CSA Global
Resource Industry Consultants

# Data Quality for Reporting – How Good is Good Enough?

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# Outline

- What do the codes say?
  - NI43-101
  - JORC
- Sampling
- QAQC
- What should our quality expectations be?

# NI43-101

- **Item 11: Sample Preparation, Analyses, and Security** – Describe
  - (a) **sample preparation methods and quality control measures employed before dispatch of samples** to an analytical or testing laboratory, the method or process of sample splitting and reduction, and the security measures taken to ensure the validity and integrity of samples taken;
  - (b) relevant information regarding sample preparation, assaying and analytical procedures used, the name and location of the analytical testing laboratories, the relationship of the laboratory to the is whether the laboratories are certified by any standards associ the particulars of any certification;
  - (c**) a summary of the nature, extent, and results of quality cont ol procedures employed and <u>quality assurance actions taken or recommended to provide adequate confidence in the data collection and processing</u>**; and
  - (d) the author's opinion on the adequacy of sample preparation, security, and analytical procedures.

But that's not always the QP's job!

# JORC 2012 Table 1

- "The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total."
- "For geophysical tools, spectrometers, handheld XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibrations factors applied and their derivation, etc."
- "Nature of quality control procedures adopted (standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (ie lack of bias) and precision have been established."

# Sampling & Analysis

- Sample size, grain size and analytical methods generally default to convention.
- Should be optimised for individual projects.
- Objective is to obtain representative samples.
- The data should be relevant for proposed processing.
- Have we maximized precision (i.e. minimized uncertainty)?

# Is Fire Assay Alone Appropriate?

| CL Test | Oxidation | Grain Size (µm) | Grade | Au Recovery (%) |
|---|---|---|---|---|
| Oxide | 100 % | 96 | 7.0 | 96.0 |
| Oxide | 100 % | 99 | 7.0 | 96.5 |
| Transitional | 95 % | 108 | 3.4 | 90.7 |
| Transitional | 95 % | 114 | 3.4 | 91.5 |
| Fresh | 0 % | 90 | 4.4 | 2.0 |
| Fresh | 0 % | 35 | 4.4 | 2.8 |
| Fresh | 0 % | 20 | 4.4 | 5.3 |

- ~50 % of resource is from transitional material.
- Primary sulphide mineralization strongly refractory.
- Recoveries in the transition zone proportional to oxidation.
- Cyanide Au recoveries important for heap leach operation.

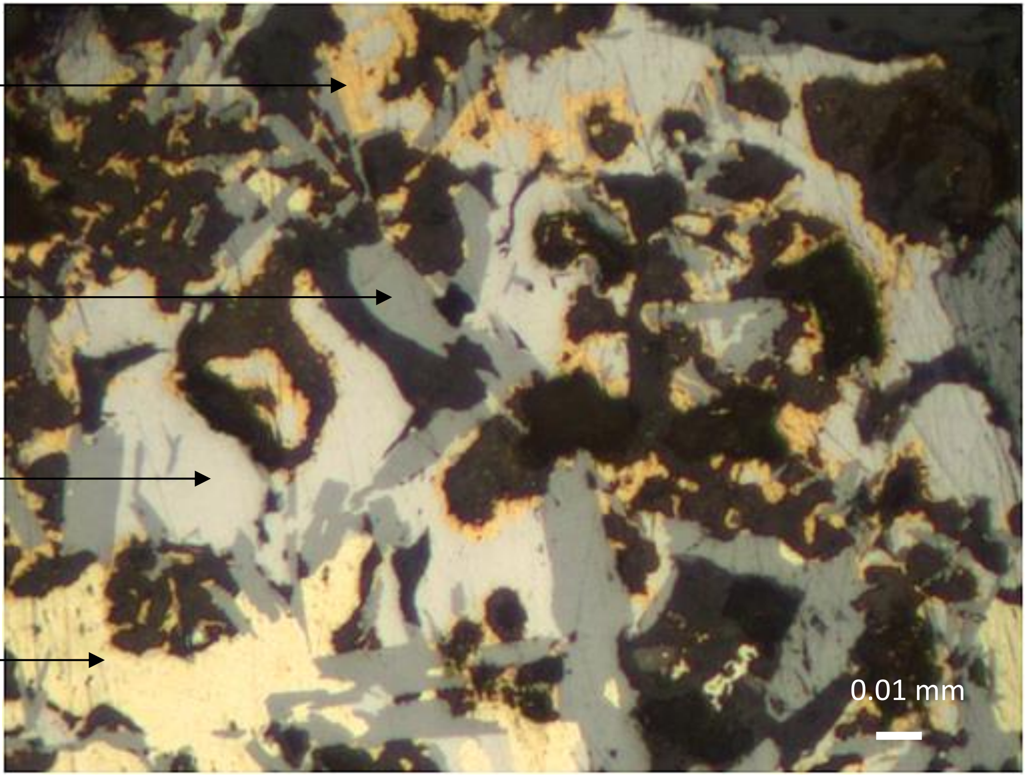
# Effects of Complex Mineralogy

High fineness Au

Sb-Ag-Au sulphosalt

Aurostibite ($AuSb_2$)

Au with ~20% Ag




A fire assay gives a total Au value for this sample.

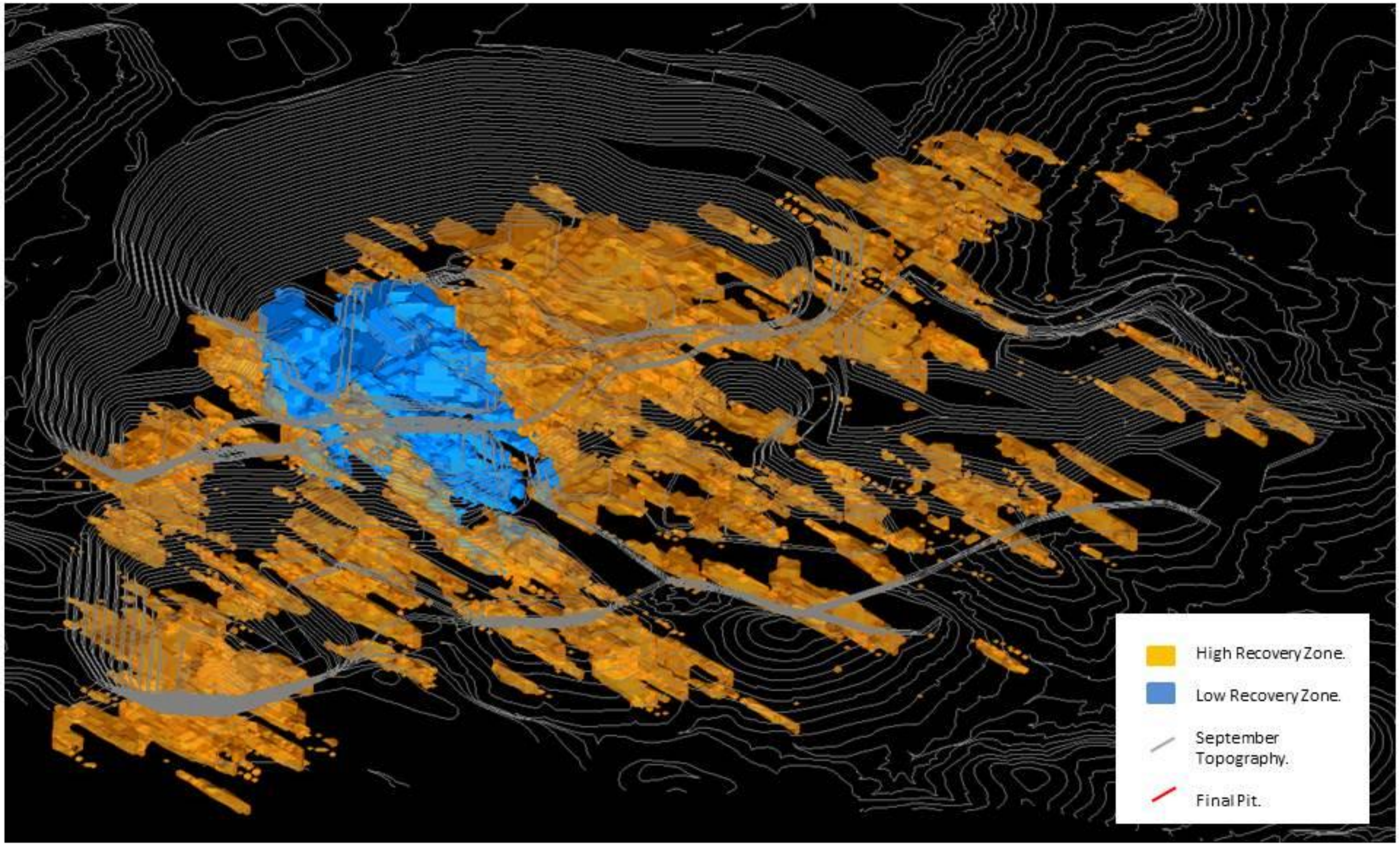
# Appropriate Assay Methods

| Sample | 25 g Fire Assay (ppm) | 25 g Fire Assay Repeat (ppm) | 200 g Leachwell (ppm) | 25 g Leachwell Tails Fire Assay (ppm) | Total Au from BLEG + Fire Assay (ppm) | % Cyanide soluble to total Au |
|---|---|---|---|---|---|---|
| Sample008 | 13.16 | n/a | 1.16 | 12.73 | 13.89 | 8.8 |
| Sample009 | 17.23 | 13.03 | 5.00 | 12.32 | 17.32 | 33.0 |
| Sample010 | 5.23 | n/a | 0.43 | 5.35 | 5.78 | 8.2 |
| Sample011 | 13.12 | 12.33 | 4.72 | 5.50 | 10.22 | 37.0 |
| Sample012 | 30.24 | 30.60 | 19.95 | 12.38 | 32.33 | 65.6 |
| Sample013 | 38.70 | 27.98 | 47.85 | 0.75 | 48.6 | 98 |

Leachwell analysis with a tails fire assay of provides:

- an estimate of the CN-extractable Au in the sample
- a bulk analysis – more precise

# El Castillo Gold Recovery Block Model



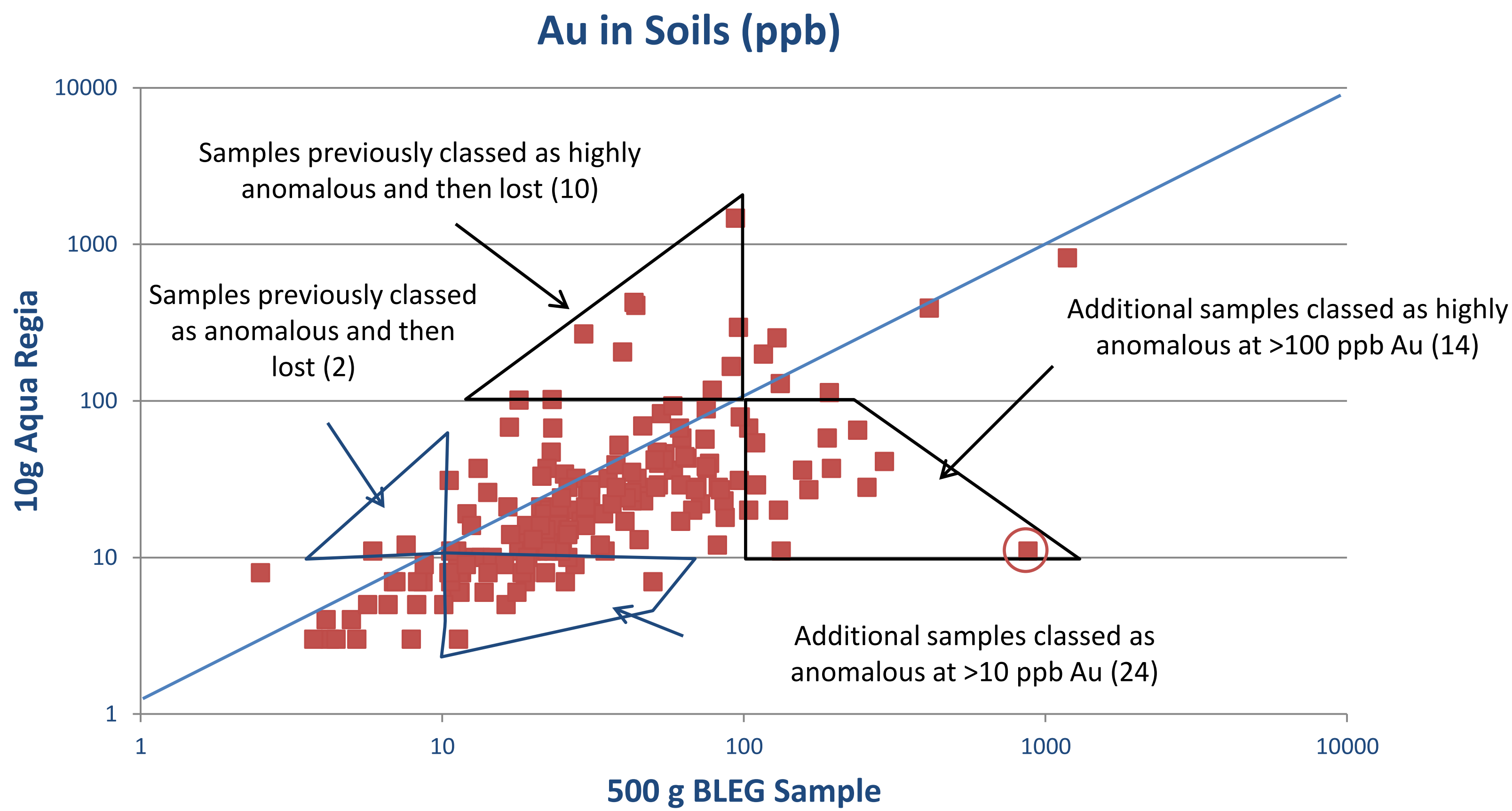

Either quantitative or semi-quantitative information on metal recoveries can be built into block models

# Appropriate Sample Size?

| | 25 g FA | CV | LW + tails | SFA | Bulk CV (SFA/LW) |
|---|---|---|---|---|---|
| Average grade | 13.23 | | 13.73 | 13.11 | |
| Average (all) | | 28 | | | 9 |
| Average (area 1) | | 25 | | | 11 |
| Average (area 2) | | 33 | | | 8 |
| Average (> 10 ppm) | | 30 | | | 10 |
| Average (> 5 ppm) | | 30 | | | 10 |

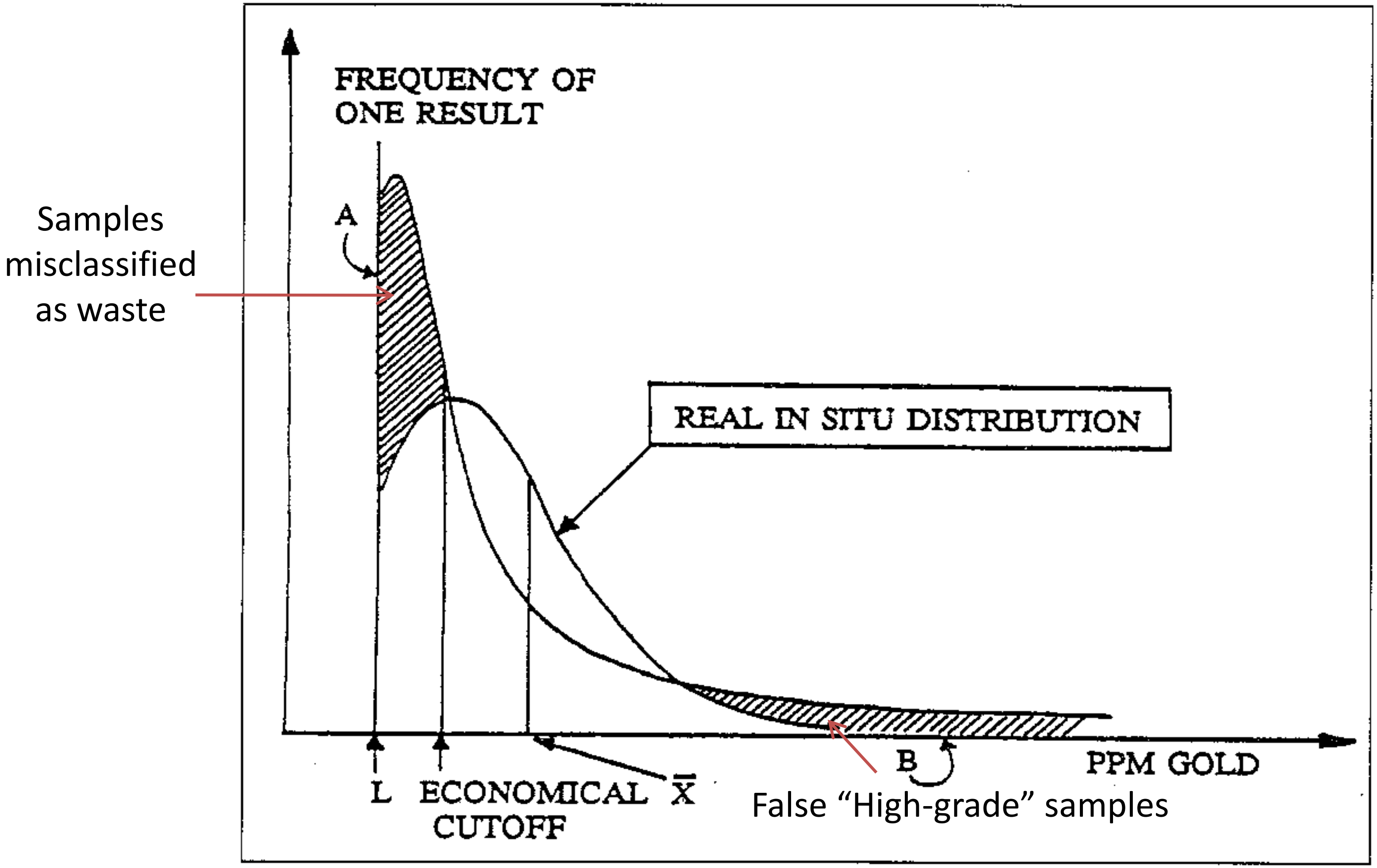
- Average grades and standard deviations calculated for 25 samples
- The bulk coefficient of variation is ~1/3 of that obtained for the 25 g fire assays

# Particulate Au in Soil – Lost Opportunities?




- Significantly more anomalous samples @ 10 ppb Au
- 20% more highly anomalous samples @ 100 ppb Au

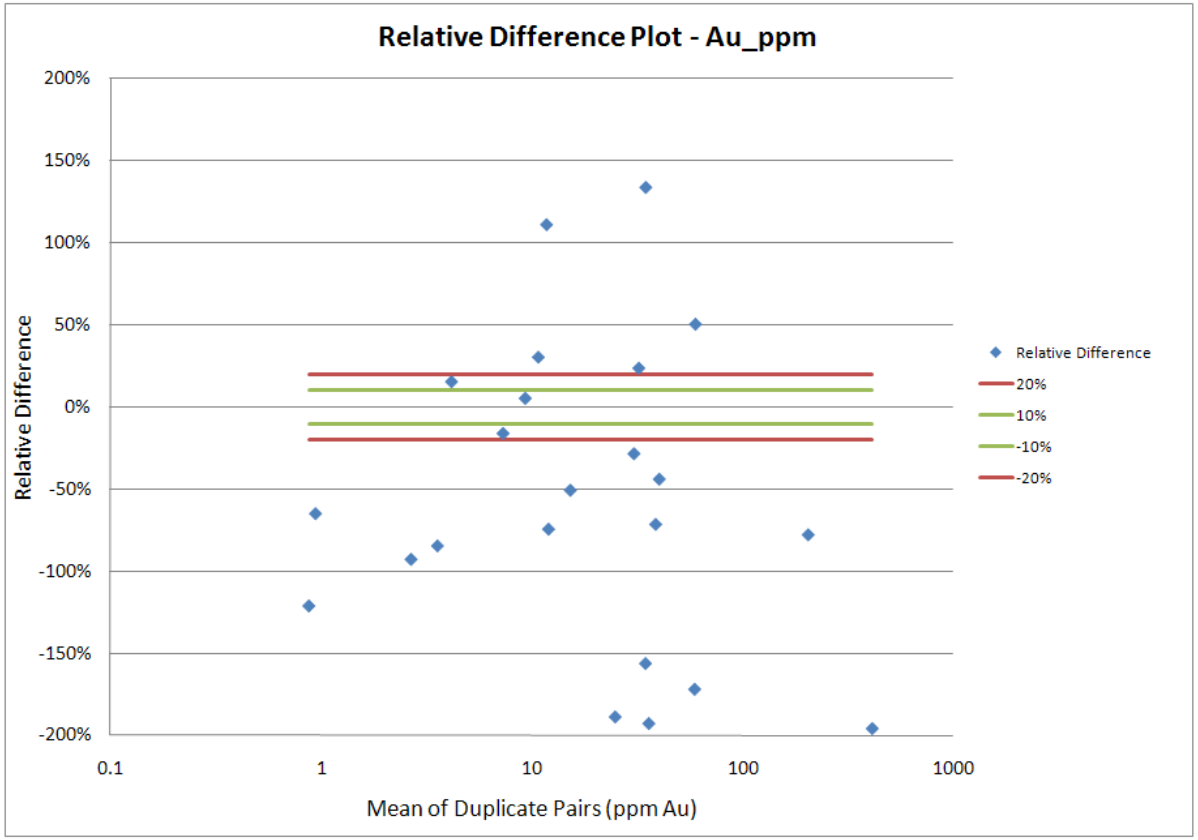
# Economic Consequences of Poor Sampling




Non-representative sampling does not reflect the underlying distribution.

From Sketchley, 1998; after Pitard, 1994

# Gold Assay Reproducibility Problems




- Relative differences between ½ core and ¼ core check samples.
  - Bias toward higher values in the original half-core sample.

# Upgrade in Gold Assay Results

| From (m) | To (m) | Interval (m) | Au (g/t) original fire assay | Au (g/t) metallic screen | Change % |
|---|---|---|---|---|---|
| 116.0 | 117.5 | 1.5 | 2.26 | 2.35 | 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 | 382 | 13.1 |
| 122.0 | 123.5 | 1.5 | 236 | 231 | -2.3 |
| 123.5 | 125.0 | 1.5 | 73.0 | 92.8 | 27.1 |
| 125.0 | 126.5 | 1.5 | 681 | 880 | 29.3 |
| 126.5 | 128.0 | 1.5 | 17.2 | 16.2 | -5.6 |
| 128.0 | 129.5 | 1.5 | 140 | 157 | 11.8 |
| 129.5 | 131.0 | 1.5 | 3.89 | 3.63 | -6.6 |
| **Total: 12.0 metres (117.5m-129.5m) averaging:** | | | **193 g/t** | **227 g/t** | **17.50%** |

- Example is from a Au-rich epithermal system in Turkey
- Samples were re-assayed using 500 g screened metallics

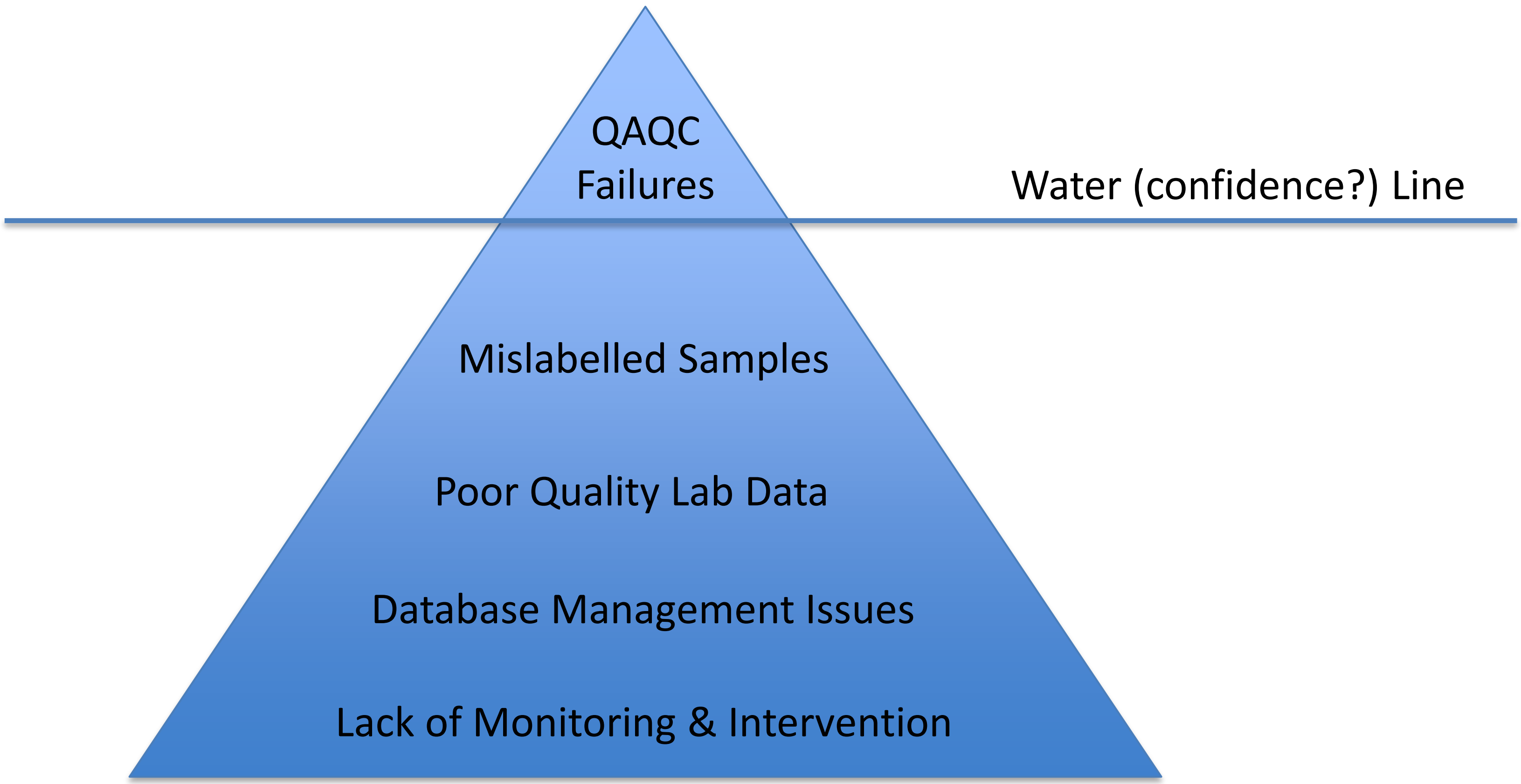


Data from Pilot Gold press release 22/01/2013

# Aspects of Setting up a QAQC Program

- What level of control is required?
- Where is the major source of variation (sampling?)
- Are the certified reference materials (CRMs) appropriate?
- Do the CRMs cover the range of expected grades & anticipated cut-off?
- Are suitable procedures documented?
- Can you access internal laboratory QAQC data?
- What constitutes a QAQC failure?

# Tip of the Iceberg




Too many QAQC failures reduce confidence in the data

# What CRM Value do I Use?

Table 14. Performance gates for precious and base metals by aqua regia digest ICPOES/MS.

| Constituent | 1 σ | | 2 σ | | 3 σ | | 5% | |
|---|---|---|---|---|---|---|---|---|
| | Low | High | Low | High | Low | High | Low | High |
| Antimony, Sb (ppm) | 0.27 | 0.36 | 0.22 | 0.41 | 0.17 | 0.45 | 0.30 | 0.33 |
| Arsenic, As (ppm) | 2.1 | 3.8 | 1.3 | 4.7 | 0.4 | 5.6 | 2.8 | 3.1 |
| Bismuth, Bi (ppm) | 0.16 | 0.19 | 0.15 | 0.20 | 0.14 | 0.22 | 0.17 | 0.19 |
| Cadmium, Cd (ppm) | 0.10 | 0.11 | 0.09 | 0.12 | 0.08 | 0.13 | 0.10 | 0.11 |
| Chromium, Cr (ppm) | 614 | 719 | 561 | 772 | 509 | 825 | 633 | 700 |
| Cobalt, Co (ppm) | 71.5 | 76.1 | 69.3 | 78.3 | 67.0 | 80.6 | 70.1 | 77.5 |
| Copper, Cu (ppm) | 414 | 484 | 378 | 519 | 343 | 554 | 426 | 471 |
| Gold, Au (ppb) | 28 | 35 | 24 | 38 | 21 | 41 | 30 | 33 |
| Lead, Pb (ppm) | 20 | 23 | 18 | 24 | 17 | 25 | 20 | 22 |
| Nickel, Ni (ppm) | 187 | 208 | 176 | 218 | 166 | 229 | 187 | 207 |
| Palladium, Pd (ppb) | 28 | 42 | 22 | 49 | 15 | 55 | 33 | 37 |
| Platinum, Pt (ppb) | 40 | 55 | 32 | 63 | 24 | 71 | 45 | 50 |
| Silver, Ag (ppm) | 0.19 | 0.21 | 0.17 | 0.23 | 0.16 | 0.24 | 0.19 | 0.21 |
| Zinc, Zn (ppm) | 165 | 181 | 157 | 190 | 149 | 198 | 165 | 182 |

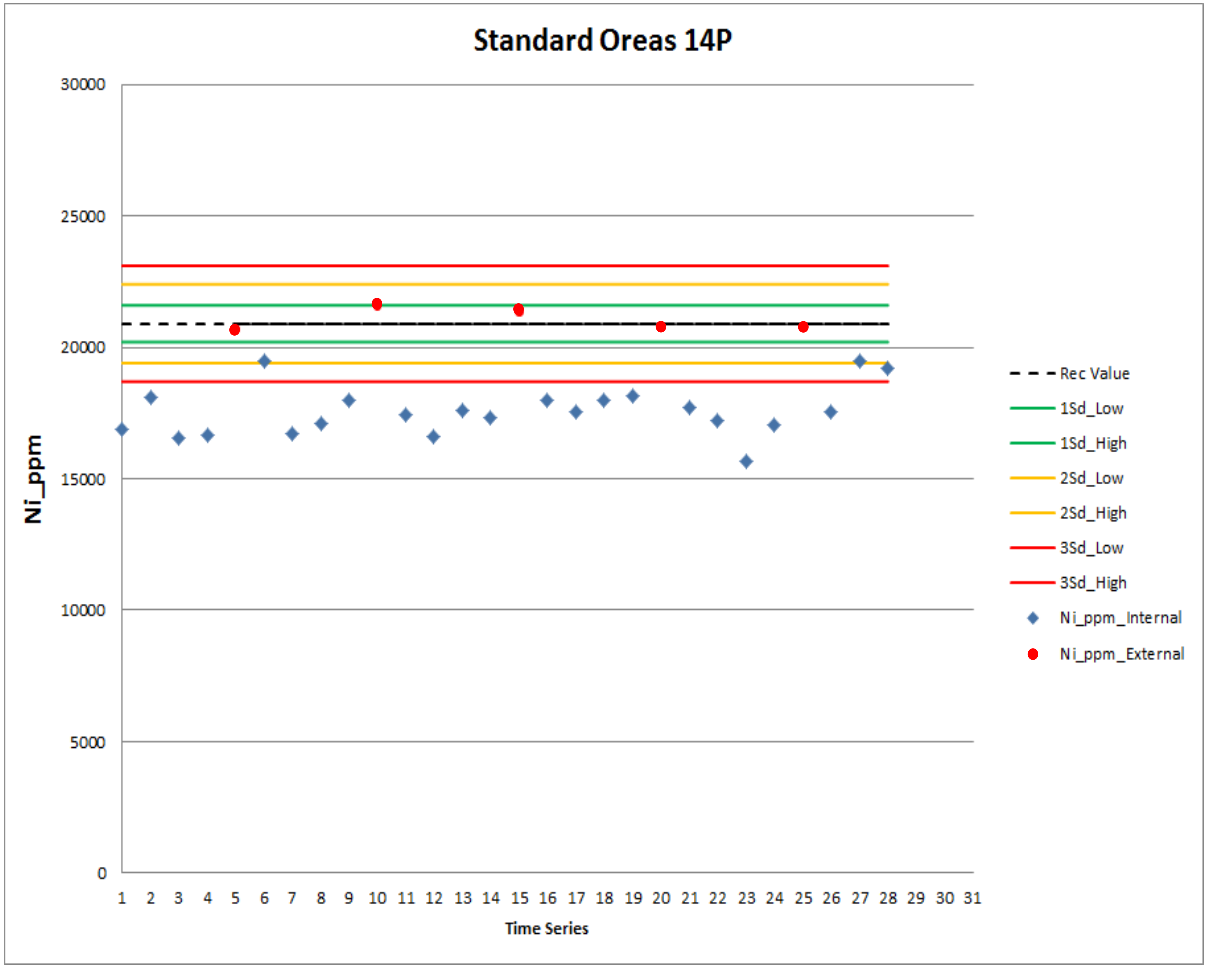
- Use the standard deviation from the clean round robin data
  - Not the confidence interval on the mean determination
    - Make sure digestion method is appropriate

# The CRM Should be Matrix Appropriate

- Inappropriate matrix
- Inappropriate grade
- Target anomaly >7 ppb Au
- Data needed to be cleaned

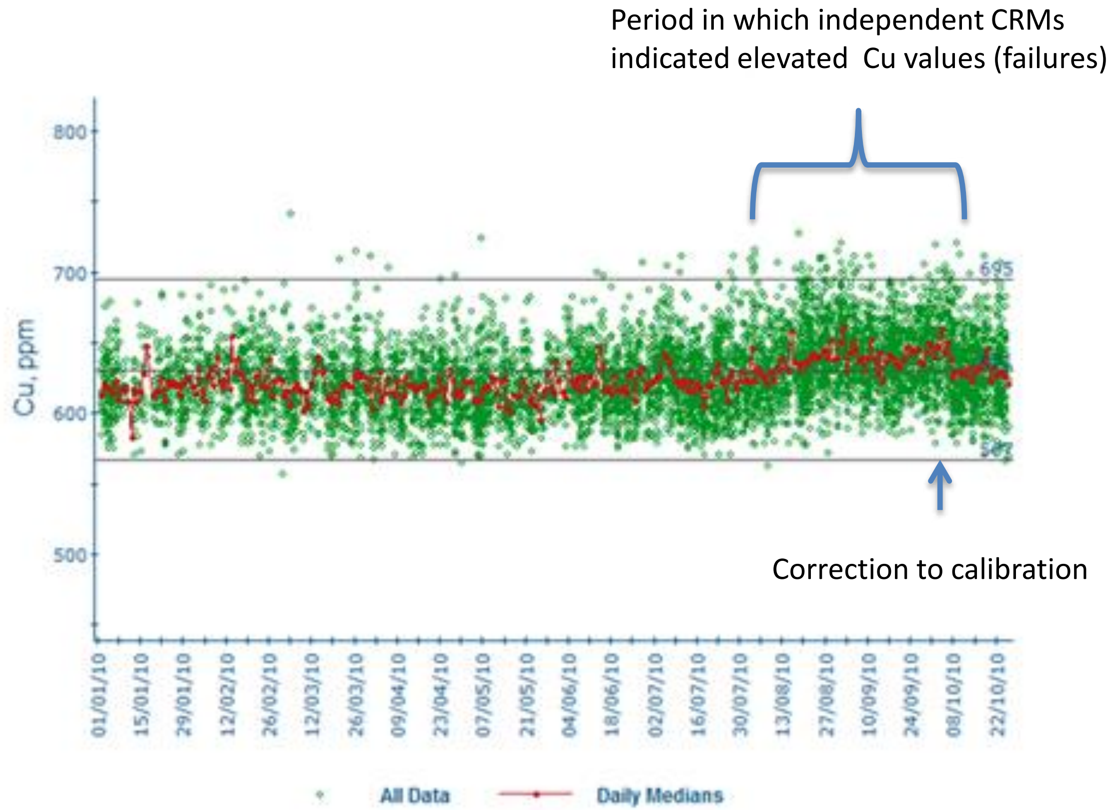
| Sample Type | Au (ppb) |
|---|---|
| Soil | 1.5 |
| Soil | 2 |
| Fresh sulphide CRM | 2720 |
| **Soil (memory effect)** | **32.1** |
| **Soil (memory effect)** | **7.5** |
| Soil | 3.4 |
| Soil | 2.5 |
| Soil | 2.3 |
| Soil | 2.2 |
| Soil | 1.5 |
| Soil | 1.3 |

# Are the Sulphide CRMs Fresh?



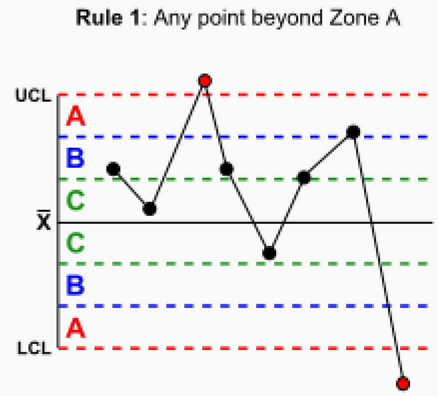
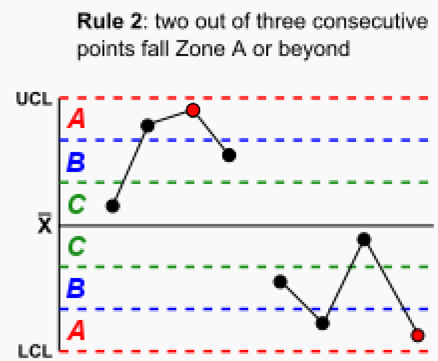

Old bulk CRM (blue) compared to fresh CRM (red).

# All Labs Have a Bias




- Internal laboratory QAQC data
- Re-assays performed after correction
- Intervention was timely – overall data quality >98 % pass rate

# What Constitutes a CRM Failure?

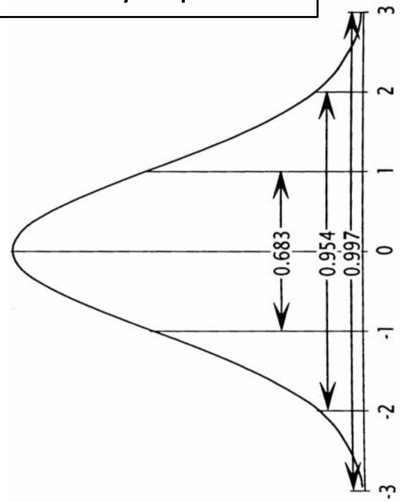
| Rule | Description | Chart Example |
|---|---|---|
| Rule 1 | Any single data point falls outside the 3σ limit from the centerline (i.e., any point that falls outside Zone A, beyond either the upper or lower control limit) |   |
| Rule 2 | Two out of three consecutive points fall beyond the 2σ limit (in zone A or beyond), on the same side of the centerline |   |

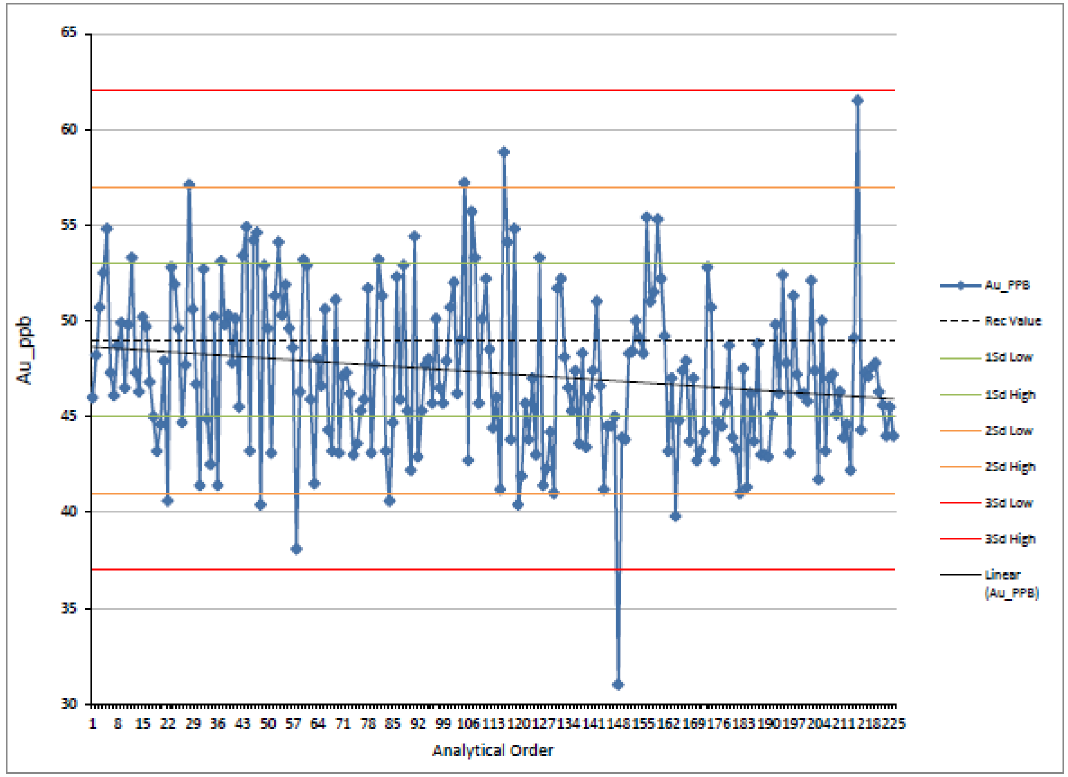
Codified in 1956 by the Western Electric Company

(Modified from Wikepedia, accessed Sept. 13, 2013)

# There Are Statistical "Failures"

11 of 225 > 2 SD
= ~5%, which is
statistically expected

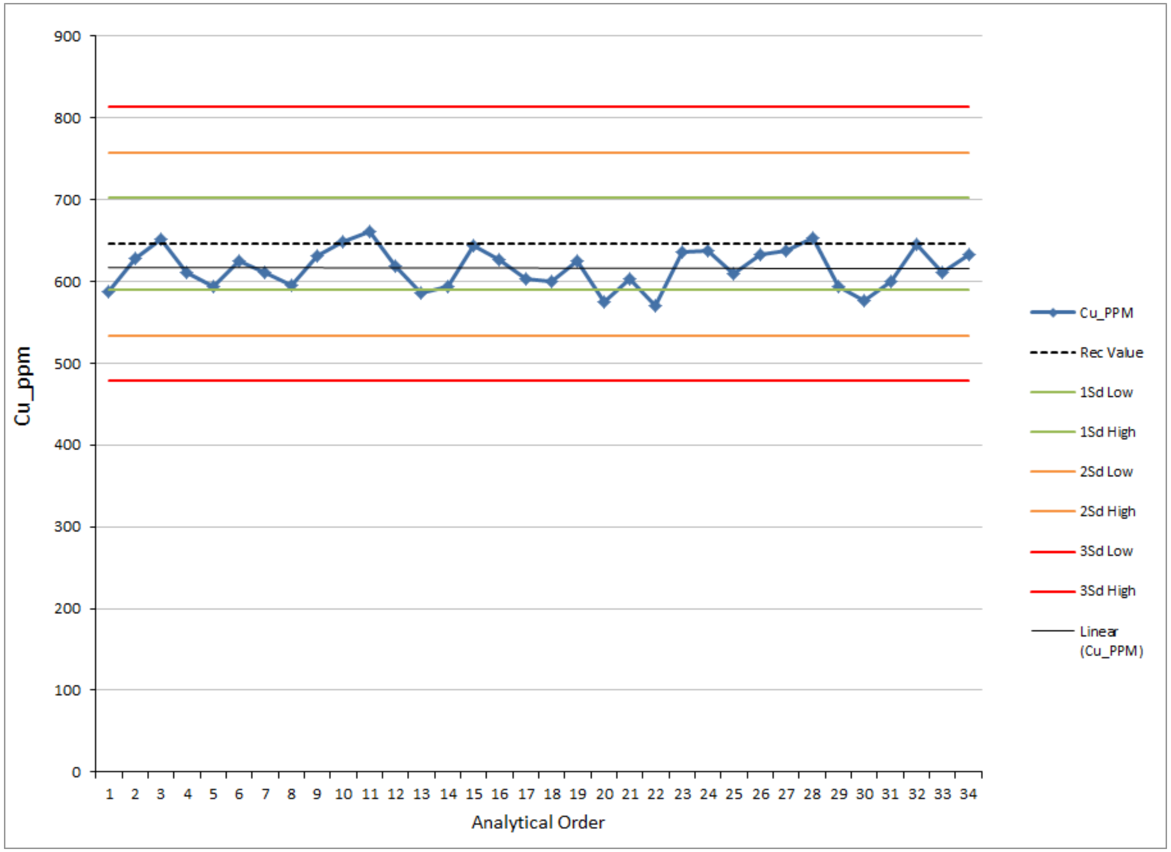



1 of 225 > 3 SD
= ~0.4%, which is also
statistically expected

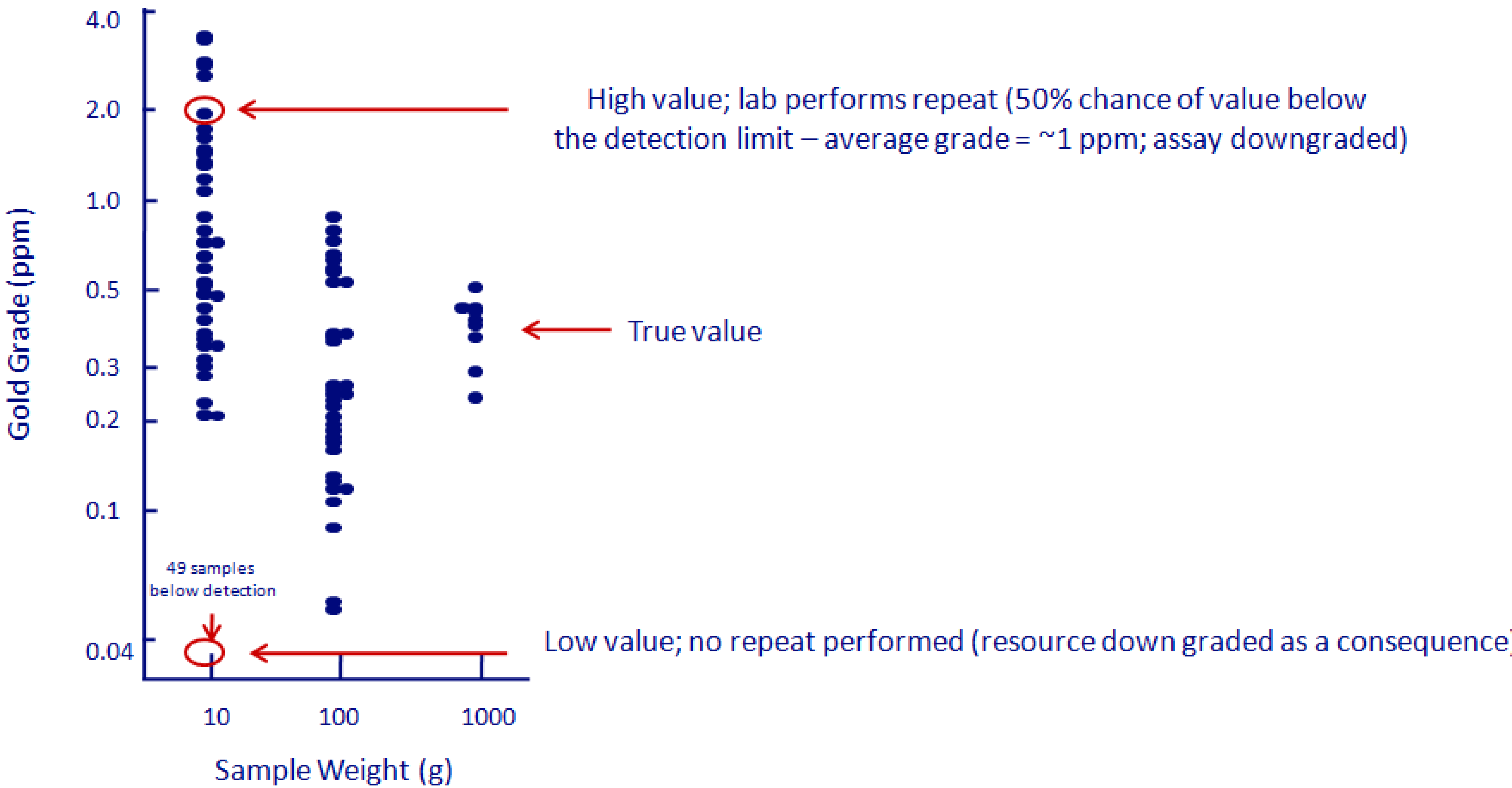
The Au results show the natural spread in data

# What's an Acceptable Bias?




Bias is ~5 % - similar to the uncertainty of the certified mean

# Induced Bias

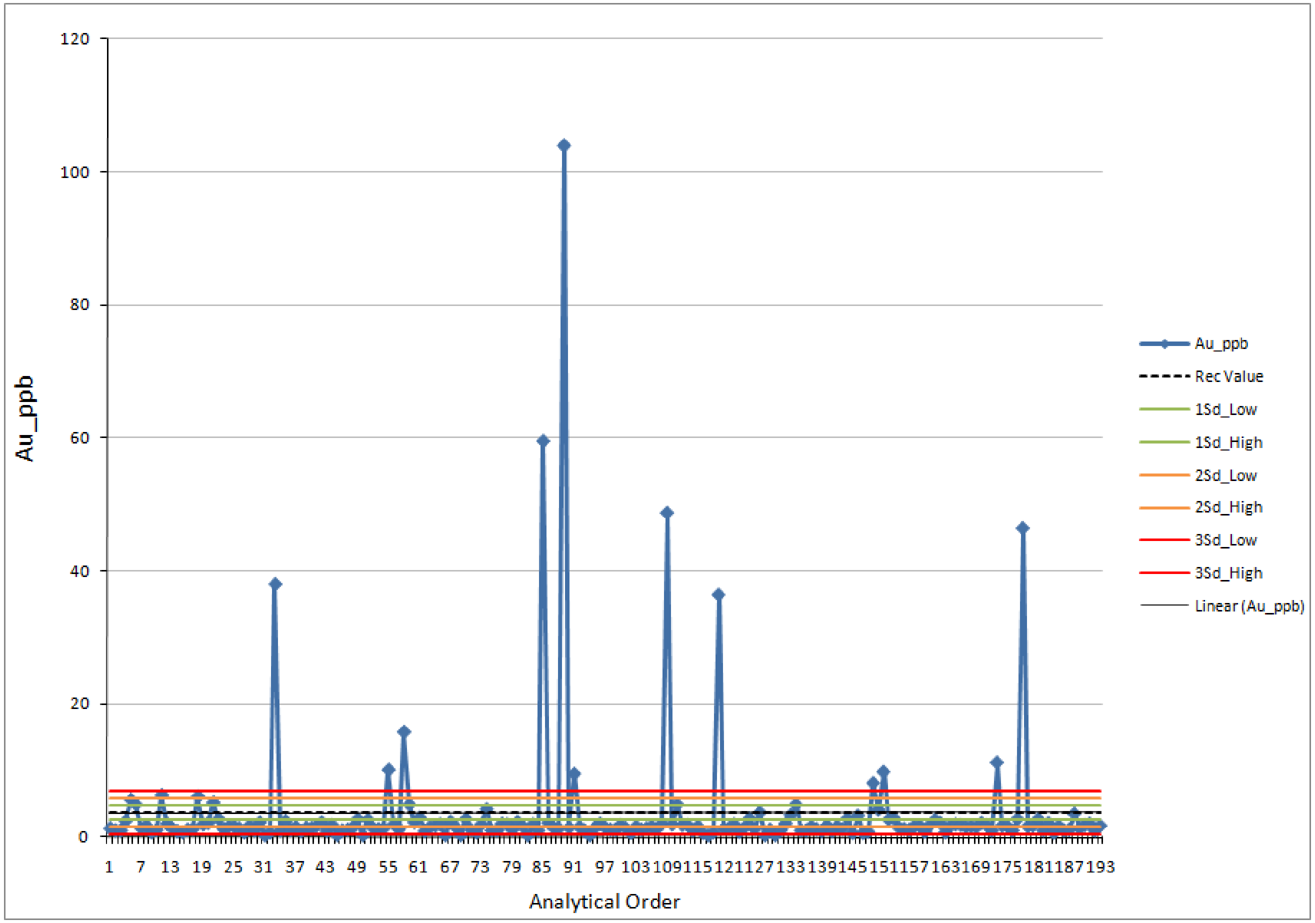



A negative bias can be introduced into a data set by selectively re-assaying only high values <u>and averaging the results</u>.



*(Figure modified from Clifton et al., 1969, Sample size and meaningful gold analysis, USGS Prof. Paper 625C)*

# Is Your Blank Contaminated?




- Locally sourced sand not analyzed to demonstrate homogeneity
  - Contains nuggetty Au (best anomalies!)

# How do we Define Precision?

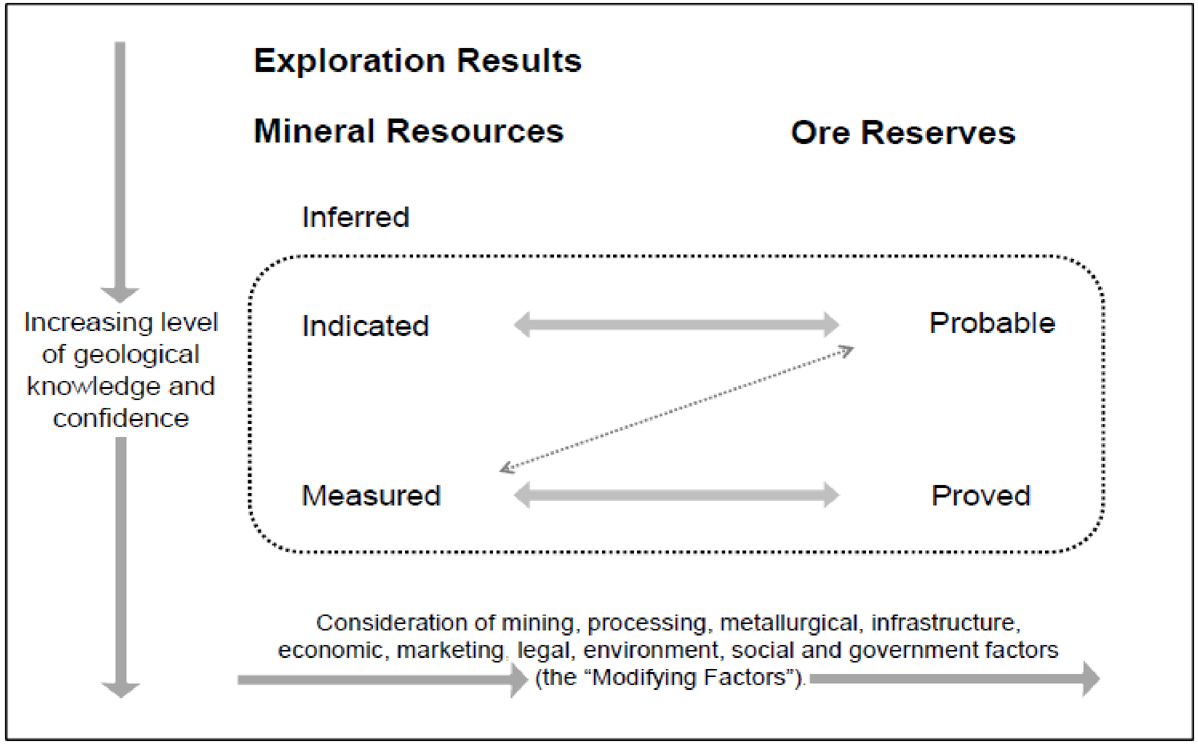
Table 1. List of Common Measures of Relative Error Calculated from Duplicate Pairs of Measurements and Used in a Variety of Geological Applications

| Measurement | Conceptual Formula | Single Duplicate Pair Formula | Average Formula for Several Duplicate Pairs | Relationship with $CV$ |
|---|---|---|---|---|
| Coefficient of Variation ($CV$) | $CV = \frac{\sigma}{\mu}$ | $CV = \frac{2}{\sqrt{2}} \frac{\lvert x_1 - x_2 \rvert}{(x_1 + x_2)}$ | $\overline{CV} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{2}{\sqrt{2}} \frac{\lvert x_{1i} - x_{2i} \rvert}{(x_{1i} + x_{2i})}\right)^2}$ | $CV$ |
| Relative Precision ($RP$) | $RP = \frac{2\sigma}{\mu}$ | $RP = \frac{4}{\sqrt{2}} \frac{\lvert x_1 - x_2 \rvert}{(x_1 + x_2)}$ | $\overline{RP} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{4}{\sqrt{2}} \frac{\lvert x_{1i} - x_{2i} \rvert}{(x_{1i} + x_{2i})}\right)^2}$ | $2 \times CV$ |
| Relative Variance ($RV$) | $RV = \frac{\sigma^2}{\mu^2}$ | $RV = 2\frac{(x_1 - x_2)^2}{(x_1 + x_2)^2}$ | $\overline{RV} = \frac{1}{n}\sum_{i=1}^{n}\left(2\frac{(x_{1i} - x_{2i})^2}{(x_{1i} + x_{2i})^2}\right)$ | $CV^2$ |
| Absolute Relative Difference ($ARD$) | $ARD = \frac{\lvert x_1 - x_2 \rvert}{\mu}$ | $ARD = 2\frac{\lvert x_1 - x_2 \rvert}{(x_1 + x_2)}$ | $\overline{ARD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(2\frac{\lvert x_{1i} - x_{2i} \rvert}{(x_{1i} + x_{2i})}\right)^2}$ | $\sqrt{2} \times CV$ |
| Half Absolute Relative Difference ($HARD$) | $HARD = \frac{1}{2}\frac{\lvert x_1 - x_2 \rvert}{\mu}$ | $HARD = \frac{\lvert x_1 - x_2 \rvert}{(x_1 + x_2)}$ | $\overline{HARD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{\lvert x_{1i} - x_{2i} \rvert}{(x_{1i} + x_{2i})}\right)^2}$ | $\frac{\sqrt{2}}{2} \times CV$ |

Stanley, C.R. and Lawie, D., 2007, Average relative error in geochemical determinations: Clarification, calculation and a plea for consistency. Exploration & Mining Geology, vol. 16, pp. 267-275.

# Quality Expectations

Increasing assay data accuracy, precision and relevance




– Exploration: >90 % CRM pass rate; <10 % bias; CV<15 %
– Inferred resources: >95 % CRM pass rate; <5 % bias; CV<10 %
– Measured & indicated: >98 % CRM pass rate; <5 % bias; CV<5 %

Figure 1 from JORC 2012

# Conclusions

- Errors are additive  - it starts with sampling
- Set corporate data quality objectives
- Data should be fit for purpose
- Quality expectations should evolve with project
- Focus on the desired result (JORC), not the process (NI43-101)
- Don’t forget the quality assurance
- As an industry we are imprecise on precision