

CERTIFICATE OF ANALYSIS FOR
CERTIFIED REFERENCE MATERIAL
OREAS 523b
Iron Oxide Copper-Gold Ore, Australia

Table 1. Certified Value, Uncertainty & Tolerance Intervals for Au by FA in OREAS 523b.

Constituent	Certified Value [†]	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
Pb Fire Assay					
Au, Gold (ppm)	1.05	1.04	1.06	1.05*	1.06*

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg.

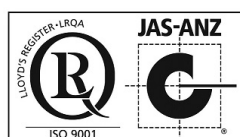
[†]This operationally defined measurand meets the requirements of ISO 17034 and all participating laboratories comply with the requirements of ISO 17025.

*Gold Tolerance Limits for typical 30g fire assay are determined from 20 x 85mg INAA results and the Sampling Constant (Ingamells & Switzer, 1973).

Note: intervals may appear asymmetric due to rounding.



Accredited for compliance with ISO 17034



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Table 2. Certified Value, Uncertainty & Tolerance Intervals for other measurands in OREAS 523b.

Constituent	Certified Value	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
Aqua Regia Digestion (sample weights 10-50g)					
Au, Gold (ppm)	1.03	0.99	1.06	1.02*	1.03*
4-Acid Digestion					
Ag, Silver (ppm)	3.18	3.00	3.36	3.11	3.25
Al, Aluminium (wt.%)	5.32	5.15	5.49	5.22	5.42
As, Arsenic (ppm)	157	150	164	153	161
Be, Beryllium (ppm)	1.83	1.71	1.95	1.77	1.89
Bi, Bismuth (ppm)	8.47	8.09	8.86	8.20	8.75
Ca, Calcium (wt.%)	2.04	1.98	2.11	2.00	2.08
Cd, Cadmium (ppm)	0.40	0.36	0.45	0.38	0.43
Ce, Cerium (ppm)	100	92	107	96	103
Co, Cobalt (ppm)	247	237	257	241	253
Cr, Chromium (ppm)	36.2	33.1	39.4	34.5	38.0
Cs, Caesium (ppm)	2.53	2.42	2.64	2.45	2.61
Cu, Copper (wt.%)	1.66	1.63	1.69	1.64	1.68
Dy, Dysprosium (ppm)	3.86	3.63	4.08	3.71	4.01
Er, Erbium (ppm)	1.89	1.72	2.06	1.80	1.98
Eu, Europium (ppm)	1.55	1.42	1.69	1.50	1.61
Fe, Iron (wt.%)	17.07	16.41	17.72	16.78	17.36
Ga, Gallium (ppm)	17.3	16.5	18.1	16.8	17.7
Gd, Gadolinium (ppm)	5.20	4.83	5.57	5.02	5.38
Ge, Germanium (ppm)	0.23	0.19	0.27	0.19	0.27
Hf, Hafnium (ppm)	4.94	4.67	5.21	4.77	5.11
Ho, Holmium (ppm)	0.71	0.66	0.76	0.67	0.75
In, Indium (ppm)	0.38	0.35	0.40	0.36	0.39
K, Potassium (wt.%)	3.05	2.95	3.14	2.96	3.13
La, Lanthanum (ppm)	77	72	82	75	79
Li, Lithium (ppm)	15.7	14.9	16.5	15.3	16.2
Lu, Lutetium (ppm)	0.27	0.25	0.29	0.26	0.29
Mg, Magnesium (wt.%)	0.611	0.590	0.632	0.595	0.626
Mn, Manganese (wt.%)	0.175	0.169	0.180	0.171	0.179
Mo, Molybdenum (ppm)	223	214	233	218	229
Na, Sodium (wt.%)	1.24	1.21	1.28	1.22	1.27
Nb, Niobium (ppm)	11.7	10.9	12.6	11.2	12.3
Nd, Neodymium (ppm)	34.0	31.7	36.4	32.7	35.4
Ni, Nickel (ppm)	61	58	63	59	62
P, Phosphorus (wt.%)	0.118	0.114	0.123	0.116	0.120

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

*Gold Tolerance Limits are calculated for a typical 25g aqua regia digestion and determined from 20 x 85mg INAA results and the Sampling Constant (Ingamells & Switzer, 1973).

Note: intervals may appear asymmetric due to rounding.

Table 2 continued.

Constituent	Certified Value	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
4-Acid Digestion continued					
Pb, Lead (ppm)	141	135	147	136	145
Pr, Praseodymium (ppm)	9.92	9.29	10.55	9.59	10.26
Rb, Rubidium (ppm)	109	101	117	105	113
Re, Rhenium (ppm)	0.11	0.10	0.13	0.11	0.12
S, Sulphur (wt.%)	2.86	2.77	2.95	2.82	2.91
Sb, Antimony (ppm)	4.55	4.29	4.81	4.40	4.70
Sc, Scandium (ppm)	8.82	8.32	9.32	8.53	9.11
Se, Selenium (ppm)	3.45	2.56	4.35	3.10	3.80
Sm, Samarium (ppm)	6.02	5.42	6.62	5.76	6.28
Sn, Tin (ppm)	5.22	4.92	5.53	4.99	5.46
Sr, Strontium (ppm)	163	157	170	159	167
Ta, Tantalum (ppm)	0.81	0.73	0.89	0.77	0.85
Tb, Terbium (ppm)	0.73	0.67	0.80	0.70	0.76
Te, Tellurium (ppm)	1.17	1.07	1.27	1.09	1.25
Th, Thorium (ppm)	11.9	11.0	12.7	11.4	12.3
Ti, Titanium (wt.%)	0.320	0.304	0.335	0.309	0.330
Tl, Thallium (ppm)	0.68	0.64	0.72	0.66	0.70
Tm, Thulium (ppm)	0.27	0.25	0.29	0.25	0.28
U, Uranium (ppm)	18.3	17.4	19.2	17.8	18.8
V, Vanadium (ppm)	105	101	109	103	107
W, Tungsten (ppm)	23.7	22.4	25.1	22.8	24.7
Y, Yttrium (ppm)	18.7	17.7	19.7	18.3	19.1
Yb, Ytterbium (ppm)	1.67	1.54	1.80	1.61	1.73
Zn, Zinc (ppm)	529	516	542	521	538
Zr, Zirconium (ppm)	187	180	194	183	191
Aqua Regia Digestion					
Ag, Silver (ppm)	2.96	2.85	3.07	2.88	3.04
Al, Aluminium (wt.%)	0.939	0.908	0.970	0.920	0.958
As, Arsenic (ppm)	150	145	154	147	153
Be, Beryllium (ppm)	0.77	0.71	0.83	0.74	0.80
Bi, Bismuth (ppm)	8.30	7.95	8.65	8.09	8.51
Ca, Calcium (wt.%)	1.77	1.71	1.82	1.70	1.83
Cd, Cadmium (ppm)	0.41	0.36	0.45	0.38	0.43
Ce, Cerium (ppm)	75	71	78	73	77
Co, Cobalt (ppm)	242	234	251	238	246
Cr, Chromium (ppm)	24.2	22.7	25.6	23.1	25.2
Cs, Caesium (ppm)	0.61	0.57	0.66	0.59	0.63

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

Note: intervals may appear asymmetric due to rounding.

Table 2 continued.

Constituent	Certified Value	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
Aqua Regia Digestion continued					
Cu, Copper (wt.%)	1.67	1.64	1.69	1.64	1.69
Fe, Iron (wt.%)	15.56	14.94	16.18	15.33	15.80
Ga, Gallium (ppm)	7.52	7.06	7.97	7.28	7.76
Ge, Germanium (ppm)	0.24	0.22	0.27	0.22	0.27
Hf, Hafnium (ppm)	1.22	1.15	1.29	1.17	1.26
Hg, Mercury (ppm)	0.078	0.056	0.100	0.072	0.085
In, Indium (ppm)	0.34	0.32	0.36	0.33	0.36
K, Potassium (wt.%)	0.368	0.352	0.383	0.357	0.378
La, Lanthanum (ppm)	64	60	68	62	65
Li, Lithium (ppm)	7.76	7.46	8.05	7.53	7.98
Lu, Lutetium (ppm)	0.16	0.14	0.18	IND	IND
Mg, Magnesium (wt.%)	0.534	0.513	0.555	0.524	0.543
Mn, Manganese (wt.%)	0.164	0.158	0.170	0.161	0.167
Mo, Molybdenum (ppm)	217	208	226	213	221
Na, Sodium (wt.%)	0.084	0.078	0.090	0.082	0.087
Nb, Niobium (ppm)	0.69	0.59	0.79	0.64	0.74
Ni, Nickel (ppm)	56	54	58	54	57
P, Phosphorus (wt.%)	0.108	0.103	0.112	0.105	0.110
Pb, Lead (ppm)	118	112	123	115	121
Rb, Rubidium (ppm)	20.1	19.0	21.2	19.4	20.8
Re, Rhenium (ppm)	0.11	0.11	0.12	0.11	0.12
S, Sulphur (wt.%)	2.82	2.75	2.89	2.77	2.86
Sb, Antimony (ppm)	2.96	2.72	3.20	2.85	3.06
Sc, Scandium (ppm)	5.21	4.96	5.46	5.08	5.35
Se, Selenium (ppm)	2.88	2.54	3.21	2.58	3.17
Sn, Tin (ppm)	3.19	2.96	3.41	3.06	3.31
Sr, Strontium (ppm)	37.9	35.2	40.6	36.9	38.9
Ta, Tantalum (ppm)	< 0.05	IND	IND	IND	IND
Tb, Terbium (ppm)	0.48	0.45	0.52	0.46	0.51
Te, Tellurium (ppm)	0.97	0.85	1.09	0.91	1.04
Th, Thorium (ppm)	8.41	7.90	8.93	8.15	8.67
Ti, Titanium (wt.%)	0.089	0.083	0.094	0.086	0.092
Tl, Thallium (ppm)	0.21	0.20	0.23	0.20	0.23
U, Uranium (ppm)	15.0	14.2	15.8	14.5	15.6
V, Vanadium (ppm)	97	93	100	95	98
W, Tungsten (ppm)	16.3	15.3	17.2	15.6	16.9
Y, Yttrium (ppm)	11.9	11.4	12.4	11.6	12.2

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to limited reading resolution of the methods employed. For practical purposes the 95% Expanded Uncertainty can be set between zero and a two times multiple of the upper bound/non-detect limit value).

Table 2 continued.

Constituent	Certified Value	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
Aqua Regia Digestion continued					
Yb, Ytterbium (ppm)	1.02	0.93	1.11	IND	IND
Zn, Zinc (ppm)	489	473	506	481	498
Zr, Zirconium (ppm)	47.8	45.7	49.9	46.5	49.2
Peroxide Fusion ICP					
Al, Aluminium (wt.%)	5.43	5.29	5.56	5.35	5.50
As, Arsenic (ppm)	149	132	165	144	154
Ba, Barium (ppm)	5816	5654	5978	5714	5918
Be, Beryllium (ppm)	< 5	IND	IND	IND	IND
Bi, Bismuth (ppm)	9.03	8.32	9.74	8.63	9.43
Ca, Calcium (wt.%)	2.06	1.96	2.15	2.01	2.11
Ce, Cerium (ppm)	113	107	119	109	117
Co, Cobalt (ppm)	249	237	260	243	255
Cr, Chromium (ppm)	56	45	67	49	63
Cs, Caesium (ppm)	2.56	2.33	2.80	2.44	2.69
Cu, Copper (wt.%)	1.68	1.63	1.72	1.65	1.70
Dy, Dysprosium (ppm)	4.09	3.64	4.54	3.89	4.29
Er, Erbium (ppm)	1.99	1.83	2.16	1.88	2.11
Fe, Iron (wt.%)	18.33	17.94	18.71	18.09	18.56
Ga, Gallium (ppm)	17.4	16.0	18.8	16.4	18.5
Gd, Gadolinium (ppm)	5.17	4.67	5.67	4.90	5.43
Ge, Germanium (ppm)	2.23	1.50	2.96	IND	IND
Ho, Holmium (ppm)	0.80	0.75	0.85	0.75	0.85
In, Indium (ppm)	0.39	0.31	0.47	IND	IND
K, Potassium (wt.%)	3.11	3.00	3.21	3.03	3.18
La, Lanthanum (ppm)	87	82	92	85	89
Li, Lithium (ppm)	17.4	14.9	19.8	16.7	18.1
Lu, Lutetium (ppm)	0.30	0.26	0.33	0.27	0.33
Mg, Magnesium (wt.%)	0.638	0.619	0.657	0.628	0.648
Mn, Manganese (wt.%)	0.183	0.177	0.189	0.179	0.186
Mo, Molybdenum (ppm)	228	210	246	223	233
Nb, Niobium (ppm)	13.9	12.4	15.4	13.0	14.8
Nd, Neodymium (ppm)	36.0	33.1	38.9	34.3	37.6
Ni, Nickel (ppm)	63	57	69	59	67
P, Phosphorus (wt.%)	0.116	0.100	0.133	IND	IND
Pb, Lead (ppm)	141	132	150	136	146
Pr, Praseodymium (ppm)	9.96	8.95	10.96	9.61	10.30
Rb, Rubidium (ppm)	111	105	117	108	113

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to limited reading resolution of the methods employed. For practical purposes the 95% Expanded Uncertainty can be set between zero and a two times multiple of the upper bound/non-detect limit value).

Table 2 continued.

Constituent	Certified Value	95% Expanded Uncertainty		95% Tolerance Limits	
		Low	High	Low	High
Peroxide Fusion ICP continued					
Pr, Praseodymium (ppm)	9.96	8.95	10.96	9.61	10.30
Rb, Rubidium (ppm)	111	105	117	108	113
S, Sulphur (wt.%)	2.99	2.89	3.10	2.93	3.05
Sb, Antimony (ppm)	5.09	4.26	5.93	3.76	6.43
Si, Silicon (wt.%)	21.48	20.98	21.98	21.09	21.87
Sm, Samarium (ppm)	6.29	5.59	7.00	5.91	6.67
Sr, Strontium (ppm)	175	163	186	171	179
Ta, Tantalum (ppm)	1.11	0.89	1.32	IND	IND
Tb, Terbium (ppm)	0.74	0.64	0.84	0.68	0.80
Th, Thorium (ppm)	13.4	12.1	14.6	13.0	13.7
Ti, Titanium (wt.%)	0.370	0.359	0.382	0.361	0.380
Tl, Thallium (ppm)	0.69	0.58	0.81	IND	IND
Tm, Thulium (ppm)	0.29	0.25	0.33	0.28	0.30
U, Uranium (ppm)	18.6	17.5	19.7	18.1	19.1
V, Vanadium (ppm)	110	102	119	108	113
3-Acid Digestion (no HF)					
Ag, Silver (ppm)	2.98	2.44	3.52	2.87	3.09
As, Arsenic (ppm)	153	146	161	150	157
Co, Cobalt (ppm)	241	230	253	236	247
Cu, Copper (wt.%)	1.66	1.59	1.72	1.62	1.69
Fe, Iron (wt.%)	16.15	15.10	17.19	15.82	16.47
Mo, Molybdenum (ppm)	217	206	228	210	224
S, Sulphur (wt.%)	2.92	2.80	3.04	2.81	3.02
Infrared Combustion					
S, Sulphur (wt.%)	2.98	2.91	3.06	2.95	3.02
Ion Selective Electrode					
F, Fluorine (ppm)	805	719	892	783	828

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to limited reading resolution of the methods employed).

Table 3. Indicative Values for OREAS 523b.

Constituent	Unit	Value	Constituent	Unit	Value	Constituent	Unit	Value
Pb Fire Assay								
Pd	ppb	3.12	Pt	ppb	1.68			
4-Acid Digestion								
Ba	ppm	198	Hg	ppm	< 1			
Aqua Regia Digestion								
B	ppm	7.08	Gd	ppm	3.38	Pt	ppb	8.25
Ba	ppm	67	Ho	ppm	0.47	Sm	ppm	3.78
Dy	ppm	2.55	Nd	ppm	22.4	Tm	ppm	0.14
Er	ppm	1.25	Pd	ppb	< 10			
Eu	ppm	1.04	Pr	ppm	6.61			
Peroxide Fusion ICP								
Ag	ppm	3.15	Hg	ppm	< 5	Sn	ppm	< 50
B	ppm	53	Na	wt. %	0.075	Te	ppm	< 1
Cd	ppm	0.78	Re	ppm	0.10	Zr	ppm	159
Eu	ppm	2.25	Sc	ppm	7.15			
Hf	ppm	6.01	Se	ppm	< 20			
Infrared Combustion								
C	wt. %	0.563						
Ion Selective Electrode								
Cl	ppm	191						
Borate Fusion XRF								
Al ₂ O ₃	wt. %	10.29	MnO	wt. %	0.237	Sr	ppm	133
BaO	ppm	7032	Na ₂ O	wt. %	1.72	TiO ₂	wt. %	0.618
CaO	wt. %	2.88	NiO	ppm	82	V ₂ O ₅	ppm	192
Cu	wt. %	1.56	P	wt. %	0.119	Zn	ppm	809
Fe	wt. %	18.36	Pb	ppm	332	ZrO ₂	ppm	1261
K ₂ O	wt. %	3.72	S	wt. %	2.84			
MgO	wt. %	1.08	SiO ₂	wt. %	45.49			
Thermogravimetry								
LOI ¹⁰⁰⁰	wt. %	3.63						
Laser Ablation ICP-MS								
Ag	ppm	3.20	Hf	ppm	6.03	Sm	ppm	6.12
As	ppm	164	Ho	ppm	0.76	Sn	ppm	5.60
Ba	ppm	5740	In	ppm	0.33	Sr	ppm	166
Be	ppm	2.40	La	ppm	86	Ta	ppm	1.02
Bi	ppm	8.66	Lu	ppm	0.28	Tb	ppm	0.73
Cd	ppm	0.45	Mn	wt. %	0.182	Te	ppm	1.20
Ce	ppm	104	Mo	ppm	218	Th	ppm	12.5
Co	ppm	248	Nb	ppm	13.7	Ti	wt. %	0.367
Cr	ppm	49.0	Nd	ppm	34.9	Tl	ppm	0.20
Cs	ppm	2.49	Ni	ppm	66	Tm	ppm	0.30
Cu	wt. %	1.67	Pb	ppm	146	U	ppm	18.1
Dy	ppm	3.95	Pr	ppm	10.4	V	ppm	108
Er	ppm	2.03	Rb	ppm	107	W	ppm	24.3

SI unit equivalents: ppb (parts per billion; 1×10^{-9}) \equiv μ g/kg; ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt. % (weight per cent) \equiv % (mass fraction).

Note: the number of significant figures reported is not a reflection of the level of certainty of stated values. They are instead an artefact of ORE's in-house CRM-specific LIMS.

Table 3 continued.

Constituent	Unit	Value	Constituent	Unit	Value	Constituent	Unit	Value
Laser Ablation ICP-MS continued								
Eu	ppm	1.51	Re	ppm	0.10	Y	ppm	20.2
Ga	ppm	16.7	Sb	ppm	5.10	Yb	ppm	1.91
Gd	ppm	5.03	Sc	ppm	8.75	Zn	ppm	540
Ge	ppm	2.00	Se	ppm	< 5	Zr	ppm	222

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg.

Note: the number of significant figures reported is not a reflection of the level of certainty of stated values. They are instead an artefact of ORE's in-house CRM-specific LIMS.

TABLE OF CONTENTS

INTRODUCTION	10
SOURCE MATERIAL	10
COMMUNITION AND HOMOGENISATION PROCEDURES	11
PHYSICAL PROPERTIES.....	11
ANALYTICAL PROGRAM.....	11
STATISTICAL ANALYSIS	12
Homogeneity Evaluation.....	12
PERFORMANCE GATES	14
PARTICIPATING LABORATORIES.....	20
PREPARER AND SUPPLIER	24
METROLOGICAL TRACEABILITY	24
COMMUTABILITY	25
INTENDED USE	25
MINIMUM SAMPLE SIZE.....	25
PERIOD OF VALIDITY & STORAGE INSTRUCTIONS	26
INSTRUCTIONS FOR HANDLING & CORRECT USE	26
LEGAL NOTICE.....	27
DOCUMENT HISTORY.....	27
CERTIFYING OFFICER.....	27
QMS CERTIFICATION.....	27
REFERENCES	28

LIST OF TABLES

Table 1. Certified Value, Uncertainty & Tolerance Intervals for Au by FA in OREAS 523b.....	1
Table 2. Certified Value, Uncertainty & Tolerance Intervals for other measurands in OREAS 523b.	2
Table 3. Indicative Values for OREAS 523b.....	7
Table 4. Physical properties of OREAS 523b.....	11
Table 5. Neutron Activation Analysis of Au on 20 x 85mg subsamples.	13
Table 6. Performance Gates for OREAS 523b.....	15

LIST OF FIGURES

Figure 1. Au by Fire Assay in OREAS 523b	21
Figure 2. Co by 4-Acid digestion in OREAS 523b	22
Figure 3. Cu by 4-Acid digestion in OREAS 523b	23

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. In evaluating laboratory performance with this CRM, the section headed 'Instructions for correct use' should be read carefully.

Table 1 (all laboratories accredited to ISO 17025) and Table 2 (most laboratories accredited to ISO 17025) provide the certified values and their associated 95% expanded uncertainty and tolerance intervals, Table 3 shows indicative values including major and trace element characterisation, Table 4 provides some indicative physical properties. Gold homogeneity (via INAA) is shown in Table 5 and is also demonstrated by a nested ANOVA (see 'Homogeneity Evaluation' section) and Table 6 presents the performance gate intervals for all certified values.

Tabulated results of all analytes together with uncorrected means, medians, standard deviations, relative standard deviations and per cent deviation of lab means from the corrected mean of means (PDM³) are presented in the detailed certification data for this CRM (**OREAS 523b-DataPack.1.0.231121_171544.xlsx**). Results are also presented in scatter plots for Au by fire assay, Co and Cu by 4-acid digestion (Figures 1 to 3, respectively) together with $\pm 3SD$ (magenta) and $\pm 5\%$ (yellow) control lines and certified value (green line). Accepted individual results are coloured blue and individual and dataset outliers are identified in red and violet, respectively.

SOURCE MATERIAL

OREAS 523b was prepared from a blend of iron oxide copper-gold (IOCG) ore, barren rhyodacite and iron oxide ore. The IOCG ore was sourced from the Ernest Henry Mine located about 38 kilometres north-east of Cloncurry in north-west Queensland. The barren rhyodacite was sourced from a quarry in the Mt Dandenong Igneous Complex located approximately 34km east of Melbourne, Australia. The iron oxide ore was sourced from an iron ore mine located in the Northern Cape province of South Africa.

IOCG mineralisation at the Ernest Henry Mine is hosted in breccia comprising strongly altered and replaced felsic volcanic fragments in a matrix largely composed of magnetite, calcite, pyrite, biotite, chalcopyrite, K feldspar titanite and quartz. Accessory minerals include garnet, barite, molybdenite, fluorite, amphibole, apatite, monazite, arsenopyrite, a LREE fluorocarbonate, galena, cobaltite, sphalerite, scheelite, uraninite and tourmaline. Copper occurs as native copper, bornite and chalcopyrite. Gold occurs mainly in the molecular framework of the chalcopyrite. Significant levels of cobalt, molybdenum, rare earth elements and low levels of uranium are also present.

COMMINUTION AND HOMOGENISATION PROCEDURES

The material constituting OREAS 523b was prepared in the following manner:

- Drying of ore and barren materials to constant mass at 105° C;
- Crushing and milling of the ore materials to 100% minus 30 microns;
- Crushing and milling of the barren rhyodacite to >98% minus 75 microns;
- Blending ores and rhyodacite in appropriate proportions to achieve the desired grades;
- Homogenisation using OREAS' novel processing technologies;
- Packaging in 10g and 60g units sealed under nitrogen in laminated foil pouches.

PHYSICAL PROPERTIES

OREAS 523b was tested at ORE Research & Exploration Pty Ltd's onsite facility for various physical properties. Table 4 presents these findings that should be used for informational purposes only.

Table 4. Physical properties of OREAS 523b.

Bulk Density (kg/m ³)	Moisture (wt.%)	Munsell Notation [‡]	Munsell Color [‡]
697	0.7	5R 5/4	Grayish Red

[‡]The Munsell Rock Color Chart helps geologists and archeologists communicate with colour more effectively by cross-referencing ISCC-NBS colour names with unique Munsell alpha-numeric colour notations for rock colour samples.

ANALYTICAL PROGRAM

Twenty-nine commercial analytical laboratories participated in the program to certify the elements reported in Tables 1 and 2. The following methods were employed:

- Gold by fire assay (25-50g charge weight) with AAS (18 laboratories), ICP-OES (8 laboratories) finish and ICP-MS (1 laboratory) finish;
- Gold by aqua regia digestion (15-30g sample weight) with AAS (4 laboratories) finish, ICP-OES and/or ICP-MS (14 laboratories) finish;
- Full ICP-OES and ICP-MS elemental suites by 4-acid (HNO₃-HF-HClO₄-HCl) digestion (up to 26 laboratories depending on the element);
- Full ICP-OES and ICP-MS elemental suites by aqua regia digestion (up to 23 laboratories depending on the element);
- Full ICP-OES and ICP-MS elemental suites by peroxide fusion (up to 21 laboratories depending on the element);
- Ag, As, Cu, Co, Fe, Mo and S by 3-acid (HNO₃-HClO₄-HCl) digestion with ICP-OES finish (10 laboratories);
- Total Sulphur by infrared combustion furnace (25 laboratories) and
- Fluorine by various methods (16 laboratories).

Instrumental neutron activation analysis for Au on 20 x 85mg subsamples was also undertaken at ANSTO, Lucas Heights to confirm homogeneity (see Table 5).

Table 3 shows indicative values including major and trace element characterisation based on two samples analysed at Bureau Veritas in Perth, Western Australia which includes:

- Major oxides by lithium borate fusion with X-ray fluorescence;
- LOI at 1000° C by thermogravimetric analyser;
- Trace elements by laser ablation (on the fused bead) with ICP-MS finish and
- Total Carbon and Sulphur by infrared combustion furnace.

For the round robin program, ten 2.5kg test units (lots) were taken at predetermined intervals during the bagging stage, immediately following homogenisation and are considered representative of the entire prepared batch. The six samples received by each laboratory were obtained by taking a 110g scoop split from six different 2.5kg lots.

The 20 individual INAA results upon which much of the homogeneity evaluation is based, included paired 10g samples taken from each of the 10 different test units. This format enabled a nested ANOVA treatment of the INAA results to evaluate homogeneity (see 'Homogeneity Evaluation' section below).

STATISTICAL ANALYSIS

Certified Values and their uncertainty intervals (Tables 1 and 2) have been determined for each analyte following removal of individual, laboratory dataset (batch) and 3SD outliers (single iteration).

For individual outliers within a laboratory batch the z-score test is used in combination with a second method that determines the per cent deviation of the individual value from the batch median. Outliers in general are selected on the basis of z-scores > 2.5 and with per cent deviations (i) > 3 and (ii) more than three times the average absolute per cent deviation for the batch. Each laboratory data set mean is tested for outlying status based on z-score discrimination and rejected if > 2.5 . After individual and laboratory data set (batch) outliers have been eliminated a non-iterative 3 standard deviation filter is applied, with those values lying outside this window also relegated to outlying status. However, while statistics are taken into account, the exercise of a statistician's prerogative plays a significant role in identifying outliers.

Certified Values are the means of accepted laboratory means after outlier filtering and are the present best estimate of the true value. The INAA data (see Table 5) is omitted from determination of the certified value for Au and is used solely for the calculation of Tolerance Limits and homogeneity evaluation.

95% Expanded Uncertainty provides a 95% probability that the true value of the analyte under consideration lies between the upper and lower limits and is calculated according to the method outlined in ISO 98-3:2008 [6]. All known or suspected sources of bias have been investigated or taken into account.

Indicative (uncertified) values (Table 3) are present where the number of laboratories reporting a particular analyte is insufficient (< 5) to support certification or where interlaboratory consensus is poor.

Homogeneity Evaluation

The tolerance limits (ISO 16269:2014) shown in Tables 1 and 2 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 ($1-\alpha=0.99$) at least 95% of subsamples ($\rho=0.95$) will have

concentrations lying between 1.64 and 1.68 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 (ISO Guide 35:2017). **Please note that tolerance limits pertain to the homogeneity of the CRM only and should not be used as control limits for laboratory performance.**

Table 5 below shows the gold INAA data determined on 20 x 85mg subsamples of OREAS 523b. An equivalent scaled version of the results is also provided to demonstrate an appreciation of what this data means if 30g fire assays were undertaken without the normal measurement error associated with this methodology. In this instance, the 1RSD of 0.12% calculated for a 30g fire assay sample (2.32% at 85mg weights) confirms the high level of gold homogeneity in OREAS 523b.

Table 5. Neutron Activation Analysis of Au (in ppm) on 20 x 85mg subsamples and showing the equivalent results scaled to a 30g sample mass typical of fire assay determination.

Replicate No	Au 85mg actual	Au 30g equivalent*
1	1.084	1.098
2	1.075	1.097
3	1.148	1.101
4	1.090	1.098
5	1.131	1.100
6	1.105	1.099
7	1.075	1.097
8	1.090	1.098
9	1.111	1.099
10	1.056	1.096
11	1.126	1.100
12	1.072	1.097
13	1.109	1.099
14	1.130	1.100
15	1.098	1.099
16	1.098	1.099
17	1.086	1.098
18	1.054	1.096
19	1.115	1.100
20	1.121	1.100
Mean	1.099	1.099
Median	1.098	1.099
Std Dev.	0.026	0.001
Rel.Std.Dev.	2.32%	0.12%

*Results calculated for a 30g equivalent sample mass using the formula: $x^{30g Eq} = \frac{(x^{INAA} - \bar{X}) \times RSD@30g}{RSD@85mg} + \bar{X}$
 where $x^{30g Eq}$ = equivalent result calculated for a 30g sample mass
 (x^{INAA}) = raw INAA result at 85mg
 \bar{X} = mean of 85mg INAA results

The homogeneity of gold has been determined by INAA at ANSTO using the reduced analytical subsample method which utilises the known relationship between standard

deviation and analytical subsample weight (Ingamells and Switzer, 1973 [2]). In this approach the sample aliquot is substantially reduced to a point where most of the variability in replicate assays should be due to inhomogeneity of the reference material and measurement error becomes negligible.

The homogeneity of OREAS 523b has also been evaluated in an Analysis of Variance (**ANOVA**) of the INAA data. The 20 samples were comprised of paired samples from each of 10 sampling lot intervals (representative of the prepared batch) and were randomised prior to assigning sample numbers. The duplicate samples enabled an ANOVA by comparison of within- and between-unit variances across the 10 pairs. The purpose of the ANOVA is to test that no statistically significant difference exists in the variance between units to that of the variance within units. This allows an assessment of homogeneity across the entire prepared batch of OREAS 523b. The test was performed using the following parameters:

- Gold INAA – 20 results (1 laboratory providing duplicate analyses on 10 samples where each sample can be viewed as a ‘unit’);
- Null Hypothesis, H_0 : Between-unit variance is no greater than within-unit variance (reject H_0 if p -value < 0.05);
- Alternative Hypothesis, H_1 : Between-unit variance is greater than within-unit variance.

The data was not filtered for outliers prior to the calculation of the p -value. This process derived a p -value of 0.47, a statistically insignificant result so the Null Hypothesis is accepted.

It is important to note that ANOVA is not an absolute measure of homogeneity. Rather, it establishes whether or not the analytes are distributed in a similar manner throughout the packaging run of OREAS 523b and whether the variance between two subsamples from the same unit is statistically distinguishable from the variance of two subsamples taken from any two separate units. A reference material therefore can possess poor absolute homogeneity yet still pass a relative homogeneity (ANOVA) test if the within-unit heterogeneity is large and similar across all units.

Based on the statistical analysis of ANOVA and the results of the interlaboratory certification program, it can be concluded that OREAS 523b is fit-for-purpose as a certified reference material (see ‘Intended Use’ below).

PERFORMANCE GATES

The standard deviations (SD’s) intervals reported in Table 6 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.

In the application of SD’s in monitoring performance it is important to note that not all laboratories function at the same level of proficiency and that different methods in use at a particular laboratory have differing levels of precision. Each laboratory has its own inherent SD (for a specific concentration level and analyte-method pair) based on the analytical process and this SD is not directly related to the round robin program (see ‘Intended Use’ section for more detail). 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.**

Table 6 below shows intervals 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 (also see 'Intended Use' section below). Westgard Rules extend the basics of single-rule QC monitoring using multi-rules (for more information visit www.westgard.com/mltirule.htm). 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. One approach used at commercial laboratories is to set the acceptance criteria at twice the detection level (DL) \pm 10%.

i.e., Certified Value \pm 10% \pm 2DL [1].

Table 6. Performance Gates for OREAS 523b.

Constituent	Certified Value	Absolute Standard Deviations					Relative Standard Deviations			5% window	
		1SD	2SD Low	2SD High	3SD Low	3SD High	1RSD	2RSD	3RSD	Low	High
Pb Fire Assay											
Au, ppm	1.05	0.029	0.99	1.11	0.97	1.14	2.76%	5.52%	8.28%	1.00	1.11
Aqua Regia Digestion (sample weights 10-50g)											
Au, ppm	1.03	0.067	0.89	1.16	0.83	1.23	6.55%	13.10%	19.66%	0.98	1.08
4-Acid Digestion											
Ag, ppm	3.18	0.126	2.93	3.43	2.80	3.56	3.95%	7.91%	11.86%	3.02	3.34
Al, wt. %	5.32	0.174	4.97	5.67	4.80	5.84	3.26%	6.53%	9.79%	5.05	5.59
As, ppm	157	8	140	174	132	182	5.26%	10.51%	15.77%	149	165
Be, ppm	1.83	0.145	1.54	2.12	1.39	2.27	7.94%	15.88%	23.81%	1.74	1.92
Bi, ppm	8.47	0.398	7.68	9.27	7.28	9.67	4.70%	9.40%	14.09%	8.05	8.90
Ca, wt. %	2.04	0.076	1.89	2.20	1.82	2.27	3.72%	7.44%	11.17%	1.94	2.15
Cd, ppm	0.40	0.04	0.31	0.49	0.27	0.53	10.81%	21.63%	32.44%	0.38	0.42
Ce, ppm	100	7.2	85	114	78	121	7.20%	14.40%	21.60%	95	105
Co, ppm	247	10	228	266	218	276	3.87%	7.74%	11.62%	235	259
Cr, ppm	36.2	3.9	28.4	44.1	24.4	48.1	10.87%	21.74%	32.60%	34.4	38.1
Cs, ppm	2.53	0.097	2.34	2.73	2.24	2.82	3.84%	7.68%	11.52%	2.40	2.66
Cu, wt. %	1.66	0.041	1.58	1.74	1.54	1.78	2.46%	4.92%	7.38%	1.58	1.74
Dy, ppm	3.86	0.196	3.46	4.25	3.27	4.45	5.09%	10.18%	15.27%	3.66	4.05
Er, ppm	1.89	0.105	1.68	2.10	1.57	2.20	5.56%	11.13%	16.69%	1.80	1.98
Eu, ppm	1.55	0.111	1.33	1.78	1.22	1.89	7.12%	14.24%	21.35%	1.48	1.63
Fe, wt. %	17.07	0.862	15.34	18.79	14.48	19.65	5.05%	10.10%	15.15%	16.21	17.92

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt. % (weight per cent) \equiv % (mass fraction).

Note 1: intervals may appear asymmetric due to rounding.

Note 2: the number of decimal places quoted does not imply accuracy of the certified value to this level but are given to minimise rounding errors when calculating 2SD and 3SD windows.

Table 6 continued.

Constituent	Certified Value	Absolute Standard Deviations					Relative Standard Deviations			5% window	
		1SD	2SD Low	2SD High	3SD Low	3SD High	1RSD	2RSD	3RSD	Low	High
4-Acid Digestion continued											
Ga, ppm	17.3	1.04	15.2	19.4	14.1	20.4	6.04%	12.07%	18.11%	16.4	18.1
Gd, ppm	5.20	0.224	4.75	5.65	4.53	5.87	4.30%	8.61%	12.91%	4.94	5.46
Ge, ppm	0.23	0.04	0.15	0.31	0.12	0.35	16.71%	33.42%	50.12%	0.22	0.24
Hf, ppm	4.94	0.257	4.42	5.45	4.17	5.71	5.20%	10.40%	15.60%	4.69	5.18
Ho, ppm	0.71	0.027	0.66	0.77	0.63	0.79	3.84%	7.69%	11.53%	0.68	0.75
In, ppm	0.38	0.021	0.34	0.42	0.31	0.44	5.51%	11.02%	16.53%	0.36	0.40
K, wt. %	3.05	0.105	2.84	3.26	2.73	3.36	3.45%	6.90%	10.35%	2.89	3.20
La, ppm	77	7.4	62	92	55	99	9.65%	19.30%	28.95%	73	81
Li, ppm	15.7	1.00	13.7	17.7	12.7	18.7	6.35%	12.69%	19.04%	14.9	16.5
Lu, ppm	0.27	0.021	0.23	0.31	0.21	0.33	7.57%	15.14%	22.72%	0.26	0.29
Mg, wt. %	0.611	0.026	0.559	0.662	0.534	0.688	4.21%	8.41%	12.62%	0.580	0.641
Mn, wt. %	0.175	0.005	0.165	0.185	0.159	0.190	2.94%	5.88%	8.82%	0.166	0.184
Mo, ppm	223	10	203	243	193	253	4.51%	9.01%	13.52%	212	234
Na, wt. %	1.24	0.049	1.15	1.34	1.10	1.39	3.91%	7.81%	11.72%	1.18	1.31
Nb, ppm	11.7	1.2	9.3	14.2	8.1	15.4	10.43%	20.86%	31.29%	11.2	12.3
Nd, ppm	34.0	1.74	30.6	37.5	28.8	39.3	5.13%	10.25%	15.38%	32.3	35.7
Ni, ppm	61	3.0	55	67	52	70	4.92%	9.84%	14.76%	58	64
P, wt. %	0.118	0.005	0.108	0.128	0.103	0.134	4.32%	8.63%	12.95%	0.112	0.124
Pb, ppm	141	7	126	155	119	162	5.07%	10.14%	15.22%	134	148
Pr, ppm	9.92	0.316	9.29	10.55	8.97	10.87	3.19%	6.38%	9.56%	9.43	10.42
Rb, ppm	109	6	97	121	91	127	5.45%	10.90%	16.36%	104	115
Re, ppm	0.11	0.008	0.10	0.13	0.09	0.14	6.73%	13.47%	20.20%	0.11	0.12
S, wt. %	2.86	0.093	2.68	3.05	2.58	3.14	3.24%	6.48%	9.72%	2.72	3.00
Sb, ppm	4.55	0.251	4.05	5.05	3.80	5.30	5.52%	11.04%	16.55%	4.32	4.78
Sc, ppm	8.82	0.548	7.73	9.92	7.18	10.46	6.21%	12.41%	18.62%	8.38	9.26
Se, ppm	3.45	0.57	2.32	4.58	1.75	5.15	16.39%	32.79%	49.18%	3.28	3.62
Sm, ppm	6.02	0.335	5.35	6.69	5.01	7.02	5.57%	11.13%	16.70%	5.72	6.32
Sn, ppm	5.22	0.359	4.50	5.94	4.15	6.30	6.88%	13.76%	20.64%	4.96	5.48
Sr, ppm	163	11	142	184	132	195	6.45%	12.90%	19.35%	155	171
Ta, ppm	0.81	0.09	0.64	0.98	0.55	1.07	10.56%	21.12%	31.68%	0.77	0.85
Tb, ppm	0.73	0.064	0.60	0.86	0.54	0.92	8.78%	17.56%	26.34%	0.70	0.77
Te, ppm	1.17	0.090	0.99	1.35	0.90	1.44	7.67%	15.35%	23.02%	1.11	1.23
Th, ppm	11.9	0.98	9.9	13.8	8.9	14.8	8.26%	16.51%	24.77%	11.3	12.5
Ti, wt. %	0.320	0.022	0.277	0.363	0.255	0.384	6.75%	13.49%	20.24%	0.304	0.336
Tl, ppm	0.68	0.034	0.62	0.75	0.58	0.78	4.92%	9.84%	14.76%	0.65	0.72
Tm, ppm	0.27	0.009	0.25	0.28	0.24	0.29	3.22%	6.43%	9.65%	0.25	0.28
U, ppm	18.3	0.93	16.4	20.1	15.5	21.1	5.08%	10.17%	15.25%	17.4	19.2
V, ppm	105	4	97	113	92	117	3.98%	7.95%	11.93%	100	110
W, ppm	23.7	1.44	20.8	26.6	19.4	28.1	6.08%	12.17%	18.25%	22.5	24.9
Y, ppm	18.7	1.37	15.9	21.4	14.6	22.8	7.36%	14.71%	22.07%	17.8	19.6
Yb, ppm	1.67	0.097	1.47	1.86	1.38	1.96	5.82%	11.63%	17.45%	1.58	1.75
Zn, ppm	529	15	498	560	483	576	2.92%	5.84%	8.77%	503	556
Zr, ppm	187	9	169	205	160	214	4.86%	9.72%	14.58%	178	196

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt. % (weight per cent) \equiv % (mass fraction).

Note 1: intervals may appear asymmetric due to rounding.

Note 2: the number of decimal places quoted does not imply accuracy of the certified value to this level but are given to minimise rounding errors when calculating 2SD and 3SD windows.

Table 6 continued.

Constituent	Certified Value	Absolute Standard Deviations					Relative Standard Deviations			5% window	
		1SD	2SD Low	2SD High	3SD Low	3SD High	1RSD	2RSD	3RSD	Low	High
Aqua Regia Digestion											
Ag, ppm	2.96	0.118	2.73	3.20	2.61	3.31	3.98%	7.96%	11.94%	2.81	3.11
Al, wt. %	0.939	0.038	0.863	1.015	0.825	1.053	4.04%	8.08%	12.12%	0.892	0.986
As, ppm	150	6	139	161	133	166	3.70%	7.41%	11.11%	142	157
Be, ppm	0.77	0.074	0.62	0.92	0.55	0.99	9.60%	19.20%	28.80%	0.73	0.81
Bi, ppm	8.30	0.313	7.67	8.92	7.36	9.24	3.77%	7.53%	11.30%	7.88	8.71
Ca, wt. %	1.77	0.072	1.62	1.91	1.55	1.98	4.06%	8.11%	12.17%	1.68	1.85
Cd, ppm	0.41	0.07	0.26	0.56	0.18	0.63	18.46%	36.93%	55.39%	0.39	0.43
Ce, ppm	75	5.3	64	85	59	91	7.07%	14.14%	21.21%	71	78
Co, ppm	242	9	223	261	214	270	3.87%	7.74%	11.61%	230	254
Cr, ppm	24.2	2.03	20.1	28.2	18.1	30.3	8.39%	16.77%	25.16%	23.0	25.4
Cs, ppm	0.61	0.061	0.49	0.73	0.43	0.79	9.92%	19.85%	29.77%	0.58	0.64
Cu, wt. %	1.67	0.027	1.61	1.72	1.58	1.75	1.65%	3.30%	4.95%	1.58	1.75
Fe, wt. %	15.56	0.891	13.78	17.34	12.89	18.23	5.73%	11.45%	17.18%	14.78	16.34
Ga, ppm	7.52	0.605	6.31	8.73	5.70	9.33	8.05%	16.10%	24.15%	7.14	7.89
Ge, ppm	0.24	0.03	0.19	0.30	0.16	0.33	12.17%	24.35%	36.52%	0.23	0.26
Hf, ppm	1.22	0.071	1.08	1.36	1.01	1.43	5.80%	11.60%	17.41%	1.16	1.28
Hg, ppm	0.078	0.019	0.040	0.116	0.021	0.135	24.30%	48.60%	72.90%	0.074	0.082
In, ppm	0.34	0.014	0.31	0.37	0.30	0.38	3.98%	7.96%	11.94%	0.32	0.36
K, wt. %	0.368	0.022	0.324	0.411	0.302	0.433	5.90%	11.80%	17.69%	0.349	0.386
La, ppm	64	7	51	77	44	83	10.22%	20.45%	30.67%	61	67
Li, ppm	7.76	0.365	7.03	8.49	6.66	8.85	4.70%	9.41%	14.11%	7.37	8.14
Lu, ppm	0.16	0.015	0.13	0.19	0.12	0.21	9.34%	18.68%	28.02%	0.15	0.17
Mg, wt. %	0.534	0.039	0.455	0.612	0.416	0.652	7.37%	14.73%	22.10%	0.507	0.560
Mn, wt. %	0.164	0.011	0.142	0.186	0.131	0.196	6.64%	13.28%	19.92%	0.156	0.172
Mo, ppm	217	11	196	239	185	249	4.95%	9.91%	14.86%	206	228
Na, wt. %	0.084	0.008	0.069	0.100	0.061	0.108	9.20%	18.39%	27.59%	0.080	0.089
Nb, ppm	0.69	0.11	0.47	0.91	0.36	1.02	15.98%	31.97%	47.95%	0.66	0.73
Ni, ppm	56	3.0	50	62	47	65	5.43%	10.85%	16.28%	53	59
P, wt. %	0.108	0.005	0.098	0.117	0.093	0.122	4.48%	8.96%	13.44%	0.102	0.113
Pb, ppm	118	9	100	136	91	144	7.49%	14.99%	22.48%	112	124
Rb, ppm	20.1	1.29	17.5	22.7	16.2	24.0	6.43%	12.86%	19.29%	19.1	21.1
Re, ppm	0.11	0.005	0.10	0.12	0.10	0.13	4.13%	8.27%	12.40%	0.11	0.12
S, wt. %	2.82	0.118	2.58	3.05	2.46	3.17	4.19%	8.37%	12.56%	2.68	2.96
Sb, ppm	2.96	0.45	2.06	3.85	1.62	4.30	15.10%	30.20%	45.29%	2.81	3.10
Sc, ppm	5.21	0.406	4.40	6.02	4.00	6.43	7.78%	15.57%	23.35%	4.95	5.47
Se, ppm	2.88	0.224	2.43	3.32	2.20	3.55	7.80%	15.60%	23.41%	2.73	3.02
Sn, ppm	3.19	0.222	2.74	3.63	2.52	3.85	6.97%	13.94%	20.91%	3.03	3.35
Sr, ppm	37.9	4.8	28.3	47.5	23.5	52.3	12.65%	25.31%	37.96%	36.0	39.8
Ta, ppm	< 0.05	IND	IND	IND	IND	IND	IND	IND	IND	IND	IND
Tb, ppm	0.48	0.024	0.44	0.53	0.41	0.56	4.96%	9.91%	14.87%	0.46	0.51
Te, ppm	0.97	0.18	0.62	1.32	0.44	1.50	18.10%	36.20%	54.30%	0.92	1.02
Th, ppm	8.41	0.672	7.07	9.76	6.40	10.43	7.99%	15.98%	23.97%	7.99	8.83
Ti, wt. %	0.089	0.008	0.073	0.104	0.065	0.112	8.95%	17.90%	26.85%	0.084	0.093
Tl, ppm	0.21	0.015	0.18	0.24	0.17	0.26	7.04%	14.08%	21.11%	0.20	0.23

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt. % (weight per cent) \equiv % (mass fraction).

Note 1: intervals may appear asymmetric due to rounding; IND = indeterminate.

Note 2: the number of decimal places quoted does not imply accuracy of the certified value to this level but are given to minimise rounding errors when calculating 2SD and 3SD windows.

Table 6 continued.

Constituent	Certified Value	Absolute Standard Deviations					Relative Standard Deviations			5% window	
		1SD	2SD Low	2SD High	3SD Low	3SD High	1RSD	2RSD	3RSD	Low	High
Aqua Regia Digestion continued											
U, ppm	15.0	0.87	13.3	16.7	12.4	17.6	5.77%	11.54%	17.31%	14.3	15.8
V, ppm	97	5.9	85	108	79	114	6.10%	12.20%	18.31%	92	101
W, ppm	16.3	1.00	14.2	18.3	13.2	19.3	6.16%	12.33%	18.49%	15.4	17.1
Y, ppm	11.9	0.57	10.8	13.1	10.2	13.6	4.77%	9.54%	14.30%	11.3	12.5
Yb, ppm	1.02	0.079	0.86	1.18	0.78	1.26	7.75%	15.49%	23.24%	0.97	1.07
Zn, ppm	489	23	443	535	420	558	4.70%	9.39%	14.09%	465	514
Zr, ppm	47.8	2.29	43.2	52.4	40.9	54.7	4.79%	9.57%	14.36%	45.4	50.2
Peroxide Fusion ICP											
Al, wt. %	5.43	0.079	5.27	5.59	5.19	5.67	1.46%	2.93%	4.39%	5.16	5.70
As, ppm	149	20	108	189	87	210	13.76%	27.53%	41.29%	141	156
Ba, ppm	5816	156	5505	6127	5349	6283	2.68%	5.35%	8.03%	5525	6107
Be, ppm	< 5	IND	IND	IND	IND	IND	IND	IND	IND	IND	IND
Bi, ppm	9.03	0.312	8.41	9.65	8.10	9.97	3.45%	6.90%	10.36%	8.58	9.48
Ca, wt. %	2.06	0.090	1.88	2.24	1.79	2.33	4.39%	8.79%	13.18%	1.95	2.16
Ce, ppm	113	3	107	119	103	122	2.76%	5.52%	8.27%	107	118
Co, ppm	249	10	230	268	220	277	3.84%	7.68%	11.52%	236	261
Cr, ppm	56	11	34	78	23	89	19.81%	39.62%	59.42%	53	59
Cs, ppm	2.56	0.159	2.25	2.88	2.09	3.04	6.19%	12.39%	18.58%	2.44	2.69
Cu, wt. %	1.68	0.036	1.60	1.75	1.57	1.78	2.17%	4.34%	6.51%	1.59	1.76
Dy, ppm	4.09	0.336	3.42	4.76	3.08	5.10	8.21%	16.42%	24.63%	3.89	4.30
Er, ppm	1.99	0.157	1.68	2.31	1.52	2.47	7.89%	15.77%	23.66%	1.89	2.09
Fe, wt. %	18.33	0.377	17.57	19.08	17.19	19.46	2.06%	4.12%	6.18%	17.41	19.24
Ga, ppm	17.4	0.91	15.6	19.2	14.7	20.2	5.24%	10.47%	15.71%	16.6	18.3
Gd, ppm	5.17	0.502	4.17	6.17	3.66	6.67	9.71%	19.41%	29.12%	4.91	5.43
Ge, ppm	2.23	0.39	1.45	3.01	1.06	3.39	17.46%	34.92%	52.38%	2.12	2.34
Ho, ppm	0.80	0.029	0.74	0.86	0.71	0.89	3.66%	7.33%	10.99%	0.76	0.84
In, ppm	0.39	0.033	0.32	0.45	0.29	0.48	8.51%	17.02%	25.53%	0.37	0.41
K, wt. %	3.11	0.094	2.92	3.29	2.82	3.39	3.01%	6.02%	9.04%	2.95	3.26
La, ppm	87	5.1	77	97	72	103	5.90%	11.80%	17.69%	83	91
Li, ppm	17.4	1.8	13.8	20.9	12.0	22.7	10.30%	20.60%	30.90%	16.5	18.2
Lu, ppm	0.30	0.014	0.27	0.33	0.25	0.34	4.80%	9.59%	14.39%	0.28	0.31
Mg, wt. %	0.638	0.022	0.593	0.683	0.571	0.705	3.52%	7.03%	10.55%	0.606	0.670
Mn, wt. %	0.183	0.005	0.173	0.193	0.168	0.198	2.75%	5.50%	8.25%	0.174	0.192
Mo, ppm	228	22	185	271	163	293	9.46%	18.91%	28.37%	217	239
Nb, ppm	13.9	1.12	11.7	16.1	10.5	17.3	8.05%	16.10%	24.14%	13.2	14.6
Nd, ppm	36.0	1.88	32.2	39.7	30.3	41.6	5.23%	10.46%	15.69%	34.2	37.8
Ni, ppm	63	4.7	54	72	49	77	7.43%	14.86%	22.30%	60	66
P, wt. %	0.116	0.017	0.082	0.150	0.065	0.167	14.63%	29.25%	43.88%	0.110	0.122
Pb, ppm	141	10	122	160	112	170	6.79%	13.58%	20.37%	134	148
Pr, ppm	9.96	0.791	8.37	11.54	7.58	12.33	7.95%	15.89%	23.84%	9.46	10.45
Rb, ppm	111	5	101	120	96	125	4.31%	8.61%	12.92%	105	116
S, wt. %	2.99	0.134	2.72	3.26	2.59	3.39	4.48%	8.95%	13.43%	2.84	3.14
Sb, ppm	5.09	0.56	3.97	6.22	3.40	6.78	11.05%	22.11%	33.16%	4.84	5.35
Si, wt. %	21.48	0.686	20.11	22.85	19.42	23.54	3.19%	6.38%	9.57%	20.41	22.56
Sm, ppm	6.29	0.582	5.13	7.46	4.55	8.04	9.25%	18.49%	27.74%	5.98	6.61

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt. % (weight per cent) \equiv % (mass fraction).

Note 1: intervals may appear asymmetric due to rounding; IND = indeterminate.

Note 2: the number of decimal places quoted does not imply accuracy of the certified value to this level but are given to minimise rounding errors when calculating 2SD and 3SD windows.

Table 6 continued.

Constituent	Certified Value	Absolute Standard Deviations					Relative Standard Deviations			5% window	
		1SD	2SD Low	2SD High	3SD Low	3SD High	1RSD	2RSD	3RSD	Low	High
Peroxide Fusion ICP continued											
Sr, ppm	175	11	152	197	141	208	6.43%	12.86%	19.28%	166	183
Ta, ppm	1.11	0.14	0.82	1.39	0.68	1.53	12.72%	25.43%	38.15%	1.05	1.16
Tb, ppm	0.74	0.052	0.63	0.84	0.58	0.90	7.08%	14.16%	21.24%	0.70	0.78
Th, ppm	13.4	1.4	10.6	16.1	9.3	17.5	10.22%	20.44%	30.66%	12.7	14.0
Ti, wt. %	0.370	0.013	0.345	0.396	0.332	0.409	3.44%	6.89%	10.33%	0.352	0.389
Tl, ppm	0.69	0.067	0.56	0.83	0.49	0.89	9.69%	19.37%	29.06%	0.66	0.73
Tm, ppm	0.29	0.04	0.22	0.36	0.18	0.39	12.31%	24.62%	36.93%	0.27	0.30
U, ppm	18.6	1.11	16.4	20.8	15.3	21.9	5.97%	11.94%	17.90%	17.7	19.5
V, ppm	110	11	88	132	78	143	9.92%	19.84%	29.76%	105	116
W, ppm	24.2	1.97	20.2	28.1	18.2	30.1	8.17%	16.34%	24.51%	23.0	25.4
Y, ppm	20.9	1.15	18.6	23.2	17.5	24.4	5.50%	11.00%	16.50%	19.9	22.0
Yb, ppm	1.82	0.20	1.43	2.21	1.23	2.40	10.74%	21.48%	32.22%	1.73	1.91
Zn, ppm	540	40	460	620	420	660	7.40%	14.80%	22.19%	513	567
3-Acid Digestion (no HF)											
Ag, ppm	2.98	0.46	2.05	3.91	1.59	4.37	15.59%	31.19%	46.78%	2.83	3.13
As, ppm	153	5	144	163	139	168	3.23%	6.47%	9.70%	146	161
Co, ppm	241	11	220	263	209	274	4.50%	9.01%	13.51%	229	254
Cu, wt. %	1.66	0.027	1.60	1.71	1.57	1.74	1.61%	3.23%	4.84%	1.57	1.74
Fe, wt. %	16.15	1.116	13.91	18.38	12.80	19.50	6.91%	13.83%	20.74%	15.34	16.95
Mo, ppm	217	8	202	233	194	240	3.54%	7.07%	10.61%	206	228
S, wt. %	2.92	0.057	2.80	3.03	2.75	3.09	1.95%	3.90%	5.85%	2.77	3.06
Infrared Combustion											
S, wt. %	2.98	0.062	2.86	3.11	2.80	3.17	2.07%	4.14%	6.22%	2.84	3.13
Ion Selective Electrode											
F, ppm	805	122	562	1049	441	1170	15.09%	30.19%	45.28%	765	846

SI unit equivalents: ppm (parts per million; 1×10^{-6}) \equiv mg/kg; wt.% (weight per cent) \equiv % (mass fraction).

Note 1: intervals may appear asymmetric due to rounding.

Note 2: the number of decimal places quoted does not imply accuracy of the certified value to this level but are given to minimise rounding errors when calculating 2SD and 3SD windows.

PARTICIPATING LABORATORIES

1. Actlabs, Ancaster, Ontario, Canada
2. Alex Stewart International, Mendoza, Argentina
3. ALS, Johannesburg, South Africa
4. ALS, Lima, Peru
5. ALS, Loughrea, Galway, Ireland
6. ALS, Malaga, WA, Australia
7. ALS, Vancouver, BC, Canada
8. ANSTO, Lucas Heights, NSW, Australia
9. ARGETEST Mineral Processing, Ankara, Central Anatolia, Turkey
10. Bureau Veritas Commodities Canada Ltd, Vancouver, BC, Canada
11. Bureau Veritas Geoanalytical, Perth, WA, Australia
12. Bureau Veritas Minerals, Ankara, Central Anatolia, Turkey
13. CERTIMIN, Lima, Peru
14. Inspectorate (BV), Lima, Peru
15. Intertek Genalysis, Adelaide, SA, Australia
16. Intertek Genalysis, Perth, WA, Australia
17. Intertek Testing Services Philippines, Cupang, Muntinlupa, Philippines
18. MSALABS, Vancouver, BC, Canada
19. PT Geoservices Ltd, Cikarang, Jakarta Raya, Indonesia
20. PT Intertek Utama Services, Jakarta Timur, DKI Jakarta, Indonesia
21. SGS, Ankara, Anatolia, Turkey
22. SGS, Randfontein, Gauteng, South Africa
23. SGS Australia Mineral Services, Perth, WA, Australia
24. SGS Canada Inc., Vancouver, BC, Canada
25. SGS de Mexico SA de CV, Cd. Industrial, Durango, Mexico
26. SGS del Peru, Lima, Peru
27. Shiva Analyticals Ltd, Bangalore North, Karnataka, India
28. Skyline Assayers & Laboratories, Tucson, Arizona, USA
29. Stewart Assay & Environmental Laboratories LLC, Kara-Balta, Chüy, Kyrgyzstan

Please note: To preserve anonymity, the above numbered alphabetical list of participating laboratories does not correspond with the Lab ID numbering on the scatter plots below.

Figure 2. Co by 4-Acid Digestion in OREAS 523b

SPC.1592.RR1.OREAS 523b.2.4-Acid.Co.Lab.231121.165816.SN

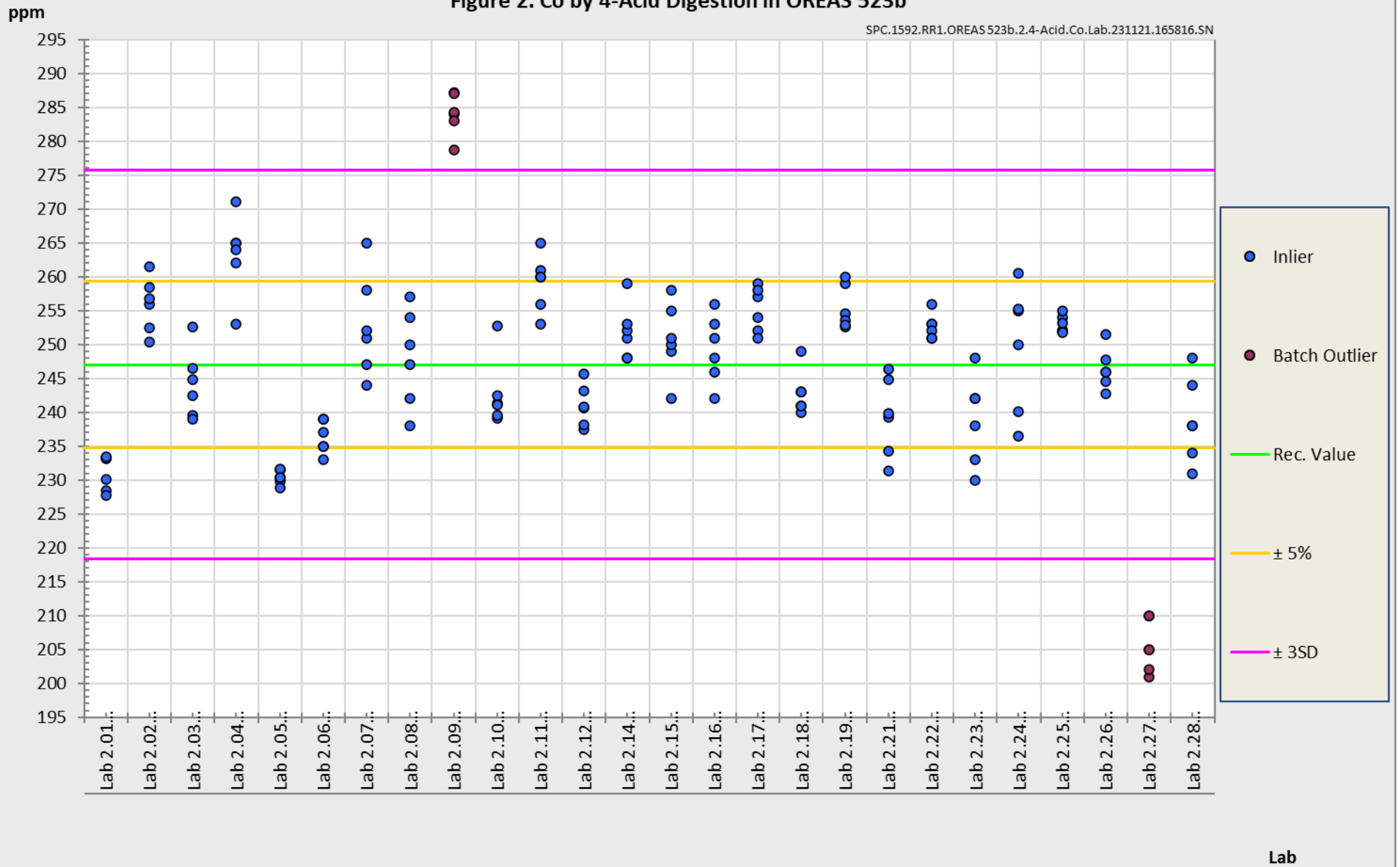
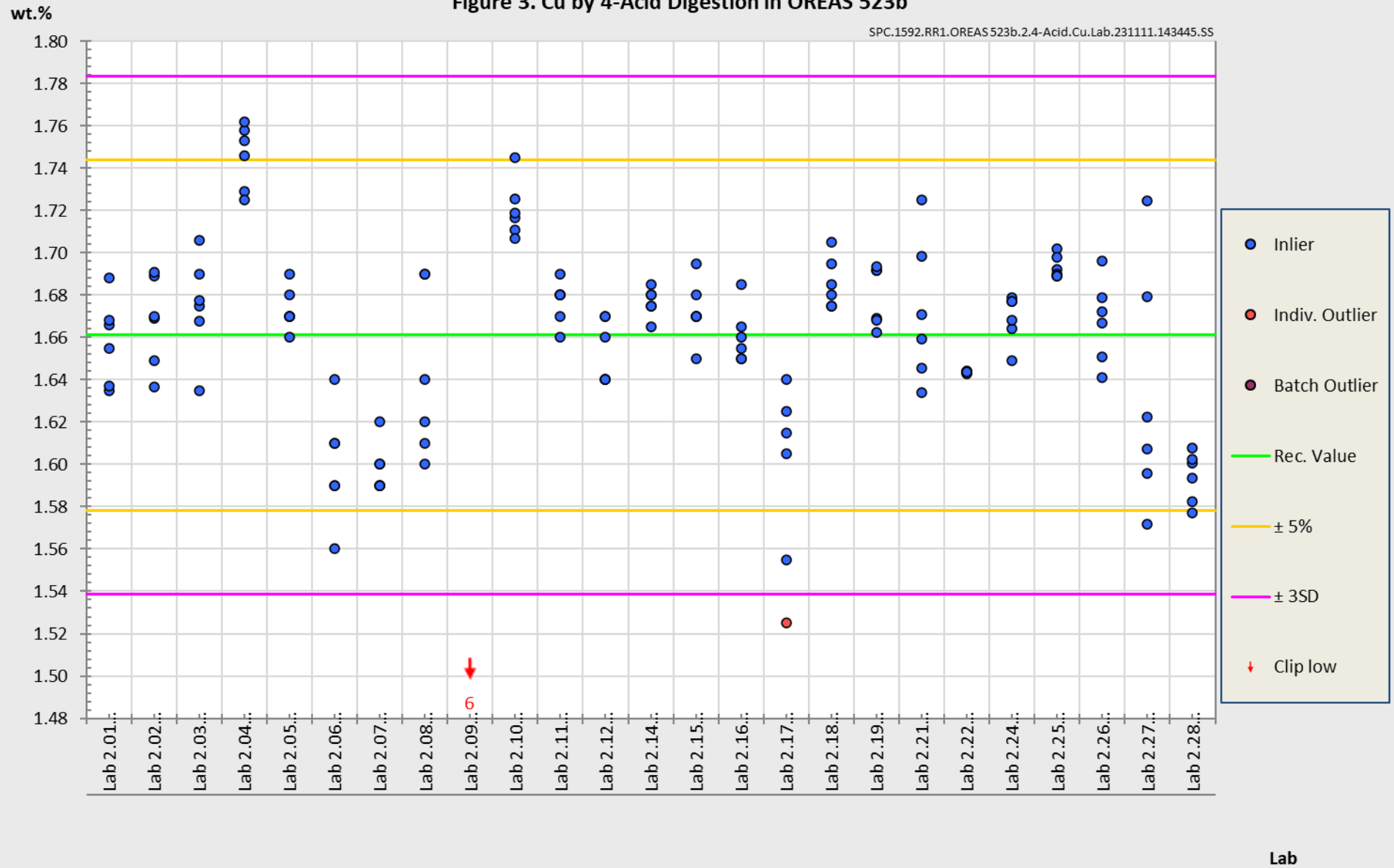


Figure 3. Cu by 4-Acid Digestion in OREAS 523b

SPC.1592.RR1.OREAS 523b.2.4-Acid.Cu.Lab.231111.143445.SS



PREPARER AND SUPPLIER

Certified reference material OREAS 523b is prepared, certified and supplied by:



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METROLOGICAL TRACEABILITY

The interlaboratory results that underpin the certified values are metrologically traceable to the international measurement scale (SI) of mass (either as a % mass fraction or as milligrams per kilogram (mg/kg)). In line with popular use, all data within tables in this certificate are expressed as the mass fraction in either weight percent (wt.%) or parts per million (ppm).

The analytical samples sent to participating laboratories were selected in a manner to be representative of the entire prepared batch of 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. The systematic sampling method was chosen due to the low risk of overlooking repetitive effects or trends in the batch due to the way the CRM was processed. In line with ISO 17025 [10], each analytical data set received from the participating laboratories has been validated by its assayer through the inclusion of internal reference materials and QC checks during and post analysis.

The participating laboratories were chosen on the basis of their competence (from past performance in interlaboratory programs undertaken by ORE Pty Ltd) for a particular analytical method, analyte or analyte suite and sample matrix. These laboratories are accredited to ISO 17025 for Au by fire assay (Table 1). The other operationally defined measurands characterised in this certificate (Table 2) are derived from data procured mostly from ISO 17025 accredited laboratories. The certified values presented in this report are calculated from the means of accepted data following robust technical and statistical analysis 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 procedure is possible. In this case, it is impossible to demonstrate absence of method bias; therefore, the result is an operationally defined measurand (ISO Guide 35:2017, 9.2.4c)."* Certification takes place on the basis of agreement among operationally defined, independent measurement results.

COMMUTABILITY

The measurements of the results that underlie the certified values contained in this report were undertaken by methods involving pre-treatment (fusion/digestion) 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 the field samples being analysed.

INTENDED USE

OREAS 523b is intended to cover all activities needed to produce a measurement result. This includes extraction, possible separation steps and the actual measurement process (the signal producing step). OREAS 523b may be used to calibrate the entire procedure by producing a pure substance CRM transformed into a calibration solution.

OREAS 523b is intended for the following uses:

- For the monitoring of laboratory performance in the analysis of analytes reported in Tables 1 and 2 in geological samples;
- For the verification of analytical methods for analytes reported in Tables 1 and 2;
- For the calibration of instruments used in the determination of the concentration of analytes reported in Tables 1 and 2. When a value provided in this certificate is used to calibrate a measurement process, the uncertainty associated with that value should be appropriately propagated into the user's uncertainty calculation. Users can determine an approximation of the standard uncertainty by calculating one fourth of the width of the Expanded Uncertainty interval given in this certificate (Expanded Uncertainty intervals are provided in Tables 1 and 2).

MINIMUM SAMPLE SIZE

To relate analytical determinations to the values in this certificate, the minimum mass of sample used should match the typical mass that the laboratories used in the interlaboratory (round robin) certification program. This means that different minimum sample masses should be used depending on the operationally defined methodology as follows:

- Au by fire assay: $\geq 25\text{g}$;
- Au by aqua regia digestion: $\geq 15\text{g}$;
- 4-acid digestion with ICP-OES and/or MS finish: $\geq 0.25\text{g}$;
- Aqua regia digestion with ICP-OES and/or MS finish: $\geq 0.5\text{g}$;
- Peroxide fusion with ICP-OES and/or MS finish: $\geq 0.1\text{g}$;
- 3-acid digestion with ICP-OES finish: $\geq 0.3\text{g}$;
- Total Sulphur by infrared combustion furnace/CS analyser: $\geq 0.1\text{g}$;
- Fluorine by ion selective electrode: $\geq 0.2\text{g}$.

PERIOD OF VALIDITY & STORAGE INSTRUCTIONS

The certification of OREAS 523b remains valid, within the specified measurement uncertainties, until November 2033, provided the CRM is handled and stored in accordance with the instructions given below. This certification is nullified if the CRM is any way changed or contaminated.

Store in a clean and cool dry place away from direct sunlight.

Long-term stability will be monitored at appropriate intervals and purchasers notified if any changes are observed. The period of validity may well be indefinite and will be reassessed prior to expiry with the aim of extending the validity if possible.

Single-use sachets (e.g., 10g and 60g units)

Following analysis, it is the manufacturer's expectation that any remaining material is discarded unless the sachet is promptly resealed. It is the user's responsibility to prevent contamination and minimise exposure to the atmosphere.

INSTRUCTIONS FOR HANDLING & CORRECT USE

Pre-homogenisation of the CRM prior to subsampling and analysis is not necessary as there is no particle segregation under transport [13].

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

QC monitoring using multiples of the Standard Deviation (SD)

In the application of SD's in monitoring performance it is important to note that not all laboratories function at the same level of proficiency and that different methods in use at a particular laboratory have differing levels of precision. Each laboratory has its own inherent SD (for a specific concentration level and analyte-method pair) based on the analytical process and this SD is not directly related to the round robin program.

The majority of data generated in the round robin program was produced by a selection of world class laboratories. The SD's thus generated are more constrained than those that would be produced across a randomly selected group of laboratories. To produce more generally achievable SD's the 'pooled' SD's provided in this report include interlaboratory bias. This 'one size fits all' approach may require revision at the discretion of the QC manager concerned following careful scrutiny of QC control charts.

The performance gates shown in Table 6 are intended only to be used as a preliminary guide as to what a laboratory may be able to achieve. Over a period of time monitoring your own laboratory's data for this CRM, SD's should be calculated directly from your own laboratory's process. This will enable you to establish more specific performance gates that are fit for purpose for your application as well as the ability to monitor bias. If your long-term trend analysis shows an average value that is within the 95% expanded uncertainty then generally there is no cause for concern in regard to bias.

For use with the aqua regia digestion method

It is important to note that in the analytical industry there is no standardisation of the aqua regia digestion process. This method is a partial empirical digest and differences in recoveries for various analytes are commonplace. These are caused by variations in the digest conditions and can include the ratio of nitric to hydrochloric acids, acid strength, temperatures, leach times and secondary digestions. Recoveries for sulphide-hosted base metal sulphides approach total values, however, other analytes, in particular the lithophile elements, show greater sensitivity to method parameters. This can result in lack of consensus in an inter-laboratory certification program for these elements.

The approach applied here is to report certified values in those instances where reasonable agreement exists amongst a majority of participating laboratories. The results of specific laboratories may differ significantly from the certified values, but will, nonetheless, be valid and reproducible in the context of the specifics of the aqua regia method in use. Users of this reference material should, therefore, be mindful of this limitation when applying the certified values in a quality control program.

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.

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DOCUMENT HISTORY

Revision No.	Date	Changes applied
0	12 th December, 2023	First publication.

CERTIFYING OFFICER



12th December, 2023

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

QMS CERTIFICATION

ORE Pty Ltd is accredited for compliance with ISO 17034:2016.



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



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