MICRO-XRF

Mineral composition analysis using the M4 TORNADO^{AMICS}

Application Note # XRF 469

Introduction

The M4 TORNADO micro-XRF spectrometer is well established as a useful and reliable tool to provide element distribution maps. However, in the field of geosciences, the mineralogical composition of a sample is crucial in understanding the origin and formation of rocks.

Minerals, and not elements, are also what is mined to produce aluminum, steel, gold, and diamonds, for example, and are therefore economically and environmentally very relevant.

The M4 TORNADO^{AMICS} (**A**dvanced **M**ineral **I**ndentification and **C**haracterization **S**ystem) converts X-ray fluorescence spectra to minerals to produce detailed mineralogical maps. These mineral maps can be used to provide data such as modal abundance, calculated assay, mineral association and textural aspects.

This lab report focuses on the application of the M4 TORNADO^{AMICS} to differentiate even slight compositional variations in minerals – specifically the zonation of plagioclase feldspar in a granite sample.

Feldspar is the most common mineral in the Earth's crust. The type of feldspar species is an essential criterion in igneous rock classification. Furthermore, changes in the composition of a feldspar crystal (zoning) detail the crystallization history of the magma.

Functional principle

All minerals have a specific chemical composition or composition range. Therefore, the fluorescence X-ray spectra that are collected from exciting the sample with the X-ray beam can be used as a "fingerprint" of a specific mineral.

AMICS compares the collected spectra to a library of known mineral spectra to convert the X-ray spectral pattern to a classified mineral (Figure 1).

The M4 TORNADO's large chamber and minimal sample preparation requirements make the M4 TORNADO^{AMICS} ideal to obtain mineralogical data, especially on large rock slabs or core sections.

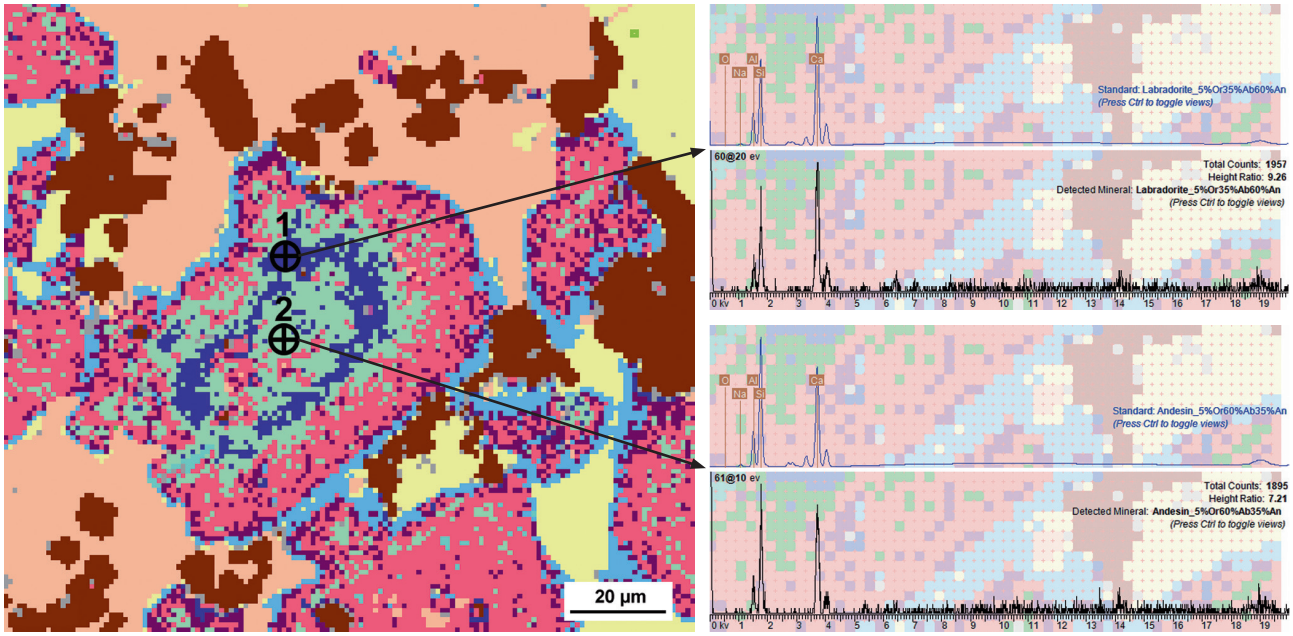

Figure 1
X-ray points (indicated by black plus signs) with corresponding collected spectra (black) and matching reference spectra (blue) for Labradorite (1) and Andesine (2).

Sample

The presented sample consists of a granite slab of 16 cm x 10 cm.

Measurement conditions

The measurements were performed with a Bruker M4 TORNADO micro-XRF spectrometer equipped with an Rh X-ray tube and two XFlash® silicon drift detectors with an active area of 60 mm² each. The following measurement conditions were chosen:

- tube voltage: 50 kV
- current: 600 µA
- chamber pressure: 20 mbar
- acquisition time: 25 ms/pixel
- step size: 50 µm.

An overview of the sample, which can be seen in Figure 2, was generated by acquiring several images using the 10x magnification camera (mosaic function). A map area of 1000 x 1000 pixels (green frame) was defined. The measurement required a total time of 5 hours and 49 minutes to complete.

A more prolonged acquisition time is required for AMICS to collect spectra with reasonable counts in order to perform the spectral matching. For this sample using the selected conditions, the average count rate on quartz was 1800 counts.

Mineralogical map results

The fundamental approach of the AMICS software is to compare the collected X-ray spectral data with a reference list of known mineral spectra. This list of spectra can be extended, and the data repeatedly reclassified to resolve unclassified X-ray points (unknowns).

Bruker's ability to create synthetic spectra from compositional data simplifies the creation of the reference list. In addition, the capability of

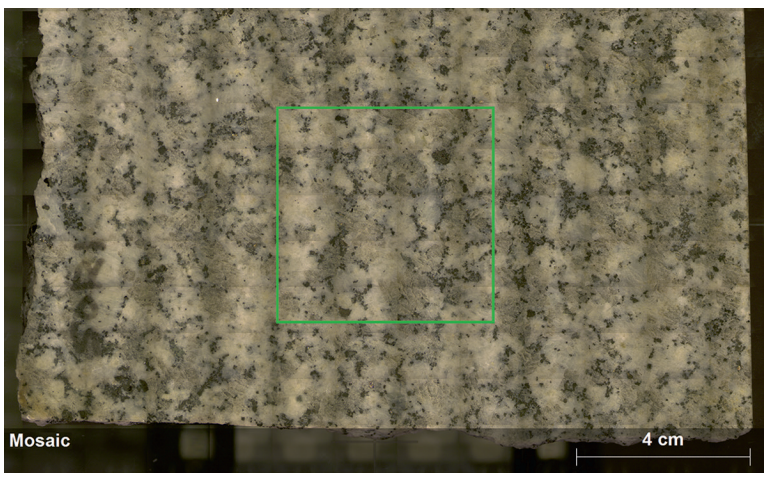

Figure 2
Mosaic image of the granite sample with the analyzed area (indicated by the green square).

#	Mineral name	wt%	Area%
1	Quartz	33.8	35.8
2	Orthoclase	25.2	24.0
3	Albite_0% Or, 100% Ab, 0% An	0.2	0.2
4	Oligoclase_5% Or, 80% Ab, 15% An	7.7	7.1
5	Oligoclase_5% Or, 75% Ab, 20% An	4.9	4.6
6	Andesin_5% Or, 60% Ab, 35% An	3.3	3.4
7	Andesin_5% Or, 55% Ab, 40% An	12.5	13.0
8	Labradorite_5% Or, 35% Ab, 60% An	0.9	0.9
9	Anorthite_0% Or, 0% Ab, 100% An	0.0	0.0
10	Biotite	10.4	9.3
11	Other	1.1	1.6

Table 1
Modal composition determined for the analyzed area

the AMICS software to cluster the collected spectra using a variety of parameters assists in verifying the classified result and assigning unknown phases.

The mineral map for the selected area (green frame in Figure 2) is presented in Figure 3. An array of synthetic plagioclase composition added to the reference list enabled the identification of zoning in plagioclase from Ca-rich cores to Na-rich rims.

Modal data for the analyzed area is given in Table 1 and displayed in Figure 4 in chart format. "Other" includes the minerals calcite, apatite, zircon and remaining unknown phases.

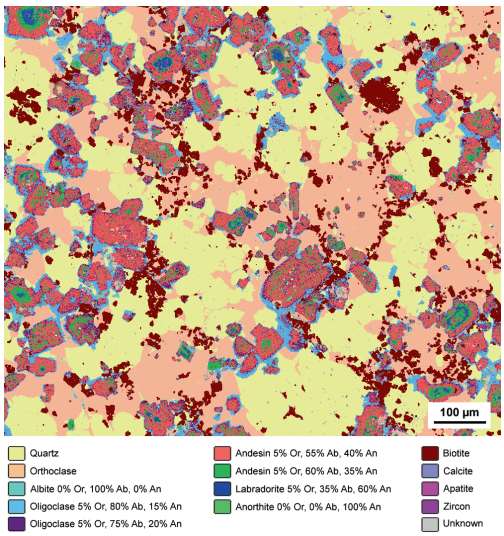

Figure 3
Mineral map produced with the AMICS software, indicating detailed mineralogy including zoning within the plagioclase crystals (Or = Orthoclase, Ab = Albite, An = Anorthite).

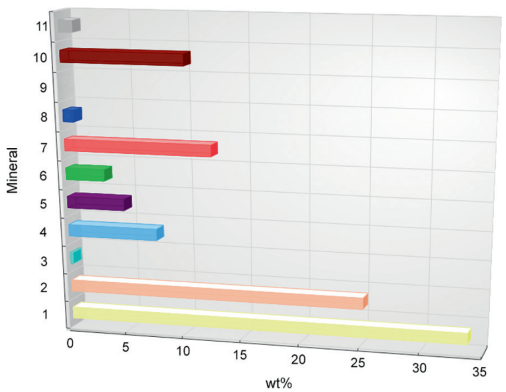

Figure 4
Modal composition determined for the analyzed area, displayed in graph format.

Conclusion

The M4 TORNADO^{AMICS} allows the creation of mineral maps from spatially resolved X-ray Fluorescence (XRF) signals. The information provided is critical for the understanding of many Earth processes and rock histories and can be vital in pinpointing potential economically viable deposits.

Additionally, sample preparation is minimal – the only requirement being a reasonably flat surface. The minimal need for sample preparation makes the M4 TORNADO^{AMICS} the ideal screening tool and complement to other highresolution techniques.

The addition of an extensive database of synthetically generated mineral spectra, and the capability of AMICS to cluster spectra according to various parameters, allows the user to identify variations in X-ray spectra with a sensitivity and confidence previously not possible.

Acknowledgements

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