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QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

QCRM-5-054

COPPER ORE

CERTIFICATE OF ANALYSIS

CERTIFIED VALUES			
	UNITS	**CONCENTRATIONS**	**EXPANDED UNCERTAINTY**
Al	%	0.88	±0.04
Cu	%	0.57	±0.01
Fe	%	18.34	±0.48
S	%	0.43	±0.04
Zn	%	0.012	±0.004
ASSIGNED VALUES (FOR INFORMATION ONLY)			
ANALYTES	**UNITS**	**CONCENTRATIONS**	**EXPANDED UNCERTAINTY**
Ca	%	19.67	±0.51
Co	%	0.010	±0.002
Cu (Soluble)	%	0.12	±0.01
Mg	%	4.78	±0.13
Mn	%	0.12	±0.01
Ni	%	0.014	±0.002
Pb	%	0.008	±0.004
Si	%	3.92	±0.30

1. **Use:**
   QCRM-5-054 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 more data became available, enabling the certification of more analytes. Furthermore, the dataset was subjected to our improved and accredited statistical protocol, which was adopted in 2019.

2. **Origin of Material:**
   The material was supplied by Palabora Mining Company Ltd. It is a copper mine that also operates a smelter and refinery complex based in the town of Phalaborwa, in South Africa's Limpopo Province.

3. **Mineral and Chemical Composition:**
   The ore traces its origin from a unique geological formation known as the Palabora Igneous Complex. The geology of the ore includes carbonitites and a host of other minerals such as phosphates, vermiculite, phlogopite, magnetite, nickel, gold, silver, platinum and palladium.

4. **Date of Initial Issue:**
   8 July 2018.

5. **Packaging & Handling instructions:**
   The material was packaged as 100g unit sizes, placed in geo-envelopes, within a vacuum sealed aluminium 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 digestion with AAS finish
   - Multi-acid digestion with ICP-OES finish
   - Sodium peroxide fusion with ICP-OES finish
   - Acid soluble copper by mild sulphuric leach and AAS finish
   - Au & Ag by Lead collection fire assay and ICP-OES finish
   - Iron and Copper by multi-acid digestion and potentiometric titration
   - Copper by aqua regia digestion and electro-gravimetric finish
   - Silica by multi-acid digestion and gravimetric finish
   - Fused beads with XRF finish
   - Pressed powders with XRF finish
   - Sulphur by 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, Au, Ca, Co, Cu, Cu (Soluble), Fe, Mg, Mn, Ni, Pb, S, Si and Zn.

9. Participating Laboratories:

No	LABORATORY	COUNTRY
1.	AHK DRC South	Democratic Republic of Congo
2.	AHK Kitwe	Zambia
3.	AHK Lumwana	Zambia
4.	ALS Geochemistry Kempton Park	South Africa
5.	ALS Inspection UK	United Kingdom
6.	ALS Kansanshi	Zambia
7.	ALS Zambia	Zambia
8.	BMC Analysis	United Kingdom
9.	Intertek Tschudi	Namibia
10.	Kamoto Copper Company	Democratic Republic of Congo
11.	Lubambe Copper Mine	Zambia
12.	Mineracao Caraiba S/A	Brazil
13.	Mitra Sk South Africa	South Africa
14.	Mopani Mufulira	Zambia
15.	Mopani Nkana	Zambia
16.	Mutanda Mining	Democratic Republic of Congo
17.	OCC Likasi	DRC
18.	Palabora Mining Company	South Africa
19.	Quality Lab Services Nababeeb	South Africa
20.	Rio Tinto Kennecott	United States of America
21.	Robinson International	Democratic Republic of Congo
22.	Suntech	South Africa
23.	UIS Analytical Services	South Africa
24.	Zambia Revenue Authority	Zambia

10. Assay Data:

Data used for Assigning Values and Certification.

LABORATORY	Ag	Al	As	Au	Ca	Co	Cu	Cu (Soluble)
UNIT	g/t	%	ppm	g/t	%	%	%	%
LAB001		1.032			19.608			
LAB002							0.552	
LAB003		0.919			19.865	0.01	0.582	
LAB004		0.901			20.25	0.01	0.564	
LAB005		0.849				0.014	0.567	
LAB006		0.837				0.009	0.587	0.116
LAB007								0.117
LAB008							0.558	
LAB009		0.962			20.044	0.007	0.53	0.12
LAB010	4		< 100.000	< 0.100				
LAB011					22.15	0.01	0.579	
LAB012					17.368		0.623	0.116
LAB013					18.37		0.635	
LAB014					17.486		0.593	
LAB015							0.595	
LAB016		0.804			16.335	0.009		
LAB017							0.315	
LAB018								0.225
LAB019							0.597	
LAB020	2		< 20.000	0.15	19.715	< 0.010		0.11
LAB021	< 0.500		< 5.000		19.975		0.6	0.157
LAB022	7.333	0.825	80.417		20.051	0.009	0.55	
LAB023								
LAB024	3.702	0.915	15.794		18.565	0.009	0.635	0.16
LAB025							0.569	
LAB026								0.15
LAB027							0.57	
LAB028		0.871				0.008	0.611	0.124
LAB029	< 0.500	0.89	< 0.020		19.925	< 0.020	0.6	0.143
LAB030							0.565	
LAB031								0.102
LAB032							0.543	
LAB033		0.802			21.732	0.013	0.507	
LAB034								0.085

LABORATORY	Ag	Al	As	Au	Ca	Co	Cu	Cu (Soluble)
UNIT	g/t	%	ppm	g/t	%	%	%	%
LAB035							0.589	
LAB036	6.85	1.093	< 0.001	0.12	28.42	< 0.001	0.535	0.115
LAB037		0.883			20.254	< 0.010	0.55	0.106
LAB038							0.556	
LAB039						0.022		
LAB040		0.97			20.297		0.55	
LAB041							0.551	
LAB042	3.66	1.8			20.81	0.008	0.74	0.085
LAB043		0.861				0.009	0.599	0.123
LAB044	< 0.500	0.885	< 0.020		20.15	< 0.020	0.6	0.15
LAB045							0.58	
LAB046							0.543	0.103
LAB047		0.859			21.538	0.014	0.544	
LAB048					20.185	0.014	0.525	0.118
LAB049								0.098
LAB050							0.583	
LAB051		0.849	< 0.001		18.245	< 0.001	0.55	0.12
LAB052		0.821			19.725	0.007	0.583	0.093
LAB053							0.637	
LAB054		0.921			16.764		0.562	
LAB055	0.71	0.734	< 20.000	0.051	20.15	0.01	0.577	
LAB056							0.571	
LAB057		0.913			19.279	0.014	0.565	

LABORATORY	Fe	Mg	Mn	Ni	Pb	S	Si	U	Zn
UNIT	%	%	%	%	%	%	%	ppm	%
LAB001	18.453	4.653		0.017	0.348	0.735	3.923		
LAB002									
LAB003	19.246	5.313	0.128			0.421	4.301		
LAB004	18.5	4.87	0.122	0.015		0.44	4.23		
LAB005		4.787	0.119	0.013					0.01
LAB006	17.83	4.547					4.278		0.013
LAB007									
LAB008									
LAB009	16.578	4.716	0.11	0.014			4.213		0.017
LAB010									
LAB011		4.955	0.124	0.009	0.003				
LAB012		4.764	0.116			0.346		7.7	
LAB013		4.395	0.107						
LAB014		4.575							
LAB015									
LAB016	18.605	4.545		0.001	0.005	0.475	7.965		0.011
LAB017									
LAB018									
LAB019									
LAB020		4.815	0.115	0.01	< 0.010		3.9	15	
LAB021	18.25					0.425			
LAB022	17.438	4.748	0.093		0.006				0.009
LAB023				0.01					
LAB024	18.06	4.62	0.54	0.016	0.01	0.453			0.013
LAB025									
LAB026									
LAB027									
LAB028	18.086	4.347			0.006	0.401	3.768		0.006
LAB029	17.41	4.635	0.106	0.015	< 0.010	0.43			0.025
LAB030									
LAB031									
LAB032									
LAB033	19.315	4.933	0.12						
LAB034									
LAB035									
LAB036	19.123	5.133	0.117	0.018	< 0.001	0.494	4.034		0.117
LAB037	18.45	5.043	0.123	< 0.010	< 0.010	0.494	3.545		

LABORATORY	Fe	Mg	Mn	Ni	Pb	S	Si	U	Zn
UNIT	%	%	%	%	%	%	%	ppm	%
LAB038									
LAB039									
LAB040	19.049	4.973					3.801		
LAB041									
LAB042	18.35	4.86		0.018	0.009	0.44			0.046
LAB043	18.692	4.171			0.007	0.411	3.561		
LAB044	17.175	4.845	0.108	0.015	< 0.010	0.41			0.01
LAB045									
LAB046									
LAB047	19.764	4.98	0.114						
LAB048	15.158	4.62	0.085			0.448			
LAB049									
LAB050									
LAB051	16.747	4.807		0.044	< 0.001	0.352	3.637		
LAB052	18.88	4.819	0.114	0.011	< 0.010	0.589	3.43		0.009
LAB053									
LAB054	18.377	4.968		0.013	0.011		3.968		
LAB055	19.45	4.534	0.11	0.012	0.004	0.38	9.235		0.01
LAB056									
LAB057	18.407	5.197	0.131	0.016	0.015		4.234		

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 3 and 4 of 2019 and Round 3 of 2022. 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. 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, uCRM, 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: UCRM = kuCRM, 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: xCRM ± UCRM.

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

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
Al	%	0.079	23	2.069	0.02	± 0.04	± 0.04
Ca	%	1.183	26	2.056	0.249	± 0.50	± 0.51
Co	%	0.002	18	2.101	0.001	± 0.002	± 0.002
Cu	%	0.035	44	2.015	0.006	± 0.01	± 0.01
Cu (Soluble)	%	0.022	22	2.074	0.006	± 0.01	± 0.01
Fe	%	0.875	24	2.064	0.233	± 0.47	± 0.48
Mg	%	0.267	29	2.045	0.061	± 0.12	± 0.13
Mn	%	0.013	19	2.093	0.003	± 0.01	± 0.01
Ni	%	0.005	17	2.110	0.001	± 0.002	± 0.002
Pb	%	0.005	10	2.228	0.002	± 0.004	± 0.004
S	%	0.064	17	2.110	0.018	± 0.04	± 0.04
Si	%	0.466	16	2.120	0.139	± 0.28	± 0.30
Zn	%	0.007	12	2.179	0.002	± 0.004	± 0.004

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	***24 August 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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