	18.9
0.1	33.3	31.7	23.6	30.9	16.7
0.2	31.5	30.8	22.3	30.4	15.8
0.5	30.6	30.3	21.6	30.2	15.3
1	30.3	30.2	21.4	30.1	15.2

Ravenswood case study

In August 2021, measurements on a suite of 26 plant samples and 4 CRMs provided by Ravenswood were performed on the first deployed PhotonAssay™ system in Western Australia. Each of the materials were supplied in individual PhotonAssay™ jars. The sample suite was run using a special 10-cycle gold analysis service. Four additional CRMs and jars of blank material were run alongside the sample suite. Fire-assays performed on the original bulk materials were subsequently provided by Ravenswood.

All possible combinations of 2, 4 and 8 cycles were sampled from the 10 measurement cycles for each jar and aggregated offline to simulate measurement using the 2-, 4- and 8-cycle services. Results for the plant samples are shown in the plots below.

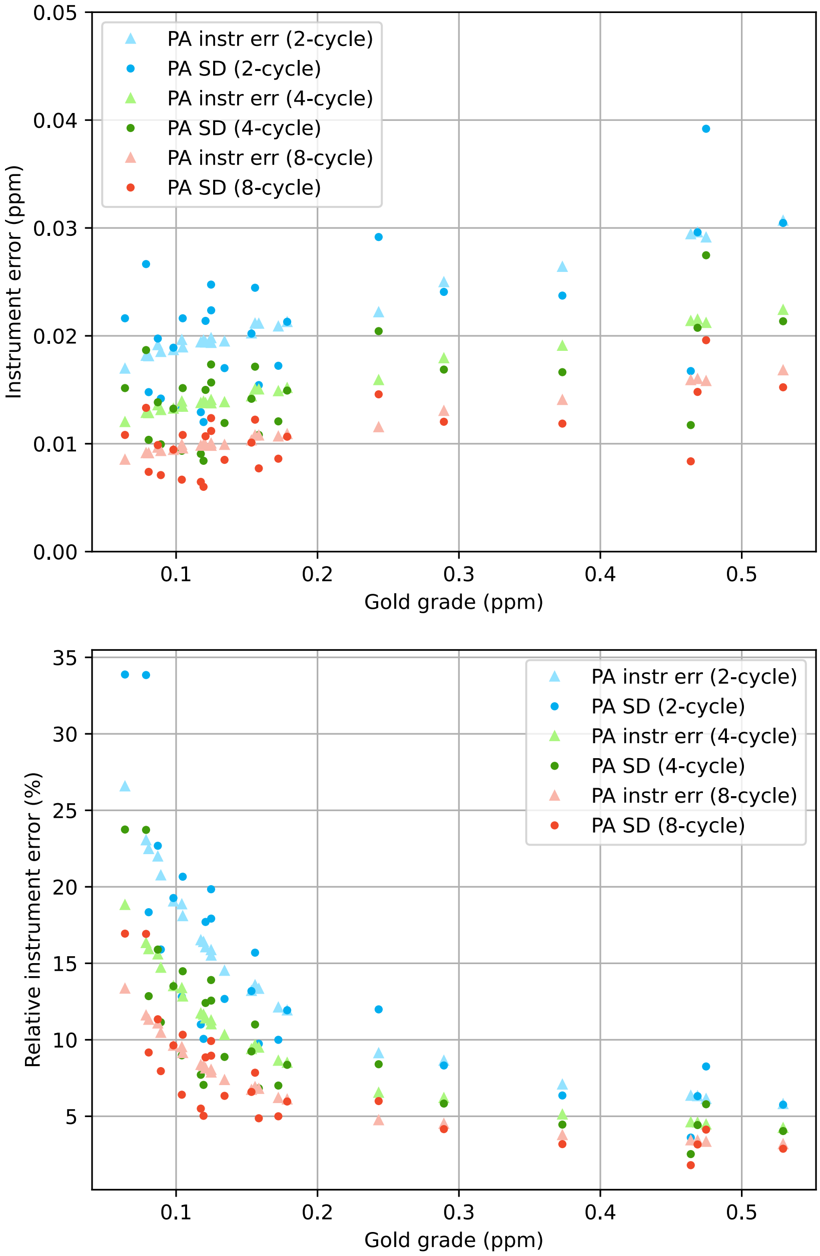

Figure 3. PhotonAssay™ absolute (top) and relative (bottom) estimated instrument errors and measured repeatability values plotted against gold grade for the plant samples supplied by Ravenswood.

Due to the presence of background elements in the samples, the PhotonAssay^{TM} gold instrument precision is elevated for the plant samples in comparison with the low-background CRMs shown in Figure 1. However, the instrument errors provide good estimates of the repeatability errors for the plant samples. The instrument precision decreases by approximately a factor of a square root of 2 with each doubling of the number of measurement cycles. Extrapolating a fit to the repeatability errors for the sample suite indicates that the detection limit for the 2-cycle gold service is 0.03 ppm.

Given that only one jar of material was provided for PhotonAssay^{TM}, and only one aliquot was taken from the original bulk material for fire-assay, it is not possible to separately estimate the error contributions from sampling the PhotonAssay^{TM} splits or the fire-assay aliquots. However, by comparing the PhotonAssay^{TM} and fire-assay grades for the Ravenswood samples, we can estimate the combined sampling errors for the two techniques.

The spread in the grade ratios is equal to the sum in quadrature of the instrument errors and sampling errors for the two techniques. Therefore, an estimate of the combined sampling error can be derived by substituting the spread in the 8-cycle PhotonAssay^{TM} to fire-assay grade ratios (23.4%) and the RMS PhotonAssay^{TM} instrument error for the 8-cycle service (8.1%). If we conservatively assume a fire-assay instrument error of 5% based on Table 2, the approximate combined error contribution from sampling of the PhotonAssay^{TM} split and fire-assay aliquot is 21.4%.

The mean net PhotonAssay^{TM} jar mass for the sample suite was approximately 400 g, about 8 times the mass of a typical fire-assay aliquot (50 g). Therefore, the sampling error from taking a split for PhotonAssay^{TM} is approximately 7%, and the sampling error associated with taking an aliquot for fire-assay is 20%. Consequently, the PhotonAssay^{TM} instrument error for the standard 2-cycle analysis only becomes dominant for grades below about 0.35 ppm. For the 8-cycle precision gold service the PhotonAssay^{TM} instrument error only begins to dominate the error in the grade measurement below about 0.15 ppm.

For the lowest grade samples in this suite (< 0.1 ppm), the PhotonAssay^{TM} instrument precision improves from 25% with the 2-cycle service, to 13% with the 8-cycle service. This corresponds to a reduction in total measurement error (including also the sampling contribution) from 26% to 14%.

Conclusions

Measurements performed on reagent blank and low-grade CRMs demonstrate that the instrument precision and detection of PhotonAssay^{TM} can be significantly improved using the 4-cycle and 8-cycle high precision services. For example, the detection limit on reagent blank material improves from about 10-11 ppb using the standard 2-cycle service to 5-6 ppb using the 8-cycle service, and measurement precision at 0.1 ppm improves from about 15% relative 1-SD to 7-8% for the same services.

Detection limits are higher and measurement precision reduces for materials containing higher levels of background-causing elements U, Th and Ba. For real ores, with typical concentrations of background elements, the detection limit for the 2-cycle service ranges from 10 to 30 ppb, or 5-15 ppb for the 8-cycle service.

In general, the high precision services have the greatest utility for samples with gold grades below about 0.05-0.1 ppm. An important factor influencing the selection of the best PhotonAssay^{TM} service to use for low grade ores is sampling error, which can often significantly exceed instrument precision except at the very lowest grades. If sampling error dominates the measurement uncertainty, then it is preferable to run more aliquots of a given sample using a 2-cycle service than to switch to the 4- or 8-cycle precision services. However, for sufficiently homogeneous samples at low grades where the PhotonAssay^{TM} instrument error dominates the gold grade uncertainty, opting for one of the precision gold analysis services is advisable.

Measurements performed on a suite of plant samples from the Ravenswood mine demonstrate the impacts of elevated levels of background elements and sampling error on PhotonAssay^{TM} gold precision. A detection limit of 0.03 ppm was demonstrated on these samples for the 2-cycle service, improving to 0.015 ppm for the 8-cycle service. For the lowest grade samples in this suite (< 0.1 ppm), the total measurement error improves from about 26% for the 2-cycle service to 14% for the 8-cycle service.

References and further reading

(1) Hoffman, E., Clark, J., & Yeager, J. (1999). Gold analysis - fire assaying and alternative methods. *Exploration and Mining Geology, 7 (1+2)*, 155-160.

Appendix

Table A1: Tabulated PhotonAssay^{TM} grades and instrument errors, as well as standard deviations in repeat measurements of each CRM included in the study.

CRM	Mean Au, ppm	2-cycle			4-cycle			8-cycle			Gross mass, g	Fill, %
		N	Au SD, ppm	Instr err, ppm	N	Au SD, ppm	Instr err, ppm	N	Au SD, ppm	Instr err, ppm		
Geostats GLG304-1	0.146	192	0.016	0.016	96	0.011	0.011	48	0.008	0.008	347.20	93.86
Geostats GLG305-3	0.054	384	0.012	0.011	192	0.009	0.008	96	0.006	0.006	378.03	89.49
Geostats GLG310-5	0.076	384	0.018	0.018	192	0.013	0.012	96	0.010	0.009	259.33	94.73
Geostats GLG314-3	0.100	192	0.017	0.015	96	0.011	0.010	48	0.008	0.007	411.75	100.00
Geostats GLG904-4	0.193	192	0.019	0.018	96	0.013	0.013	48	0.010	0.009	406.60	95.33
Geostats GLG920-5	0.021	384	0.010	0.010	192	0.006	0.007	96	0.005	0.005	349.83	91.97
OREAS 230	0.322	192	0.024	0.022	96	0.017	0.016	48	0.013	0.012	359.45	98.37
OREAS 264	0.312	192	0.038	0.034	96	0.026	0.024	48	0.017	0.017	239.80	99.50
OREAS 684	0.246	192	0.022	0.022	96	0.016	0.015	48	0.012	0.011	291.75	99.81
Gannet ST484	7.337	96	0.160	0.143	48	0.139	0.128	24	0.128	0.119	444.98	95.24
Gannet ST588	1.714	96	0.060	0.055	48	0.052	0.043	24	0.044	0.036	477.88	99.56
Gannet ST620	46.163	96	0.677	0.758	48	0.620	0.725	24	0.586	0.708	400.65	92.59
Gannet ST643	4.932	96	0.108	0.108	48	0.084	0.093	24	0.072	0.084	441.55	98.36