

# Certification Report of MAKR-NP-B01

Processing and certification of a microanalytical reference material including its way from magnetite crystals to Nano-Pellets



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## Abstract

The microanalytical certified reference material (CRM) MAKR-NP-B01 is designed for use by laboratories undertaking the determination of major and trace element mass fractions in magnetite minerals ( $\text{Fe}_3\text{O}_4$ ) and equivalent matrices with LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometry). The original magnetite crystals from the Kennedy Ridge in Australia were cleaned, crushed, and milled to a particle size of  $< 63 \mu\text{m}$ . This powder was subjected to a material-specific milling protocol, freeze-dried, homogenised, and split into batches, resulting in the material MAKR-NP. All batches are sufficient for approximately 1500 units, which should make it available for the foreseeable future. Batch number 1 was pressed, into 10 mm diameter nanoparticulate pressed powder pellets, without any binders using a programmable hydraulic press.

This report describes the selection, production, and characterisation of the material.

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## 1. Introduction

MAKR-NP is the abbreviation for **M**agnetite **A**ustralia **K**ennedy **R**idge **N**ano-**P**ellet. Magnetite is the 2<sup>nd</sup> most popular iron ore mineral due to its high iron content. As the name suggests magnetite is ferromagnetic meaning it can be attracted by a magnet and become permanently magnetised itself.

## 2. Starting Material

A total amount of 500 g magnetite crystals was purchased from a mineral dealership (Fig.1).



*Fig. 1 Photograph of magnetite crystals and the resulting Nano-Pellet.*

To verify the identity of the material in accordance with ISO 17034:2016<sup>[1]</sup> it was mineralogically investigated for habit, streak and breakage and magnetic properties and thusly identified as magnetite. Additionally, an X-ray diffraction (XRD) analysis was performed. The diffractogram confirms the identity (Fig.2).

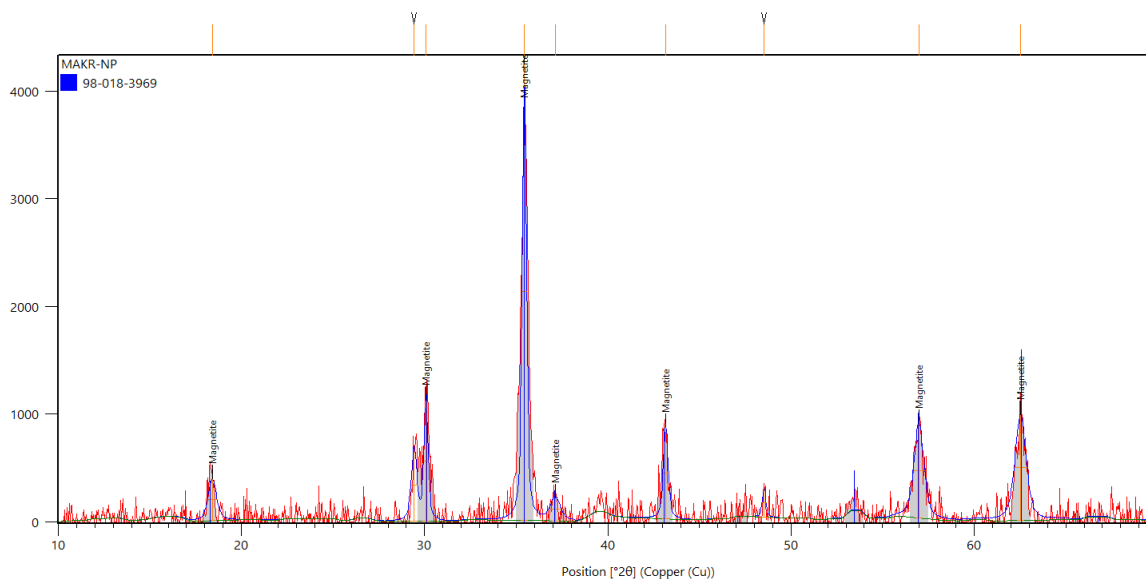


Fig. 2 X-ray diffractogram of powdered crystals confirming the identity as magnetite.

### 3. Sample Preparation

The first preparation step was removing dirt and dust using distilled water. Thereafter, the crystals were rinsed using deionised water (18.2 MΩ resistivity) and dried in a laminar flow hood.

Approximately 500 g of the cleaned crystals were crushed manually in an agate pestle and mortar to a particle-size < 2 mm. These fragments were then milled in an agate planetary ball mill to a particle size of < 63 µm.

The final grinding step was performed using our patented milling technique. The resulting slurry was freeze-dried, homogenised in a mixer-mill, and split into batches of about 10 g using a rotary sample splitter and filled into hydrolytic class 1 glass vials for storage. A total of 39 batches was prepared, 14 of which were used for the analyses.

Finally, batch number 1 (B01) was pressed into Nano-Pellets (10 mm diameter) resulting in a total of 63 units.

## 4. Homogeneity & Stability Testing

The homogeneity test was performed on the pellets (final packaged form). For this purpose, the samples were taken according to a random stratified sampling strategy. The number of units recommended to perform a homogeneity study are outlined in ISO Guide 35:2017<sup>[2]</sup>. For batches < 100 units it is suggested to test 10 % of the batch for homogeneity. In this case 10 % of 63 units is 6.3, which is rounded up to 7 units.

Homogeneity testing was performed adapting a procedure from the ASTM Guide E-826-14<sup>[3]</sup>. To transfer this procedure to LA-ICP-MS, the pellet surface was divided into seven analytical zones (Fig. 3). However, instead of making three repeated measurements on the same spot, three repeated measurements in close proximity were made (n=21). In total the homogeneity test is comprised of 105 spot measurements. The three results (a, b, c) in each analytical zone are then averaged, so each pellet contributes 7 results for the calculation of the uncertainty component pertaining to homogeneity. The resulting data were reduced using the software LADR (Norris Scientific Pty. Ltd.). The uncertainty component resulting from homogeneity was calculated following Annex C.1 in ISO Guide 35:2017.

Stability and its uncertainty component were assessed and calculated following Annex E.2 in ISO Guide 13528:2015<sup>[4]</sup>. Therefore, two randomly chosen pellets were placed in an oven at 60 °C for 8 h to simulate shipping in the back of a warm delivery vehicle. This assesses short-term stability. Long-term stability will be assessed in intervals of 4, 8 and 12 months. After successful assessment the stability will be monitored annually.

Ultimately, the usability of an uncertainty is determined by the manufacturer and the reference materials' intended use. Therefore, the Horwitz equation<sup>[5]</sup> and Horwitz Ratio (HORRAT) (eq. 1 & 2) was used to provide a mathematical basis for determining the usability of an uncertainty.

$$RSD_{Horwitz} = 2 \times Concentration^{(-0,1505)} \quad (1)$$

$$HORRAT = \frac{RSD_{Measured}}{RSD_{Horwitz}} \quad (2)$$

A HORRAT of  $\leq 1$  is ideal, between 1 and 2 acceptable and  $> 2$  unacceptable.

A working example of such evaluations can be found here:

[Example of our Data Evaluation for Certified Values](#)

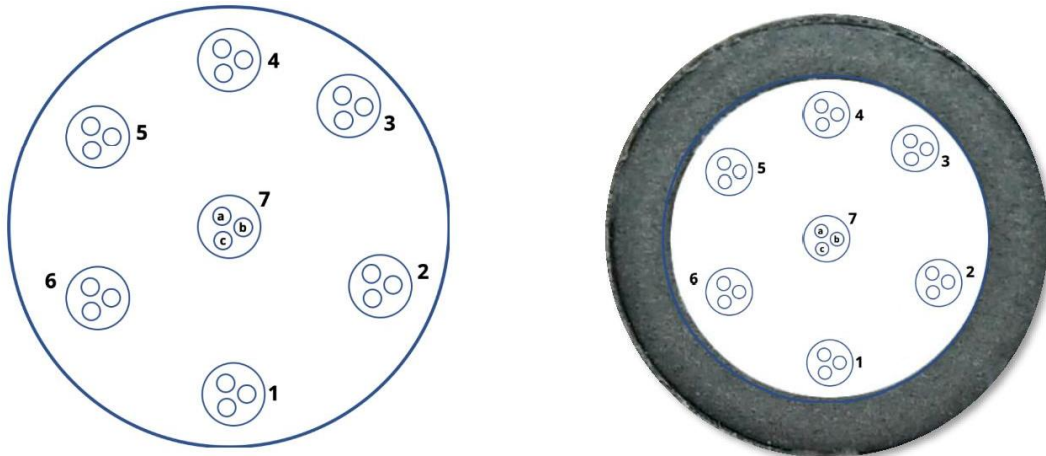


Fig. 3 Ablation pattern adapted from ASTM Guide E826-14.

## 5. Characterisation & Value Assignment

For characterisation of major and trace elements two different characterisation approaches were applied.

For one thing: “Characterisation of a non-operationally defined measurand using two or more methods of demonstrable accuracy in one or more competent laboratories”

For this purpose, samples from 14 aliquots of the MAKR-NP powder were analysed in two accredited laboratories (ISO 17025:2017) using lithium borate fusion followed by XRF and ICP-MS and or ICP-AES analyses.

The other: “Characterization using a single reference measurement procedure (as defined in ISO/IEC Guide 99<sup>[6]</sup>) in two laboratories”

For this purpose, the approach “using a single reference measurement procedure (as defined in ISO/IEC Guide 99) in a single laboratory” was extended by additional validation measurements in a second laboratory. Samples from 14 aliquots of the MAKR-NP powder were also taken and analysed in two accredited laboratories (ISO 17025:2017) using lithium borate fusion followed by ICP-MS or XRF analyses.

Certified and information values (including the list of methods) can be found in the Certificate of Analysis here: [Certificate of Analysis](#)

The assigned values and the uncertainty component resulting from the characterisation were calculated using equation 3 and 4.

$$\text{Assigned Value} = \frac{\sum \text{accepted data set means}}{\text{number of data sets}} \quad (3)$$

$$\text{Uncertainty}_{\text{characterisation}} = \frac{\text{Std. Dev. of data set means}}{\sqrt{\text{number of data sets}}} \quad (4)$$

To use equations 3 & 4 the data set means must show an approximately normal distribution. This prerequisite was tested using the software XLSTAT.

Finally, each certified value needs to be accompanied by a combined expanded uncertainty at the 95 % CL. The uncertainty is calculated (eq. 5) by combining the uncertainty components from characterisation as well as homogeneity- and stability testing.

$$\text{Unc.}_{\text{Final}} = k \times \sqrt{\text{Unc.}_{\text{Homog.}}^2 + \text{Unc.}_{\text{Char.}}^2 + \text{Unc.}_{\text{Stabil.}}^2} \quad (5)$$

The expansion factor  $k$  is determined by the effective degrees of freedom and their corresponding value in Student's  $t$ -distribution. The coverage factor was applied to reach a confidence level of 95 %, as defined in the Guide to the Expression of Uncertainty in Measurement (GUM)<sup>[7]</sup>. According to ISO Guide 35:2017 it is permissible to use an expansion factor of 2 if there are  $\geq 10$  degrees of freedom. If there are  $< 10$  degrees of freedom the appropriate factor should be taken from a Student's- $t$  table, i.e., the distribution at the desired confidence level.

Here (eq. 6 & Tab. 1) is an example on how the final uncertainty is calculated:

*Tab. 1 Calculation of the final combined and expanded uncertainty, using the analyte Uranium as an example.*

	<b>Certified Value</b>	<b>Unit</b>
<b>Uranium (U)</b>	31.9	µg/g
<b>Uncertainty</b> <sub>Characterisation</sub>	0.2	µg/g
<b>Uncertainty</b> <sub>Homogeneity</sub>	0.9	µg/g
<b>Uncertainty</b> <sub>Stability</sub>	0.6	µg/g
<b>Expansion factor (k)</b>	2	[-]

$$\text{Unc.}_{\text{Final}} = 2 \times \sqrt{0.2^2 + 0.9^2 + 0.6^2} = 2.2 \quad (6)$$

<b>Analyte [µg/g]</b>	<b>Certified Value</b>	<b>Expanded Uncertainty @ 95 % CL</b>
Uranium (U)	31.9	2.2

## 6. Minimal Sample Size

Every CRM must have a statement of its minimal sample size. Minimal sample size for powdered certified reference materials is typically given in milligrams (mg). LA-ICP-MS analyses only take subsamples of e.g. a pressed powder pellet, meaning, that the mass of the powder used to make the pellet becomes irrelevant.

Therefore, the minimal sample size was determined by the spot-size used during the homogeneity- and stability test, which in the case of MAKR-NP-B01 was 80 µm. Further ablation conditions and signal acquisition parameters are shown in Tab. 2.

*Tab. 2 Ablation and signal acquisition parameters during homogeneity- and stability-testing.*

Laser fluence	5.6 J/cm <sup>2</sup>
Repetition rate	10 Hz
Background	10 s
Signal acquisition	50 s

## 7. Acknowledgements

We would like to thank Dr. Axel Sjöqvist of Axray Scientific AB and Thomas Zack of the University of Gothenburg for their tireless efforts during the LA-ICP-MS analyses and providing a high-quality data set.



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## 8. References

- [1] **EN ISO 17034:2016 (D/E)**, *General requirements for the competence of reference material producers*
- [2] **ISO Guide 35:2017 (E)**, *Reference materials – Guidance for characterization and assessment of homogeneity and stability*
- [3] **ASTM E826-14**, *Standard Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectroscopy*. ASTM International, West Conshohocken, PA, 2014.  
www.astm.org
- [4] **ISO 13528:2015 (E)**, *Statistical methods for use in proficiency testing by interlaboratory comparison*
- [5] **Horwitz, W., Albert, R. (1995)**, *Precision in analytical measurements: Expected values and consequences in geochemical analyses*. Fresenius Journal of Analytical Chemistry. 351:507-513
- [6] **ISO/IEC Guide 99:2007**, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*
- [7] **ISO/IEC Guide 98-3:2008**, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

## 9. Document History

Version	Date	Changes applied
1.0	26.09.2022	First publication