

QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

QCRM-5-069

COPPER CONCENTRATE

CERTIFICATE OF ANALYSIS

CERTIFIED VALUES			
ANALYTES	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Ag	g/t	98.2	±1.3
Al	%	1.44	±0.07
As	ppm	1474	±23
Ca	%	0.87	±0.03
Co	%	0.008	±0.002
Cu	%	15.54	±0.12
Fe	%	19.23	±0.34
Mg	%	1.45	±0.07
Mn	%	0.030	±0.004
Mo	%	3.74	±0.05
Ni	%	0.009	±0.002
Pb	%	0.23	±0.01
S	%	25.17	±0.69
Zn	%	0.224	±0.008

ASSIGNED VALUES (FOR INFORMATION ONLY)			
	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Au	g/t	9.05	±0.48
Bi	%	0.016	±0.015
Cu (Soluble)	%	0.53	±0.18
Se	ppm	128	±19
Si	%	11.47	±0.50

1. Use:

QCRM-5-069 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 Concentrate and as a calibration standard for the calibration of equipment used for analysing similar materials.

This document was updated, as more data became available for As, Bi, Mo and Se. Only the data for these for analytes were received during this update, with two of the analytes becoming certifiable.

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 sulfides 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 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:

- 4-Acid digestion with ICP-OES or AAS finish
- 3-Acid digestion with IC-OES or AAS Finish
- Aqua Regia digestion with ICP-OES finish
- Aqua Regia digestion with Electro Gravimetric Finish
- Sodium peroxide fusion with ICP-OES finish
- 3 Acid digestion with Manual Titration
- Fused beads with XRF finish
- Pressed Powder 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, 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.	Dundee Precious Metals	Namibia
7.	Intertek LSI	Netherlands
8.	Kamoto Copper Company	Democratic Republic of Congo
9.	Lubambe Copper Mine	Zambia
10.	Mintek	South Africa
11.	Mopani Mufulira	Zambia
12.	Mopani Nkana Analytical Services	Zambia
13.	OCC Kolwezi	Democratic Republic of Congo
14.	OCC Likasi	Democratic Republic of Congo
15.	OCC Lubumbashi	Democratic Republic of Congo
16.	OCC Tenke	Democratic Republic of Congo
17.	Palabora Mining Company	South Africa
18.	Rio Tinto Kennecott	United States of America
19.	SGS Lakefield	Canada
20.	SGS Netherlands BV	Netherlands
21.	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
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%
LAB001					< 1000.00					
LAB002					< 1000.00					
LAB003			1338.5		121.5					
LAB004			1348.5		121.5					
LAB005			1490		218.5					
LAB006			1520		263					
LAB007			2220							
LAB008			2205							
LAB009					110					
LAB010					111.5					
LAB011										
LAB012										
LAB013										
LAB014										
LAB015										
LAB016										
LAB017										
LAB018										

LAB	Ag	Al	As	Au	Bi	Ca	Co	Cu	Cu (Soluble)	Fe
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%
LAB019										
LAB020										
LAB021										
LAB022										
LAB023	95.837	1.304	1445	9.78		0.835	0.008	13.73		19.175
LAB024								16.35		
LAB025								15.975		
LAB026		1.365				0.905				19.446
LAB027								19.98		
LAB028		1.474				1.248	0.015	15.617		19.582
LAB029								15.44		18.265
LAB030								15.608		
LAB031							0.011		0.678	
LAB032		1.546				0.818	0.038	15.42	0.328	21.2
LAB033								15.515	0.215	
LAB034	99	1.225				1.02		14.705		
LAB035								15.445		
LAB036						0.86			0.718	17.349
LAB037							0.01	15.526		17.627
LAB038								17.625		19.475
LAB039								16.346		
LAB040								16.85		
LAB041	97.65	1.43	1505	9.3		0.92	0.007	15.44		19.3
LAB042	98	1.51	1499.065			0.825	0.007	15.56	0.487	18.99
LAB043								15.435		
LAB044		1.576		7.835		0.861	0.003	15.628	0.72	20.512
LAB045	97	1.495	1500	9.45		0.86	< 0.010	15.4		19.375
LAB046	99	1.5		9.06		0.885	< 0.020	15.4	0.643	19.19
LAB047								15.39		
LAB048									0.468	
LAB049								15.555		
LAB050	99.33	1.38				0.86	0.008			19.8
LAB051								15.45		
LAB052										18.96
LAB053								15.325		
LAB054								15.316		
LAB055	98.77	1.265				0.875	0.009			19.725
LAB056								15.435		
LAB057								15.355	0.206	
LAB058	101.2	1.565				0.905	< 0.020	15.8	0.661	20.1
LAB059								15.83		
LAB060	98	1.51	1502.815			0.83	0.006	15.63	0.489	18.965

LAB	Ag	Al	As	Au	Bi	Ca	Co	Cu	Cu (Soluble)	Fe
UNIT	g/t	%	ppm	g/t	ppm	%	%	%	%	%
LAB061								15.46		
LAB062	97.5	1.17				1.02		15.165		
LAB063								15.81		
LAB064	99.7	1.43	1496.5	9.15		0.905	0.007	15.395		19.385
LAB065						0.79			0.877	17.415
LAB066									0.399	
LAB067								15.356		
LAB068		1.578		8.405		0.865	0.003	15.651	0.73	20.465
LAB069		1.512				0.798	0.037	15.375	0.351	19.95
LAB070								15.16		18
LAB071								15.265		
LAB072										19.28
LAB073								15.65		
LAB074								15.319		
LAB075							0.01	15.695		17.725
LAB076								17.67		19.615
LAB077		1.349				1.394				18.582
LAB078								19.382		
LAB079	92.05	1.308	1448	9.095		0.848	0.008	13.975		19.31
LAB080								16.3		
LAB081								16		
LAB082	98.5	1.5	1500	9.05		0.875	< 0.010	15.34		19.26
LAB083		1.491				0.877	0.014	15.587		19.563

LAB	Mg	Mn	Mo	Ni	Pb	S	Se	Si	U	Zn
UNIT	%	%	%	%	%	%	ppm	%	ppm	%
LAB001							< 200.00			
LAB002							< 200.00			
LAB003							145.5			
LAB004							151			
LAB005							155.5			
LAB006							150.5			
LAB007										
LAB008										
LAB009							110			
LAB010							109.5			
LAB011			3.69							
LAB012			3.67							
LAB013			3.645							
LAB014			3.725							
LAB015			3.715							

LAB	Mg	Mn	Mo	Ni	Pb	S	Se	Si	U	Zn
UNIT	%	%	%	%	%	%	ppm	%	ppm	%
LAB016			3.755							
LAB017			3.75							
LAB018			3.735							
LAB019			3.75							
LAB020			3.845							
LAB021			3.805							
LAB022			3.78							
LAB023	1.385	0.03		0.012	0.175	25.95		10.215		0.216
LAB024										
LAB025										
LAB026	1.591					24.361		11.648		
LAB027										
LAB028	1.565	0.04			0.239	25.026		12.831		0.205
LAB029		0.068		0.013						
LAB030										
LAB031						27.3				
LAB032	1.363	0.026		< 0.010	0.202			11.195		0.22
LAB033						25.657				
LAB034	1.31				0.25	24.72		11.225		0.235
LAB035										
LAB036	0.718	0.01								
LAB037				0.017	0.212					0.231
LAB038		0.029		0.009						
LAB039										
LAB040										
LAB041	1.455	0.028		0.008	0.225	24.11		11.6	< 10.00	0.23
LAB042	1.375	0.035		0.007	0.225			12.037	< 5.00	0.22
LAB043										
LAB044	1.611			0.008	0.23	25.465		10.44		0.252
LAB045	1.51	0.03		< 0.010	0.23	25.98		12.07		0.22
LAB046	1.38	0.026		0.01	0.225	20.1			7.5	0.23
LAB047										
LAB048										
LAB049										
LAB050	1.35	0.034		0.011	0.24			11.545		0.215
LAB051										
LAB052										
LAB053										
LAB054										
LAB055	1.415	0.033		0.011	0.24			11.48		0.21
LAB056										
LAB057						25.599				

LAB	Mg	Mn	Mo	Ni	Pb	S	Se	Si	U	Zn
UNIT	%	%	%	%	%	%	ppm	%	ppm	%
LAB058	1.41	0.028		0.01	0.235	19.75			< 10.00	0.24
LAB059										
LAB060	1.375	0.035		0.009	0.225			12.024	< 5.000	0.22
LAB061										
LAB062	1.305				0.255	25.02		11.255		0.235
LAB063										
LAB064	1.47	0.029		0.008	0.22	24.16		11.64	< 10.00	0.23
LAB065	0.658	0.021								
LAB066										
LAB067										
LAB068	1.603				0.262	25.017		10.53		0.259
LAB069	1.326	0.026		< 0.010	0.197			11.105		0.213
LAB070		0.044		0.009						
LAB071										
LAB072										
LAB073										
LAB074										
LAB075				0.017	0.214					0.228
LAB076		0.022		0.008						
LAB077	1.541					23.848		11.359		
LAB078										
LAB079	1.402	0.029		0.012	0.174	26		10.61		0.22
LAB080										
LAB081										
LAB082	1.525	0.03		< 0.010	0.23	25.545		12.04		0.22
LAB083	1.576	0.058			0.242	25.125		12.853		0.203

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 1 of 2020. 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 assays were done for certain analytes, upon the request of the client. 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.

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)	ν (Degrees of Freedom)	k (Coverage Factor)	u (Standard Uncertainty)	95% Measurement Uncertainty	Expanded Uncertainty
Ag	g/t	1.861	13	2.160	0.569	± 1.1	± 1.3
Al	%	0.125	21	2.080	0.033	± 0.07	± 0.07
As	ppm	55.662	13	2.160	10.753	± 22	± 23
Au	g/t	0.629	8	2.306	0.206	± 0.41	± 0.48
Bi	%	0.006	7	2.365	0.006	± 0.013	± 0.015
Ca	%	0.062	23	2.069	0.015	± 0.03	± 0.03
Co	%	0.004	20	2.086	0.001	± 0.002	± 0.002
Cu	%	0.349	49	2.010	0.058	± 0.12	± 0.12
Cu (Soluble)	%	0.248	14	2.145	0.083	± 0.17	± 0.18
Fe	%	0.727	29	2.045	0.163	± 0.33	± 0.34
Mg	%	0.128	23	2.069	0.031	± 0.06	± 0.07
Mn	%	0.007	21	2.080	0.002	± 0.004	± 0.004
Mo	%	0.068	11	2.201	0.023	± 0.05	± 0.05
Ni	%	0.004	20	2.086	0.001	± 0.002	± 0.002
Pb	%	0.019	21	2.080	0.006	± 0.01	± 0.01
S	%	1.24	18	2.101	0.327	± 0.65	± 0.69
Se	ppm	17.503	7	2.365	7.794	± 16	± 19
Si	%	0.791	19	2.093	0.238	± 0.48	± 0.50
Zn	%	0.016	21	2.080	0.004	± 0.008	± 0.008

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	29 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.

END