EXPLORE
Newsletter for the
Association of Applied Geochemists
www.appliedgeochemists.org
NUMBER 204 September 2024

The use of bulk cyanide leach in gold assays of drill core and rock samples

Dennis Arne
Telemark Geosciences Pty Ltd, Yackandandah, Victoria, Australia
dennis.arne@telemarkgeosciences.com
https://doi.org/10.70499/QRGX6581

INTRODUCTION

The use of cyanide in the form of NaCN to digest Au and other metals for analysis is well established (e.g. Wang and Forssberg 1990). Most exploration geologists will be familiar with the use of bulk cyanide leach (BCL), also referred to as bulk leach extractable gold (BLEG), applied to surficial samples, such as stream sediments and soil (Rate et al. 2010). This contribution reviews some of the advantages of using BCL on rock and drill core samples.

The analysis of pulverized rock material may be conducted using a standard BCL, with or without agitation such as a bottle roll, or an accelerated process using LeachWELL™ 60X (Menne and Revey 1994). Factors that need to be considered to ensure efficacy of Au recovery include liberation of Au particles for digestion, the strength of the NaCN solution, grain size of the liberated Au particles, duration of the digestion, pH of the solution, oxidation of the lixiviant, and the presence of activated carbon (preg-robbing) or copper and iron sulphides (cyanicides) (Rate et al. 2010; Cetin et al. 2017; Kianinia et al. 2018). In many regards the use of BCL assays overlaps with metallurgical testing and can be used to give an early indication of anticipated Au recoveries from exploration samples, although BCL analyses from geochemical laboratories do not generally include pH control or the addition of other additives common to metallurgical test laboratories.

It must be borne in mind that a BCL assay for Au may not be a total analysis if Au is encapsulated in quartz (i.e. not liberated) or in sulphides at the atomic level (i.e. refractory), or because of the many factors outlined in the preceding paragraph. Therefore, to compare BCL data with fire assay (FA) data, it is necessary to undertake a fire assay of the BCL tailings. The BCL assay and the tailings assay are then summed to provide a total assay for the sample. There is also clearly valuable information in the component of Au not digested in NaCN.

CASE STUDIES

Some styles of Au mineralization are mineralogically complex. An example is illustrated in Figure 1 showing a reflected photomicrograph from an Australian Au deposit that will provide the source of much of the data presented in this article. The sample consists of an intergrowth of gangue minerals, mainly quartz and carbonate, with Pb-Sb-Ag sulphosalts (dark grey), aurostibite (light grey; $AuSb_2$), primary Au containing up to 20% Ag (pale yellow), and supergene Au of high fineness (orange-yellow colour) associated with the decomposition of aurostibite. Historically, coarse Au was recovered from this deposit using gravity methods and floatation was used to concentrate the sulphosalts and aurostibite for smelting. The deposit therefore contains both free and unliberated (at a nominal 85% passing 75 mm grain size) or refractory Au, the proportions of which may vary across the deposit.

A summary of LeachWELL™ (LW) and tails FA data are presented from this deposit in Table 1. The 25 g FA assay results with duplicate analyses for most samples can be contrasted with combined 200 g LW analyses and 25 g FA assays of the LW tails. More significantly from a mineral processing perspective, a ratio of cyanide-soluble to total Au can also be calculated for each sample. These ratios vary from a low of 8.2% to a high of 98%, indicating significant variation in the proportion of free Au in samples derived from different areas of the deposit as a function of mineralogy. This information can be built into block models to allow planning for mineral processing requirements.

One aspect that is easily controlled in using BCL is the digestion time, which influences the size of the Au grains to be dissolved. A BCL for exploration purposes may use a dilute NaCN solution to avoid digest-

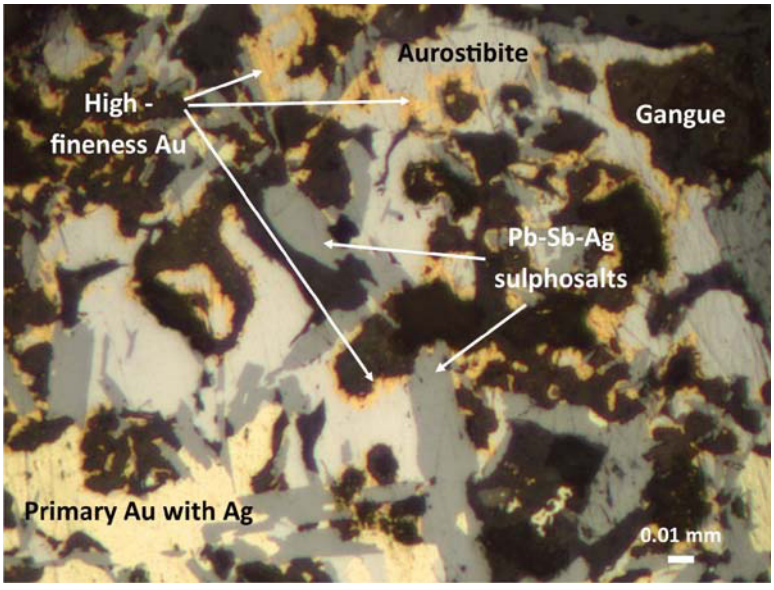

Fig. 1. *Reflected light photomicrograph of complex mineralization from an Australian Au deposit.*

continued on page 6

The use of bulk cyanide leach in gold assays of drill core and rock samples

continued from page 1

Table 1. *Summary of conventional fire assay (FA) and LeachWELL™ (LW) + tails fire assay Au results from fresh samples in a deposit containing both free and refactory/unliberated Au (n/a = not applicable).*

Sample	25 g FA (ppm)	25 g FA Repeat (ppm)	200 g LW (ppm)	25 g LW tails FA (ppm)	Total Au (LW + tails FA) (ppm)	Cyanide-soluble Au to total Au (%)
Sample 8	13.16	n/a	1.16	12.73	13.89	8.8
Sample 9	17.23	13.03	5.00	12.32	17.32	33.0
Sample 10	5.23	n/a	0.43	5.35	5.78	8.2
Sample 11	13.12	12.33	4.72	5.50	10.22	37.0
Sample 12	30.24	30.6	19.95	12.38	32.33	65.6
Sample 13	38.70	27.98	47.85	0.75	48.60	98.0

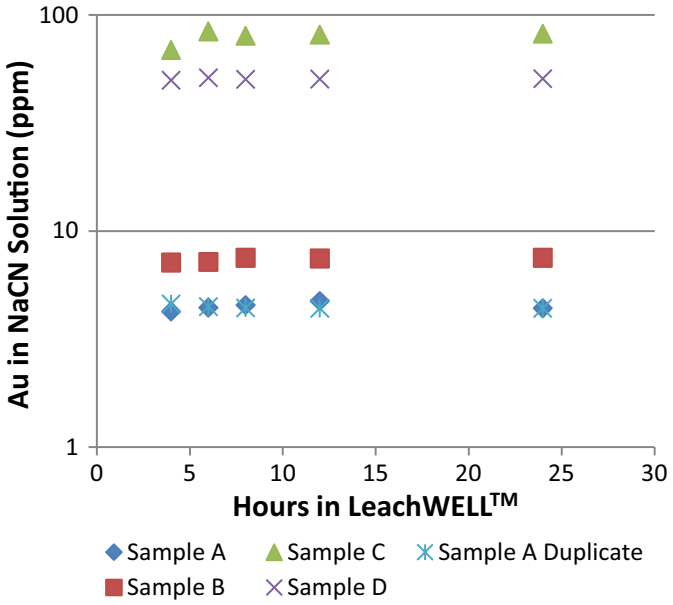

Fig. 2. *Gold concentration in solution at various times during a static accelerated bulk cyanide leach (LeachWELL™) digest.*

ing the larger Au grains that produce a nugget effect. However, for an accelerated BCL such as LW used on drill core or rock samples, it is necessary to ensure that even the coarse Au is dissolved. Many labs will offer a standard 4-hour static digestion time, but the appropriateness of this duration should be established at the outset by drawing off the pregnant solution at various times to determine when the Au concentration plateaus (Fig. 2). A 4-hour digestion is adequate for some samples in this trial (e.g. sample D), but not for all. Sample A required 6 hours before reaching a plateau in the Au concentration whereas it is arguable that sample B required 8 hours. Time trials such as these can be used to optimize the leach duration of a BCL by selecting a leach time that dissolves the largest Au grains in the samples.

Another obvious benefit to the use of BCL for Au assay is that it uses a larger sample mass than normally available for most routine Au analyses. In this regard, the advantages are similar to those obtained using screened metallics fire assay or PhotonAssay™ (Dominy et al. 2024). Analyses of particulate Au suffer from the effects of nuggetty distribution within a pulverized sample. An improvement in the relative precision of sampling is typically achieved either using a finer grain size or an increased sampling mass (Stanley 2007; Smee et al. 2024), both of which act to increase the number of Au particles in the sample. The number of Au particles in a sample can also be increased by an increase in grade but, for obvious reasons, this is outside the control of either the sampler or the analyst!

Changes in relative precision related to changes in sample mass can be assessed using duplicate samples and the calculation of the average coefficient of variation (CV_{AVG}) for many duplicate analyses for a particular range of grades (Stanley and Lawie 2007; Abzalov 2008, 2011; Smee et al. 2024). Duplicates include the use of core, reverse circulation (RC) rock chips, coarse crush material (preparation duplicates) or pulps. It is important to understand that an increase in the mass of the sample pulp using BCL only improves the relative precision of sub-sampling pulp material. It has no effect on the relative precision of sampling drill core or cuttings, which are the main sources of uncertainty (Stanley and Smee 2007), although it can reduce the total CV_{AVG} estimated from field duplicates because the variances associated with each sub-sampling stage are additive (Equation 1).

$$\sigma_T^2 = \sigma_{FS}^2 + \sigma_{CS}^2 + \sigma_{PS}^2 + \sigma_A^2 \qquad \textit{Equation 1}$$

where σ_T^2 = total variance; σ_{FS}^2 = field sampling variance; σ_{CS}^2 = coarse crush sub-sampling variance; σ_{PS}^2 = pulp sub-sampling variance; σ_A^2 = analytical variance.

Note: *This EXPLORE article has been extracted from the original EXPLORE Newsletter. Therefore, page numbers may not be continuous and any advertisement has been masked.*

continued on page 7

The use of bulk cyanide leach in gold assays of drill core and rock samples

continued from page 6

Table 2. *Summary of pulp duplicate data from drill core samples in a deposit containing coarse free Au.*

	25 g FA CV_{AVG} %	400 g Bulk CV_{AVG} %	25 g FA s^2	400 g Bulk s^2	400 g Bulk Predicted* s^2
Pulp Duplicates	28.4	8.8	806.4	77.4	50.4

*predicted using equation 5 from Stanley (2007) assuming a homogenous distribution of Au

CV_{AVG} - average coefficient of variation; FA - fire assay

An example of where an improvement in the relative precision (i.e. 2 times CV_{AVG}) of sub-sampling pulp material from a Au deposit containing nuggetty free Au is provided in Table 2. The CV_{AVG} for Au values that are greater than an order of magnitude above the LLD based on 9 pulp duplicate 25 g fire assays (FA) is 28.4%, which is not an unusual result. A CV_{AVG} for nominal 400 g bulk analyses used data from 25 samples, with 400 g LW analyses paired with data from nominal 400 g screen fire assays (SFA; also referred to as screened metallics), although there is a slight negative bias in the SFA relative to the LW results. A more rigorous assessment of the improvement in relative precision from using BCL would involve the analysis of duplicate LW analyses. Regardless, and based on the data available, the CV_{AVG} for the bulk analyses averages 8.8% for all samples.

A better indication of the changes in relative precision for the two masses of analyzed pulp lies in the relative variances (CV_{AVG}^2) of the data. The pulp duplicate relative variances for all samples have been reduced from 806.4 for the 25 g FA duplicate analyses to 77.4 for the 400 g bulk analyses, or just over an order of magnitude reduction, which is significant but slightly less than the decrease expected for the increase in sample mass using the relationship in equation 5 from Stanley (2007).

A common observation in moving from conventional fire assay charge weights to bulk analyses, be they BCL or SFA, is an increase in overall grade (Campbell-Hicks 1996). Table 3 shows the results of re-assaying of a 12 m high-grade Au intersection from an epithermal Au deposit in Turkey using 500 g SFA compared to the original 50 g fire assays. Overall, there is an increase in Au grade over the high-grade interval with the bulk analyses. The median increase in grade on a sample-by-sample basis is 8.6 %, which is significant if it can be maintained across an entire resource estimate. A similar effect is also apparent in the data from Table 1. Of course, these are small data sets with much variability and the bulk analyses would need to be carried through all ore-grade intersections before the economic benefit would be realized, but they serve to illustrate the potential monetary value of more precise assay data.

Table 3. *Comparison of 50 g fire assay and 500 g screen fire assay results from an epithermal Au deposit in Turkey (from Pilot Gold press release 22/01/2013).*

From (m)	**To** (m)	**Interval** (m)	**Au** (g/t) **original 50 g fire assay**	**Au** (g/t) **screened metallics**	**Change** %
116.0	117.5	1.5	2.3	2.4	4.1
117.5	119.0	1.5	47.9	44.7	-6.6
119.0	120.5	1.5	12.8	13.5	5.4
120.5	122.0	1.5	338.0	382.0	13.1
122.0	123.5	1.5	236.0	231.0	-2.3
123.5	125.0	1.5	73.0	92.8	27.1
125.0	126.5	1.5	681.0	880.0	29.3
126.5	128.0	1.5	17.2	16.2	-5.6
128.0	129.5	1.5	140.0	157.0	11.8
129.5	131.0	1.5	3.9	3.6	-6.6

There would have been adequate pulverized material available in the Pilot Gold example to supply a 500 g sample for screened metallics and conventional fire assay from a single 1 kg crusher split. However, if the screened metallics assay required the pulverization of additional crushed material, this sample would constitute a coarse crush duplicate and add an extra component of uncertainty into the comparison of the screened metallics results with conventional fire assays.

The coarse fraction from a screened metallic assay is typically >100 microns and can provide an indication of the proportion of Au in the sample that might be recoverable using gravity separation (L. Bloom, pers. comm., June 2024), much as the cyanide-soluble Au in a BCL assay provides an indication of Au recovery during cyanide treatment.

The reason for the increase in average Au grades using bulk analytical methods lies in the narrowing of the variance

continued on page 8

The use of bulk cyanide leach in gold assays of drill core and rock samples

continued from page 7

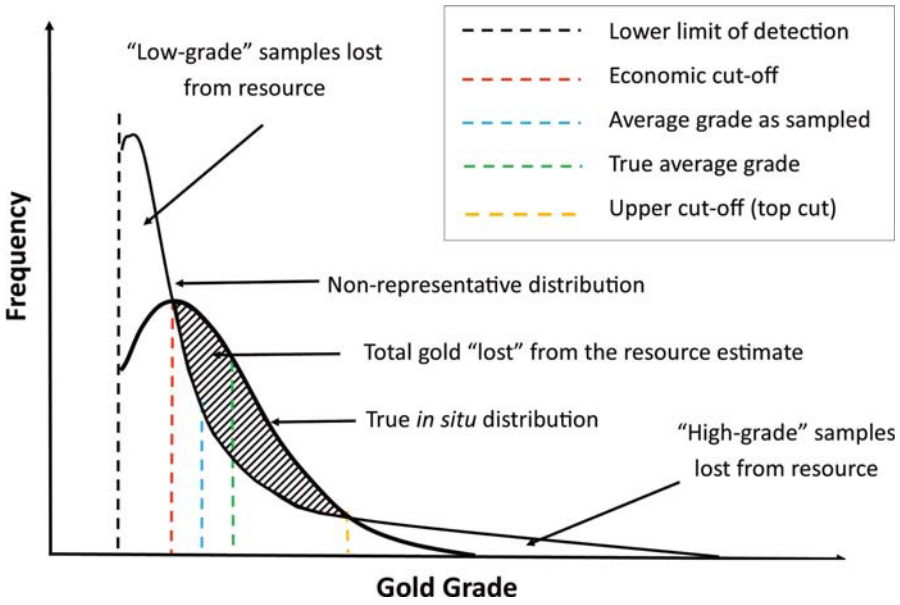

Fig. 3. *A schematic real in situ distribution of Au in a deposit compared to a distribution skewed and flattened by imprecise assay data (modified from Sketchley 1998).*

with more precise data (Sketchley 1998). Imprecise data results in a spread in the data, with more samples falling below the lower limit of detection as well as below economic cut-off grades. At the same time, more samples will display unnaturally high values that, in a resource estimate, will be removed (or top-cut) from the estimation (Fig. 3). Broadening the natural in situ distribution of Au results in a lowering of average grade and effectively the apparent "loss" of Au from the distribution. Recovering this "lost" Au using bulk analytical methods more than justifies the added analytical costs to produce more precise assay data that reflect the true value of the resource.

As a practical example of the use of BCL to support conventional 50 g fire assay results, E79 Resources routinely used a 500 g LW with a tails fire assay in 2021 to verify 50 g fire assay results for drill core intersections containing visible Au associated with abundant associated pyrite from its Victorian tenements in Australia. Samples were selected for BCL based on the presence of visible Au within an intersection rather than on initial fire assays to minimize the selection bias in samples for BCL. For example, an extremely high-grade Au intercept over 0.60 m in drillhole HVD002 that returned a 50 g fire assay of 2,430 g/t Au was confirmed by a LW + tails fire assay of 2,443 (E79 Resources press release dated August 9, 2021). In a press release dated January 27, 2022, E79 Resources upgraded previously released 50 g fire assay results

continued on page 10

The use of bulk cyanide leach in gold assays of drill core and rock samples

continued from page 8

for drilling intercepts to 2.3 m @ 40.5 g/t from 2.3 m @14.4 g/t (drillhole HVD006) and 5.4 m @ 70.0 g/t from 5.4 m @ 32 g/t (drillhole HVD007) based on LW with tails fire assay results. Further, the LW + tails fire assay results indicated that >99% of Au within the samples was digested in the BCL despite the presence of abundant sulphide minerals in the samples. It is important to note that certified reference materials included with the original assays containing lesser amounts of sulphide were acceptable and that the significant under-reporting of Au in these examples was only revealed using BCL. The reason for the significant under-reporting of Au assays from the original 50 g fire assays was never determined, but the LW + tails results were subsequently replicated by conventional fire assay using a gravimetric finish, suggesting an issue with the original AAS instrumental finish.

CONCLUSION

The use of BCL methods for the analysis of rock and drill core samples provides information on the amount of cyanide-soluble Au in a sample as a proportion of the Au present when combined with a total analysis of the cyanide tailings. It also provides improvements in the relative precision of Au assays due to the larger sample mass used compared to conventional total analyses, such as fire assay. The use of BCL at an early stage of a project can identify potential issues with Au recovery and highlight areas for focused metallurgical test work. More representative sampling using a larger sample mass often leads to higher Au grades that can more than offset the higher analytical cost with an increase in estimated value.

ACKNOWLEDGEMENTS

The author would like to thank Lynda Bloom for a thoughtful review of the original submission. While the present manuscript has certainly benefited as a result, the material presented remains the responsibility of the author. I would also like to dedicate this article to the late Ed Dronseika. Ed was always up for a geochemical challenge and usually found a solution (literally!).

REFERENCES

Abzalov, M. 2008. Quality control of assay data: A review of procedures for measuring and monitoring precision and accuracy. Exploration and Mining Geology, 17, 131–144.

Abzalov, M. 2011. Sampling errors and control of assay data quality in exploration and mining geology. *In:* Ivanov, O. (ed.), Applications and Experiences of Quality Control. Intech Open. 611–644.

Cambell-Hicks, C. 1996. Resource estimation and control by cyanide assay techniques. *In:* Proceedings. Randol Gold Form, Olympic Valley, California, April 1996, 19–28.

Cetin, M.C., Altun, N.E., Atalay, M.U. and Büyüktanır, K. 2017. Bottle roll testing for cyanidation of gold ores: Problems related to standardized procedures on difficult-to-process ores. *In:* Proceedings. 3rd World Congress on Mechanical, Chemical, and Material Engineering (MCM'17), Rome, Italy, June 8–10, 2017, Paper No. MMME 148. https://doi.org/10.11159/mmme17.148

Dominy, S.C., Graham, J.C., Esbensen, K.H. and Purevgerel, S. 2024. Application of PhotonAssay™ to coarse-gold mineralisation – the importance of rig to assay optimisation. Sampling Science & Technology, 1, 2–30. https://doi.org/10.62178/sst.001.002

Kianinia, Y., Khalesi, M.R., Abdollahy, M., Hefter, G., Senanayake, G., Hnedkovsky, L., Darban, A.K. and Shahbazi, M. 2018. Predicting cyanide consumption in gold aeaching: A kinetic and thermodynamic modeling approach. Minerals, 8. https://doi.org/10.3390/min8030110

Menne, D. and Revy, T. 1994. Accelerated cyanidation assays using LeachWELL™ 60X – the Bannockburn experience. Proceedings of the AusIMM Annual Conference, Darwin, August 1994, 287–289.

Rate, A.W., Vidot, J., Hamon, R.E., Radford, N.W., Griffin, W.J., Bettenay, L.F. and Gilkes, R.J. 2010. Systematic evaluation of bulk cyanide leach (BCL) parameters affecting extractability of

continued on page 12

The use of bulk cyanide leach in gold assays of drill core and rock samples

continued from page 10

metals from soils. Geochemistry: Exploration, Environment, Analysis, 10, 189–198.

Sketchley, D.A. 1998. Gold deposits: Establishing sampling protocols and monitoring quality control. Exploration and Mining Geology, 7, 129–138.

Smee, B.W., Bloom, L., Arne, D. and Heberlein, D. 2024. Practical applications of quality assurance and quality control in mineral exploration, resource estimation and mining programmes: a review of recommended international practices. Geochemistry: Exploration, Environment, Analysis. https://doi.org/10.1144/geochem2023-046

Stanley, C.R. 2007. The fundamental relationship between sample mass and sampling variance in real geological samples and corresponding ideal statistical models. Exploration and Mining Geology, 16, 111–125.

Stanley, C.R. and Lawie, D. 2007. Average relative error in geochemical determinations: Clarification, calculations and a plea for consistency. Exploration and Mining Geology, 16, 267–275.

Stanley, C.R. and Smee, B.W. 2007. Strategies for reducing sampling errors in exploration and resource definition drilling programs for gold deposits. Geochemistry: Exploration, Environment, Analysis, 7, 329–340.

Wang, X. and Forssberg, K.S. 1990. The chemistry of cyanide-metal complexes in relation to hydrometallurgical processes of precious metals. Mineral Processing and Extractive Metallurgy Review, 6, 81–125.