



AMIS0162

Certified Reference Material

**Copper cobalt oxide ore
Mukondo, DRC**

Certificate of Analysis

**Recommended Concentrations and Limits¹
(at two Standard Deviations)**

Certified Concentrations²

Co F	9604	±	906	ppm
Co M/ICP	9500	±	507	ppm
Co P	9284	±	665	ppm
Co XRF	9377	±	790	ppm
Cu F	2573	±	270	ppm
Cu M/ICP	2586	±	106	ppm
Cu P	2532	±	141	ppm
Cu XRF	2534	±	193	ppm
Specific Gravity	2.72	±	0.08	

1. Manufacturers recommended limits for use of the material as control samples, based on two standard deviations, calculated using "Between Laboratory" statistics for treatment of the data for trivial, non-trivial and technically invalid results. See sections 1, 9 and 12.
2. There is additional certified major element data presented on p2 and uncertified trace element data presented as an appendix.

Major Element Recommended Concentrations and Limits (at two Standard Deviations)

Certified Concentrations

Al ₂ O ₃	8.13	±	0.16	%
CaO	0.29	±	0.02	%
Fe ₂ O ₃	1.76	±	0.06	%
K ₂ O	1.68	±	0.02	%
MgO	3.79	±	0.14	%
MnO	0.059	±	0.004	%
P ₂ O ₅	0.075	±	0.008	%
SiO ₂	78.30	±	0.88	%
TiO ₂	0.51	±	0.02	%

Provisional Concentrations

Cr ₂ O ₃	0.05	±	0.01	%
LOI	3.71	±	0.64	%

Informational Mean

Na ₂ O	0.07	%
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1. Intended Use: AMIS0162 can be used to check analysis of samples of copper cobalt ores with a similar grade and matrix.

It is a matrix matched Certified Reference Material, fit for use as control samples in routine assay laboratory quality control when inserted within runs of samples and measured in parallel to the unknown. Its purpose is to monitor inter-laboratory or instrument bias and within lab precision. It can be used, indirectly, to establish the traceability of results to an SI system of units.

The recommended concentrations and limits for this material are property values based on a measurement campaign (round robin) and reflect consensus results from the laboratories that participated in the round robin.

Slight variations in analytical procedures between laboratories will reflect as slight biases to the recommended concentrations (see 19). Good laboratories will report results within the two standard deviation levels with a failure rate of <10 %.

The material can also be used for method development and for the calibration of equipment.

2. Origin of Material: AMIS0162 was made using run-of-mine oxide Cobalt-Copper ore from the Mukondo mine, owned and operated by BOSS Mining. The latter is a Joint Venture between the Central African Mining and Exploration Company (CAMEC), owned by Eurasian Natural Resources Corporation (Africa) (ENRC), and the parastatal mining company GECAMINES. The mine is situated in Katanga Province of the Democratic Republic of Congo 50km northwest of Likasi, 160km northwest of the regional capital Lubumbashi and 95km east of Kolwezi. The Mukondo deposit is located in the Katangan part of the Neoproterozoic Central African Copperbelt, a world-class metallogenic province of sediment hosted Cu-Co deposits. Mineralisation is hosted within the Mines Series, a package of sediments comprising largely altered dolomite and dolomitic shale units. Two ore horizons are commonly present although the high grade cobalt ore at Mukondo is largely concentrated in the "Upper Orezone" hosted by the SDB, a strongly dolomitic sandy shale at the base of a largely dolomitic shale sequence. The Mukondo deposit comprises two fragments of the Mines Series that strike approximately east-west and dip to the north. These

two rafts exhibit reversed stratigraphic sequences which may indicate they represent the limbs of an isoclinal, recumbent anticlinal fold the crest of which has been eroded.

3. Mineral and Chemical Composition: The main economic mineralogy comprises heterogenite and malachite with lesser amounts of pseudomalachite. Low levels of hematite and traces of goethite, rutile and dolomite have been observed in selected core samples. Co carbonate (sphaerocobaltite) mineralisation has been intersected in boreholes at depth.

4. Appearance: The material is a very fine Pale Yellowish Brown powder (Corstor colour chart – 10R 6/4).

5. Handling instructions: The material is packaged in Laboratory Packs and Explorer Packs that must be shaken or otherwise agitated before use. Normal safety precautions for handling fine particulate matter are suggested, such as the use of safety glasses, breathing protection, gloves and a laboratory coat.

6. Method of Preparation: The material was crushed, dry-milled and air-classified to <54µm. Wet sieve particle size analysis of random samples confirmed the material was 98.5% <54µm. It was then blended in a bi-conical mixer, systematically divided and then sealed into 1kg Laboratory Packs. Explorer Packs are subdivided from the Laboratory packs as required. Samples were randomly selected for homogeneity testing and third party analysis. Statistical analysis of both homogeneity and consensus test results were carried out by an independent statistician.

7. Methods of Analysis requested:

1. Co,Cu. Fusion AAS or ICP-OES.
2. Multi-acid digest multi-element scan - (to include Co, Cu). ICP-OES or ICP-MS.
3. Aqua regia digest – Co, Cu. ICP-OES or ICP-MS.
4. Pressed pellet multi-element scan - (to include Co, Cu). XRF.
5. Majors (Al₂O₃, CaO, Cr₂O₃, Fe₂O₃, K₂O, MgO, MnO, Na₂O, SiO₂, TiO₂. LOI.) XRF fusion.
6. SG. Gas pycnometer.

8. Information requested:

1. State and provide brief description of analytical techniques used.
2. State aliquots used for all determinations.
3. Results for individual analyses to be reported (not averages)
4. All results for Zn and major elements to be reported in %.
5. All results for multi-element scans to be reported in ppm.
6. Report all QC data, to include replicates, blanks and certified reference materials used.

9. Method of Certification: Nineteen laboratories were each given eight packages, comprising eight samples scientifically selected from throughout the batch. Eighteen laboratories reported results in time for certification of the economic elements. Eight of these laboratories reported results for the major elements.

Final limits were calculated after first determining if all data was compatible within a spread normally expected for similar analytical methods done by reputable laboratories. Data from any one laboratory was then removed from further calculations when the mean of all analyses from that laboratory failed a “t test” of the global means of the other laboratories. The means and standard deviations were then re-calculated using all remaining data. Any analysis that fell outside of the new two standard deviations was removed from the ensuing data base. The mean and standard deviations were again calculated using the remaining data.

The “between-laboratory” standard deviation is used in the calculation to eliminate technically and statistically invalid data. Upper and lower limits are based on the standard deviation of the remaining data, which reflect individual analyses and can be used to monitor accuracy in routine laboratory quality control. This is different to limits based on standard deviations derived from grouped set of analyses (see 12), which provide important measures for precision and trueness, but which are less useful for routine QC.

Standards with an RSD of near or less than 5 % are termed "Certified", RSD's of between near 5 % and 15 % are termed "Provisional", and RSD's over 15 % are termed "Informational".

10. Participating Laboratories: (Not in same order as in the table of assays):

1. Alex Stewart International Corporation Zambia
2. ALS Chemex Laboratory Group Brisbane Australia
3. ALS Chemex Laboratory Group Johannesburg SA
4. ALS Chemex Laboratory Group Lima (Peru)
5. ALS Chemex Laboratory Group Perth WA
6. ALS Chemex Laboratory Group Vancouver CA
7. Anglo Research (Crown Campus)
8. Genalysis Laboratory Services (South Africa) Pty
9. Genalysis Laboratory Services WA
10. Intertek Utama Services (Indonesia)
11. OMAC Laboratories Limited (Ireland)
12. Set Point Laboratories (Isando) SA
13. SGS Australia Pty Ltd (Newburn) WA
14. SGS Mineral Services Callao (Peru)
15. SGS Mineral Services Lakefield (Canada)
16. SGS South Africa (Pty) Ltd - Booyens
17. SGS Toronto (Canada)
18. Ultra Trace (Pty) Ltd WA

11. Assay Data: Data as received from the laboratories for the important certified elements listed on p1 is set out below. A proficiency report has been sent to the managers of the participating laboratories. Additional digital data from this round robin is available on request.

Lab Code	Co F	Co M/ICP	Co P	Co XRF	Cu F	Cu M/ICP	Cu P	Cu XRF	Al2O3 XRF	CaO XRF	Cr2O3 XRF	Fe2O3 XRF	K2O XRF	MgO XRF	MnO XRF	Na2O XRF	P2O5 XRF	SiO2 XRF	TiO2 XRF	LOI XRF	SG	
A	10100	9930		9790	2620	2630		2630	8.12	0.29	0.05	1.77	1.68	3.79	0.06	0.07		78.18	0.51	3.42	2.73	
A	9950	9850		9800	2600	2630		2600	8.14	0.29	0.05	1.78	1.68	3.80	0.06	0.08		78.14	0.51	3.45	2.74	
A	9950	9850		9750	2620	2620		2640	8.12	0.29	0.05	1.78	1.69	3.80	0.06	0.07		78.08	0.51	3.50	2.70	
A	9850	9760		9710	2560	2570		2570	8.14	0.29	0.05	1.78	1.69	3.81	0.06	0.08		78.28	0.51	3.46	2.70	
A	9950	10000		9800	2620	2630		2600	8.14	0.29	0.06	1.80	1.69	3.81	0.06	0.07		78.17	0.51	3.43	2.70	
A	9850	9850		9800	2580	2600		2610	8.11	0.29	0.05	1.77	1.68	3.80	0.06	0.07		78.16	0.51	3.47	2.78	
A	10100	9850		9860	2620	2580		2630	8.12	0.29	0.06	1.77	1.68	3.80	0.06	0.07		78.22	0.50	3.46	2.72	
A	9950	9850		9830	2640	2580		2590	8.13	0.29	0.05	1.78	1.69	3.80	0.06	0.07		78.34	0.51	3.40	2.72	
B	9700	9500	9100	8730	2800	2600	2400	2359	8.14	0.28	0.05	1.76	1.69	3.70	0.06	0.12	0.08	78.08	0.50	4.07	2.74	
B	9700	9500	9000	8500	2800	2600	2500	2361	8.13	0.27	0.05	1.76	1.69	3.70	0.06	0.11	0.08	78.12	0.50	4.07	2.74	
B	9800	9500	9100	8540	2800	2700	2400	2356	8.18	0.28	0.05	1.76	1.69	3.70	0.06	0.11	0.08	77.99	0.49	4.08	2.72	
B	9900	9500	8900	8530	2900	2700	2500	2363	8.15	0.28	0.05	1.77	1.69	3.70	0.06	0.11	0.08	78.09	0.50	4.08	2.73	
B	9900	9500	8900	8550	2800	2600	2400	2362	8.24	0.28	0.05	1.77	1.69	3.70	0.06	0.11	0.08	77.96	0.50	4.09	2.75	
B	9900	9500	8900	8530	2800	2600	2400	2351	8.00	0.27	0.05	1.75	1.68	3.60	0.06	0.11	0.08	78.36	0.50	4.07	2.72	
B	9900	9700	8900	8520	2800	2600	2500	2338	8.19	0.26	0.05	1.76	1.69	3.70	0.06	0.11	0.08	78.07	0.49	4.08	2.73	
B	9900	9500	9100	8650	2900	2600	2500	2357	8.16	0.28	0.05	1.77	1.70	3.70	0.06	0.12	0.08	78.03	0.50	4.06	2.74	
C	9070	9560			2390	2550			8.15	0.30	0.05	1.80	1.69	3.78	0.06	0.09		78.30	0.51	3.50		
C	9130	9590			2500	2550			8.16	0.29	0.05	1.80	1.68	3.79	0.06	0.08		78.30	0.51	3.51		
C	9270	9460			2500	2510			8.15	0.30	0.06	1.80	1.70	3.78	0.06	0.09		78.30	0.52	3.51		
C	8940	9600			2440	2560			8.13	0.30	0.06	1.80	1.69	3.77	0.06	0.08		78.30	0.51	3.50		
C	9350	9720			2480	2560			8.15	0.30	0.06	1.80	1.69	3.78	0.06	0.10		78.30	0.51	3.52		
C	8960	9680			2490	2570			8.14	0.29	0.06	1.80	1.68	3.80	0.06	0.09		78.30	0.51	3.51		
C	10400	9490			2870	2530			8.15	0.30	0.05	1.80	1.69	3.79	0.06	0.09		78.30	0.51	3.52		
C	9180	9610			2550	2570			8.17	0.30	0.05	1.80	1.69	3.79	0.06	0.09		78.30	0.51	3.52		
D				9400		2550	2590															
D				10000		2540	2570															
D				10100		2600	2600															
D				9400		2590	2630															
D				10300		2590	2630															
D			9880	9900		2450	2480															
D				9600		2330	2590															
D			9980	9400		2470	2620															
E		10000	9300			2600	2400	8.02	0.30	0.06	1.78	1.69	3.74	0.05	0.05	0.08	78.00	0.51	4.16			
E		9800	9300			2500	2500	8.05	0.30	0.05	1.77	1.64	3.74	0.06	0.06	0.08	77.40	0.53	4.16			
E		9900	9400			2600	2500	8.03	0.29	0.05	1.77	1.66	3.72	0.06	0.06	0.07	78.00	0.52	4.05			
E		9800	9300			2600	2500	8.06	0.29	0.06	1.76	1.69	3.71	0.05	0.06	0.07	78.00	0.52	4.16			
E		9500	9400			2400	2500	8.06	0.29	0.05	1.75	1.68	3.74	0.05	0.07	0.07	77.50	0.52	4.23			
E		9800	9200			2500	2500	8.06	0.28	0.05	1.77	1.65	3.75	0.06	0.06	0.07	76.80	0.51	4.20			
E		9400	9300			2400	2500	8.06	0.29	0.05	1.77	1.68	3.72	0.05	0.07	0.07	77.50	0.51	4.12			
E			9400	9300			2400	2600	7.99	0.30	0.06	1.79	1.69	3.75	0.05	0.06	0.07	77.70	0.52	4.06		
F		9885	9956			2639	2543															
F		9772	9956			2626	2562															
F		9949	9962			2629	2606															
F		9828	9944			2597	2556															
F		9927	9977			2640	2578															
F		9849	9989			2607	2556															
F		9931	9979			2612	2545															
F		9810	9957			2629	2582															
G		9640	9520	8700		2600	2570	2500	7.81	0.30	0.18	1.76	1.66	3.70	0.06	0.09	0.07	75.10	0.50	3.96	2.74	
G		9490	9400	9100		2640	2570	2400	7.79	0.29	0.05	1.71	1.68	3.70	0.06	0.08	0.07	74.50	0.50	3.94	2.71	
G		9600	9260	9000		2580	2570	2500	7.92	0.30	0.07	1.74	1.68	3.75	0.06	0.09	0.07	75.70	0.50	3.98	2.71	
G		9600	9260	8500		2580	2620	2500	7.83	0.30	0.06	1.72	1.69	3.74	0.06	0.08	0.07	75.00	0.49	3.89	2.77	
G		9570	9300	9100		2560	2570	2500	7.87	0.29	0.07	1.74	1.69	3.75	0.06	0.08	0.06	75.20	0.50	3.86	2.70	
G		9550	9360	9000		2640	2580	2500	7.80	0.29	0.05	1.71	1.68	3.72	0.06	0.08	0.07	74.90	0.50	3.88	2.70	
G		9530	9410	8800		2560	2600	2400	7.83	0.30	0.05	1.74	1.69	3.73	0.05	0.09	0.07	74.90	0.51	3.87	2.71	
G			9510	9330	9200		2540	2620	2500	7.77	0.30	0.05	1.71	1.72	3.74	0.06	0.08	0.07	74.30	0.50	4.05	2.72

12. Measurement of Uncertainty: The samples used in the certification process were selected in such a way as to represent the entire batch of material and were taken from the final packaged units; therefore all possible sources of uncertainty (sample uncertainty and measurement uncertainty) are included in the final combined standard uncertainty determination.

The uncertainty measurement takes into consideration the between lab and the within lab variances and is calculated from the square roots of the variances of these components using the formula:

$$\text{Combined standard uncertainty} = \sqrt{(\text{between lab.var/no of labs}) + (\text{mean square within lab.var /no of assays})}$$

These uncertainty measurements may be used, by laboratories, as a component for calculating the total uncertainty for method validation according to the relevant ISO guidelines.

Analyte	Method	Unit	S ¹	σ_L ²	SW ³	CSU ⁴
Co	F	ppm	453.2	415.4	216.8	149.4
Co	M/ICP	ppm	253.7	179.2	133.4	53.6
Co	P	ppm	332.6	233.1	146.3	66.4
Co	XRF	ppm	431.7	423.1	165.0	151.0
Cu	F	ppm	135.2	120.2	67.4	43.4
Cu	M/ICP	ppm	57.7	26.5	46.4	8.4
Cu	P	ppm	70.7	43.7	45.3	12.9
Cu	XRF	ppm	96.6	88.7	45.9	31.9
SG	pycnometer		0.038	0.027	0.026	0.009
Al ₂ O ₃	XRF	%	0.127	0.096	0.046	0.027
CaO	XRF	%	0.011	0.008	0.005	0.002
Fe ₂ O ₃	XRF	%	0.031	0.019	0.019	0.005
K ₂ O	XRF	%	0.015	0.009	0.011	0.003
MgO	XRF	%	0.095	0.076	0.022	0.021
MnO	XRF	%	0.003	0.002	0.002	0.001
P ₂ O ₅	XRF	%	0.005	0.004	0.004	0.001
SiO ₂	XRF	%	0.831	0.613	0.280	0.172
TiO ₂	XRF	%	0.009	0.006	0.005	0.002

1. S - Std Dev for use on control charts.
2. σ_L - Betw Lab Std Dev, for use to calculate a measure of accuracy.
3. SW - Within Lab Stc Dev, for use to calculate a measure of precision.
4. CSU - Combined Standard Uncertainty, a component for use to calculate the total uncertainty in method validation.

13. Certified values: The Certified, Provisional and Informational values listed on p1 and p2 of this certificate fulfill the AMIS statistical criteria regarding agreement for certification and have been independently validated by Dr Barry Smee.

14. Metrological Traceability: The values quoted herein are based on the consensus values derived from statistical analysis of the data from an inter laboratory measurement program. Traceability to SI units is via the standards used by the individual laboratories, the majority of which are accredited, who have maintained measurement traceability during the analytical process.

15. Certification: AMIS0162 is a new material.

16. Period of validity: The certified values are valid for this product, while still sealed in its original packaging, until notification to the contrary. The stability of the material will be subject to continuous testing for the duration of the inventory. Should product stability become an issue, all customers will be notified and notification to that effect will be placed on the www.amis.co.za website.

17. Minimum sample size: The majority of laboratories reporting used a 0.5g sample size for the ICP. This is the recommended minimum sample size for the use of this material.

18. Availability: This product is available in Laboratory Packs containing 1kg of material and Explorer Packs containing custom weights (from 50g to 250g) of material. The Laboratory Packs are sealed bottles delivered in sealed foil pouches. The Explorer Packs contain material in standard geochem envelopes, vacuum sealed in foil pouches.

19. Recommended use: The data used to characterize this CRM has been scrutinized using outlier treatment techniques. This, together with the number of participating laboratories, should overcome any "inter-laboratory issues" and should lead to a very accurate measure for the given methods, notwithstanding the underlying assumption that what the good inter-laboratory labs reported was accurate. However an amount of bad data might have had an effect, resulting in limits which in some situations might be too broad for the effective monitoring of a single analytical method, laboratory or production process. Users should set their own limits based on their own data quality objectives and control measurements, after determining the performance characteristics of their own particular method, using a minimum of 20 analyses using this CRM. User set limits should normally be within the limits recommended on p1 and 2 of this certificate.

20. Legal Notice: This certificate and the reference material described in it have been prepared with due care and attention. However AMIS, Set Point Technology (Pty) Ltd, Mike McWha, Dr Barry Smee and Smee and Associates Ltd; accept no liability for any decisions or actions taken following the use of the reference material.

19 May 2010

Certifying Officers:



African Mineral Standards: _____

Mike McWha
BSc (Hons), FGSSA, MAusIMM, Pr.Sci.Nat



Geochemist: _____

Barry W. Smee
BSc, PhD, P.Geo, (B.C.)

Appendix 1. – Uncertified trace element statistics

Eight of the laboratories submitted significant total digestion / multi element scan trace element data. This data has been compiled and iterated; some of the elements could be certified (if requested). It is presented below for informational use.

AMIS0162 Trace

Analyte	Method	Unit	Mean	2SD	RSD%	n
Al	M/ICP	%	4.3	0.21	2.5	40
As	M/ICP	ppm	12	8.7	37.0	55
B	M/ICP	ppm	393	30	3.8	8
Ba	M/ICP	ppm	118	11	4.8	55
Be	M/ICP	ppm	2.7	0.33	6.1	39
Bi	M/ICP	ppm	2.3	0.10	2.2	15
Ca	M/ICP	%	0.21	0.02	4.9	54
Cd	M/ICP	ppm	0.10			6
Ce	M/ICP	ppm	52	4.1	4.0	24
Cr	M/ICP	ppm	265	122	23.1	55
Cs	M/ICP	ppm	1.6	0.09	2.7	16
Dy	M/ICP	ppm	3.3	0.17	2.5	16
Er	M/ICP	ppm	2.0	0.11	2.7	16
Eu	M/ICP	ppm	0.80	0.06	3.8	16
Fe	M/ICP	%	1.2	0.05	2.0	53
Ga	M/ICP	ppm	11	1.9	8.3	23
Gd	M/ICP	ppm	3.8	0.26	3.4	16
Hf	M/ICP	ppm	3.3	1.4	21.4	16
Ho	M/ICP	ppm	0.71	0.05	3.4	16
In	M/ICP	ppm	0.16	0.02	7.8	16
K	M/ICP	%	1.4	0.07	2.6	53
La	M/ICP	ppm	31	2.8	4.5	39
Li	M/ICP	ppm	145	16	5.3	56
Lu	M/ICP	ppm	0.29	0.02	2.6	16
Mg	M/ICP	%	2.4	0.14	2.9	39
Mn	M/ICP	ppm	466	45	4.8	54
Mo	M/ICP	ppm	2.5	0.79	15.6	37
Na	M/ICP	%	0.05	0.01	9.3	51
Nb	M/ICP	ppm	10	13	65.7	39
Nd	M/ICP	ppm	26	0.56	1.1	15
Ni	M/ICP	ppm	46	7.5	8.1	76
P	M/ICP	%	0.03	0.004	6.1	47
Pb	M/ICP	ppm	11	4.1	19.3	55
Pr	M/ICP	ppm	6.5	0.27	2.1	16
Rb	M/ICP	ppm	52	2.1	2.0	18
S	M/ICP	%	0.02	0.01	14.8	48
Sb	M/ICP	ppm	3.7	2.7	37.5	22
Sc	M/ICP	ppm	8.9	0.58	3.3	45
Si	M/ICP	per	37			8
Sm	M/ICP	ppm	4.9	0.19	2.0	16
Sn	M/ICP	ppm	2.0			15
Sr	M/ICP	ppm	15	2.2	7.7	54
Ta	M/ICP	ppm	1.4	2.6	93.6	24
Tb	M/ICP	ppm	0.56	0.04	3.5	16
Te	M/ICP	ppm	0.13	0.12	43.3	3
Th	M/ICP	ppm	7.8	1.0	6.5	24
Ti	M/ICP	%	0.23	0.12	25.8	48
Tl	M/ICP	ppm	15	43	142.6	24
Tm	M/ICP	ppm	0.31	0.02	3.1	16
U	M/ICP	ppm	8.4	1.5	9.0	16
V	M/ICP	ppm	89	11	6.0	56
W	M/ICP	ppm	0.56	0.82	72.8	16
Y	M/ICP	ppm	21	3.1	7.5	39
Yb	M/ICP	ppm	1.9	0.18	4.9	16
Zn	M/ICP	ppm	67	15	11.1	94
Zr	M/ICP	ppm	106	16	7.5	48