

QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

QCRM-1-154

CHROME ORE

CERTIFICATE OF ANALYSIS

| CERTIFIED VALUES | | | |
|--|-------|----------------|----------------------|
| ANALYTES | UNITS | CONCENTRATIONS | EXPANDED UNCERTAINTY |
| Al ₂ O ₃ | % | 14.69 | ±0.12 |
| CaO | % | 0.35 | ±0.05 |
| Cr ₂ O ₃ | % | 39.19 | ±0.18 |
| FeO | % | 25.90 | ±0.23 |
| MgO | % | 10.09 | ±0.11 |
| P | % | 0.004 | ±0.002 |
| S | % | 0.010 | 0.004 |
| SiO ₂ | % | 5.51 | ±0.08 |
| ASSIGNED VALUES (FOR INFORMATION ONLY) | | | |
| ANALYTES | UNITS | CONCENTRATIONS | EXPANDED UNCERTAINTY |
| MnO | % | 0.22 | ±0.01 |
| TiO ₂ | % | 0.96 | ±0.04 |
| V ₂ O ₅ | % | 0.34 | ±0.11 |

1. Use:

QCRM-1-154 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 Chrome ore and as a calibration standard for the calibration of equipment used for analyzing similar materials.

2. Origin of Material:

This standard was sponsored by Glencore Boshhoek Smelter.

3. Mineral and Chemical Composition:

Chromite is found as orthocumulate lenses of chromitite in peridotite from the Earth's mantle. It also occurs in layered ultramafic intrusive rocks. In addition, it is found in metamorphic rocks such as some serpentinites. Ore deposits of chromite formed as early magmatic differentiates. It is commonly associated with olivine, magnetite, serpentine, and corundum. The vast Bushveld igneous complex of South Africa is a large layered mafic to ultramafic igneous body with some layers consisting of 90% chromite making the rare rock type. The ore originates from Glencore Mining operations in the Western Limb of the Bushveld complex.

4. Date of Initial Issue:

10 March 2020.

5. Packaging & Handling instructions:

The material is packaged as 100g 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:

- Sodium peroxide fusion with ICP-OES finish
- Sodium peroxide fusion with Auto/Manual Titration
- Fused beads with XRF finish
- Pressed pellet 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 Al_2O_3 , C, CaO, Cr_2O_3 , FeO, MgO, MnO, P, S, SiO_2 , TiO_2 and V_2O_5 .

9. Participating Laboratories:

| NO | LABORATORY | COUNTRY |
|-----|--------------------------------|--------------|
| 1. | AHK North West | South Africa |
| 2. | AHK Richards Bay | South Africa |
| 3. | AHK Steelpoort | South Africa |
| 4. | ALS Geochemistry | South Africa |
| 5. | ALS Inspection Richards Bay | South Africa |
| 6. | ALS SAIL - Limpopo | South Africa |
| 7. | Chromtech | South Africa |
| 8. | Cotecna Richards Bay | South Africa |
| 9. | Dwarsrivier Chrome Mine | South Africa |
| 10. | Glencore Boshhoek | South Africa |
| 11. | Glencore Eastern Mines | South Africa |
| 12. | Glencore Kroondal | South Africa |
| 13. | Glencore Lion | South Africa |
| 14. | Glencore Lydenburg Smelter | South Africa |
| 15. | Glencore Rustenburg Smelter | South Africa |
| 16. | Glencore UG2 Alloys | South Africa |
| 17. | Intertek JHB | South Africa |
| 18. | Intertek Steelpoort | South Africa |
| 19. | Mitra Sk South Africa | South Africa |
| 20. | Nkomati JV | South Africa |
| 21. | PCL Rustenburg | South Africa |
| 22. | PCL Steelpoort | South Africa |
| 23. | Quality Laboratory Services | South Africa |
| 24. | Samancor Dikwena | South Africa |
| 25. | Samancor Tubatse Alloy Smelter | South Africa |
| 26. | SGS Richards Bay | South Africa |
| 27. | Zimasco Kwekwe | Zimbabwe |
| 28. | Zimbabwe Alloys Chrome | Zimbabwe |
| 29. | Zimlabs (GNK Laboratories) | Zimbabwe |

10. Assay Data:

Data used for Assigning Values and Certification.

| Laboratory | Al ₂ O ₃ | C | CaO | Cr ₂ O ₃ | FeO | MgO | MnO | P | S | SiO ₂ | TiO ₂ | V ₂ O ₅ |
|------------|--------------------------------|-------|-------|--------------------------------|--------|--------|-------|---------|-------|------------------|------------------|-------------------------------|
| Unit | % | % | % | % | % | % | % | % | % | % | % | % |
| LAB001 | 14.37 | | 0.388 | 39.498 | 26.01 | 10.164 | | | 0.01 | 5.743 | | |
| LAB002 | 14.715 | | 0.288 | | 26.635 | 10.088 | | | | 5.511 | | |
| LAB003 | 14.658 | | 0.86 | 39.155 | 26.075 | 9.967 | 0.226 | 0.009 | 0.01 | 5.665 | 0.947 | 0.305 |
| LAB004 | | | | 39.138 | | | | | | | | |
| LAB005 | 14.947 | | 0.545 | 39.212 | 26.181 | 10.13 | | | | 5.658 | 0.935 | |
| LAB006 | | | | 39.386 | | | | | | | | |
| LAB007 | 14.79 | | | 38.98 | 25.065 | 9.835 | | 0.002 | | 5.1 | 0.92 | |
| LAB008 | | | | 39.38 | | | | | | | | |
| LAB009 | | 0.067 | | 39.085 | | | | | | | | |
| LAB010 | | | | 38.3 | 25.169 | | | | | 5.495 | | |
| LAB011 | 14.745 | | 0.39 | 39.365 | 26.21 | 10.015 | | 0.001 | 0.004 | 5.44 | | |
| LAB012 | 14.704 | | 0.36 | 39.092 | 25.462 | 10.102 | 0.218 | | | 5.494 | | |
| LAB013 | | | | 38.674 | | | | | | | | |
| LAB014 | 14.78 | | 0.295 | 38.995 | 25.67 | 9.865 | 0.21 | | | 5.275 | 0.958 | 0.35 |
| LAB015 | 14.235 | | 0.27 | 38.535 | 25.715 | | 0.22 | | | | | |
| LAB016 | | | | 38.77 | | | | | | | | |
| LAB017 | 14.444 | | 0.393 | 39.277 | 25.971 | 10.047 | | | | 5.521 | | |
| LAB018 | | | | 38.927 | | | | | | | | |
| LAB019 | 14.82 | | 0.325 | 39.53 | 26.03 | 10.105 | | 0.004 | 0.01 | 5.545 | | |
| LAB020 | 14.31 | | | 39.1 | 25.64 | 9.975 | | | | 5.465 | | |
| LAB021 | 14.795 | | 0.31 | | 27.645 | 10.98 | | | | 5.675 | | |
| LAB022 | 14.995 | | 0.36 | 39.71 | 26.395 | 10.225 | | 0.003 | | 5.625 | | |
| LAB023 | 14.5 | | 0.66 | 39.04 | 26.31 | 10.52 | | 0.005 | 0.006 | 5.455 | | |
| LAB024 | | | | 39.14 | | | | | | 5.43 | | |
| LAB025 | 14.854 | | | 39.428 | 25.776 | 9.959 | | | | 5.423 | | |
| LAB026 | 14.729 | 0.129 | 0.35 | 39.698 | 26.208 | 10.219 | | 0.003 | 0.013 | 5.649 | 0.989 | |
| LAB027 | 14.705 | 0.079 | 0.39 | 39.28 | 25.99 | 9.965 | | 0.004 | 0.007 | 5.51 | | |
| LAB028 | | | | 39.3 | | | | | | | | |
| LAB029 | | | | 38.355 | | | | | | | | |
| LAB030 | | | | | 25.5 | | | | | | | |
| LAB031 | 14.841 | | 0.829 | 39.662 | 26.129 | 10.278 | 0.223 | 0.004 | | 5.591 | 0.97 | 0.274 |
| LAB032 | | | | 39.72 | | | | | | | | |
| LAB033 | | | | 40.4 | 25.45 | 10.325 | | | 0.016 | | | |
| LAB034 | 14.479 | | | 39.307 | 25.971 | 10.025 | 0.209 | | 0.012 | 5.021 | 0.93 | 0.319 |
| LAB035 | 15.172 | | 0.294 | 39.338 | 25.895 | 10.294 | 0.23 | 0.003 | 0.009 | 5.572 | 0.998 | 0.439 |
| LAB036 | 14.62 | 0.01 | 0.345 | 38.88 | 25.798 | 9.96 | 0.22 | < 0.010 | 0.09 | 5.475 | 0.975 | |
| LAB037 | | | | 38.885 | | | | | | | | |

11. Method of Certification:

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

This material was distributed as test items, in the Qotho Chrome PT round 1 of 2020. Twenty-nine of the participating laboratories were each given 1 randomly selected sample from the batch, to analyze and report on in duplicate. Some laboratories reported results via more than one analytical method. The data was collated, after which it was processed using Robust Statistics, through PROLab Plus.

Not all the participating laboratories were accredited. Equivalence tests were performed on all analytes to determine whether the data from the accredited and non-accredited laboratories, can be treated as equal (at a level of significance of $\alpha = 0.05$). Where equivalent, all the data was used. Where not, only the data from the accredited laboratories were considered. Certification of analytes were then done, provided that a minimum of 10 datapoints remained available.

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

12. Measurement of Uncertainty:

Measurement 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, QLS further applies an expanded uncertainty, for certification purposes. $UCRM = k u_{CRM}$, 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: $x_{CRM} \pm UCRM$.

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

For laboratories 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 | ν (degrees of freedom) | k (coverage factor) | u (standard error) | 95% measurement uncertainty | Expanded Uncertainty |
|--------------------------------|-----------------|-------------------------------|--------------------------|-------------------------|-----------------------------|----------------------|
| Al ₂ O ₃ | % | 21 | 2.080 | 0.056 | ± 0.11 | ± 0.12 |
| CaO | % | 17 | 2.110 | 0.024 | ± 0.05 | ± 0.05 |
| Cr ₂ O ₃ | % | 33 | 2.035 | 0.085 | ± 0.17 | ± 0.18 |
| FeO | % | 24 | 2.064 | 0.110 | ± 0.22 | ± 0.23 |
| MgO | % | 21 | 2.080 | 0.052 | ± 0.10 | ± 0.11 |
| MnO | % | 7 | 2.365 | 0.004 | ± 0.01 | ± 0.01 |
| P | % | 10 | 2.228 | 0.001 | ± 0.002 | ± 0.002 |
| S | % | 10 | 2.228 | 0.002 | ± 0.004 | ± 0.004 |
| SiO ₂ | % | 22 | 2.074 | 0.035 | ± 0.07 | ± 0.08 |
| TiO ₂ | % | 8 | 2.306 | 0.015 | ± 0.03 | ± 0.04 |
| V ₂ O ₅ | % | 4 | 2.776 | 0.039 | ± 0.08 | ± 0.11 |

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. Most laboratories reported on the QA/QC CRM's used during the analysis of this QRM and reported the values obtained during the sample run. This provides additional evidence of measurement traceability.

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 have been 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 Laboratory Services, 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/Analytical Report.

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|----------------------------------|----------------------|
| Certifying & Technical Signatory | |
| <i>Dr Hannelie de Beer</i> | |
| Qotho Managing Director | 10 March 2020 |

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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