

QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

QCRM-5-063

COPPER ORE

CERTIFICATE OF ANALYSIS

CERTIFIED VALUES			
ANALYTES	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Al	%	3.89	±0.08
Ca	%	1.80	±0.04
Co	%	0.003	±0.002
Cu	%	0.34	±0.01
Fe	%	3.56	±0.12
Mg	%	1.60	±0.05
Mn	%	0.022	±0.005
Mo	%	0.039	±0.002
Ni	%	0.005	±0.002
Pb	%	0.018	±0.002
S	%	1.91	±0.06
Si	%	33.2	±1.1
Zn	%	0.015	±0.002

ASSIGNED VALUES (FOR INFORMATION ONLY)			
ANALYTES	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Ag	g/t	2.88	±0.88
As	ppm	63	±23
Au	g/t	0.21	±0.07
Bi	ppm	13	±13
Cu (Soluble)	%	0.04	±0.02
K	%	3.11	±0.14
Na	%	0.52	±0.16
Se	ppm	18	±13

1. Use:

QCRM-5-063 is a certified reference material which is suitable for use as random control samples in routine analytical laboratory quality control, when inserted within a batch of samples and measured in parallel to the unknown. The QCRM can also be used as a control sample in the analysis of samples of a similar type, verification of analytical methods for Copper Ore and as a calibration standard for the calibration of equipment used for analysing similar materials.

This COA was updated, as additional data became available for Molybdenum, Selenium, Bismuth and Arsenic. Only these analytes were considered, during this re-evaluation.

2. Origin of Material:

This composite mill feed copper ore sample was sponsored by Rio Tinto, Kennecott, in the USA.

3. Mineral and Chemical Composition:

The head or mill feed is dominated by meta-sediments with minor amounts of intermediate to felsic intrusive rocks of the Bingham Stock. The metasedimentary rocks comprise roughly equal proportions of pyrite-poor and -rich clean, orthoquartzite and hornfels with accessory amounts of skarn. Intrusive rocks are dominated by molybdenum-enriched monzonite and lesser quartz monzonite. The mineralogy of this ore is compositionally in agreement with the above ore-based assessment. Relative to historic data, 2006 through 2019, the ore exhibits higher concentrations of quartz, pyrite and magnesium-rich clay minerals. Lower than historic percentages of the economic minerals, i.e. Cu sulphides and molybdenite, as well as typical rock forming minerals, such as: feldspars, biotite and amphibole / pyroxenes are observed.

4. Date of Initial Issue:

2 June 2020.

5. Packaging & Handling instructions:

The material was packaged as 100g unit sizes, placed in geo-envelopes, within a vacuum sealed aluminum foil bag. Open the seal of the foil with care and shake or otherwise agitate prior to use. Normal safety precautions for handling fine particulate matter are recommended, such as the use of safety glasses, breathing protection, gloves, and a laboratory coat. Once opened, material must be stored in a cool, dry environment. Results on page 1 is presented on dry basis. Analysis should therefore be done on dry basis, after drying to constant mass, at 105 degrees Celsius.

6. Method of Preparation:

The material was sieved through a 75-micron screen and the oversize was re-milled to ensure 100% passing through the screen. It was then blended, systematically divided, and packaged into 100-gram zip-lock bags. Randomly selected samples, from the bags, were tested in-house via XRF, to confirm homogeneity. Once confirmed and certification completed, the items were placed in geo-envelopes and vacuum sealed in aluminium foil bags.

7. Methods of Analysis used:

- Multi-acid digestions with ICP-OES finish
- Multi-acid digestion with AAS finish
- Sodium peroxide fusion with ICP-OES finish
- Copper by sodium peroxide fusion with Potentiometric Titration
- Copper by 3-acid digestion with Potentiometric Titration
- Copper by multi-acid digestion and electro-gravimetric finish
- Copper by peroxide fusion and electro-gravimetric finish
- Soluble copper by dilute sulphuric acid leach and AAS finish
- Pressed powder with XRF finish
- Fused beads with XRF finish
- Au & Ag by lead collection Fire Assay and ICP-OES or AAS finish
- Sulphur by Thermal Combustion analysis.

8. Analysis required:

An instruction letter was sent to all participants. The analysis required was noted in the instruction letter and reporting template, including but not limited to Ag, Al, As, Ca, Co, Cu, Cu (Soluble), Fe, K, Mg, Mn, Mo, Na, Ni, Pb, S, Si and Zn.

9. Participating Laboratories:

No	LABORATORY	COUNTRY
1.	AHK Gozetme ve Anatiz	Turkey
2.	AHK Kitwe	Zambia
3.	AHK Lumwana	Zambia
4.	ALS Geochemistry Kempton Park	South Africa
5.	ALS Inspection UK	United Kingdom
6.	ALS Zambia	Zambia
7.	Intertek LSI	Netherland
8.	Intertek Tschudi	Namibia
9.	Lubambe Copper Mine	Zambia
10.	Mintek	South Africa
11.	Mopani Mufulira	Zambia
12.	Mutanda Mining	Democratic Republic of Congo
13.	OCC Likasi	Democratic Republic of Congo
14.	Palabora Mining Company	South Africa
15.	Rio Tinto Kennecott	United States of America
16.	SGS Lakefield	Canada
17.	SGS Netherlands BV	Netherland
18.	UIS Analytical Services	South Africa

10. Assay Data:
Data used for Assigning Values and Certification.

LAB	Ag	Al	As	Au	Bi	Ca	Co	Cu	Cu (Soluble)	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Si	U	Zn	
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	%	ppm	%	
LAB001			< 200.00		< 1000.00									0.041					< 200.00				
LAB002			< 200.00		< 1000.00									0.041					< 200.00				
LAB003			< 500.00											0.041									
LAB004			< 500.00											0.038									
LAB005			41.5		< 31.000									0.035					25				
LAB006			46.5		22									0.044					< 20.000				
LAB007			< 10.000		< 25.000									0.041					19				
LAB008			< 10.000		< 23.000									0.04					11.5				
LAB009			81.5											0.037									
LAB010			85											0.037									
LAB011			15.35		3.4														4.9				
LAB012			15.95		3.15														4.5				
LAB013														0.039									
LAB014														0.038									
LAB015														0.038									
LAB016														0.038									
LAB017														0.051									
LAB018														0.041									
LAB019	2	3.71	30	7	< 12.000	1.708	0.003	0.315		3.175	3.005	1.541		0.033	0.405	0.004	0.014	1.93	< 30.000				0.012
LAB020								0.324															
LAB021		3.815				1.638		0.32		3.67		1.714									33.767		

LAB	Ag	Al	As	Au	Bi	Ca	Co	Cu	Cu (Soluble)	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Si	U	Zn
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	%	ppm	%
LAB022		3.988	177.05			1.825	0.006	0.344		3.72	3.067					0.125	0.025	1.843		34.782		
LAB023		3.423				1.931	0.003	0.301		3.575	3.268	1.532				0.004	0.016	1.72		32.516		0.015
LAB024		4.113					0.003	0.383	0.032	3.495		1.744		0.034			0.017	2.125		28.74		0.015
LAB025								0.343														
LAB026	2	3.83	33.5	0.175		1.84	0.003	0.33		3.75		1.61	0.022			0.004	0.015	1.925		34.05	< 10.000	0.015
LAB027	3	3.9	40.69			1.775	0.003	0.34	0.055	3.48		1.555	0.02			0.004	0.015	1.81		34.588	< 5.000	0.02
LAB028								0.44														
LAB029								0.041														
LAB030								0.34														
LAB031	10.2	4.007	180	0.22				0.356	0.04	4.019		1.703						2.233		32.02		0.012
LAB032	< 10.00	3.965	< 100.00	0.2		1.815	< 0.010	0.32		3.765		1.705	0.02			< 0.010	0.02	1.895		33.1		0.02
LAB033	2.15	3.965	30		< 1000.00	1.83	< 0.020	0.3	0.051	3.535	3.13	1.57	0.025	0.036	0.475	< 0.010	0.01	1.84	< 200.00		< 10.000	0.01
LAB034								0.35														
LAB035									0.021													
LAB036								0.319														
LAB037		3.655				1.828	0.001	0.325		3.119		1.516										
LAB038	3.17	4.015	75.315		30	1.47	0.003	0.3		3.625	3.96	1.445	0.042		0.685	0.006	0.026	1.901				0.016
LAB039								0.34		3.228												
LAB040								0.35														
LAB041	3.45	3.95	78.77		85	1.51	0.003	0.29		3.525	3.945	1.47	0.04		0.68	0.007	0.023	1.879				0.018
LAB042		4.058					0.003	0.386	0.034	3.485		1.724		0.034			0.018	2.121		30.014		0.014
LAB043	2.3	3.92	30		< 1000.00	1.81	< 0.020	0.3	0.049	3.62	3.08	1.56	0.025	0.036	0.47	< 0.010	0.015	1.865	< 200.00		< 10.00	0.015
LAB044								0.39														
LAB045								0.041														

LAB	Ag	Al	As	Au	Bi	Ca	Co	Cu	Cu (Soluble)	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	S	Se	Si	U	Zn
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	%	ppm	%
LAB046								0.355														
LAB047		3.673				1.809	0.001	0.352		3.263		1.535										
LAB048									0.021													
LAB049								0.33														
LAB050	10.7	4.024	165	0.22				0.353	0.035	3.915		1.687					2.088			31.599		0.01
LAB051								0.345														
LAB052								0.339		3.314												
LAB053								0.35														
LAB054		4.044				1.986		0.323		3.785		1.758								33.841		
LAB055	2	3.688	52	7.5	10	1.671	0.003	0.315		3.145	2.997	1.526		0.033	0.405	0.004	0.014	2.005	10			0.012
LAB056								0.321														
LAB057		3.375				1.874	0.003	0.298		3.588	3.277	1.514				0.004	0.017	1.755		32.154		0.015
LAB058		4.006	201.35			1.811	0.005	0.345		3.692	3.054					0.119	0.026	1.835		34.614		
LAB059	2.5	3.925	37.345			1.775	0.002	0.35	0.026	3.48		1.56	0.02			0.004	0.015	1.91		34.977	< 5.00	0.015
LAB060								0.47														
LAB061	2	3.77	30.5	0.185		1.83	0.003	0.33		3.73		1.61	0.023			0.004	0.015	1.88		33.97	< 10.00	0.015
LAB062	< 10.00	3.95	< 100.00	0.25		1.82	< 0.010	0.325		3.775		1.695	0.02			< 0.010	0.02	1.945		33.32		0.02

Note: "less than" values were de-selected from the dataset, for all calculation purposes. They were however added back to the dataset, for information purposes only.

11. Method of Certification:

QM is a SANAS Accredited Proficiency Testing Scheme Provider, No. PTS0012

This material was distributed as test items, in the Qotho Copper PT Round 6 of 2019. The participating laboratories were each given 1 randomly selected sample from the batch, to analyse and report on in duplicate. Some laboratories reported results via more than one analytical method. Additional commercial analyses were later contracted to commercial laboratories. Obvious blunders were resolved with the laboratories (if any), after which the data was processed using Robust Statistics, through PROLab Plus.

Not all the participating laboratories were accredited. Historical performance in Qotho PT Schemes, as well as an evaluation of the CRM QA/QC data generated by the laboratories, during the analysis of this QRM, were considered, to evaluate the competence of laboratories. Where competence could not be confirmed, the affected data was deselected from the dataset. Certification of analytes was then done, provided that a minimum of 10 qualifying datapoints remained available.

Where analytes could not be certified, estimate concentrations were assigned, using all the data in the dataset.

12. Measurement of Uncertainty:

Standard uncertainty, u_{CRM} , was calculated according to ISO 13528:2015 (equation 6), and it includes the effects of uncertainty due to inhomogeneity, transport, potential instability, and laboratory uncertainty. Because of all the uncertainties under consideration, QM further applies an expanded uncertainty, for certification purposes. The measurement uncertainty of the certified value is therefore calculated as follows: $U_{CRM} = k u_{CRM}$, where k is a coverage factor, which is determined from the Student's t -distribution, based on the degrees of freedom, per analyte. This presents a certified value, as follows: $x_{CRM} \pm U_{CRM}$.

Measurement uncertainty for Assigned values, are calculated in the same manner.

For laboratories which prefer to use the 95% measurement uncertainty, rather than the expanded uncertainty, all available information relating to measurement uncertainty of the certified/assigned values, are given below:

Analyte	Unit of measure	s (Standard Deviation of Dataset)	v (Degrees of Freedom)	k (Coverage Factor)	u (Standard Uncertainty)	95% Measurement Uncertainty	Expanded Uncertainty
Ag	g/t	1.629	13	2.160	0.409	± 0.82	± 0.88
Al	%	0.152	23	2.069	0.036	± 0.07	± 0.08
As	ppm	49.141	27	2.052	11.312	± 23	± 23
Au	g/t	0.073	7	2.365	0.028	± 0.06	± 0.07
Bi	ppm	17.369	13	2.160	5.938	± 12	± 13
Ca	%	0.09	19	2.093	0.02	± 0.04	± 0.04
Co	%	0.002	19	2.093	0.001	± 0.002	± 0.002
Cu	%	0.034	41	2.020	0.006	± 0.01	± 0.01
Cu (Soluble)	%	0.016	9	2.262	0.006	± 0.01	± 0.02
Fe	%	0.24	25	2.060	0.057	± 0.11	± 0.12
K	%	0.18	9	2.262	0.06	± 0.12	± 0.14
Mg	%	0.104	21	2.080	0.023	± 0.05	± 0.05
Mn	%	0.004	9	2.262	0.002	± 0.004	± 0.005
Mo	%	0.003	9	2.262	0.001	± 0.002	± 0.002
Na	%	0.121	5	2.571	0.062	± 0.12	± 0.16
Ni	%	0.003	15	2.131	0.001	± 0.002	± 0.002
Pb	%	0.006	17	2.110	0.001	± 0.002	± 0.002
S	%	0.102	19	2.093	0.03	± 0.06	± 0.06

Analyte	Unit of measure	s (Standard Deviation of Dataset)	v (Degrees of Freedom)	k (Coverage Factor)	u (Standard Uncertainty)	95% Measurement Uncertainty	Expanded Uncertainty
Se	ppm	16.455	11	2.201	6.041	± 12	± 14
Si	%	1.668	15	2.131	0.516	± 1.0	± 1.1
Zn	%	0.004	17	2.110	0.001	± 0.002	± 0.002

13. 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 accredited laboratories, as ISO 17025 requires laboratories to use CRM's traceable to the SI units, during the calibration of their equipment. Not all laboratories were accredited.

Fortunately, most laboratories reported on the QA/QC CRMs used during the analysis of this QRM and reported the values obtained during the sample run. Evaluation of their QA/QC performance serves as further evidence of metrological traceability.

Equivalence tests were performed on all analytes to determine whether the metrologically traceable data and those for which traceability evidence was not available, could be treated as equal (at a level of significance of $\alpha = 0.05$). Where equivalent, all the data was used. Where not equivalent, only the metrologically traceable data was considered.

14. Minimum sample size:

The recommended minimum sample size for the use of this material is as per the participants method validation criteria.

15. Period of validity:

The certified values are valid for this product, while still sealed in its original packaging, for a minimum period of 5 years from date of Initial Certification. Stability monitoring of inventory will be done at regular intervals. Any concerns regarding potential instability of the material, will immediately be communicated to all consumers.

16. Legal:

This certificate and the reference material described in it were prepared with due care and attention. The requirements of ISO Guide 31, ISO 17043 and ISO 17034 were followed in the preparation of this reference material and certificate of analysis.

Qotho Minerals, however, accepts no liability for any decisions or actions taken following the use of the reference material. The company has a complaints procedure, which will be made available upon request, should there be any dissatisfaction with either the product or the COA.

Certifying & Technical Signatory	
Qotho Managing Director	4 April 2022

This Certificate of Analysis (CoA) has been electronically signed using an Advanced Electronic Signature (AES) in terms of the Electronic Communications and Transactions Act No. 15, 2002 (ECT Act). Any amendments to the CoA can be detected by reference to the Signature Panel displayed in the electronic pdf version of the CoA.

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