



African Mineral Standards

MATRIX REFERENCE MATERIALS

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AMIS0392

Certified Reference Material

**Ferrochrome alloy (LYD GX Grade),
Kroondal Mine, Bushveld, South Africa**

Certificate of Analysis

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

Certified Concentrations²

Cr Fus	50.1	±	3.50	%
Si Fus	2.01	±	0.15	%
Fe Fus	36.81	±	2.15	%
Ti Fus	0.409	±	0.041	%

Provisional Concentration

V Fus	3346	±	437	ppm
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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 uncertified element data presented as an appendix.

- 1. Intended Use:** AMIS0392 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 LYD GX grade material supplied by Glencore Xstrata plc from the Kroondal 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 MG1 chromite ore concentrate in a conventional submerged arc smelting operation. From the molten alloy state, this particular sample was granulated – a standard process whereby the molten alloy is rapidly cooled to ambient temperature in a stream of fast moving water

- 3. Mineral and Chemical Composition:** The alloy has main phases of $(Cr,Fe)_7C_3$, $(Cr,Fe)_{23}C_6$, 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.

- 4. Appearance:** The material is a very fine powder. It is colored Dark Grey.
- 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. Sodium Peroxide Fusion, Cr, Si, Fe, Al, Mg, Ti, P, V - ICP-OES or ICP-MS.
2. Multi element scan. Multi-acid total digestion, including HF, ICP-OES or ICP-MS.

3. C & S, combustion analysis.
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: Twenty nine laboratories were each given eight scientifically selected packages of sample. Fourteen 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 14 out of 29 laboratories that provided results timeously were (not in same order as in the table of assays):

1. Activation Laboratories Pty Ltd (ActLabs) CA
2. ALS Chemex Laboratory Group Johannesburg SA
3. BV Rustenburg (South Africa)
4. Genalysis Laboratory Services (W Australia P)
5. GNK Laboratories (Pvt) Ltd
6. Labtium Inc Finland
7. Set Point Laboratories (Isando) SA
8. SGS Australia Pty Ltd (Newburn) WA
9. SGS Geosol Laboratories Ltda (Brazil)
10. SGS Mineral Services Lakefield (Canada)
11. SGS South Africa (Pty) Ltd - Booysens JHB
12. Suntech Geometallurgical SA
13. Xstrata Eland Mine
14. 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 %	Fe Fus %	Si Fus %	Ti Fus %	V Fus ppm
A		36.9	2.00	0.40	3368
A		35.8	2.00	0.40	3355
A		36.7	2.00	0.40	3372
A		36.6	2.00	0.40	3399
A		37.6	2.10	0.40	3415
A		37.0	2.00	0.40	3407
A		38.2	2.10	0.40	3440
A		38.9	2.00	0.40	3398
H	48.0	36.4	1.93	0.39	3250
H	47.7	36.3	1.80	0.39	3240
H	48.4	36.7	1.92	0.40	3280
H	47.6	35.9	1.87	0.39	3200
H	47.7	36.2	1.84	0.39	3250
H	47.8	36.3	1.89	0.39	3230
H	47.1	35.6	1.86	0.38	3170
H	47.9	36.3	1.92	0.39	3250
I	50.5	37.4	2.00	0.43	3800
I	50.4	37.4	2.00	0.43	3800
I	50.7	37.2	1.90	0.43	3800
I	50.4	37.3	2.00	0.43	3800
I	50.5	37.2	1.90	0.44	3800
I	50.5	37.2	2.00	0.43	3800
I	50.5	37.2	2.00	0.44	3900
I	50.4	37.3	2.00	0.42	3700
L		36.1	2.20	0.42	3680
L		35.0	2.10	0.41	3570
L		35.6	2.00	0.39	3290
L		34.5	2.00	0.39	3360
L		35.0	2.00	0.40	3460
L		34.7	2.00	0.39	3490
L		34.8	2.00	0.39	3350
L		35.8	2.10	0.40	3310
N				0.42	3132
N				0.42	3125
N				0.42	3085
N				0.42	3079
N				0.41	3060
N				0.41	3086
N				0.42	3091
N				0.42	3090
O	50.7	36.5			
O	53.1	39.1			
O	53.2	37.8			
O	53.8	38.1			
O	52.3	37.5			
O	50.1	36.3			
O	51.5	37.3			
O	50.1	36.7			

Assay Data (cont)

Lab Code	Cr Fus %	Fe Fus %	Si Fus %	Ti Fus %	V Fus ppm
R	48.7	37.6	2.16	0.39	3550
R	48.8	37.7	2.18	0.37	3650
R	49.2	37.5	2.15	0.39	3450
R	48.9	37.6	2.13	0.37	3500
R	49.0	37.3	2.13	0.38	3550
R	49.2	37.7	2.09	0.39	3550
R	49.0	37.8	2.10	0.38	3550
R	48.9	37.5	2.05	0.37	3550
U	50.4	38.8	2.07	0.45	3200
U	49.1	37.8	1.97	0.43	3100
U	46.6	37.1	1.99	0.43	3100
U	49.2	37.7	1.96	0.44	3100
U	50.0	38.9	1.99	0.45	3200
U	52.2	40.1	2.15	0.46	3300
U	49.5	37.8	2.00	0.44	3100
U	48.2	37.3	1.96	0.43	3100
W	50.0				
W	49.9				
W	50.0				
W	50.0				
W	49.9				
W	49.9				
W	49.9				
W	49.9				
Z	51.3	37.7	2.04	0.44	3400
Z	49.2	36.1	1.94	0.42	3280
Z	48.6	35.8	1.96	0.42	3270
Z	49.4	36.4	1.96	0.42	3280
Z	48.9	35.9	1.93	0.42	3250
Z	49.8	36.7	1.97	0.43	3320
Z	49.2	36.5	1.92	0.42	3270
Z	48.9	36.0	1.91	0.42	3270
ZA		38.9			
ZA		38.5			
ZA		37.5			
ZA		38.5			
ZA		34.7			
ZA		34.1			
ZA		35.4			
ZA		35.6			
ZB	53.8	36.2	2.01	0.47	3020
ZB	54.7	35.9	2.04	0.47	3190
ZB	53.6	36.3	2.05	0.49	3083
ZB	53.5	36.6	2.05	0.48	2801
ZB	53.3	36.5	2.06	0.47	3364
ZB	53.3	35.9	2.08	0.42	3589
ZB	54.0	35.8	2.06	0.46	3030
ZB	53.1	35.5	2.08	0.42	3287
ZC	51.0	32.9	1.94		5324
ZC	50.3	31.6	1.92		4876
ZC	49.5	32.1	1.82		4634
ZC	44.3	28.8	1.63		4498
ZC	50.1	32.6	1.95		6418
ZC	48.2	31.3	1.74		4982
ZC	58.8	39.3	2.72		4902
ZC	53.1	35.1	2.06		4664

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	%	1.760	1.390	0.901	0.537
Fe	Fus	%	1.077	0.864	0.624	0.313
Si	Fus	%	0.073	0.065	0.047	0.025
Ti	Fus	%	0.020	0.020	0.007	0.007
V	Fus	ppm	218.4	218.1	65.4	77.5

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: AMIS0392 is a new material.

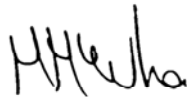
16. Period of validity: The certified values are valid for this product, while still sealed in its original packaging, until notification to the contrary. The stability of the material will be subject to continuous testing for the duration of the inventory. Should product stability become an issue, all 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.

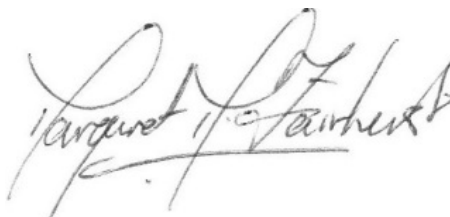
09 February 2015

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
Ag	M/ICP	ppm	3.1	5.0	79.8	13
Al	Fusion	%	0.08	0.02	11.8	40
Al	M/ICP	%	0.06	0.02	15.8	31
Al ₂ O ₃	XRF	%	0.23	0.16	34.9	16
As	M/ICP	ppm	14.4	20.3	70.3	32
Au	Pb Coll	g/t	0.07	0.02	13.3	14
Bi	M/ICP	ppm	0.09	0.06	32.9	14
C		%	7.6	0.8	5.0	40
Ca	M/ICP	%	0.03	0.02	32.8	24
CaO	XRF	%	0.08	0.12	71.6	16
Cd	M/ICP	ppm	0.64	1.2	95.0	16
Ce	M/ICP	ppm	0.60	0.06	5.3	15
Co	M/ICP	ppm	458	195	21.3	48
Cs	M/ICP	ppm	0.06	0.02	13.6	8
Cu	M/ICP	ppm	243	15.7	3.2	36
Dy	M/ICP	ppm	0.06	0.02	13.6	8
Er	M/ICP	ppm	0.10	0.12	64.0	13
Eu	M/ICP	ppm	0.10	0.11	54.7	15
Fe	M/ICP	%	35.1	6.2	8.9	32
Fe ₂ O ₃	XRF	%	49.8	9.0	9.0	16
Ga	M/ICP	ppm	76.7	20.5	13.4	24
Gd	M/ICP	ppm	0.07	0.02	17.1	8
Ge	M/ICP	ppm	0.34	0.41	60.7	15
Hf	M/ICP	ppm	0.08	0.02	11.4	8
Ho	M/ICP	ppm	0.05	0.01	9.7	6
In	M/ICP	ppm	0.04	0.02	21.5	8
La	M/ICP	ppm	0.35	0.08	11.5	16
Li	M/ICP	ppm	0.39	0.17	21.5	8
Lu	M/ICP	ppm	0.05	0.01	11.2	8
Mg	Fusion	%	0.10	0.03	13.0	48
Mg	M/ICP	%	0.09	0.01	6.4	32
MgO	XRF	%	0.10	0.11	56.7	16
Mn	M/ICP	ppm	2385	197	4.1	31
MnO	XRF	%	0.31	0.03	5.1	15
Mo	M/ICP	ppm	7.1	11.6	81.5	32
Nb	M/ICP	ppm	9.8	4.4	22.6	24
Nd	M/ICP	ppm	0.20	0.0	0.0	14
Ni	M/ICP	ppm	1496	363	12.1	45
P	Fusion	ppm	120	38.5	16.0	28
P	M/ICP	ppm	134	45.5	17.0	31
Pb	M/ICP	ppm	3.3	0.5	8.2	8
Pd	Pb Coll	g/t	0.16	0.04	13.7	15
Pr	M/ICP	ppm	0.08	0.04	28.2	16
Pt	Pb Coll	g/t	0.20	0.05	13.7	15
Rb	M/ICP	ppm	2.0	1.9	46.3	24
S	M/ICP	%	0.57	1.8	159.7	32
S	Comb/LECO	%	0.06	0.1	44.7	40
Sb	M/ICP	ppm	1.8	0.9	24.5	23
Sc	M/ICP	ppm	7.2	1.2	8.2	8
Se	M/ICP	ppm	23.3	20.3	43.6	16
SiO ₂	XRF	%	4.4	0.94	10.7	15
Sn	M/ICP	ppm	1.8	0.87	24.2	24
SG	pyc		7.0	0.21	1.5	44
Sr	M/ICP	ppm	0.8	0.27	17.2	8
Ta	M/ICP	ppm	0.51	0.39	38.3	24
Te	M/ICP	ppm	6.6	15.9	119.8	16
Th	M/ICP	ppm	0.23	0.09	20.6	8
Ti	M/ICP	%	0.39	0.05	7.1	32
TiO ₂	XRF	%	0.68	0.07	5.2	8
Tl	M/ICP	ppm	82.7	171	103	16
U	M/ICP	ppm	63.3	222	175	32
V	M/ICP	ppm	2814	508	9.0	32
W	M/ICP	ppm	3.7	9.5	129	28
Y	M/ICP	ppm	0.78	1.8	113	24
Zn	M/ICP	ppm	112	303	136	32
Zr	M/ICP	ppm	3.1	1.3	21.7	16