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**CERTIFICATE OF ANALYSIS FOR**

# COPPER ORE

# CERTIFIED REFERENCE MATERIAL

# OREAS 903

**Table 1. Certified Values, SDs, 95% Confidence and Tolerance Limits for OREAS 903.**

| Constituent | Certified Value | 1SD | 95% Confidence Limits | | 95% Tolerance Limits | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| **4 Acid Digestion** | | | | | | |
| Ag, Silver (ppm) | 0.432 | 0.051 | 0.406 | 0.458 | 0.409 | 0.455 |
| Al, Aluminium (wt.%) | 5.89 | 0.279 | 5.75 | 6.03 | 5.75 | 6.03 |
| As, Arsenic (ppm) | 49.7 | 3.77 | 48.0 | 51.3 | 47.2 | 52.1 |
| Ba, Barium (ppm) | 197 | 9 | 193 | 202 | 191 | 204 |
| Be, Beryllium (ppm) | 4.42 | 0.387 | 4.23 | 4.62 | 4.27 | 4.57 |
| Bi, Bismuth (ppm) | 8.94 | 0.481 | 8.70 | 9.18 | 8.69 | 9.20 |
| Ca, Calcium (wt.%) | 0.625 | 0.029 | 0.613 | 0.637 | 0.605 | 0.646 |
| Cd, Cadmium (ppm) | 0.20 | 0.019 | 0.19 | 0.21 | 0.18 | 0.22 |
| Ce, Cerium (ppm) | 82 | 5.6 | 79 | 86 | 79 | 85 |
| Co, Cobalt (ppm) | 131 | 8 | 127 | 135 | 127 | 135 |
| Cr, Chromium (ppm) | 73 | 4.6 | 70 | 75 | 70 | 76 |
| Cs, Cesium (ppm) | 3.57 | 0.121 | 3.50 | 3.63 | 3.46 | 3.68 |
| Cu, Copper (wt.%) | 0.652 | 0.020 | 0.642 | 0.661 | 0.639 | 0.665 |
| Fe, Iron (wt.%) | 4.16 | 0.179 | 4.07 | 4.25 | 4.06 | 4.26 |
| Ga, Gallium (ppm) | 15.0 | 1.7 | 14.4 | 15.6 | 14.5 | 15.5 |
| Hf, Hafnium (ppm) | 4.56 | 0.350 | 4.35 | 4.77 | 4.44 | 4.68 |
| In, Indium (ppm) | 0.16 | 0.02 | 0.15 | 0.17 | 0.15 | 0.17 |
| K, Potassium (wt.%) | 3.31 | 0.207 | 3.19 | 3.42 | 3.20 | 3.41 |
| La, Lanthanum (ppm) | 40.2 | 4.02 | 38.0 | 42.4 | 39.1 | 41.4 |
| Li, Lithium (ppm) | 18.3 | 0.72 | 18.0 | 18.7 | 17.7 | 19.0 |
| Lu, Lutetium (ppm) | 0.36 | 0.04 | 0.34 | 0.39 | 0.34 | 0.39 |
| Mg, Magnesium (wt.%) | 0.714 | 0.051 | 0.687 | 0.741 | 0.695 | 0.733 |
| Mn, Manganese (wt.%) | 0.069 | 0.003 | 0.067 | 0.071 | 0.067 | 0.071 |
| Mo, Molybdenum (ppm) | 4.32 | 0.335 | 4.17 | 4.47 | 4.08 | 4.56 |
| Na, Sodium (wt.%) | 0.030 | 0.001 | 0.029 | 0.031 | 0.029 | 0.031 |
| Ni, Nickel (ppm) | 54 | 4.7 | 52 | 56 | 52 | 56 |
| P, Phosphorus (wt.%) | 0.107 | 0.009 | 0.102 | 0.112 | 0.104 | 0.110 |
| Pb, Lead (ppm) | 11.3 | 1.7 | 10.4 | 12.1 | 10.8 | 11.8 |
| Rb, Rubidium (ppm) | 137 | 19 | 126 | 148 | 131 | 142 |
| S, Sulphur (wt.%) | 0.500 | 0.036 | 0.481 | 0.518 | 0.483 | 0.516 |
| Sb, Antimony (ppm) | 1.57 | 0.141 | 1.49 | 1.65 | 1.51 | 1.63 |
| Sc, Scandium (ppm) | 10.2 | 0.50 | 10.0 | 10.5 | 9.9 | 10.6 |
| Se, Selenium (ppm) | 6.06 | 0.85 | 5.59 | 6.54 | IND | IND |
| Sn, Tin (ppm) | 2.63 | 0.261 | 2.50 | 2.76 | 2.49 | 2.77 |
| Sr, Strontium (ppm) | 77 | 3.7 | 75 | 79 | 75 | 79 |
| Ta, Tantalum (ppm) | 0.54 | 0.08 | 0.48 | 0.59 | 0.48 | 0.59 |
| Tb, Terbium (ppm) | 0.83 | 0.09 | 0.76 | 0.91 | 0.79 | 0.88 |
| Th, Thorium (ppm) | 13.6 | 0.71 | 13.2 | 14.1 | 13.2 | 14.1 |
| Ti, Titanium (wt.%) | 0.192 | 0.037 | 0.171 | 0.214 | 0.181 | 0.204 |
| Tl, Thallium (ppm) | 0.62 | 0.041 | 0.60 | 0.64 | 0.60 | 0.65 |
| U, Uranium (ppm) | 7.58 | 0.584 | 7.26 | 7.90 | 7.32 | 7.84 |
| V, Vanadium (ppm) | 74 | 2.3 | 73 | 75 | 72 | 76 |
| Y, Yttrium (ppm) | 22.5 | 2.3 | 21.2 | 23.7 | 21.8 | 23.2 |
| Yb, Ytterbium (ppm) | 2.36 | 0.163 | 2.23 | 2.50 | 2.22 | 2.50 |
| Zn, Zinc (ppm) | 24.3 | 2.24 | 23.1 | 25.4 | 22.6 | 26.0 |
| Zr, Zirconium (ppm) | 152 | 11 | 146 | 158 | 147 | 157 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 1. Certified Values, SDs, 95% Confidence and Tolerance Limits for OREAS 903 continued.**

| Constituent | Certified Value | 1SD | 95% Confidence Limits | | 95% Tolerance Limits | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| **Aqua Regia Digestion** | | | | | | |
| Ag, Silver (ppm) | 0.349 | 0.038 | 0.331 | 0.366 | 0.332 | 0.365 |
| Al, Aluminium (wt.%) | 0.538 | 0.036 | 0.516 | 0.559 | 0.513 | 0.562 |
| As, Arsenic (ppm) | 47.5 | 2.12 | 46.6 | 48.4 | 46.2 | 48.8 |
| Au, Gold (ppb) | < 5 | IND | IND | IND | IND | IND |
| Ba, Barium (ppm) | 63 | 4.3 | 60 | 65 | 60 | 66 |
| Be, Beryllium (ppm) | 2.69 | 0.268 | 2.54 | 2.85 | 2.62 | 2.77 |
| Bi, Bismuth (ppm) | 8.76 | 0.771 | 8.36 | 9.16 | 8.52 | 8.99 |
| Ca, Calcium (wt.%) | 0.633 | 0.030 | 0.618 | 0.649 | 0.618 | 0.649 |
| Cd, Cadmium (ppm) | 0.21 | 0.012 | 0.20 | 0.21 | 0.19 | 0.22 |
| Ce, Cerium (ppm) | 46.2 | 2.56 | 44.5 | 48.0 | 44.3 | 48.2 |
| Co, Cobalt (ppm) | 131 | 7 | 127 | 134 | 128 | 134 |
| Cr, Chromium (ppm) | 26.1 | 1.81 | 25.2 | 27.1 | 24.6 | 27.7 |
| Cs, Cesium (ppm) | 0.28 | 0.04 | 0.25 | 0.31 | 0.27 | 0.30 |
| Cu, Copper (wt.%) | 0.671 | 0.020 | 0.663 | 0.679 | 0.659 | 0.682 |
| Fe, Iron (wt.%) | 3.94 | 0.266 | 3.80 | 4.08 | 3.85 | 4.03 |
| Ga, Gallium (ppm) | 1.58 | 0.22 | 1.42 | 1.73 | 1.49 | 1.66 |
| Ge, Germanium (ppm) | 0.098 | 0.015 | 0.087 | 0.109 | IND | IND |
| Hf, Hafnium (ppm) | 0.61 | 0.052 | 0.57 | 0.65 | 0.58 | 0.64 |
| In, Indium (ppm) | 0.11 | 0.010 | 0.11 | 0.12 | 0.11 | 0.12 |
| K, Potassium (wt.%) | 0.331 | 0.029 | 0.314 | 0.348 | 0.314 | 0.348 |
| La, Lanthanum (ppm) | 22.8 | 3.8 | 20.7 | 24.9 | 22.0 | 23.6 |
| Lu, Lutetium (ppm) | 0.099 | 0.010 | 0.089 | 0.109 | IND | IND |
| Mg, Magnesium (wt.%) | 0.234 | 0.030 | 0.217 | 0.251 | 0.224 | 0.244 |
| Mn, Manganese (wt.%) | 0.071 | 0.004 | 0.069 | 0.073 | 0.069 | 0.073 |
| Mo, Molybdenum (ppm) | 4.26 | 0.47 | 4.01 | 4.50 | 4.10 | 4.41 |
| Ni, Nickel (ppm) | 48.7 | 3.06 | 47.1 | 50.3 | 47.3 | 50.1 |
| P, Phosphorus (wt.%) | 0.103 | 0.005 | 0.100 | 0.105 | 0.100 | 0.106 |
| Pb, Lead (ppm) | 8.95 | 0.91 | 8.49 | 9.41 | 8.68 | 9.22 |
| Rb, Rubidium (ppm) | 12.6 | 1.13 | 11.9 | 13.3 | 11.8 | 13.4 |
| S, Sulphur (wt.%) | 0.501 | 0.036 | 0.481 | 0.521 | 0.485 | 0.516 |
| Sb, Antimony (ppm) | 0.96 | 0.11 | 0.89 | 1.02 | 0.92 | 1.00 |
| Sc, Scandium (ppm) | 3.15 | 0.211 | 3.03 | 3.27 | 3.03 | 3.27 |
| Se, Selenium (ppm) | 5.34 | 0.57 | 5.04 | 5.64 | 5.07 | 5.62 |
| Sr, Strontium (ppm) | 17.7 | 1.36 | 16.9 | 18.4 | 17.0 | 18.4 |
| Tb, Terbium (ppm) | 0.47 | 0.05 | 0.42 | 0.52 | 0.46 | 0.48 |
| Te, Tellurium (ppm) | 0.034 | 0.006 | 0.031 | 0.037 | IND | IND |
| Th, Thorium (ppm) | 6.36 | 0.563 | 6.03 | 6.68 | 6.19 | 6.52 |
| Ti, Titanium (wt.%) | 0.008 | 0.001 | 0.007 | 0.009 | 0.008 | 0.009 |
| Tl, Thallium (ppm) | 0.14 | 0.02 | 0.13 | 0.15 | IND | IND |
| U, Uranium (ppm) | 3.24 | 0.293 | 3.06 | 3.41 | 3.15 | 3.33 |
| V, Vanadium (ppm) | 13.3 | 0.72 | 12.9 | 13.7 | IND | IND |
| W, Tungsten (ppm) | 0.53 | 0.08 | 0.48 | 0.58 | 0.47 | 0.59 |
| Y, Yttrium (ppm) | 9.23 | 0.654 | 8.83 | 9.62 | 8.96 | 9.50 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 1. Certified Values, SDs, 95% Confidence and Tolerance Limits for OREAS 903 continued.**

| Constituent | Certified Value | 1SD | 95% Confidence Limits | | 95% Tolerance Limits | |
|---|---|---|---|---|---|---|
| | | | Low | High | Low | High |
| **Aqua Regia Digestion ICP-OES/MS** | | | | | | |
| Yb, Ytterbium (ppm) | 0.69 | 0.07 | 0.62 | 0.76 | IND | IND |
| Zn, Zinc (ppm) | 21.3 | 1.46 | 20.6 | 22.1 | 20.2 | 22.5 |
| Zr, Zirconium (ppm) | 18.2 | 1.73 | 16.9 | 19.4 | 17.5 | 18.8 |
| **Sulphuric Acid Leach** | | | | | | |
| Copper Soluble, Cu-Sol (wt.%) | 0.434 | 0.030 | 0.417 | 0.451 | 0.426 | 0.442 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 2. Indicative Values for OREAS 903.**

| Constituent | Unit | Value | Constituent | Unit | Value | Constituent | Unit | Value |
|---|---|---|---|---|---|---|---|---|
| **Borate Fusion XRF** | | | | | | | | |
| $Al_2O_3$ | wt.% | *11.48* | $Fe_2O_3$ | wt.% | *6.19* | $SnO_2$ | ppm | *< 13* |
| As | ppm | *80* | $K_2O$ | wt.% | *4.23* | $SO_3$ | wt.% | *1.25* |
| BaO | ppm | *218* | MgO | wt.% | *1.26* | SrO | ppm | *95* |
| CaO | wt.% | *0.857* | MnO | wt.% | *0.091* | $TiO_2$ | wt.% | *0.501* |
| Cl | ppm | *30.0* | NiO | ppm | *115* | $V_2O_5$ | ppm | *152* |
| CoO | ppm | *178* | $P_2O_5$ | wt.% | *0.251* | ZnO | ppm | *18.7* |
| $Cr_2O_3$ | ppm | *88* | PbO | ppm | *10.8* | $ZrO_2$ | ppm | *216* |
| CuO | ppm | *8206* | $SiO_2$ | wt.% | *71.11* | | | |
| **Thermogravimetry** | | | | | | | | |
| $LOI^{1000}$ | wt.% | *4.15* | | | | | | |
| **Laser Ablation ICP-MS** | | | | | | | | |
| Ag | ppm | *0.350* | Ho | ppb | *885* | Sr | ppm | *74* |
| As | ppm | *50* | In | ppm | *0.13* | Ta | ppb | *955* |
| Ba | ppm | *192* | La | ppm | *42.8* | Tb | ppb | *740* |
| Be | ppm | *4.00* | Lu | ppb | *365* | Te | ppb | *< 200* |
| Bi | ppm | *9.53* | Mo | ppm | *4.70* | Th | ppm | *13.8* |
| Cd | ppm | *0.10* | Nb | ppm | *11.2* | Tl | ppm | *0.60* |
| Ce | ppm | *83* | Nd | ppm | *33.8* | Tm | ppb | *350* |
| Co | ppm | *135* | Ni | ppm | *53* | U | ppm | *7.60* |
| Cr | ppm | *51* | Pb | wt.% | *0.001* | V | ppm | *80* |
| Cs | ppm | *3.64* | Pr | ppm | *9.89* | W | ppm | *2.28* |
| Dy | ppm | *4.16* | Rb | ppm | *148* | Y | ppm | *23.8* |
| Er | ppm | *2.24* | Re | ppb | *< 10* | Yb | ppb | *2400* |
| Eu | ppb | *1330* | Sb | ppm | *1.50* | Zn | ppm | *10.0* |
| Ga | ppm | *15.1* | Sc | ppm | *10.7* | Zr | ppm | *165* |
| Gd | ppm | *5.49* | Se | ppm | *5.00* | Cu | ppm | *6545* |
| Ge | ppb | *1500* | Sm | ppm | *6.93* | | | |
| Hf | ppb | *4750* | Sn | ppm | *3.50* | | | |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 2. Indicative Values for OREAS 903 continued.**

| Constituent | Unit | Value | Constituent | Unit | Value | Constituent | Unit | Value |
|---|---|---|---|---|---|---|---|---|
| **4 Acid Digestion** | | | | | | | | |
| Dy | ppm | *4.43* | Ho | ppm | *0.84* | Sm | ppm | *6.90* |
| Er | ppm | *2.45* | Nb | ppm | *6.45* | Te | ppm | *0.039* |
| Eu | ppm | *1.30* | Nd | ppm | *32.2* | Tm | ppm | *0.36* |
| Gd | ppm | *5.82* | Pr | ppm | *8.76* | W | ppm | *1.87* |
| Ge | ppm | *0.19* | Re | ppm | *< 0.002* | | | |
| **Aqua Regia Digestion** | | | | | | | | |
| B | ppm | *11.7* | Ho | ppm | *0.35* | Re | ppm | *< 0.001* |
| Dy | ppm | *1.88* | Li | ppm | *1.98* | Sm | ppm | *4.37* |
| Er | ppm | *0.82* | Na | wt.% | *0.010* | Sn | ppm | *0.40* |
| Eu | ppm | *0.80* | Nb | ppm | *0.13* | Ta | ppm | *< 0.01* |
| Gd | ppm | *3.61* | Nd | ppm | *20.2* | Tm | ppm | *0.099* |
| Hg | ppm | *0.060* | Pr | ppm | *4.89* | | | |
| **Pb Fire Assay** | | | | | | | | |
| Au | ppb | *49.6* | | | | | | |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

## INTRODUCTION

OREAS reference materials are intended to provide a low cost method of evaluating and improving the quality of analysis of geological samples. To the geologist they provide a means of implementing quality control in analytical data sets generated in exploration from the grass roots level through to prospect evaluation, and in grade control at mining operations. To the analyst they provide an effective means of calibrating analytical equipment, assessing new techniques and routinely monitoring in-house procedures.

OREAS reference materials enable users to successfully achieve process control of these tasks because the observed variance from repeated analysis has its origin almost exclusively in the analytical process rather than the reference material itself.

## SOURCE MATERIALS

OREAS 903 is a medium grade transitional-oxide copper ore certified reference material. It is one of a suite of four transitional to oxide copper CRMs prepared from samples sourced from CST's Lady Annie Mine, located 120 kms northwest of Mount Isa, Queensland, Australia. Mineralisation at Lady Annie is hosted in dolomitic, carbonaceous and argillaceous sandstones and siltstones. The oxide deposits consist primarily of near surface malachite mineralisation with minor cuprite, chrysocolla and chalcocite extending from surface to a depth of 60 to 100 m. The oxide copper deposit is underlain by deeper transition and sulphide mineralisation. The primary copper sulphide mineralisation at depth is dominated by chalcocite and chalcopyrite and appears to be structurally controlled, being commonly associated with fault-related silicification.

## COMMINUTION AND HOMOGENISATION PROCEDURES

The material constituting OREAS 903 was prepared in the following manner:

- Drying to constant mass at 105°C;
- Crushing;
- Milling to 100% minus 30 microns;
- Homogenisation;
- Packaging into 10g units in laminated foil pouches and into 1kg units in plastic jars.

## ANALYTICAL PROGRAM

Nineteen commercial analytical laboratories participated in the program to characterise the elements reported in Table 1 to 2. The following methods were employed:

- Four acid digestion with ICP-OES and ICP-MS finish (18 laboratories)
- Aqua regia digestion with ICP-OES and ICP-MS finish (19 laboratories)
- 5% $H_2SO_4$ acid leach with AAS or ICP-OES finish (14 laboratories)

For the round robin program twenty 1kg test units were taken at predetermined intervals during the bagging stage after final blending and are considered representative of the entire batch. The six samples received by each laboratory were obtained by taking two 110g scoop splits from each of three separate 1kg test units. This format enabled nested ANOVA treatment of the results to evaluate homogeneity.

Tabulated results of all elements together with analytical method codes, uncorrected means, medians, standard deviations, relative standard deviations and per cent deviation of lab means from the corrected mean of means ($PDM^3$) are presented in the detailed certification data for this CRM (**OREAS 903 DataPack-3.0.180823_152253.xlsx**).

Table 1 presents the certified values together with their associated 1SD's, 95% confidence and tolerance limits and Table 2 provides the approximate major and trace element composition.

## STATISTICAL ANALYSIS

**Certified Values, Standard Deviations, Confidence and Tolerance Limits** have been determined for each analytical method following removal of individual and laboratory outliers (see Table 1). Certified Values are the mean of means after outlier filtering. The 95% Confidence Limit is a measure of the reliability of the certified value, i.e. the narrower the Confidence Interval the greater the certainty in the Certified Value. It should not be used as a control limit for laboratory performance.

**Indicative (uncertified) values** (Table 2) are provided for the major and trace elements determined by borate fusion XRF ($Al_2O_3$ to $TiO_2$), laser ablation with ICP-MS (Ag to Zr) and LOI at 1000°C and are the means of duplicate assays from Bureau Veritas, Perth. Additional indicative values by other analytical methods are present where the number of laboratories reporting a particular analyte is insufficient (< 5) to support certification or where inter-laboratory consensus is poor.

**Standard Deviation** values (1SDs) are reported in Table 1 and provide an indication of a level of performance that might reasonably be expected from a laboratory being monitored by this CRM in a QA/QC program. They take into account errors attributable to measurement uncertainty and CRM variability. For an effective CRM the contribution of the latter should be negligible in comparison to measurement errors. The Standard Deviation values include all sources of measurement uncertainty: between-lab variance, within-run variance (precision errors) and CRM variability. The SD for each analyte's certified value is calculated from the same filtered data set used to determine the certified value, i.e. after removal of all individual, lab dataset (batch) and 3SD outliers (single iteration). These outliers can only be removed after the absolute homogeneity of the CRM has been independently established, i.e. the outliers must be confidently deemed to be analytical rather than arising from inhomogeneity of the CRM. The standard deviation is then calculated for each analyte from the pooled accepted analyses generated from the certification program.

As a guide two or more analytical results lying outside the 2SD window may be regarded as warning or rejection, and rejection for single results lying outside the 3SD window in QC monitoring, although their precise application should be at the discretion of the QC manager concerned.

**Tolerance Limits** (ISO Guide 3207) were determined using an analysis of precision errors method and are considered a conservative estimate of true homogeneity. The meaning of tolerance limits may be illustrated for copper by 4-acid digestion, where 99% of the time (1-α=0.99) at least 95% of subsamples (ρ=0.95) will have concentrations lying between 0.639 and 0.665 wt.%. Put more precisely, this means that if the same number of subsamples were taken and analysed in the same manner repeatedly, 99% of the tolerance intervals so constructed would cover at least 95% of the total population, and 1% of the tolerance intervals would cover less than 95% of the total population (IS0 Guide 35).
The homogeneity of OREAS 903 has also been evaluated in an ANOVA study for all certified analytes. This study indicates no evidence that between-unit variance is greater than within-unit variance.

Based on the statistical analysis of the results of the interlaboratory certification program it can be concluded that OREAS 903 is fit-for-purpose as a certified reference material (see 'Intended Use' below).

**Performance Gates**
Performance gates provide an indication of a level of performance that might reasonably be expected from a laboratory being monitored by this CRM in a QA/QC program. They take into account errors attributable to measurement and CRM variability. For an effective CRM the contribution of the latter should be negligible in comparison to measurement errors. Sources of measurement error include inter-lab bias, analytical precision (repeatability) and inter-batch bias (reproducibility).

Two methods have been employed to calculate performance gates. The first method uses the same filtered data set used to determine the certified value, i.e. after removal of all individual, lab dataset (batch) and 3SD outliers. These outliers can only be removed after the absolute homogeneity of the CRM has been independently established, i.e. the outliers must be confidently deemed to be analytical rather than arising from inhomogeneity of the CRM. The standard deviation is then calculated for each analyte from the pooled individual analyses generated from the certification program. Table 3 shows performance gates calculated for two and three standard deviations. As a guide these intervals may be regarded as warning or rejection for multiple 2SD outliers, or rejection for individual 3SD outliers in QC monitoring, although their precise application

should be at the discretion of the QC manager concerned. A second method utilises a 5% window calculated directly from the certified value. Standard deviation is also shown in relative percent for one, two and three relative standard deviations (1RSD, 2RSD and 3RSD) to facilitate an appreciation of the magnitude of these numbers and a comparison with the 5% window. Caution should be exercised when concentration levels approach lower limits of detection of the analytical methods employed as performance gates calculated from standard deviations tend to be excessively wide whereas those determined by the 5% method are too narrow.

**Table 3. Performance Gates for OREAS 903.**

| Constituent | Certified Value | 1SD | 2SD window | | 3SD window | | Relative Standard Deviations | | | 5% window | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | 1RSD | 2RSD | 3RSD | Low | High |
| **4 Acid Digestion** | | | | | | | | | | | |
| Ag, ppm | 0.432 | 0.051 | 0.331 | 0.533 | 0.280 | 0.584 | 11.72% | 23.43% | 35.15% | 0.410 | 0.454 |
| Al, wt.% | 5.89 | 0.279 | 5.33 | 6.45 | 5.05 | 6.73 | 4.73% | 9.47% | 14.20% | 5.60 | 6.18 |
| As, ppm | 49.7 | 3.77 | 42.1 | 57.2 | 38.4 | 61.0 | 7.59% | 15.18% | 22.76% | 47.2 | 52.1 |
| Ba, ppm | 197 | 9 | 180 | 215 | 171 | 224 | 4.47% | 8.94% | 13.41% | 188 | 207 |
| Be, ppm | 4.42 | 0.387 | 3.65 | 5.20 | 3.26 | 5.58 | 8.74% | 17.48% | 26.22% | 4.20 | 4.64 |
| Bi, ppm | 8.94 | 0.481 | 7.98 | 9.90 | 7.50 | 10.38 | 5.38% | 10.75% | 16.13% | 8.49 | 9.39 |
| Ca, wt.% | 0.625 | 0.029 | 0.568 | 0.682 | 0.539 | 0.711 | 4.57% | 9.15% | 13.72% | 0.594 | 0.656 |
| Cd, ppm | 0.20 | 0.019 | 0.17 | 0.24 | 0.15 | 0.26 | 9.21% | 18.42% | 27.64% | 0.19 | 0.21 |
| Ce, ppm | 82 | 5.6 | 71 | 93 | 65 | 99 | 6.83% | 13.67% | 20.50% | 78 | 86 |
| Co, ppm | 131 | 8 | 114 | 147 | 106 | 156 | 6.41% | 12.82% | 19.22% | 124 | 137 |
| Cr, ppm | 73 | 4.6 | 64 | 82 | 59 | 87 | 6.37% | 12.74% | 19.11% | 69 | 76 |
| Cs, ppm | 3.57 | 0.121 | 3.33 | 3.81 | 3.21 | 3.93 | 3.38% | 6.76% | 10.13% | 3.39 | 3.75 |
| Cu, wt.% | 0.652 | 0.020 | 0.612 | 0.691 | 0.593 | 0.711 | 3.02% | 6.03% | 9.05% | 0.619 | 0.684 |
| Fe, wt.% | 4.16 | 0.179 | 3.80 | 4.52 | 3.62 | 4.69 | 4.30% | 8.60% | 12.90% | 3.95 | 4.37 |
| Ga, ppm | 15.0 | 1.7 | 11.7 | 18.4 | 10.0 | 20.0 | 11.17% | 22.33% | 33.50% | 14.3 | 15.8 |
| Hf, ppm | 4.56 | 0.350 | 3.86 | 5.26 | 3.51 | 5.61 | 7.68% | 15.36% | 23.04% | 4.33 | 4.79 |
| In, ppm | 0.16 | 0.02 | 0.13 | 0.20 | 0.11 | 0.21 | 10.51% | 21.02% | 31.53% | 0.15 | 0.17 |
| K, wt.% | 3.31 | 0.207 | 2.89 | 3.72 | 2.69 | 3.93 | 6.25% | 12.50% | 18.75% | 3.14 | 3.47 |
| La, ppm | 40.2 | 4.02 | 32.2 | 48.3 | 28.2 | 52.3 | 10.00% | 20.00% | 30.00% | 38.2 | 42.2 |
| Li, ppm | 18.3 | 0.72 | 16.9 | 19.8 | 16.2 | 20.5 | 3.94% | 7.87% | 11.81% | 17.4 | 19.2 |
| Lu, ppm | 0.36 | 0.04 | 0.29 | 0.44 | 0.25 | 0.48 | 10.43% | 20.85% | 31.28% | 0.35 | 0.38 |
| Mg, wt.% | 0.714 | 0.051 | 0.613 | 0.815 | 0.562 | 0.866 | 7.08% | 14.17% | 21.25% | 0.678 | 0.750 |
| Mn, wt.% | 0.069 | 0.003 | 0.062 | 0.076 | 0.059 | 0.079 | 4.98% | 9.96% | 14.94% | 0.066 | 0.072 |
| Mo, ppm | 4.32 | 0.335 | 3.65 | 4.99 | 3.31 | 5.32 | 7.75% | 15.51% | 23.26% | 4.10 | 4.54 |
| Na, wt.% | 0.030 | 0.001 | 0.027 | 0.033 | 0.026 | 0.035 | 4.93% | 9.87% | 14.80% | 0.029 | 0.032 |
| Ni, ppm | 54 | 4.7 | 44 | 63 | 40 | 68 | 8.79% | 17.57% | 26.36% | 51 | 57 |
| P, wt.% | 0.107 | 0.009 | 0.089 | 0.125 | 0.080 | 0.134 | 8.43% | 16.86% | 25.29% | 0.101 | 0.112 |
| Pb, ppm | 11.3 | 1.7 | 7.9 | 14.6 | 6.3 | 16.3 | 14.78% | 29.57% | 44.35% | 10.7 | 11.9 |
| Rb, ppm | 137 | 19 | 98 | 175 | 79 | 194 | 13.95% | 27.91% | 41.86% | 130 | 143 |
| S, wt.% | 0.500 | 0.036 | 0.428 | 0.571 | 0.392 | 0.607 | 7.17% | 14.34% | 21.51% | 0.475 | 0.525 |
| Sb, ppm | 1.57 | 0.141 | 1.29 | 1.85 | 1.15 | 1.99 | 8.99% | 17.98% | 26.97% | 1.49 | 1.65 |
| Sc, ppm | 10.2 | 0.50 | 9.2 | 11.2 | 8.7 | 11.7 | 4.87% | 9.73% | 14.60% | 9.7 | 10.7 |
| Se, ppm | 6.06 | 0.85 | 4.36 | 7.77 | 3.51 | 8.62 | 14.06% | 28.12% | 42.18% | 5.76 | 6.37 |
| Sn, ppm | 2.63 | 0.261 | 2.11 | 3.15 | 1.85 | 3.41 | 9.92% | 19.84% | 29.76% | 2.50 | 2.76 |
| Sr, ppm | 77 | 3.7 | 70 | 85 | 66 | 88 | 4.85% | 9.70% | 14.55% | 73 | 81 |
| Ta, ppm | 0.54 | 0.08 | 0.37 | 0.70 | 0.29 | 0.79 | 15.58% | 31.17% | 46.75% | 0.51 | 0.56 |
| Tb, ppm | 0.83 | 0.09 | 0.66 | 1.01 | 0.57 | 1.10 | 10.54% | 21.07% | 31.61% | 0.79 | 0.88 |
| Th, ppm | 13.6 | 0.71 | 12.2 | 15.1 | 11.5 | 15.8 | 5.22% | 10.44% | 15.67% | 13.0 | 14.3 |
| Ti, wt.% | 0.192 | 0.037 | 0.119 | 0.266 | 0.082 | 0.303 | 19.08% | 38.15% | 57.23% | 0.183 | 0.202 |
| Tl, ppm | 0.62 | 0.041 | 0.54 | 0.70 | 0.50 | 0.74 | 6.58% | 13.16% | 19.74% | 0.59 | 0.65 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 3. Performance Gates for OREAS 902 continued.**

| Constituent | Certified Value | 1SD | 2SD window | | 3SD window | | Relative Standard Deviations | | | 5% window | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | 1RSD | 2RSD | 3RSD | Low | High |
| **4 Acid Digestion** | | | | | | | | | | | |
| U, ppm | 7.58 | 0.584 | 6.41 | 8.75 | 5.83 | 9.33 | 7.70% | 15.40% | 23.10% | 7.20 | 7.96 |
| V, ppm | 74 | 2.3 | 69 | 79 | 67 | 81 | 3.16% | 6.32% | 9.48% | 70 | 78 |
| Y, ppm | 22.5 | 2.3 | 17.8 | 27.1 | 15.5 | 29.5 | 10.37% | 20.74% | 31.11% | 21.3 | 23.6 |
| Yb, ppm | 2.36 | 0.163 | 2.04 | 2.69 | 1.87 | 2.85 | 6.91% | 13.82% | 20.74% | 2.25 | 2.48 |
| Zn, ppm | 24.3 | 2.24 | 19.8 | 28.8 | 17.6 | 31.0 | 9.22% | 18.43% | 27.65% | 23.1 | 25.5 |
| Zr, ppm | 152 | 11 | 130 | 173 | 120 | 184 | 7.06% | 14.12% | 21.18% | 144 | 159 |
| **Aqua Regia Digestion** | | | | | | | | | | | |
| Ag, ppm | 0.349 | 0.038 | 0.272 | 0.425 | 0.234 | 0.463 | 10.93% | 21.85% | 32.78% | 0.331 | 0.366 |
| Al, wt.% | 0.538 | 0.036 | 0.465 | 0.610 | 0.429 | 0.646 | 6.71% | 13.42% | 20.13% | 0.511 | 0.564 |
| As, ppm | 47.5 | 2.12 | 43.2 | 51.7 | 41.1 | 53.9 | 4.47% | 8.93% | 13.40% | 45.1 | 49.9 |
| Au, ppb | < 5 | IND | IND | IND | IND | IND | IND | IND | IND | IND | IND |
| Ba, ppm | 63 | 4.3 | 54 | 71 | 50 | 76 | 6.80% | 13.60% | 20.39% | 60 | 66 |
| Be, ppm | 2.69 | 0.268 | 2.16 | 3.23 | 1.89 | 3.50 | 9.93% | 19.86% | 29.79% | 2.56 | 2.83 |
| Bi, ppm | 8.76 | 0.771 | 7.22 | 10.30 | 6.44 | 11.07 | 8.81% | 17.61% | 26.42% | 8.32 | 9.20 |
| Ca, wt.% | 0.633 | 0.030 | 0.572 | 0.694 | 0.542 | 0.725 | 4.81% | 9.63% | 14.44% | 0.602 | 0.665 |
| Cd, ppm | 0.21 | 0.012 | 0.18 | 0.23 | 0.17 | 0.24 | 5.79% | 11.58% | 17.37% | 0.20 | 0.22 |
| Ce, ppm | 46.2 | 2.56 | 41.1 | 51.3 | 38.6 | 53.9 | 5.54% | 11.07% | 16.61% | 43.9 | 48.5 |
| Co, ppm | 131 | 7 | 116 | 146 | 108 | 153 | 5.70% | 11.40% | 17.11% | 124 | 137 |
| Cr, ppm | 26.1 | 1.81 | 22.5 | 29.8 | 20.7 | 31.6 | 6.93% | 13.86% | 20.79% | 24.8 | 27.4 |
| Cs, ppm | 0.28 | 0.04 | 0.20 | 0.37 | 0.15 | 0.41 | 15.32% | 30.64% | 45.96% | 0.27 | 0.30 |
| Cu, wt.% | 0.671 | 0.020 | 0.631 | 0.710 | 0.611 | 0.730 | 2.95% | 5.89% | 8.84% | 0.637 | 0.704 |
| Fe, wt.% | 3.94 | 0.266 | 3.41 | 4.47 | 3.14 | 4.74 | 6.75% | 13.49% | 20.24% | 3.74 | 4.14 |
| Ga, ppm | 1.58 | 0.22 | 1.13 | 2.02 | 0.91 | 2.25 | 14.18% | 28.36% | 42.54% | 1.50 | 1.66 |
| Ge, ppm | 0.098 | 0.015 | 0.068 | 0.127 | 0.053 | 0.142 | 15.15% | 30.30% | 45.45% | 0.093 | 0.103 |
| Hf, ppm | 0.61 | 0.052 | 0.51 | 0.71 | 0.45 | 0.77 | 8.56% | 17.12% | 25.68% | 0.58 | 0.64 |
| In, ppm | 0.11 | 0.010 | 0.09 | 0.13 | 0.08 | 0.14 | 9.33% | 18.67% | 28.00% | 0.11 | 0.12 |
| K, wt.% | 0.331 | 0.029 | 0.274 | 0.388 | 0.245 | 0.417 | 8.65% | 17.29% | 25.94% | 0.315 | 0.348 |
| La, ppm | 22.8 | 3.8 | 15.1 | 30.5 | 11.3 | 34.3 | 16.80% | 33.59% | 50.39% | 21.7 | 23.9 |
| Lu, ppm | 0.099 | 0.010 | 0.078 | 0.120 | 0.068 | 0.131 | 10.58% | 21.15% | 31.73% | 0.094 | 0.104 |
| Mg, wt.% | 0.234 | 0.030 | 0.174 | 0.294 | 0.144 | 0.324 | 12.88% | 25.77% | 38.65% | 0.222 | 0.246 |
| Mn, wt.% | 0.071 | 0.004 | 0.063 | 0.079 | 0.059 | 0.083 | 5.55% | 11.11% | 16.66% | 0.067 | 0.074 |
| Mo, ppm | 4.26 | 0.47 | 3.31 | 5.20 | 2.84 | 5.67 | 11.06% | 22.13% | 33.19% | 4.04 | 4.47 |
| Ni, ppm | 48.7 | 3.06 | 42.6 | 54.8 | 39.5 | 57.9 | 6.27% | 12.55% | 18.82% | 46.3 | 51.2 |
| P, wt.% | 0.103 | 0.005 | 0.093 | 0.112 | 0.088 | 0.117 | 4.67% | 9.35% | 14.02% | 0.098 | 0.108 |
| Pb, ppm | 8.95 | 0.91 | 7.14 | 10.76 | 6.24 | 11.67 | 10.11% | 20.23% | 30.34% | 8.50 | 9.40 |
| Rb, ppm | 12.6 | 1.13 | 10.3 | 14.8 | 9.2 | 15.9 | 8.95% | 17.90% | 26.84% | 11.9 | 13.2 |
| S, wt.% | 0.501 | 0.036 | 0.429 | 0.573 | 0.392 | 0.610 | 7.23% | 14.45% | 21.68% | 0.476 | 0.526 |
| Sb, ppm | 0.96 | 0.11 | 0.74 | 1.17 | 0.64 | 1.28 | 11.19% | 22.39% | 33.58% | 0.91 | 1.01 |
| Sc, ppm | 3.15 | 0.211 | 2.73 | 3.57 | 2.52 | 3.78 | 6.70% | 13.41% | 20.11% | 2.99 | 3.31 |
| Se, ppm | 5.34 | 0.57 | 4.20 | 6.49 | 3.62 | 7.07 | 10.75% | 21.49% | 32.24% | 5.08 | 5.61 |
| Sr, ppm | 17.7 | 1.36 | 15.0 | 20.4 | 13.6 | 21.8 | 7.69% | 15.38% | 23.08% | 16.8 | 18.6 |
| Tb, ppm | 0.47 | 0.05 | 0.36 | 0.57 | 0.31 | 0.63 | 11.34% | 22.68% | 34.02% | 0.45 | 0.49 |
| Te, ppm | 0.034 | 0.006 | 0.022 | 0.047 | 0.015 | 0.054 | 18.70% | 37.40% | 56.10% | 0.033 | 0.036 |
| Th, ppm | 6.36 | 0.563 | 5.23 | 7.48 | 4.67 | 8.05 | 8.86% | 17.72% | 26.57% | 6.04 | 6.67 |
| Ti, wt.% | 0.008 | 0.001 | 0.006 | 0.011 | 0.004 | 0.012 | 16.52% | 33.03% | 49.55% | 0.008 | 0.009 |
| Tl, ppm | 0.14 | 0.02 | 0.09 | 0.19 | 0.06 | 0.21 | 17.66% | 35.32% | 52.98% | 0.13 | 0.14 |
| U, ppm | 3.24 | 0.293 | 2.65 | 3.82 | 2.36 | 4.12 | 9.03% | 18.06% | 27.09% | 3.08 | 3.40 |
| V, ppm | 13.3 | 0.72 | 11.8 | 14.7 | 11.1 | 15.5 | 5.43% | 10.86% | 16.29% | 12.6 | 14.0 |
| W, ppm | 0.53 | 0.08 | 0.37 | 0.70 | 0.28 | 0.78 | 15.56% | 31.13% | 46.69% | 0.50 | 0.56 |
| Y, ppm | 9.23 | 0.654 | 7.92 | 10.54 | 7.27 | 11.19 | 7.08% | 14.17% | 21.25% | 8.77 | 9.69 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

**Table 3. Performance Gates for OREAS 902 continued.**

| Constituent | Certified Value | 1SD | 2SD window | | 3SD window | | Relative Standard Deviations | | | 5% window | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Low | High | Low | High | 1RSD | 2RSD | 3RSD | Low | High |
| **Aqua Regia Digestion** | | | | | | | | | | | |
| Yb, ppm | 0.69 | 0.07 | 0.54 | 0.84 | 0.46 | 0.91 | 10.79% | 21.57% | 32.36% | 0.65 | 0.72 |
| Zn, ppm | 21.3 | 1.46 | 18.4 | 24.3 | 17.0 | 25.7 | 6.84% | 13.68% | 20.52% | 20.3 | 22.4 |
| Zr, ppm | 18.2 | 1.73 | 14.7 | 21.6 | 13.0 | 23.3 | 9.54% | 19.08% | 28.62% | 17.2 | 19.1 |
| **Sulphuric Acid Leach** | | | | | | | | | | | |
| Cu-Sol, wt.% | 0.434 | 0.030 | 0.374 | 0.494 | 0.344 | 0.524 | 6.90% | 13.79% | 20.69% | 0.412 | 0.456 |

SI unit equivalents: ppm, parts per million ≡ mg/kg ≡ µg/g ≡ 0.0001 wt.% ≡ 1000 ppb, parts per billion.
Note: intervals may appear asymmetric due to rounding.

## PARTICIPATING LABORATORIES

1. Acme Analytical Laboratories, Vancouver, BC, Canada
2. Activation Laboratories, Ancaster, Ontario, Canada
3. Activation Laboratories, Thunder Bay, Ontario, Canada
4. ALS, Brisbane, QLD, Australia
5. ALS, Callao, Lima, Peru
6. ALS, Johannesburg, Gauteng, South Africa
7. ALS, La Serena, Coquimbo, Chile
8. ALS, Perth, WA, Australia
9. ALS, Vancouver, BC, Canada
10. BV Amdel, Adelaide, SA, Australia
11. Bureau Veritas (Ultra Trace) Geoanalytical, Perth, WA, Australia
12. Intertek Genalysis, Perth, WA, Australia
13. McPhar Geoservices (Phil) Inc., Manila, Philippines
14. SGS Mineral Services, Lakefield, Ontario, Canada
15. SGS Mineral Services, Perth, WA, Australia
16. SGS Mineral Services, Toronto, Ontario, Canada
17. SGS Mineral Services, Townsville, QLD, Australia
18. SGS Mineral Services, Vancouver, BC, Canada
19. Zarazma Mineral Studies, Tehran, Iran

## PREPARER AND SUPPLIER OF THE REFERENCE MATERIAL

OREAS 903 has been prepared, certified and supplied by:

ORE RESEARCH & EXPLORATION

ORE Research & Exploration Pty Ltd
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AUSTRALIA

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OREAS 903 has been packaged in single-use laminated foil pouches in 10g units. 1kg units in plastic jars are also available upon request.

## INTENDED USE

OREAS 903 is intended for the following uses:

- For the monitoring of laboratory performance in the analysis of analytes reported in Table 1 in geological samples
- For the verification of analytical methods for analytes reported in Table 1
- For the calibration of instruments used in the determination of the concentration of analytes reported in Table 1

## STABILITY AND STORAGE INSTRUCTIONS

OREAS 903 has been sourced from medium grade transitional-oxide copper ore. In its unopened state and under normal conditions of storage it has a shelf life beyond ten years. Its stability will be monitored at regular intervals and purchasers notified if any changes are observed.

## INSTRUCTIONS FOR THE CORRECT USE

The certified values refer to the concentration level of analytes in their packaged state. The CRM should therefore not be dried prior to weighing and analysis.

## HANDLING INSTRUCTIONS

Fine powders pose a risk to eyes and lungs and therefore standard precautions such as the use of safety glasses and dust masks are advised.

## METROLOGICAL TRACEABILITY

The analytical samples were selected in a manner to represent the entire batch of prepared CRM. This 'representivity' was maintained in each submitted laboratory sample batch and ensures the user that the data is traceable from sample selection through to the analytical results that underlie the consensus values. Each analytical data set has been validated by its assayer through the inclusion of internal reference materials and QC checks during analysis.

The laboratories were chosen on the basis of their competence (from past performance in inter-laboratory programs undertaken by ORE Pty Ltd) for a particular analytical method, analyte or analyte suite, and sample matrix. Most of these laboratories have and maintain ISO 17025 accreditation. The certified values presented in this report are calculated from the means of accepted data following robust statistical treatment as detailed in this report.

Guide ISO/TR 16476:2016, section 5.3.1 describes metrological traceability in reference materials as it pertains to the transformation of the measurand. In this section it states, *"Although the determination of the property value itself can be made traceable to appropriate units through, for example, calibration of the measurement equipment used,*

*steps like the transformation of the sample from one physical (chemical) state to another cannot. Such transformations may only be compared with a reference (when available), or among themselves. For some transformations, reference methods have been defined and may be used in certification projects to evaluate the uncertainty associated with such a transformation. In other cases,* ***only a comparison among different laboratories using the same method is possible. In this case, certification takes place on the basis of agreement among independent measurement results*** *(see ISO Guide 35:2006, Clause 10)."*

## COMMUTABILITY

The measurements of the results that underlie the certified values contained in this report were undertaken by methods involving pre-treatment (digestion/fusion) of the sample. This served to reduce the sample to a simple and well understood form permitting calibration using simple solutions of the CRM. Due to these methods being well understood and highly effective, commutability is not an issue for this CRM. All OREAS CRMs are sourced from natural ore minerals meaning they will display similar behaviour as routine 'field' samples in the relevant measurement process. Care should be taken to ensure 'matrix matching' as close as practically achievable. The matrix and mineralisation style of the CRM is described in the 'Source Material' section and users should select appropriate CRMs matching these attributes to their field samples.

## LEGAL NOTICE

Ore Research & Exploration Pty Ltd has prepared and statistically evaluated the property values of this reference material to the best of its ability. The Purchaser by receipt hereof releases and indemnifies Ore Research & Exploration Pty Ltd from and against all liability and costs arising from the use of this material and information.

## DOCUMENT HISTORY

| Revision No | Date | Changes applied |
|---|---|---|
| 1 | 3rd Sep, 2018 | Added major and trace element characterization; added performance gates. |
| 0 | 7th Aug, 2012 | First publication. |

## QMS ACCREDITED

ORE Pty Ltd is accredited to ISO 9001:2015 by Lloyd's Register Quality Assurance Ltd for its quality management system including development, manufacturing, certification and supply of CRMs.

## CERTIFYING OFFICER

Craig Hamlyn (B.Sc. Hons - Geology), Technical Manager - ORE P/L

## REFERENCES


ISO Guide 30 (2015), Terms and definitions used in connection with reference materials.

ISO Guide 31 (2015), Reference materials – Contents of certificates and labels.

ISO Guide 3207 (1975), Statistical interpretation of data - Determination of a statistical tolerance interval.

ISO Guide 35 (2017), Certification of reference materials - General and statistical principals.