



African Mineral Standards

MATRIX REFERENCE MATERIALS

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AMIS0394

Certified Reference Material

**Ferrochrome Alloy, WKP LX Grade,
Witkopen Mine, Bushveld, South Africa**

Certificate of Analysis

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

Certified Concentrations²

Cr FUS	47.58	±	4.32	%
C Comb/LECO	7.10	±	0.65	%
Fe FUS	36.08	±	3.90	%

Provisional Concentrations

Fe M/ICP	35.09	±	5.38	%
Ti M/ICP	0.51	±	0.06	%

Informational Mean

Al M/ICP	0.105	±	0.04	%
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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 element data presented as an appendix.

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

Provisional Concentrations

TiO ₂	0.86	%
Fe ₂ O ₃	51.25	%

Informational Mean

Al ₂ O ₃	0.20	%
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1. Intended Use: AMIS0394 is a certified reference material which may be used to demonstrate the validity of measurement results of a single analysis of chrome ore derived from mafic rocks 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: This standard was made using WKP LX grade material supplied by Glencore Xstrata plc from the Witkop Chrome Mine. The mine is situated on the Western Limb of the Bushveld Complex 12km south east of Rustenburg in the North West Province of South Africa.

The source material is a ferrochrome alloy produced from smelting LG6 and UG2 chromite ore concentrates in a conventional submerged arc smelting operation. From the molten alloy state, this particular sample was cast and crushed into a lump size product originally 10x100mm in size.

3. Mineral and Chemical Composition: The alloy has main phases of (Cr,Fe)₇C₃, (Cr,Fe)₂₃C₆, traces(Fe,Cr)₃C carbides, Cr containing α-Fe, Cr-Si and traces of S, P, along with minor (<0,5%) amounts of Mn, V, Ti – all species are present in alloy form.

It is not naturally occurring but an artefact of Pyrometallurgical processing of chromite ore to yield ferrochrome alloy and associated oxide slag phase. The sample is from the former.

Major element chemistry data from twelve of the labs has been compiled and certified. Uncertified summary statistics for trace element data are set out in the appendix.

4. **Appearance:** The material is a very fine powder. It is colored Dark Gray.
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 <54um. Wet sieve particle size analysis of random samples confirmed the material was 98.5% <54um. 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 scientifically selected for homogeneity testing and third-party analysis. Statistical analysis of both homogeneity and the consensus test results were carried out by independent statisticians.
7. **Methods of Analysis requested:**
 1. Multi element scan. Multi-acid total digestion, including HF, ICP-OES or ICP-MS.
 2. Sodium Peroxide Fusion, Cr, Si, Fe, Al, Mg, Ti, P, V - ICP-OES or ICP-MS.
 3. Majors (Al₂O₃, CaO, Cr₂O₃, Fe₂O₃, K₂O, MgO, MnO, Na₂O, P₂O₅, SiO₂, TiO₂. LOI.) XRF fusion.
 4. 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.
 4. All results for base metals to be reported in ppm.
 5. Report all QC data, to include replicates, blanks and certified reference materials used.
9. **Method of Certification:** Thirty laboratories were each given eight scientifically selected packages of sample. Fifteen of the laboratories submitted results in time for the certification.

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: The 15 out of 30 laboratories that provided results timeously were (not in same order as in the table of assays)

- 1 Activation Laboratories Pty Ltd (ActLabs) CA
- 2 Assmang Machadodorp
- 3 BV Rustenburg (South Africa)
- 4 Dwarsrivier Mine
- 5 Genalysis Laboratory Services (W Australia P)
- 6 GNK Laboratories (Pvt) Ltd
- 7 Intertek Utama Services (Indonesia)
- 8 Labtium Inc Finland
- 9 Set Point Laboratories (Isando) SA
- 10 SGS Australia Pty Ltd (Newburn) WA
- 11 SGS Geosol Laboratories Ltda (Brazil)
- 12 SGS Mineral Services Lakefield (Canada)
- 13 SGS South Africa (Pty) Ltd - Booysens JHB
- 14 Suntech Geometallurgical SA
- 15 Xstrata Wonderkop

11. Assay Data: Data as received from the laboratories for the important certified elements listed on p1 are 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.

Assay data

Lab Code	Cr FUS %	C Comb/LECO %	Al M/ICP %	Fe FUS %	Fe M/ICP %	Ti M/ICP %	Al ₂ O ₃ XRF %	Fe ₂ O ₃ XRF %	TiO ₂ XRF %
B		7.00	0.13		37.10		0.25	53.04	
B		7.00	0.13		37.10		0.25	53.04	
B		7.00	0.14		37.40		0.26	53.47	
B		7.10	0.13		37.10		0.25	53.04	
B		7.00	0.14		37.10		0.26	53.04	
B		7.10	0.13		37.30		0.24	53.33	
B		7.10	0.13		37.30		0.25	53.33	
B		7.10	0.13		37.10		0.25	53.04	
E		6.95	0.09	34.20	32.00	0.46	0.16	45.75	0.77
E		6.94	0.09	31.80	32.40	0.47	0.16	46.32	0.78
E		6.97	0.09	32.40	33.80	0.47	0.18	48.32	0.78
E		6.96	0.09	33.80	33.10	0.47	0.17	47.32	0.78
E		6.93	0.10	32.80	33.60	0.47	0.19	48.04	0.79
E		6.96	0.09	33.60	32.10	0.47	0.17	45.89	0.78
E		6.92	0.09	33.10	31.90	0.45	0.17	45.61	0.76
E		6.98	0.09	35.60	33.10	0.44	0.16	47.32	0.73
H	50.30	7.65		36.70			0.21	56.76	
H	50.10	7.67		36.80			0.19	54.61	
H	50.10	7.66		37.70			0.19	54.04	
H	49.50	7.60		35.60			0.21	53.61	
H	49.60	7.73		36.30			0.19	54.19	
H	50.40	7.62		35.90			0.19	53.18	
H	50.60	7.61		36.50			0.19	56.76	
H	50.70	7.60		36.30			0.19	56.04	
J	47.50	7.11	0.11	36.70	39.70	0.51	0.32	53.21	0.85
J	48.10	7.15	0.10	37.90	38.20	0.49	0.25	53.16	0.82
J	47.90	7.13	0.10	37.40	37.80	0.50	0.25	52.88	0.83
J	49.70	7.09	0.11	38.50	37.50	0.49	0.25	53.87	0.82
J	47.70	7.09	0.10	37.20	37.90	0.49	0.25	53.06	0.82
J	48.40	7.10	0.10	38.00	37.20	0.48	0.25	52.78	0.80
J	48.60	7.10	0.10	37.30	39.70	0.49	0.25	53.04	0.82
J	49.10	7.10	0.10	38.10	39.20	0.50	0.25	53.67	0.83

Assay Data (cont)

Lab Code	Cr FUS %	C Comb/LECO %	Al M/ICP %	Fe FUS %	Fe M/ICP %	Ti M/ICP %	Al ₂ O ₃ XRF %	Fe ₂ O ₃ XRF %	TiO ₂ XRF %
K	56.39			38.95					
K	54.59			36.86					
K	50.08			32.41					
K	42.46			28.14					
K	46.10			30.51					
K	47.77			31.80					
K	48.42			32.09					
K									
L	48.13			39.42					
L	48.58			39.46					
L	47.96			39.39					
L	48.31			39.84					
L	48.46			39.83					
L	47.52			40.04					
L	48.38			40.38					
L	46.98			39.38					
M		7.01	0.17		37.22	0.53	0.21	43.02	0.88
M		6.98	0.13		37.18	0.54	0.19	42.86	0.90
M		6.98	0.13		36.99	0.53	0.21	45.15	0.88
M		6.98	0.13		37.68	0.53	0.23	43.08	0.88
M		6.98	0.13		37.11	0.53	0.21	41.69	0.88
M		6.95	0.13		36.92	0.54	0.23	42.26	0.90
M		6.97	0.13		37.10	0.54	0.19	42.55	0.90
M		6.91	0.13		37.54	0.54	0.21	44.39	0.90
N	42.33	7.58	0.11	34.61	30.09	0.48	0.17	49.47	0.80
N	43.80	7.62	0.10	36.12	29.98	0.49	0.20	49.39	0.82
N	44.33	7.62	0.11	36.31	31.58	0.53	0.20	49.23	0.88
N	44.41	7.60	0.12	36.25	30.13	0.49	0.20	49.21	0.82
N	44.31	7.59	0.11	36.22	29.16	0.50	0.19	49.12	0.83
N	43.98	7.62	0.12	35.81	29.56	0.46	0.17	48.98	0.77
N	45.06	7.61	0.10	36.83	29.76	0.46	0.20	49.15	0.77
N	45.11	7.59	0.11	36.53	31.05	0.49	0.16	49.08	0.82
S		6.83							
S		6.92							
S		7.00							
S		6.95							
S		7.03							
S		6.90							
S		6.83							
S		6.83							
T			0.10		33.00	0.49	0.18	53.04	0.90
T			0.08		33.60	0.49	0.20	52.90	0.94
T			0.07		33.30	0.49	0.19	52.33	0.92
T			0.10		33.10	0.48	0.15	52.47	0.92
T			0.06		33.10	0.48	0.14	52.47	0.93
T			0.07		32.90	0.44	0.16	52.61	0.92
T			0.07		34.00	0.49	0.14	53.47	0.92
T			0.06		33.30	0.49	0.18	53.61	0.90

Assay data (cont)

Lab Code	Cr FUS %	C Comb/LECO %	Al M/ICP %	Fe FUS %	Fe M/ICP %	Ti M/ICP %	Al ₂ O ₃ XRF %	Fe ₂ O ₃ XRF %	TiO ₂ XRF %
U	49.00			34.40					
U	49.10			34.80					
U	49.00			34.60					
U	49.20			34.40					
U	49.00			34.40					
U	49.20			34.30					
U	49.00			34.50					
U	49.00			34.70					
V	37.22	7.01							
V	37.18	6.98							
V	36.99	6.97							
V	37.68	6.96							
V	37.11	6.96							
V	36.92	6.96							
V	37.10	6.96							
V	37.54	6.95							
ZA		6.54							
ZA		6.41							
ZA		6.38							
ZA		6.50							
ZA		6.33							
ZA		6.44							
ZA		6.48							
ZA		6.67							
ZB			0.10		37.10	0.54	0.19	47.71	0.91
ZB			0.11		37.00	0.54	0.19	47.95	0.90
ZB			0.10		36.60	0.53	0.17	46.37	0.89
ZB			0.08		36.70	0.53	0.18	48.14	0.88
ZB			0.07		36.70	0.54	0.19	49.00	0.89
ZB			0.08		36.80	0.53	0.19	49.67	0.89
ZB			0.08		37.40	0.55	0.20	50.38	0.91
ZB			0.09		37.50	0.55	0.19	49.27	0.91
ZC	43.81		0.10	34.12	33.37	0.52			0.87
ZC	43.93		0.10	34.97	33.54	0.52			0.87
ZC	45.98		0.09	34.38	32.43	0.51			0.85
ZC	45.09		0.09	34.40	33.67	0.52			0.86
ZC	44.60		0.10	34.92	34.27	0.53			0.89
ZC	44.86		0.10	35.05	34.74	0.53			0.88
ZC	44.49		0.10	34.67	35.24	0.54			0.91
ZC	45.09		0.10	35.44	34.46	0.53			0.88

12. Measurement of Uncertainty : (ref Dr Hugh Bartlett, Hugh Bartlett Consulting CC.)

The samples used in this certification process have been 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
Cr	FUS	%	2.161	2.207	0.676	0.906
C	Comb/LECO	%	0.327	0.304	0.041	0.107
Al	M/ICP	%	0.019	0.023	0.007	0.009
Fe	FUS	%	1.948	2.364	0.626	0.969
Fe	M/ICP	%	2.692	3.592	0.616	1.468
TiO ₂	M/ICP	%	0.028	0.035	0.012	0.016
Al ₂ O ₃	XRF	%	0.032	0.038	0.011	0.016
TiO ₂	XRF	%	0.052	0.074	0.020	0.033
Fe ₂ O ₃	XRF	%	2.930	4.210	0.820	1.886

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 Std 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 Ms Margaret M. Fairhurst

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 and who have maintained measurement traceability during the analytical process.

15. Certification: AMIS0394 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 and a 30g sample size for the fire assay. These are the recommended minimum sample sizes 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 50 to 250g) of material. The Laboratory Packs are sealed bottles delivered in sealed foil pouches. The Explorer Packs contain material in standard geochem envelopes, nitrogen flushed, and 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, Margaret M. Fairhurst; accept no liability for any decisions or actions taken following the use of the reference material.

Date of Version v0.01: 26 March 2019

Version: v0.01

Reason for Version v0.01: Correction of content sequential numbering.

Version v0.01 replaces the original report of AMIS0394 Certification

Version 00

11 February 2014

Certifying Officers:



African Mineral Standards: _____

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



Geochemist: _____

Margaret M. Fairhurst, PG, MAusIMM, Oreval

Appendix – uncertified element statistics

Analyte	Method	Unit	Mean	2SD	RSD%	n
Al	Fus	ppm	0.14	0.07	24.3	38
Ag	F	ppm	2.3	4.6	100	17
As	M/ICP	ppm	13.2	20.2	76.4	31
Ba	M/ICP	ppm	2.3	0.93	20.6	8
Bi	M/ICP	ppm	0.15	0.05	16.9	8
Ca	M/ICP	ppm	0.03	0.02	25.2	16
CaO	XRF	ppm	0.07	0.10	73.8	24
Cd	M/ICP	ppm	0.78	1.0	63.9	12
Ce	M/ICP	ppm	0.49	0.20	20.0	16
Cr	M/ICP	ppm	48.1	5.2	5.4	30
Cr	XRF	%	48.4	2.5	2.6	19
Cr2O3	XRF	ppm	70.5	5.3	3.8	36
Eu	M/ICP	ppm	0.08	0.05	31.2	8
Ga	M/ICP	ppm	75.0	7.8	5.2	23
Ge	M/ICP	ppm	1.1	2.0	96.5	16
Hf	M/ICP	ppm	0.06	0.03	26.4	9
K2O	XRF	ppm	0.02	0.01	20.6	8
La	M/ICP	ppm	0.36	0.10	14.5	16
Li	M/ICP	ppm	0.32	0.29	46.5	6
Mg	Fus	ppm	0.08	0.04	25.7	45
Mg	M/ICP	%	0.06	0.02	14.5	46
MgO	XRF	%	0.10	0.03	16.8	40
Mn	M/ICP	ppm	2566	662	12.9	40
MnO	XRF	ppm	0.35	0.06	8.3	40
Mo	M/ICP	ppm	8.5	11.1	65.2	24
Na2O	XRF	ppm	0.06	0.0	4.1	8
Nb	M/ICP	ppm	10117	35587	176	32
Nd	M/ICP	ppm	0.15	0.10	33.7	15
P	Fus	ppm	202	216	53.4	24
P	M/ICP	ppm	118	96.0	40.6	48
Pb	M/ICP	ppm	6.0	4.9	40.8	4
P2O5	XRF	ppm	0.04	0.01	19.8	39
Pr	M/ICP	ppm	0.06	0.01	9.2	8
Rb	M/ICP	ppm	2.3	3.0	65.3	23
S	M/ICP	ppm	0.05	0.01	12.9	32
S	Comb/LECO	ppm	0.06	0.01	6.5	44
Sb	M/ICP	ppm	1.2	1.6	68.4	25
Sc	M/ICP	ppm	7.1	0.55	3.9	7
Si	FUS	ppm	3.9	0.15	1.8	46
Si	M/ICP	%	3.9	0.20	2.5	24
SiO2	XRF	ppm	8.4	0.39	2.3	32
SG	pycnometer	ppm	6.9	0.32	2.3	27
Se	M/ICP	ppm	17.3	13.9	40.2	16
Sn	M/ICP	ppm	2.3	0.86	18.7	24
Sr	M/ICP	ppm	6.7	12.2	91.1	16
Ta	M/ICP	ppm	0.36	0.10	14.3	23
Te	M/ICP	ppm	3.5	12.2	176	25
Th	M/ICP	ppm	0.06	0.01	7.7	10
Ti	Fus	ppm	0.56	0.05	4.7	48
Tl	M/ICP	ppm	103	152	73.9	12
U	M/ICP	ppm	59.1	208	176	32
V	M/ICP	ppm	3303	1074	16.3	48
V	Fus	ppm	3549	1038	14.6	46
W	M/ICP	ppm	3.2	8.6	134	29
Y	M/ICP	ppm	0.63	1.7	133	30
Zn	M/ICP	ppm	34.1	20.7	30.3	24
Zr	M/ICP	ppm	4.6	1.3	13.9	17