



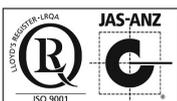
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CERTIFICATE OF ANALYSIS FOR

Copper-Cobalt Ore (Democratic Republic of the Congo)

CERTIFIED REFERENCE MATERIAL

OREAS 554



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Table 1. Certified Values and Performance Gates for OREAS 554.

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
Borate Fusion XRF											
Al ₂ O ₃ , wt. %	8.23	0.091	8.05	8.41	7.96	8.50	1.10%	2.20%	3.30%	7.82	8.64
BaO, ppm	1418	69	1280	1556	1211	1624	4.85%	9.71%	14.56%	1347	1489
CaO, wt. %	5.58	0.074	5.43	5.73	5.36	5.80	1.33%	2.66%	3.99%	5.30	5.86
Co, wt. %	0.805	0.021	0.763	0.846	0.742	0.867	2.59%	5.17%	7.76%	0.764	0.845
Cr ₂ O ₃ , ppm	97	18	61	133	43	151	18.62%	37.25%	55.87%	92	102
Cu, wt. %	1.58	0.028	1.52	1.63	1.50	1.66	1.76%	3.51%	5.27%	1.50	1.66
Fe ₂ O ₃ , wt. %	2.57	0.035	2.50	2.65	2.47	2.68	1.37%	2.74%	4.11%	2.45	2.70
K ₂ O, wt. %	2.01	0.027	1.95	2.06	1.92	2.09	1.34%	2.68%	4.02%	1.91	2.11
MgO, wt. %	5.27	0.061	5.15	5.40	5.09	5.46	1.16%	2.32%	3.49%	5.01	5.54
MnO, wt. %	0.144	0.006	0.132	0.156	0.126	0.162	4.26%	8.51%	12.77%	0.137	0.151
P ₂ O ₅ , wt. %	0.073	0.007	0.060	0.086	0.053	0.093	9.06%	18.11%	27.17%	0.070	0.077
SiO ₂ , wt. %	60.26	0.480	59.30	61.22	58.82	61.70	0.80%	1.59%	2.39%	57.25	63.28
SO ₃ , wt. %	1.98	0.031	1.92	2.05	1.89	2.08	1.57%	3.13%	4.70%	1.88	2.08
SrO, ppm	94	13	67	121	54	134	14.13%	28.27%	42.40%	89	99
TiO ₂ , wt. %	0.382	0.011	0.359	0.405	0.347	0.416	3.01%	6.02%	9.03%	0.363	0.401
Thermogravimetry											
LOI ¹⁰⁰⁰ , wt. %	10.11	0.251	9.61	10.62	9.36	10.87	2.49%	4.97%	7.46%	9.61	10.62
Infrared Combustion											
C, wt. %	2.84	0.056	2.73	2.96	2.68	3.01	1.96%	3.93%	5.89%	2.70	2.99
S, wt. %	0.771	0.020	0.730	0.812	0.710	0.833	2.65%	5.31%	7.96%	0.733	0.810
Sulphuric Acid 5% Leach											
Co, wt. %	0.555	0.042	0.471	0.640	0.428	0.683	7.64%	15.29%	22.93%	0.528	0.583
Sulphuric Acid 10% Leach											
Co, wt. %	0.546	0.042	0.462	0.629	0.421	0.671	7.63%	15.26%	22.89%	0.518	0.573
Peroxide Fusion ICP											
Ag, ppm	< 1	IND	IND	IND	IND	IND	IND	IND	IND	IND	IND
Al, wt. %	4.32	0.140	4.04	4.60	3.90	4.74	3.23%	6.47%	9.70%	4.11	4.54
As, ppm	66	5.2	56	76	50	81	7.87%	15.73%	23.60%	63	69
B, ppm	178	20	139	217	120	237	10.97%	21.93%	32.90%	169	187
Ba, ppm	1280	68	1145	1416	1078	1483	5.28%	10.56%	15.84%	1216	1345
Bi, ppm	2.83	0.53	1.77	3.88	1.24	4.41	18.73%	37.46%	56.18%	2.69	2.97
Ca, wt. %	3.96	0.166	3.62	4.29	3.46	4.45	4.19%	8.37%	12.56%	3.76	4.15
Ce, ppm	68	2.3	63	72	61	75	3.35%	6.71%	10.06%	64	71
Co, wt. %	0.809	0.024	0.761	0.858	0.737	0.882	2.99%	5.98%	8.98%	0.769	0.850
Cr, ppm	69	14	41	96	28	110	19.87%	39.73%	59.60%	65	72
Cs, ppm	2.55	0.225	2.10	3.01	1.88	3.23	8.82%	17.65%	26.47%	2.43	2.68
Cu, wt. %	1.57	0.043	1.48	1.65	1.44	1.70	2.71%	5.42%	8.14%	1.49	1.65
Dy, ppm	3.54	0.176	3.18	3.89	3.01	4.06	4.98%	9.96%	14.95%	3.36	3.71
Er, ppm	1.99	0.117	1.75	2.22	1.64	2.34	5.89%	11.77%	17.66%	1.89	2.09
Eu, ppm	0.85	0.13	0.58	1.12	0.44	1.25	15.92%	31.83%	47.75%	0.81	0.89
Fe, wt. %	1.82	0.048	1.72	1.92	1.67	1.96	2.65%	5.30%	7.95%	1.73	1.91
Ga, ppm	13.5	1.6	10.4	16.6	8.9	18.2	11.51%	23.02%	34.52%	12.8	14.2
Gd, ppm	4.27	0.43	3.40	5.14	2.96	5.57	10.19%	20.38%	30.57%	4.06	4.48
Hf, ppm	2.24	0.42	1.40	3.08	0.98	3.50	18.82%	37.63%	56.45%	2.13	2.35

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; 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 1 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											
Ho, ppm	0.72	0.050	0.63	0.82	0.58	0.87	6.84%	13.67%	20.51%	0.69	0.76
K, wt. %	1.69	0.063	1.57	1.82	1.50	1.88	3.73%	7.46%	11.20%	1.61	1.78
La, ppm	35.2	1.99	31.2	39.2	29.2	41.1	5.65%	11.29%	16.94%	33.4	36.9
Li, ppm	34.2	6.5	21.3	47.2	14.8	53.7	18.96%	37.91%	56.87%	32.5	35.9
Lu, ppm	0.29	0.03	0.23	0.36	0.19	0.40	11.57%	23.13%	34.70%	0.28	0.31
Mg, wt. %	3.14	0.062	3.02	3.27	2.96	3.33	1.98%	3.96%	5.94%	2.99	3.30
Mn, wt. %	0.110	0.005	0.100	0.120	0.095	0.125	4.57%	9.13%	13.70%	0.105	0.116
Nd, ppm	28.2	1.30	25.6	30.8	24.3	32.1	4.63%	9.25%	13.88%	26.8	29.6
Ni, ppm	33.7	8.1	17.4	49.9	9.3	58.1	24.16%	48.32%	72.48%	32.0	35.4
P, wt. %	0.034	0.005	0.024	0.044	0.019	0.048	14.35%	28.70%	43.05%	0.032	0.036
Pb, ppm	18.6	3.0	12.6	24.6	9.6	27.7	16.21%	32.42%	48.62%	17.7	19.5
Pr, ppm	7.86	0.489	6.88	8.84	6.39	9.32	6.23%	12.46%	18.69%	7.46	8.25
Rb, ppm	89	2.6	84	94	81	97	2.94%	5.88%	8.82%	84	93
S, wt. %	0.769	0.020	0.730	0.809	0.711	0.828	2.55%	5.10%	7.65%	0.731	0.808
Sb, ppm	2.24	0.43	1.38	3.11	0.94	3.54	19.31%	38.61%	57.92%	2.13	2.35
Sc, ppm	7.98	1.07	5.84	10.12	4.77	11.19	13.41%	26.82%	40.24%	7.58	8.38
Si, wt. %	28.75	0.635	27.48	30.02	26.84	30.65	2.21%	4.42%	6.63%	27.31	30.19
Sm, ppm	4.93	0.395	4.14	5.72	3.75	6.11	8.01%	16.02%	24.03%	4.68	5.18
Sr, ppm	71	3.1	65	77	62	80	4.35%	8.69%	13.04%	67	75
Ta, ppm	0.70	0.16	0.39	1.01	0.23	1.16	22.37%	44.74%	67.11%	0.66	0.73
Tb, ppm	0.59	0.10	0.40	0.79	0.30	0.88	16.38%	32.77%	49.15%	0.56	0.62
Th, ppm	9.29	0.670	7.95	10.64	7.28	11.31	7.21%	14.43%	21.64%	8.83	9.76
Ti, wt. %	0.228	0.010	0.207	0.249	0.197	0.259	4.58%	9.15%	13.73%	0.217	0.239
Tm, ppm	0.30	0.025	0.25	0.35	0.23	0.37	8.27%	16.54%	24.81%	0.29	0.32
U, ppm	14.3	0.64	13.0	15.6	12.3	16.2	4.49%	8.99%	13.48%	13.6	15.0
V, ppm	116	7	102	129	96	136	5.81%	11.63%	17.44%	110	122
Y, ppm	20.1	1.13	17.9	22.4	16.7	23.5	5.60%	11.21%	16.81%	19.1	21.1
Yb, ppm	1.95	0.20	1.56	2.34	1.36	2.54	10.07%	20.14%	30.21%	1.85	2.05
Zn, ppm	56	11	34	78	23	89	19.52%	39.05%	58.57%	53	59
Zr, ppm	81	11	59	103	48	114	13.42%	26.84%	40.26%	77	85
*4-Acid Digestion											
Ag, ppm	0.255	0.024	0.207	0.303	0.183	0.326	9.38%	18.77%	28.15%	0.242	0.267
Al, wt. %	4.32	0.136	4.04	4.59	3.91	4.73	3.16%	6.32%	9.48%	4.10	4.53
As, ppm	66	2.8	60	72	58	74	4.25%	8.51%	12.76%	63	69
Ba, ppm	1274	50	1175	1374	1126	1423	3.89%	7.78%	11.68%	1211	1338
Be, ppm	1.84	0.124	1.59	2.09	1.47	2.21	6.72%	13.44%	20.16%	1.75	1.93
Bi, ppm	2.74	0.183	2.37	3.10	2.19	3.28	6.70%	13.39%	20.09%	2.60	2.87
Ca, wt. %	3.96	0.113	3.73	4.19	3.62	4.30	2.86%	5.72%	8.58%	3.76	4.16
Cd, ppm	0.21	0.020	0.17	0.25	0.15	0.27	9.87%	19.75%	29.62%	0.20	0.22
Ce, ppm	64	3.9	56	72	52	76	6.16%	12.31%	18.47%	61	67
Co, wt. %	0.815	0.034	0.748	0.883	0.715	0.916	4.11%	8.23%	12.34%	0.775	0.856
Cr, ppm	49.5	5.6	38.3	60.7	32.7	66.3	11.31%	22.62%	33.93%	47.0	51.9

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt. % \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; 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 1 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											
Cs, ppm	2.42	0.113	2.20	2.65	2.09	2.76	4.64%	9.29%	13.93%	2.30	2.55
Cu, wt. %	1.59	0.024	1.54	1.64	1.52	1.66	1.53%	3.07%	4.60%	1.51	1.67
Dy, ppm	2.71	0.28	2.14	3.28	1.86	3.56	10.48%	20.95%	31.43%	2.57	2.84
Er, ppm	1.43	0.22	1.00	1.87	0.78	2.09	15.21%	30.43%	45.64%	1.36	1.50
Eu, ppm	0.82	0.032	0.76	0.89	0.73	0.92	3.91%	7.82%	11.73%	0.78	0.87
Fe, wt. %	1.80	0.068	1.67	1.94	1.60	2.01	3.80%	7.59%	11.39%	1.71	1.89
Ga, ppm	12.5	0.61	11.3	13.7	10.7	14.3	4.86%	9.72%	14.58%	11.9	13.1
Gd, ppm	3.78	0.199	3.38	4.18	3.19	4.38	5.26%	10.51%	15.77%	3.59	3.97
Ge, ppm	0.095	0.021	0.054	0.136	0.033	0.156	21.62%	43.24%	64.86%	0.090	0.100
Hf, ppm	1.88	0.20	1.48	2.27	1.28	2.47	10.57%	21.14%	31.72%	1.78	1.97
Ho, ppm	0.52	0.08	0.37	0.68	0.30	0.75	14.48%	28.96%	43.44%	0.50	0.55
In, ppm	0.10	0.007	0.09	0.12	0.09	0.12	6.22%	12.44%	18.65%	0.10	0.11
K, wt. %	1.71	0.065	1.58	1.84	1.51	1.90	3.81%	7.63%	11.44%	1.62	1.79
La, ppm	30.6	2.41	25.7	35.4	23.3	37.8	7.90%	15.79%	23.69%	29.0	32.1
Li, ppm	33.9	1.68	30.5	37.2	28.8	38.9	4.97%	9.94%	14.91%	32.2	35.6
Lu, ppm	0.21	0.015	0.18	0.24	0.17	0.26	7.20%	14.41%	21.61%	0.20	0.22
Mg, wt. %	3.14	0.096	2.95	3.34	2.86	3.43	3.06%	6.13%	9.19%	2.99	3.30
Mn, wt. %	0.108	0.004	0.100	0.116	0.096	0.120	3.79%	7.58%	11.37%	0.103	0.114
Mo, ppm	3.54	0.224	3.09	3.99	2.87	4.21	6.32%	12.63%	18.95%	3.36	3.72
Na, wt. %	0.060	0.007	0.046	0.073	0.040	0.080	11.25%	22.50%	33.74%	0.057	0.063
Nb, ppm	5.08	1.80	1.47	8.69	0.00	10.49	35.54%	71.08%	106.62%	4.82	5.33
Nd, ppm	25.3	1.91	21.5	29.1	19.6	31.0	7.56%	15.12%	22.68%	24.0	26.6
Ni, ppm	31.3	1.38	28.5	34.0	27.1	35.4	4.41%	8.83%	13.24%	29.7	32.8
P, wt. %	0.031	0.001	0.029	0.033	0.028	0.034	3.20%	6.41%	9.61%	0.029	0.032
Pb, ppm	16.6	0.92	14.8	18.4	13.8	19.4	5.54%	11.09%	16.63%	15.8	17.4
Pr, ppm	6.86	0.413	6.04	7.69	5.62	8.10	6.02%	12.03%	18.05%	6.52	7.20
Rb, ppm	88	3.9	80	96	76	100	4.49%	8.98%	13.46%	84	92
Re, ppm	0.044	0.003	0.038	0.050	0.034	0.054	7.29%	14.57%	21.86%	0.042	0.046
S, wt. %	0.778	0.023	0.733	0.823	0.711	0.846	2.90%	5.79%	8.69%	0.739	0.817
Sb, ppm	2.22	0.197	1.83	2.61	1.63	2.81	8.88%	17.75%	26.63%	2.11	2.33
Sc, ppm	8.10	0.219	7.66	8.54	7.44	8.76	2.71%	5.42%	8.12%	7.70	8.51
Se, ppm	5.29	0.75	3.79	6.80	3.03	7.55	14.22%	28.44%	42.66%	5.03	5.56
Sm, ppm	4.82	0.200	4.42	5.22	4.22	5.42	4.16%	8.31%	12.47%	4.58	5.06
Sn, ppm	2.22	0.158	1.90	2.53	1.74	2.69	7.14%	14.28%	21.42%	2.10	2.33
Sr, ppm	67	2.7	62	73	59	75	4.05%	8.09%	12.14%	64	71
Ta, ppm	0.35	0.10	0.14	0.56	0.03	0.66	30.11%	60.22%	90.33%	0.33	0.37
Tb, ppm	0.52	0.040	0.44	0.60	0.40	0.64	7.74%	15.49%	23.23%	0.49	0.54
Te, ppm	0.049	0.019	0.011	0.087	0.000	0.106	38.91%	77.82%	116.73%	0.047	0.052
Th, ppm	8.99	0.622	7.75	10.24	7.13	10.86	6.92%	13.84%	20.76%	8.54	9.44
Ti, wt. %	0.161	0.035	0.091	0.230	0.057	0.265	21.61%	43.21%	64.82%	0.153	0.169
Tl, ppm	0.53	0.030	0.47	0.59	0.44	0.62	5.75%	11.50%	17.25%	0.50	0.55
Tm, ppm	0.20	0.016	0.17	0.23	0.16	0.25	7.75%	15.51%	23.26%	0.19	0.21

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt. % \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; 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 1 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											
U, ppm	13.8	0.98	11.8	15.7	10.8	16.7	7.09%	14.18%	21.27%	13.1	14.5
V, ppm	112	4	103	121	99	126	3.96%	7.92%	11.88%	107	118
W, ppm	1.27	0.18	0.90	1.64	0.72	1.82	14.44%	28.87%	43.31%	1.21	1.33
Y, ppm	12.9	0.93	11.1	14.8	10.1	15.7	7.17%	14.33%	21.50%	12.3	13.6
Yb, ppm	1.42	0.20	1.02	1.81	0.83	2.00	13.83%	27.66%	41.50%	1.35	1.49
Zn, ppm	55	2.9	49	61	46	64	5.32%	10.64%	15.96%	53	58
Zr, ppm	63	3.1	56	69	53	72	4.97%	9.95%	14.92%	59	66
Aqua Regia Digestion											
Ag, ppm	0.178	0.012	0.154	0.201	0.142	0.213	6.68%	13.37%	20.05%	0.169	0.187
Al, wt. %	0.594	0.046	0.503	0.686	0.458	0.731	7.68%	15.36%	23.04%	0.565	0.624
As, ppm	65	3.3	58	71	55	75	5.06%	10.12%	15.18%	62	68
B, ppm	< 10	IND	IND	IND	IND	IND	IND	IND	IND	IND	IND
Ba, ppm	226	23	180	272	158	294	10.09%	20.17%	30.26%	215	237
Be, ppm	0.63	0.044	0.54	0.72	0.50	0.76	6.96%	13.91%	20.87%	0.60	0.66
Bi, ppm	2.58	0.117	2.35	2.81	2.23	2.93	4.55%	9.09%	13.64%	2.45	2.71
Ca, wt. %	3.85	0.124	3.61	4.10	3.48	4.23	3.21%	6.42%	9.63%	3.66	4.05
Cd, ppm	0.20	0.017	0.16	0.23	0.15	0.25	8.69%	17.37%	26.06%	0.19	0.21
Ce, ppm	34.8	3.9	27.0	42.5	23.2	46.3	11.09%	22.19%	33.28%	33.0	36.5
Co, wt. %	0.761	0.042	0.677	0.845	0.635	0.887	5.53%	11.06%	16.59%	0.723	0.799
Cr, ppm	15.5	1.9	11.7	19.3	9.8	21.2	12.30%	24.59%	36.89%	14.7	16.3
Cs, ppm	0.57	0.10	0.37	0.77	0.27	0.86	17.56%	35.13%	52.69%	0.54	0.59
Cu, wt. %	1.58	0.054	1.47	1.69	1.42	1.74	3.40%	6.80%	10.21%	1.50	1.66
Dy, ppm	1.34	0.14	1.06	1.63	0.91	1.77	10.67%	21.35%	32.02%	1.28	1.41
Er, ppm	0.57	0.039	0.49	0.65	0.46	0.69	6.73%	13.47%	20.20%	0.54	0.60
Eu, ppm	0.45	0.08	0.29	0.62	0.21	0.70	17.88%	35.76%	53.64%	0.43	0.48
Fe, wt. %	1.64	0.052	1.54	1.74	1.48	1.79	3.17%	6.33%	9.50%	1.56	1.72
Ga, ppm	1.76	0.27	1.23	2.30	0.97	2.56	15.07%	30.14%	45.22%	1.68	1.85
Gd, ppm	2.18	0.45	1.28	3.07	0.84	3.51	20.47%	40.95%	61.42%	2.07	2.28
Hf, ppm	0.27	0.03	0.21	0.33	0.18	0.36	11.41%	22.81%	34.22%	0.25	0.28
Hg, ppm	0.019	0.006	0.007	0.030	0.001	0.036	31.36%	62.71%	94.07%	0.018	0.020
Ho, ppm	0.22	0.03	0.17	0.28	0.14	0.31	12.55%	25.10%	37.65%	0.21	0.23
In, ppm	0.063	0.004	0.056	0.071	0.052	0.074	5.88%	11.75%	17.63%	0.060	0.066
K, wt. %	0.177	0.018	0.140	0.214	0.122	0.232	10.38%	20.76%	31.14%	0.168	0.186
La, ppm	14.2	1.9	10.4	18.1	8.4	20.1	13.62%	27.24%	40.85%	13.5	14.9
Li, ppm	18.4	2.6	13.2	23.5	10.7	26.1	13.97%	27.94%	41.91%	17.4	19.3
Lu, ppm	0.079	0.011	0.057	0.102	0.046	0.113	14.13%	28.26%	42.39%	0.075	0.083
Mg, wt. %	2.90	0.100	2.70	3.10	2.60	3.20	3.44%	6.89%	10.33%	2.76	3.05
Mn, wt. %	0.106	0.005	0.097	0.116	0.092	0.121	4.56%	9.12%	13.68%	0.101	0.112
Mo, ppm	3.32	0.170	2.98	3.66	2.81	3.83	5.13%	10.26%	15.39%	3.15	3.49
Nd, ppm	13.0	1.7	9.5	16.4	7.8	18.1	13.18%	26.37%	39.55%	12.3	13.6
Ni, ppm	28.4	2.26	23.9	32.9	21.6	35.2	7.98%	15.96%	23.93%	27.0	29.8
P, wt. %	0.026	0.001	0.024	0.029	0.023	0.030	4.86%	9.73%	14.59%	0.025	0.028

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt. % \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; 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 1 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											
Pb, ppm	11.0	1.3	8.3	13.7	6.9	15.0	12.25%	24.50%	36.74%	10.4	11.5
Pr, ppm	2.82	0.82	1.17	4.46	0.35	5.29	29.22%	58.43%	87.65%	2.68	2.96
Rb, ppm	8.83	0.873	7.08	10.58	6.21	11.45	9.89%	19.77%	29.66%	8.39	9.27
Re, ppm	0.045	0.003	0.040	0.050	0.037	0.052	5.68%	11.37%	17.05%	0.042	0.047
S, wt. %	0.743	0.049	0.645	0.841	0.596	0.890	6.58%	13.17%	19.75%	0.706	0.780
Sb, ppm	1.49	0.19	1.11	1.86	0.92	2.05	12.65%	25.30%	37.95%	1.41	1.56
Sc, ppm	2.23	0.163	1.91	2.56	1.74	2.72	7.31%	14.63%	21.94%	2.12	2.34
Se, ppm	4.90	0.478	3.94	5.85	3.46	6.33	9.77%	19.53%	29.30%	4.65	5.14
Sn, ppm	0.32	0.05	0.22	0.42	0.16	0.47	16.21%	32.43%	48.64%	0.30	0.34
Sr, ppm	40.2	2.35	35.5	44.9	33.2	47.3	5.85%	11.70%	17.56%	38.2	42.2
Ta, ppm	< 0.01	IND	IND	IND	IND	IND	IND	IND	IND	IND	IND
Tb, ppm	0.29	0.022	0.25	0.34	0.22	0.36	7.68%	15.35%	23.03%	0.28	0.31
Te, ppm	0.048	0.011	0.027	0.070	0.016	0.080	22.26%	44.53%	66.79%	0.046	0.051
Th, ppm	5.51	0.258	5.00	6.03	4.74	6.29	4.68%	9.36%	14.04%	5.24	5.79
Tl, ppm	0.11	0.01	0.08	0.14	0.07	0.15	12.06%	24.11%	36.17%	0.10	0.11
U, ppm	11.8	0.85	10.1	13.5	9.3	14.4	7.17%	14.34%	21.50%	11.3	12.4
V, ppm	19.3	1.49	16.3	22.3	14.8	23.8	7.70%	15.40%	23.10%	18.3	20.3
W, ppm	0.10	0.01	0.08	0.13	0.07	0.14	11.42%	22.83%	34.25%	0.10	0.11
Y, ppm	5.69	0.371	4.95	6.43	4.58	6.81	6.52%	13.04%	19.56%	5.41	5.98
Yb, ppm	0.50	0.008	0.48	0.51	0.47	0.52	1.56%	3.12%	4.69%	0.47	0.52
Zn, ppm	48.2	3.25	41.7	54.7	38.5	58.0	6.74%	13.48%	20.23%	45.8	50.6
Zr, ppm	8.99	0.395	8.20	9.78	7.81	10.18	4.39%	8.78%	13.18%	8.54	9.44

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt. % \equiv 1000 ppb, parts per billion.

Note: intervals may appear asymmetric due to rounding; 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 2. Indicative Values for OREAS 554.

Constituent	Unit	Value	Constituent	Unit	Value	Constituent	Unit	Value
Borate Fusion XRF								
As	ppm	< 10	Na ₂ O	wt. %	0.072	V ₂ O ₅	ppm	208
Bi	ppm	< 10	Ni	ppm	94	Zn	ppm	66
Cd	ppm	< 10	Pb	ppm	86	Zr	ppm	67
Cl	ppm	255	Sb	ppm	< 10			
Mo	ppm	28.7	Sn	ppm	< 10			
Thermogravimetry								
H ₂ O-	wt. %	0.128						
Sulphuric Acid 5% Leach								
Cu	wt. %	0.250						
Sulphuric Acid 10% Leach								
Cu	wt. %	0.517						

SI unit equivalents: ppm (parts per million) \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt. % \equiv 1000 ppb (parts per billion).

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 1 continued.

Constituent	Unit	Value	Constituent	Unit	Value	Constituent	Unit	Value
Peroxide Fusion ICP								
Be	ppm	2.22	Mo	ppm	4.18	Te	ppm	< 1
Cd	ppm	0.23	Nb	ppm	7.81	Tl	ppm	0.48
Ge	ppm	1.45	Re	ppm	< 0.1	W	ppm	1.55
Hg	ppm	< 0.1	Se	ppm	13.3			
In	ppm	< 0.2	Sn	ppm	2.41			
4-Acid Digestion								
B	ppm	7.31	Hg	ppm	0.053			
Aqua Regia Digestion								
Au	ppm	0.013	Pd	ppb	< 10	Ti	wt.%	0.003
Ge	ppm	0.045	Pt	ppb	13.3	Tm	ppm	0.086
Na	wt.%	0.018	Si	wt.%	0.061			
Nb	ppm	< 0.05	Sm	ppm	2.51			

SI unit equivalents: ppm (parts per million) \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb (parts per billion).

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.

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 provides performance gate intervals for the certified values. Table 2 shows indicative values, Table 3 provides some indicative physical properties and Table 4 presents the 95% confidence and tolerance limits for all certified values. Tabulated results of all elements 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 554-DataPack.1.1.210420_172131.xlsx**). Results are also presented in scatter plots for Co and Cu by 4-acid digestion and peroxide fusion ICP in Figures 1 to 4 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 554 was prepared from a blend of copper-cobalt primary ore materials supplied by Metorex (subsidiary of Jinchuan Group) from the Dilala Est Copper Cobalt Project, located

within the Kolwezi Klippe area of Lualaba Province (Democratic Republic of the Congo). Kolwezi is ~320 kilometres northwest from Lubumbashi, the provincial capital of Haut Katanga Province. Copper-cobalt ores within the Kolwezi Klippe area are stratiform, sediment-hosted deposits hosted within Neoproterozoic sedimentary rocks of the Central African Copperbelt. Primary mineralisation typically consists of bornite, chalcopyrite and cobalt sulphides (linnaeite and carrollite) hosted within dolomitic argillite, shales, sandstone and dolomite horizons.

PERFORMANCE GATES

Table 1 above 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 $\pm 10\% \pm 2DL$ (adapted from Govett, 1983).

COMMINUTION AND HOMOGENISATION PROCEDURES

The material constituting OREAS 554 was prepared in the following manner:

- Drying to constant mass at 105° Celsius;
- Multi-stage milling of each source material to achieve a particle size distribution of >98% passing 75 microns;
- Preliminary homogenisation of each source material;
- Representative sampling and check assaying of each source material;
- Blending in appropriate proportions to achieve target grades;
- Packaging in 10g units sealed in laminated foil pouches and 500g units in plastic jars.

PHYSICAL PROPERTIES

OREAS 554 was tested at ORE Research & Exploration Pty Ltd's onsite facility for various physical properties. Table 3 presents these findings that should be used for informational purposes only.

Table 3. Physical properties of OREAS 554.

Bulk Density (g/L)	Moisture%	Munsell Notation [‡]	Munsell Color [‡]
740.7	0.51	5YR 6/1	Light Brownish Gray

[‡]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

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

- Lithium borate fusion whole rock analysis package by X-ray fluorescence (up to 19 laboratories depending on the element);
- Thermogravimetry: Loss on Ignition (LOI) at 1000°C (13 laboratories used a thermogravimetric analyser, 7 laboratories included LOI with their fusion package and 4 laboratories used conventional muffle furnace);
- C and S by infrared combustion furnace/CS analyser (27 laboratories);
- Cu and Co by *5% sulphuric acid leach with ICP or AAS finish (up to 19 laboratories);
- Cu and Co by *10% sulphuric acid leach with ICP or AAS finish (up to 12 laboratories);
- Sodium peroxide fusion with full suite elemental package by ICP-OES and/or MS finish (up to 20 laboratories depending on the element);
- 4-acid digestion for full suite elemental package by ICP-OES and MS finish (up to 26 laboratories depending on the element);
- Aqua regia digestion for full elemental suite ICP-OES and ICP-MS (up to 26 laboratories depending on the element).

*See 'Appendix' for specified methodology.

For the round robin program ten 400g test units were taken at predetermined intervals immediately following homogenisation and are considered representative of the entire prepared batch. The six samples received by each laboratory were obtained by taking two 25g scoop splits from each of three separate 400g test units. This format enabled nested ANOVA treatment of the results to evaluate homogeneity, i.e., to ascertain whether between-unit variance is greater than within-unit variance (see 'Homogeneity Evaluation' section below).

STATISTICAL ANALYSIS

Standard Deviation intervals (see Table 1) 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-laboratory 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.***

Certified Values, Confidence Limits and Tolerance Limits (Table 4) have been determined for each analyte following removal of individual, laboratory dataset (batch) and 3SD outliers (single iteration).

95% Confidence Limits are inversely proportional to the number of participating laboratories and inter-laboratory agreement. It is a measure of the reliability of the certified value. A 95% confidence interval indicates a 95% probability that the true value of the analyte under consideration lies between the upper and lower limits. ***95% Confidence Limits should not be used as control limits for laboratory performance.***

Indicative (uncertified) values (Table 2) are provided where i) a laboratory reported analytes beyond those requested; ii) the number of laboratories reporting a particular analyte is insufficient (< 5) to support certification; iii) inter-laboratory consensus is poor; or iv) a significant proportion of results are outlying.

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. In certain instances, statistician's prerogative has been employed in discriminating outliers. 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.

Table 4. 95% Confidence & Tolerance Limits for OREAS 554.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
Borate Fusion XRF					
Al ₂ O ₃ , Aluminium(III) oxide (wt.%)	8.23	8.19	8.27	8.15	8.31
BaO, Barium oxide (ppm)	1418	1378	1458	1359	1477
CaO, Calcium oxide (wt.%)	5.58	5.54	5.62	5.55	5.61
Co, Cobalt (wt.%)	0.805	0.793	0.816	0.792	0.817
Cr ₂ O ₃ , Chromium(III) oxide (ppm)	97	86	108	IND	IND

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; IND = indeterminate (due to reading resolution error).

Table 1 continued.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
Borate Fusion XRF continued					
Cu, Copper (wt.%)	1.58	1.56	1.60	1.56	1.60
Fe ₂ O ₃ , Iron(III) oxide (wt.%)	2.57	2.56	2.59	2.55	2.60
K ₂ O, Potassium oxide (wt.%)	2.01	1.99	2.02	1.99	2.02
MgO, Magnesium oxide (wt.%)	5.27	5.24	5.30	5.24	5.31
MnO, Manganese oxide (wt.%)	0.144	0.141	0.147	0.142	0.146
P ₂ O ₅ , Phosphorus(V) oxide (wt.%)	0.073	0.070	0.077	0.071	0.076
SiO ₂ , Silicon dioxide (wt.%)	60.26	60.08	60.45	59.96	60.56
SO ₃ , Sulphur trioxide (wt.%)	1.98	1.96	2.01	1.95	2.01
SrO, Strontium oxide (ppm)	94	84	104	IND	IND
TiO ₂ , Titanium dioxide (wt.%)	0.382	0.377	0.387	0.372	0.392
Thermogravimetry					
LOI ¹⁰⁰⁰ , Loss On Ignition @1000°C (wt.%)	10.11	10.01	10.22	10.00	10.22
Infrared Combustion					
C, Carbon (wt.%)	2.84	2.82	2.86	2.81	2.87
S, Sulphur (wt.%)	0.771	0.763	0.779	0.755	0.788
Sulphuric Acid 5% Leach					
Co, Cobalt (wt.%)	0.555	0.515	0.595	0.534	0.577
Sulphuric Acid 10% Leach					
Co, Cobalt (wt.%)	0.546	0.519	0.572	0.529	0.563
Peroxide Fusion ICP					
Ag, Silver (ppm)	< 1	IND	IND	IND	IND
Al, Aluminium (wt.%)	4.32	4.26	4.39	4.24	4.41
As, Arsenic (ppm)	66	61	71	63	69
B, Boron (ppm)	178	160	196	IND	IND
Ba, Barium (ppm)	1280	1246	1315	1252	1309
Bi, Bismuth (ppm)	2.83	2.48	3.18	2.56	3.09
Ca, Calcium (wt.%)	3.96	3.88	4.03	3.88	4.04
Ce, Cerium (ppm)	68	66	70	66	70
Co, Cobalt (wt.%)	0.809	0.799	0.820	0.793	0.826
Cr, Chromium (ppm)	69	60	77	63	75
Cs, Caesium (ppm)	2.55	2.49	2.62	2.35	2.76
Cu, Copper (wt.%)	1.57	1.55	1.59	1.53	1.61
Dy, Dysprosium (ppm)	3.54	3.45	3.62	3.34	3.73
Er, Erbium (ppm)	1.99	1.91	2.07	1.85	2.13
Eu, Europium (ppm)	0.85	0.67	1.02	0.79	0.91
Fe, Iron (wt.%)	1.82	1.80	1.84	1.78	1.86
Ga, Gallium (ppm)	13.5	12.3	14.7	12.8	14.2
Gd, Gadolinium (ppm)	4.27	3.91	4.63	3.90	4.64

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb, parts per billion.

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to reading resolution error).

Table 4 continued.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
Peroxide Fusion ICP continued					
Hf, Hafnium (ppm)	2.24	1.77	2.71	IND	IND
Ho, Holmium (ppm)	0.72	0.70	0.75	0.67	0.78
K, Potassium (wt.%)	1.69	1.66	1.72	1.64	1.75
La, Lanthanum (ppm)	35.2	33.8	36.6	34.0	36.3
Li, Lithium (ppm)	34.2	29.9	38.6	32.7	35.8
Lu, Lutetium (ppm)	0.29	0.26	0.33	0.27	0.31
Mg, Magnesium (wt.%)	3.14	3.12	3.17	3.10	3.19
Mn, Manganese (wt.%)	0.110	0.108	0.112	0.106	0.114
Nd, Neodymium (ppm)	28.2	27.3	29.0	27.1	29.2
Ni, Nickel (ppm)	33.7	26.5	40.8	29.2	38.1
P, Phosphorus (wt.%)	0.034	0.029	0.039	IND	IND
Pb, Lead (ppm)	18.6	16.6	20.6	15.8	21.5
Pr, Praseodymium (ppm)	7.86	7.54	8.17	7.59	8.12
Rb, Rubidium (ppm)	89	88	90	86	92
S, Sulphur (wt.%)	0.769	0.757	0.782	0.754	0.785
Sb, Antimony (ppm)	2.24	1.67	2.81	1.98	2.50
Sc, Scandium (ppm)	7.98	6.79	9.17	IND	IND
Si, Silicon (wt.%)	28.75	28.38	29.11	28.37	29.13
Sm, Samarium (ppm)	4.93	4.68	5.18	4.66	5.20
Sr, Strontium (ppm)	71	69	73	69	73
Ta, Tantalum (ppm)	0.70	0.53	0.87	IND	IND
Tb, Terbium (ppm)	0.59	0.49	0.70	0.55	0.63
Th, Thorium (ppm)	9.29	8.91	9.68	8.77	9.82
Ti, Titanium (wt.%)	0.228	0.223	0.232	0.220	0.236
Tm, Thulium (ppm)	0.30	0.27	0.33	0.28	0.32
U, Uranium (ppm)	14.3	13.8	14.7	13.6	14.9
V, Vanadium (ppm)	116	113	119	111	121
Y, Yttrium (ppm)	20.1	19.5	20.7	19.2	21.0
Yb, Ytterbium (ppm)	1.95	1.82	2.07	1.71	2.18
Zn, Zinc (ppm)	56	49	63	49	63
Zr, Zirconium (ppm)	81	67	95	76	86
*4-Acid Digestion					
Ag, Silver (ppm)	0.255	0.242	0.268	0.231	0.278
Al, Aluminium (wt.%)	4.32	4.26	4.37	4.24	4.40
As, Arsenic (ppm)	66	65	67	64	68
Ba, Barium (ppm)	1274	1252	1297	1250	1299
Be, Beryllium (ppm)	1.84	1.78	1.89	1.80	1.88

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to reading resolution error).

Table 4 continued.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
*4-Acid Digestion continued					
Bi, Bismuth (ppm)	2.74	2.65	2.82	2.64	2.83
Ca, Calcium (wt.%)	3.96	3.92	4.00	3.88	4.04
Cd, Cadmium (ppm)	0.21	0.20	0.21	0.18	0.24
Ce, Cerium (ppm)	64	62	66	62	65
Co, Cobalt (wt.%)	0.815	0.802	0.829	0.796	0.835
Cr, Chromium (ppm)	49.5	47.3	51.7	45.3	53.6
Cs, Caesium (ppm)	2.42	2.37	2.48	2.36	2.49
Cu, Copper (wt.%)	1.59	1.58	1.60	1.57	1.61
Dy, Dysprosium (ppm)	2.71	2.51	2.91	2.60	2.81
Er, Erbium (ppm)	1.43	1.26	1.60	1.37	1.49
Eu, Europium (ppm)	0.82	0.79	0.86	0.79	0.86
Fe, Iron (wt.%)	1.80	1.78	1.83	1.77	1.84
Ga, Gallium (ppm)	12.5	12.3	12.8	12.2	12.8
Gd, Gadolinium (ppm)	3.78	3.63	3.93	3.61	3.95
Ge, Germanium (ppm)	0.095	0.080	0.110	IND	IND
Hf, Hafnium (ppm)	1.88	1.79	1.96	1.80	1.96
Ho, Holmium (ppm)	0.52	0.46	0.58	0.50	0.55
In, Indium (ppm)	0.10	0.10	0.11	0.10	0.11
K, Potassium (wt.%)	1.71	1.68	1.74	1.68	1.74
La, Lanthanum (ppm)	30.6	29.5	31.7	29.9	31.2
Li, Lithium (ppm)	33.9	33.1	34.6	33.0	34.8
Lu, Lutetium (ppm)	0.21	0.20	0.22	0.19	0.24
Mg, Magnesium (wt.%)	3.14	3.11	3.18	3.08	3.21
Mn, Manganese (wt.%)	0.108	0.107	0.110	0.106	0.111
Mo, Molybdenum (ppm)	3.54	3.45	3.63	3.41	3.67
Na, Sodium (wt.%)	0.060	0.056	0.063	0.057	0.062
Nb, Niobium (ppm)	5.08	4.28	5.88	4.86	5.29
Nd, Neodymium (ppm)	25.3	24.0	26.6	24.6	26.0
Ni, Nickel (ppm)	31.3	30.7	31.8	30.2	32.4
P, Phosphorus (wt.%)	0.031	0.030	0.031	0.029	0.032
Pb, Lead (ppm)	16.6	16.2	17.0	16.1	17.1
Pr, Praseodymium (ppm)	6.86	6.57	7.16	6.64	7.08
Rb, Rubidium (ppm)	88	86	90	86	90
Re, Rhenium (ppm)	0.044	0.044	0.044	0.040	0.048
S, Sulphur (wt.%)	0.778	0.770	0.787	0.759	0.798
Sb, Antimony (ppm)	2.22	2.13	2.31	2.15	2.29
Sc, Scandium (ppm)	8.10	7.99	8.21	7.89	8.31

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to reading resolution error).

Table 4 continued.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
*4-Acid Digestion continued					
Se, Selenium (ppm)	5.29	5.03	5.55	4.69	5.89
Sm, Samarium (ppm)	4.82	4.69	4.95	4.62	5.02
Sn, Tin (ppm)	2.22	2.14	2.29	2.11	2.32
Sr, Strontium (ppm)	67	66	68	66	69
Ta, Tantalum (ppm)	0.35	0.28	0.42	0.31	0.38
Tb, Terbium (ppm)	0.52	0.48	0.55	0.50	0.54
Te, Tellurium (ppm)	0.049	0.041	0.057	IND	IND
Th, Thorium (ppm)	8.99	8.74	9.25	8.77	9.22
Ti, Titanium (wt.%)	0.161	0.146	0.176	0.155	0.167
Tl, Thallium (ppm)	0.53	0.51	0.54	0.51	0.55
Tm, Thulium (ppm)	0.20	0.18	0.22	IND	IND
U, Uranium (ppm)	13.8	13.4	14.2	13.4	14.1
V, Vanadium (ppm)	112	110	114	109	115
W, Tungsten (ppm)	1.27	1.19	1.35	IND	IND
Y, Yttrium (ppm)	12.9	12.5	13.3	12.4	13.4
Yb, Ytterbium (ppm)	1.42	1.29	1.54	1.33	1.50
Zn, Zinc (ppm)	55	54	57	53	57
Zr, Zirconium (ppm)	63	61	64	61	64
Aqua Regia Digestion					
Ag, Silver (ppm)	0.178	0.173	0.183	0.161	0.195
Al, Aluminium (wt.%)	0.594	0.570	0.619	0.573	0.616
As, Arsenic (ppm)	65	63	66	63	67
B, Boron (ppm)	< 10	IND	IND	IND	IND
Ba, Barium (ppm)	226	214	238	218	234
Be, Beryllium (ppm)	0.63	0.61	0.64	0.60	0.66
Bi, Bismuth (ppm)	2.58	2.53	2.63	2.49	2.67
Ca, Calcium (wt.%)	3.85	3.80	3.91	3.79	3.92
Cd, Cadmium (ppm)	0.20	0.19	0.20	0.18	0.22
Ce, Cerium (ppm)	34.8	32.8	36.7	33.8	35.7
Co, Cobalt (wt.%)	0.761	0.741	0.781	0.745	0.777
Cr, Chromium (ppm)	15.5	14.8	16.3	14.0	17.0
Cs, Caesium (ppm)	0.57	0.51	0.62	0.54	0.59
Cu, Copper (wt.%)	1.58	1.56	1.60	1.55	1.61
Dy, Dysprosium (ppm)	1.34	1.15	1.53	IND	IND
Er, Erbium (ppm)	0.57	0.53	0.61	IND	IND
Eu, Europium (ppm)	0.45	0.35	0.56	IND	IND
Fe, Iron (wt.%)	1.64	1.62	1.66	1.61	1.67

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb, parts per billion.

*[Four acid digestion](#) quantitatively dissolves nearly all minerals in the majority of geological samples however, some refractory minerals may only be partially digested.

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to reading resolution error).

Table 4 continued.

Constituent	Certified Value	95% Confidence Limits		95% Tolerance Limits	
		Low	High	Low	High
Aqua Regia Digestion continued					
Ga, Gallium (ppm)	1.76	1.63	1.90	1.67	1.86
Gd, Gadolinium (ppm)	2.18	1.57	2.78	2.01	2.34
Hf, Hafnium (ppm)	0.27	0.25	0.28	0.25	0.28
Hg, Mercury (ppm)	0.019	0.015	0.022	IND	IND
Ho, Holmium (ppm)	0.22	0.20	0.24	IND	IND
In, Indium (ppm)	0.063	0.062	0.064	0.060	0.066
K, Potassium (wt.%)	0.177	0.169	0.185	0.171	0.183
La, Lanthanum (ppm)	14.2	13.3	15.2	13.7	14.7
Li, Lithium (ppm)	18.4	17.0	19.7	17.6	19.1
Lu, Lutetium (ppm)	0.079	0.065	0.094	IND	IND
Mg, Magnesium (wt.%)	2.90	2.86	2.94	2.84	2.97
Mn, Manganese (wt.%)	0.106	0.104	0.108	0.104	0.108
Mo, Molybdenum (ppm)	3.32	3.25	3.39	3.21	3.43
Nd, Neodymium (ppm)	13.0	10.7	15.2	12.2	13.7
Ni, Nickel (ppm)	28.4	27.4	29.3	27.1	29.6
P, Phosphorus (wt.%)	0.026	0.026	0.027	0.025	0.028
Pb, Lead (ppm)	11.0	10.3	11.6	10.5	11.4
Pr, Praseodymium (ppm)	2.82	1.71	3.92	2.64	3.00
Rb, Rubidium (ppm)	8.83	8.32	9.34	8.43	9.23
Re, Rhenium (ppm)	0.045	0.043	0.046	0.042	0.048
S, Sulphur (wt.%)	0.743	0.718	0.767	0.728	0.757
Sb, Antimony (ppm)	1.49	1.38	1.59	1.42	1.55
Sc, Scandium (ppm)	2.23	2.15	2.31	2.12	2.35
Se, Selenium (ppm)	4.90	4.70	5.09	4.37	5.42
Sn, Tin (ppm)	0.32	0.29	0.35	0.29	0.35
Sr, Strontium (ppm)	40.2	39.2	41.3	39.2	41.3
Ta, Tantalum (ppm)	< 0.01	IND	IND	IND	IND
Tb, Terbium (ppm)	0.29	0.27	0.32	0.27	0.32
Te, Tellurium (ppm)	0.048	0.045	0.052	IND	IND
Th, Thorium (ppm)	5.51	5.39	5.63	5.31	5.71
Tl, Thallium (ppm)	0.11	0.10	0.12	IND	IND
U, Uranium (ppm)	11.8	11.5	12.2	11.5	12.2
V, Vanadium (ppm)	19.3	18.6	20.0	18.3	20.3
W, Tungsten (ppm)	0.10	0.10	0.11	IND	IND
Y, Yttrium (ppm)	5.69	5.51	5.88	5.54	5.85
Yb, Ytterbium (ppm)	0.50	0.49	0.50	IND	IND
Zn, Zinc (ppm)	48.2	46.7	49.7	46.3	50.2
Zr, Zirconium (ppm)	8.99	8.78	9.20	8.66	9.32

SI unit equivalents: ppm, parts per million \equiv mg/kg \equiv μ g/g \equiv 0.0001 wt.% \equiv 1000 ppb, parts per billion.

Note: intervals may appear asymmetric due to rounding; IND = indeterminate (due to reading resolution error).

Homogeneity Evaluation

The tolerance limits (ISO 16269:2014) shown in Table 4 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 fusion with XRF, where 99% of the time ($1-\alpha=0.99$) at least 95% of subsamples ($p=0.95$) will have concentrations lying between 1.56 and 1.60 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). **Please note that tolerance limits pertain to the homogeneity of the CRM only and should not be used as control limits for laboratory performance.**

Based on the statistical analysis of the results of the inter-laboratory certification program it can be concluded that OREAS 554 is sufficiently homogenous and fit-for-purpose as a certified reference material (see 'Intended Use' below).

PARTICIPATING LABORATORIES

1. Actlabs, Ancaster, Ontario, Canada
2. AGAT Laboratories, Mississauga, Ontario, Canada
3. AH Knight, Kitwe, Copperbelt, Zambia
4. AH Knight, Lumwana, Mwinilunga, Zambia
5. ALS, Brisbane, QLD, Australia
6. ALS, Johannesburg, South Africa
7. ALS, Lima, Peru
8. ALS, Loughrea, Galway, Ireland
9. ALS, Vancouver, BC, Canada
10. American Assay Laboratories, Sparks, Nevada, USA
11. Bureau Veritas Commodities Canada Ltd, Vancouver, BC, Canada
12. Bureau Veritas Geoanalytical, Adelaide, SA, Australia
13. Bureau Veritas Geoanalytical, Perth, WA, Australia
14. Carsurin, Kendari, Sulawesi, Indonesia
15. Inspectorate (BV), Lima, Peru
16. Intertek Genalysis, Perth, WA, Australia
17. Intertek Testing Services Philippines, Cupang, Muntinlupa, Philippines
18. MSALABS, Vancouver, BC, Canada
19. Nagrom, Perth, WA, Australia
20. Ontario Geological Survey, Sudbury, Ontario, Canada
21. PT Geoservices Ltd, Cikarang, Jakarta Raya, Indonesia
22. PT Intertek Utama Services, Jakarta Timur, DKI Jakarta, Indonesia
23. Robinson International Afrique SAS, Lubumbashi, Katanga, Democratic Republic of the Congo
24. Ruashi Mine Site Laboratory, Lubumbashi, Katanga, Democratic Republic of the Congo
25. Saskatchewan Research Council, Saskatoon, Saskatchewan, Canada
26. SGS, Randfontein, Gauteng, South Africa
27. SGS Canada Inc., Vancouver, BC, Canada
28. SGS del Peru, Lima, Peru
29. SGS Geosol Laboratorios Ltda, Vespasiano, Minas Gerais, Brazil
30. UIS Analytical Services, Centurion, South Africa

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 PF ICP in OREAS 554

SPC.1475.RR1.OREAS 554.1.PF ICP.Co.Lab.210401.164908.SN

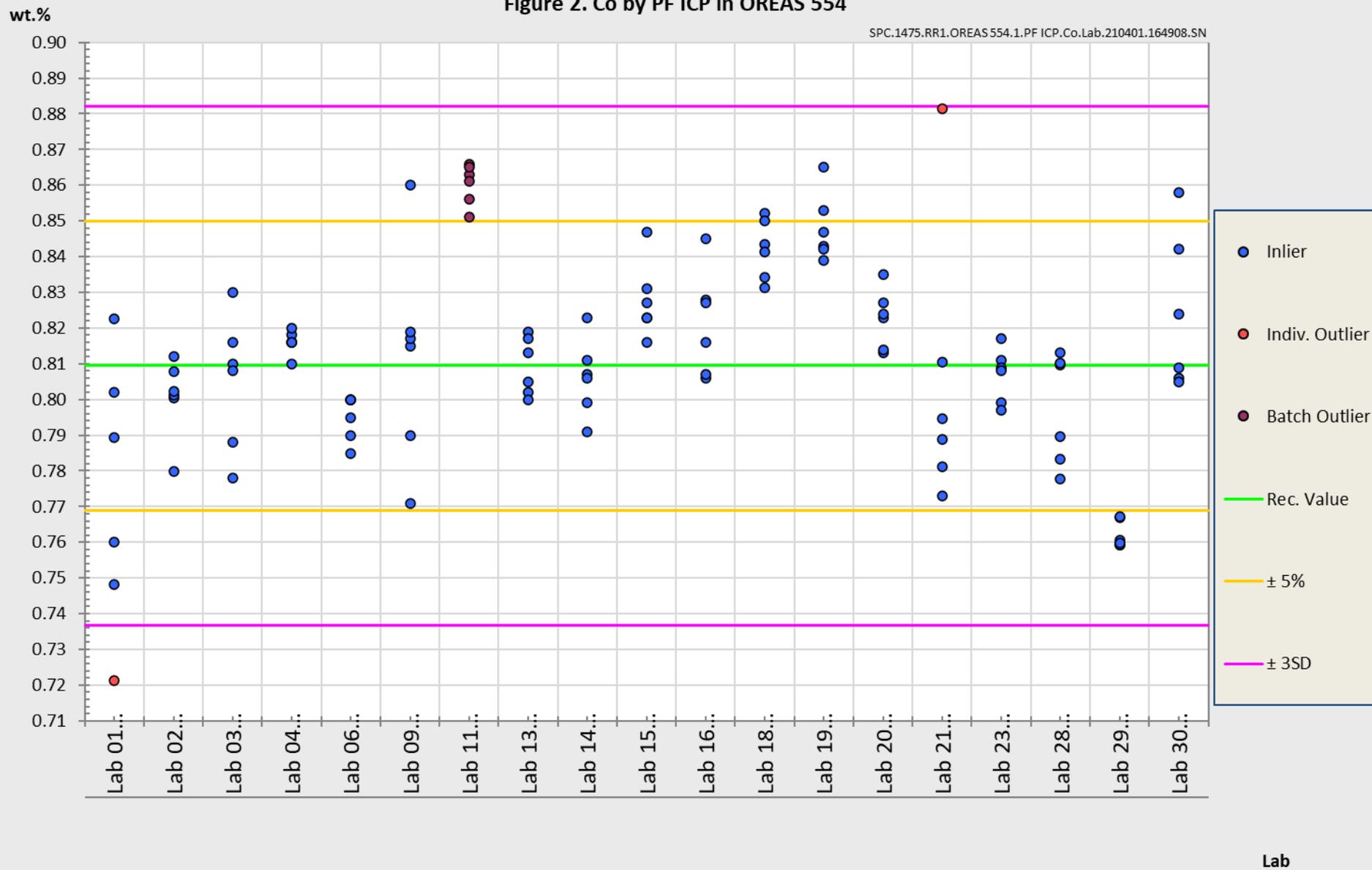


Figure 3. Cu by 4-Acid in OREAS 554

SPC.1475.RR1.OREAS 554.1.4-Acid.Cu.Lab.210401.164825.SS

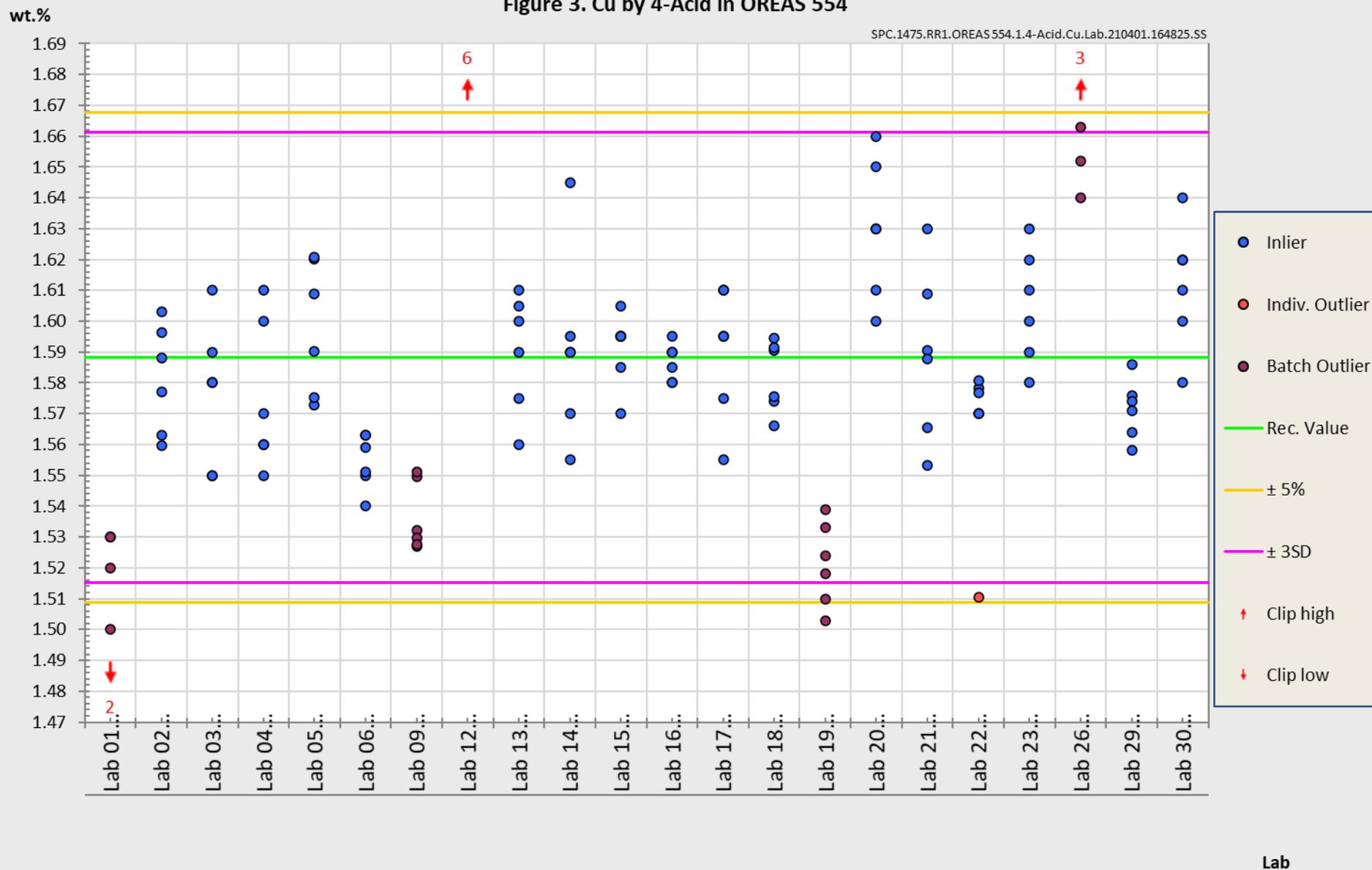
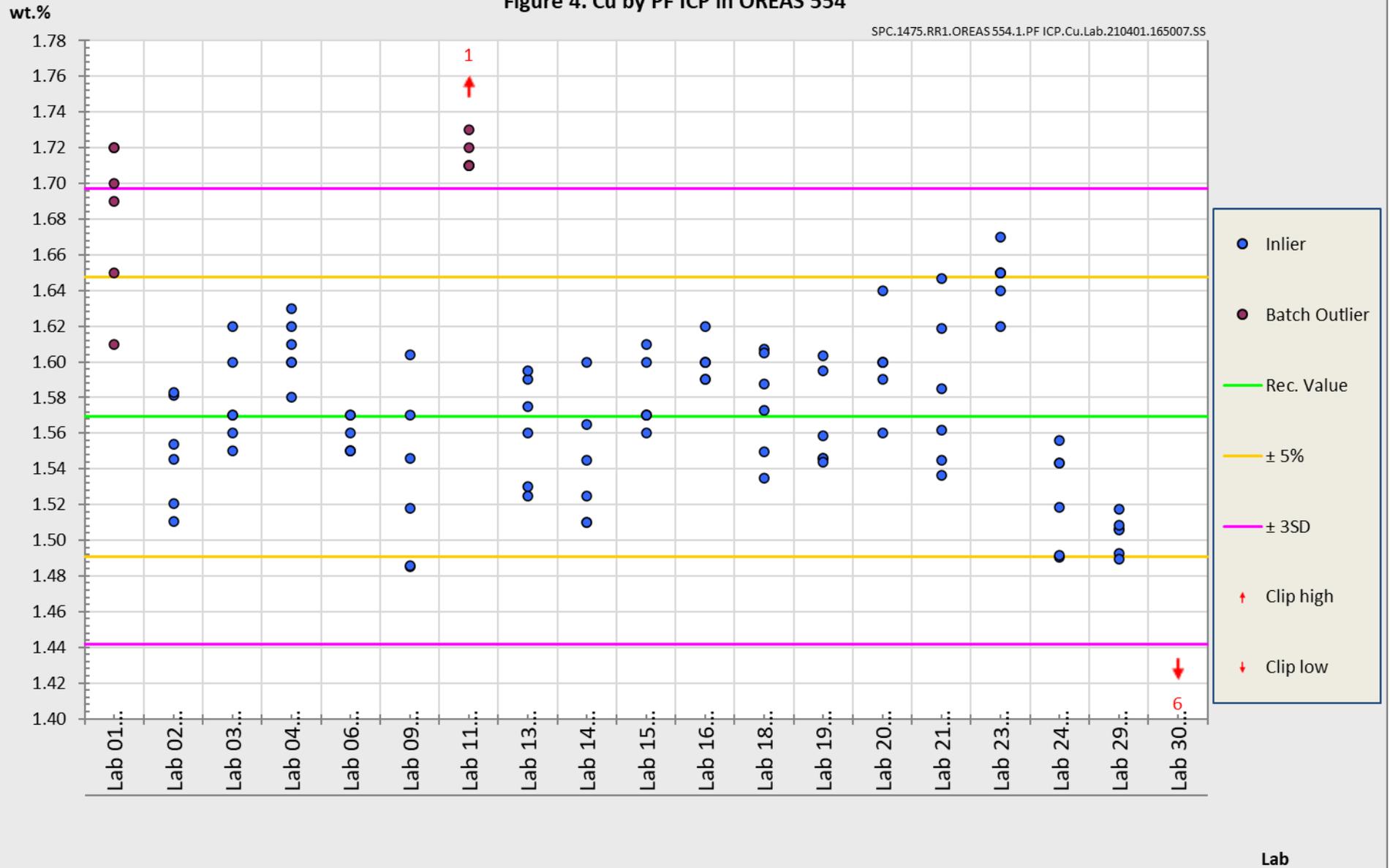


Figure 4. Cu by PF ICP in OREAS 554

SPC.1475.RR1.OREAS554.1.PF ICP.Cu.Lab.210401.165007.SS



PREPARER AND SUPPLIER

Certified reference material OREAS 554 was prepared and certified by:



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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. Being matrix-matched, OREAS 554 will display similar behaviour in the relevant measurement process to the routine 'field' samples for which OREAS 554 is designated to monitor. To maintain commutability, care should be taken to always 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.

INTENDED USE

OREAS 554 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 554 may be used to calibrate the entire procedure by producing a pure substance CRM transformed into a calibration solution. OREAS 554 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 554 has been prepared from a blend of primary copper-cobalt ore samples. It is low in reactive sulphide (0.77 wt.% S) and in its unopened state and under normal conditions of storage has a shelf life beyond ten years. Its stability will be monitored at regular intervals and purchasers notified if any changes are observed.

Single-use sachets

Following analysis of the CRM subsample it is the manufacturers' expectation that any remaining material is discarded. The stability of the material after opening the sachet is not within the scope of proper use. However, if opened sachets are resealed after opening, then under ordinary* storage conditions the CRM will have a shelf-life beyond ten years.

**ordinary storage conditions: means storage not in direct sunlight in a dry, clean, well ventilated area at temperatures between -5° and 50°C.*

Repeat-use packaging (e.g., 500g plastic jars)

The stability of the CRM after opening the lid of the plastic jar is only affected by local atmospheric conditions with regard to oxidation and hygroscopic change. There is no segregation affect (please see our [Technical Note on Particle Segregation](#)).

The primary cause of change through oxidation is in relation to the breakdown of sulphide minerals to sulphates and is negligible for OREAS 554 given its low sulphur concentration (0.77 wt.% S).

Hygroscopic change is the amount of absorbed moisture (weakly held H₂O- molecules on the surface of exposed material) following exposure to the local atmosphere. Usually, equilibration of material to the local atmosphere will only occur if the material is spread into a thin (~2mm thick) layer and left exposed for a period of 2 hours. OREAS 554 contains a non-hygroscopic matrix and therefore, exposure to a local atmosphere that is significantly different (in terms of temperature and humidity) from the climate during manufacturing will have negligible impact on the precision of results. The 'Physical Properties' section indicates the approximate moisture concentration.

INSTRUCTIONS FOR CORRECT USE

The certified values for OREAS 554 refer to the concentration level in its packaged state. It should not be dried prior to weighing and analysis.

500g jars permit repeated sampling as long as the lid is promptly re-secured to prevent airborne contamination.

Minimum sample size

As a practical guide, 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 sample masses should be used depending on the operationally defined methodology.

- Lithium borate fusion with X-ray fluorescence finish: $\geq 0.2\text{g}$;
- Loss on Ignition (LOI) at 1000°C : $\geq 1\text{g}$;
- C and S by infrared combustion furnace/CS analyser: $\geq 0.1\text{g}$;
- Cu and Co by 5% sulphuric acid leach with ICP or AAS finish: 0.5g ;
- Cu and Co by 10% sulphuric acid leach with ICP or AAS finish: $\geq 0.5\text{g}$;
- Sodium peroxide fusion with ICP-OES and/or MS finish: $\geq 0.2\text{g}$;
- 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: $\geq 0.5\text{g}$.

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 inter-laboratory 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 1 are intended only to be used as a first principle 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% confidence interval then generally there is no cause for concern in regard to bias.

It is important to note that in the analytical industry there is no standardisation of the aqua regia digestion process nor the 5% and 10% sulphuric acid leach process. These methods are partial empirical digests and differences in recoveries for various analytes are commonplace. These are caused by variations in the digest conditions and in the case for aqua regia digestion 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.

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.

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	21 st April, 2021	Applied minor statistical correction to Cobalt by XRF method results.
0	7 th April, 2021	First publication.

QMS ACCREDITATION

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

21st April, 2021

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

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Munsell Rock Color Book (2014). Rock-Color Chart Committee, Geological Society of America (GSA), Minnesota (USA).

APPENDIX

For Cu and Co by the two sulphuric acid leaches, specific methodologies were detailed for the participating laboratories to follow:

5% sulphuric acid leach

1. Weigh 0.500 ± 0.002 g of sample pulp into a clean 250 ml flask.
2. Add to the flask 0.5g of Sodium Sulphite (AR Grade).
3. Add 50 ml of approximately 55 g/l Sulphuric acid solution (prepared from a 98% pure concentrated sulphuric acid).
4. Put the cap on the flask and start automatic shaking. Leave the sample on continuous shaking to leach for four (4) hours.
5. Remove the cap and add 25 ml of hydrochloric acid.
6. Dilute to a final volume of 250 ml with distilled/deionised water up to the mark and mix again by inverting at least 10 times. Allow the solution to settle for 30 minutes.
7. The solution is now ready to be analysed by ICP or AAS.

10% sulphuric acid leach

1. Weigh 0.500 ± 0.002 g of sample pulp into a clean 250 ml flask.
2. Add to the flask 0.5g of Sodium Sulphite (AR Grade).
3. Add 50 ml of approximately 110 g/l Sulphuric acid solution (prepared from a 98% pure concentrated sulphuric acid).
4. Put the cap on the flask and start automatic shaking. Leave the sample on continuous shaking to leach for four (4) hours.
5. Remove the cap and add 25 ml of hydrochloric acid.
6. Dilute to a final volume of 250 ml with distilled/deionised water up to the mark and mix again by inverting at least 10 times. Allow the solution to settle for 30 minutes.
7. The solution is now ready to be analysed by ICP or AAS.