# AMICS - automated identification & quantification of minerals and synthetic phases.

Bruker Nano Analytics, Berlin, Germany
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# Presenters

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# Presenters cont‘d

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Bruker Nano Analytics, Berlin, Germany

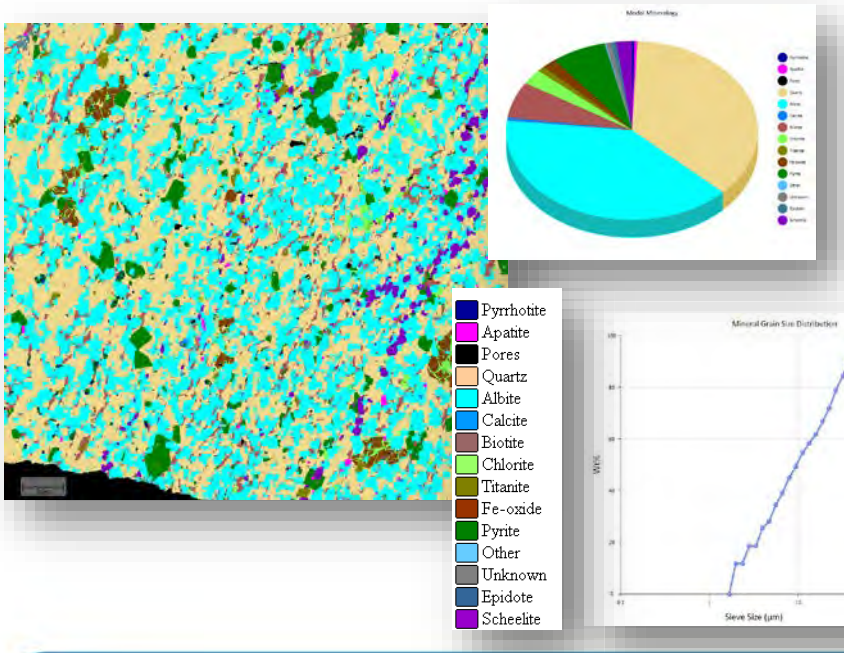
# Overview

- Introduction to Automated Mineralogy
- AMICS for QUANTAX – EDS on SEM
- Application Examples
- Summary
- AMICS for M4 TORNADO – Micro-XRF
- Comparison to EDS and Application Examples
- Summary
- Demonstration
- Conclusion

# Introduction to Automated Mineralogy

## Automated Mineralogy

It is a technology or method of performing high speed, autonomous image and spectral analysis of rocks and minerals and providing information on mineralogy and spatial distribution of the mineral phases.




## Technology Base

Traditionally, automated mineralogy has been based on an automated system comprised of electron beam imaging (SEM or µ-probe) and energy or wavelength dispersive spectrometry. Powerful classification and processing software is vital. There are numerous new methods coming onto the market, including infrared and micro-X-ray-fluorescence spectrometry

# AMICS for QUANTAX – EDS on SEM

# AMICS for QUANTAX EDS
## What makes up an AMICS system

**AMICS**

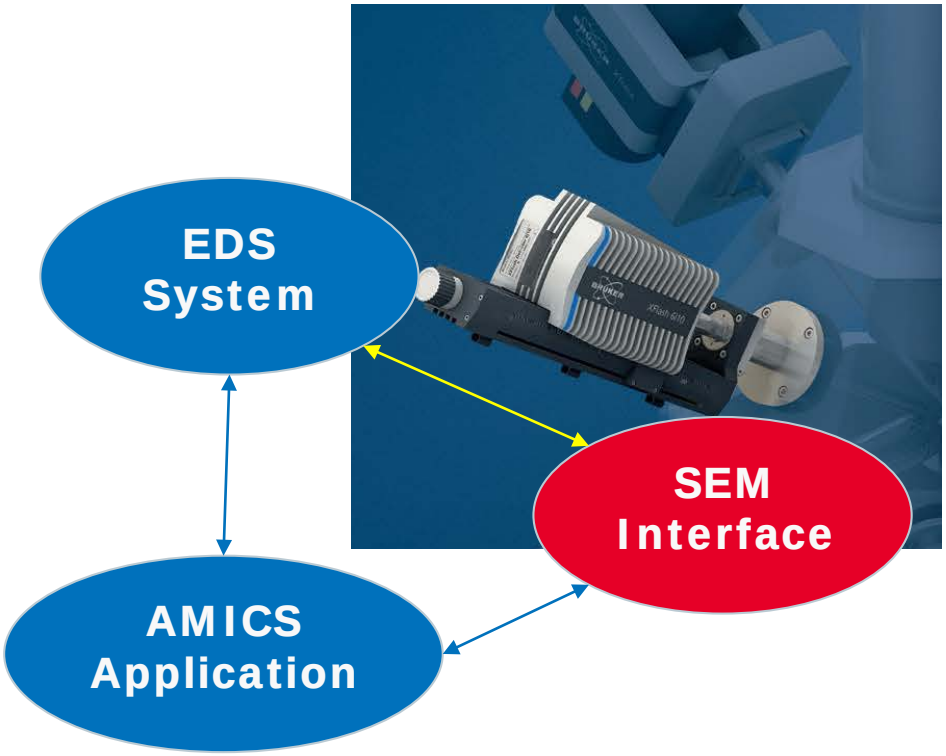
- Controls the EDS system
- Can control the SEM directly
- Acquires images and EDS spectra for analysis

**The QUANTAX EDS system**

- Controls the SEM stage, focus, HT, brightness and contrast..
- Delivers electron (BSE) image
- Delivers EDS spectra

**The SEM**

- Delivers electron beam & image
- Provides stage interface



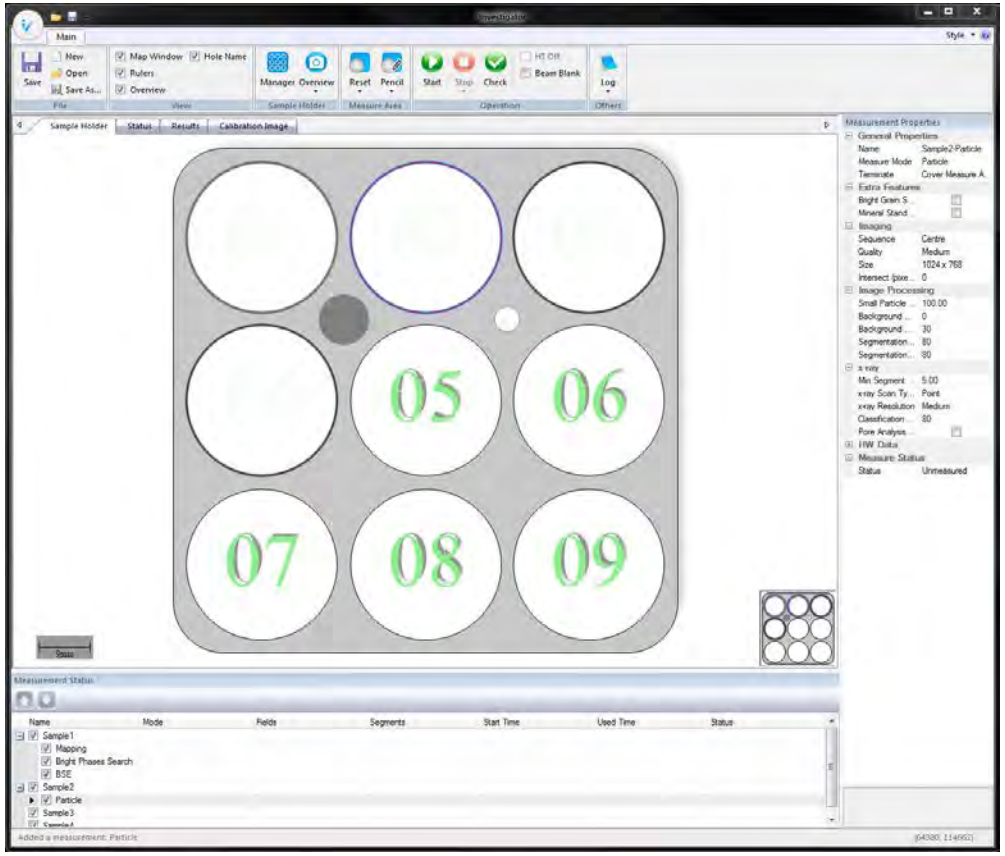
# AMICS for QUANTAX EDS
## How does AMICS work

AMICS - easy to configure measurement area by definable sample block holders

And can perform the following

- Particle
- Mapping
- BSE Image acquisition
- Standards acquisition
- Bright Phase Search

Controls SEM settings, moves stage to each position and acquires images through the QUANTAX system.



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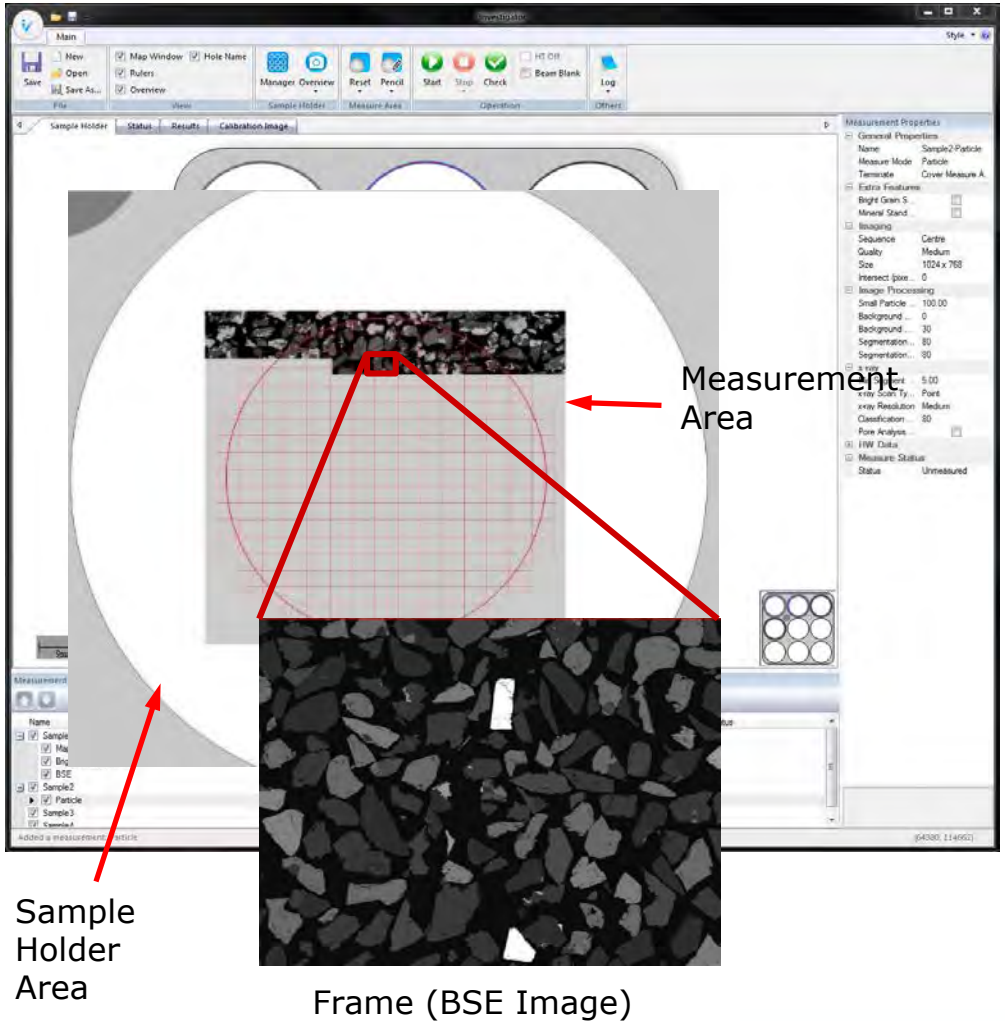


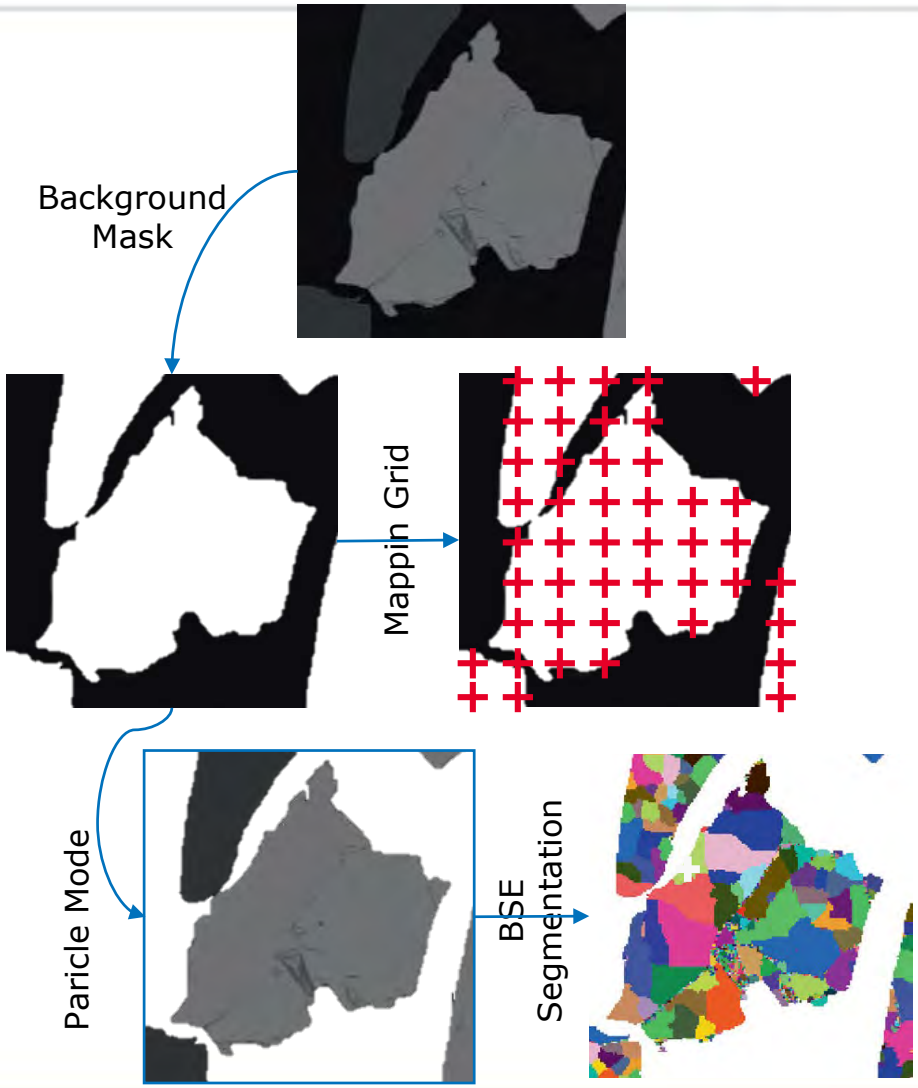
# AMICS for QUANTAX EDS
## How does AMICS work

AMICS will allow setting background thresholds and will create a mask for the particles.

When combined with mapping, particle can be mapped, e.g. with a step size of 5 µm.

In particle mode, computer vision techniques allow grey level variation and segment size to be adjusted to segment particles. Each segment (above a set size) will be analyzed by a single X-ray spot

X-ray spectra acquisition is via the QUANTAX system.



# AMICS for QUANTAX EDS
## How does AMICS work

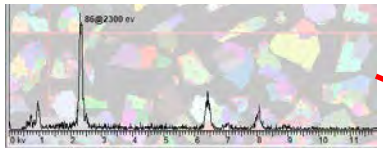
Mineral identification:

For each point or segment a spectrum is acquired, analyzed and classified live – using the specified species list.

A live distribution of minerals can be seen during measurement.

All the data is saved progressively and modal data by area and wt % and segments measured is updated after each completed frame.

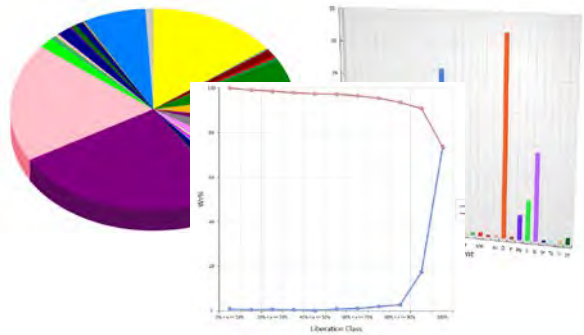
Processing and reclassification of data is done post measurement in order to create images, charts and tables for reports.



X-ray analysis
for each segement

Mineral identification
and
classification


Mineral Classified

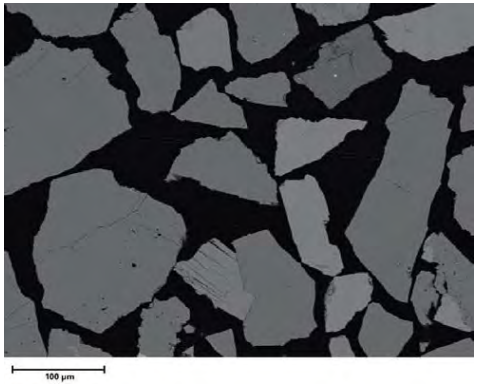


Reporting

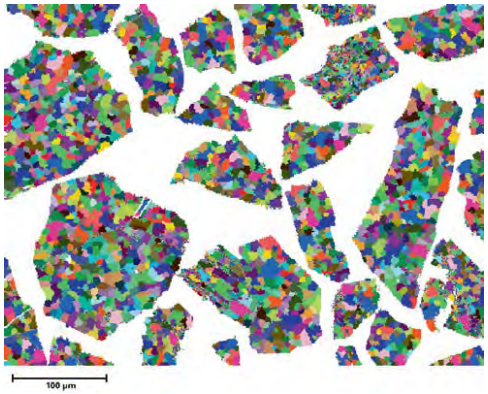
# Application Examples

# Particle Segementation Example

## Differentiate Quartz, Albite, K-Feldspar and Muscovite




BSE image of the sample showing little contrast

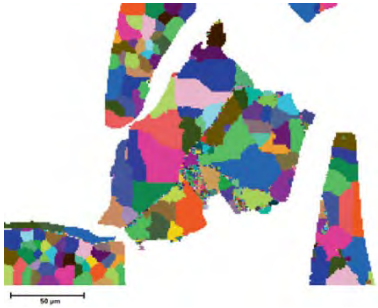



Particle segmentation image showing the result of segmentation of fine variations in BSE intensity


Resulting mineral map showing Quartz, Albite, K-feldspar and Muscovite after Particle mode analysis

# Particle Segementation Example
## Differentate Chalcopyrite, Pentlandite and Quartz

BSE image

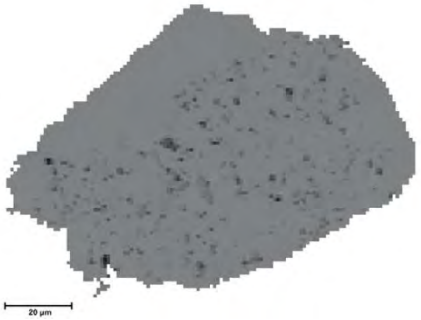


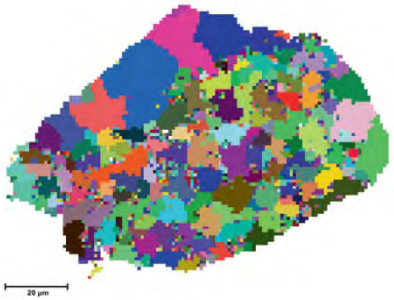
Segmented image

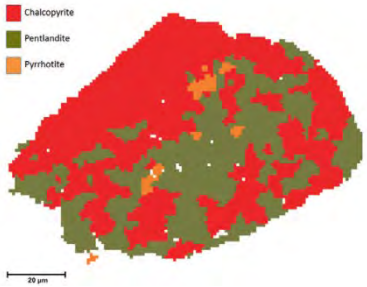

Resulting mineral map showing Chalcopyrite, Pentlandite and Quartz in Particle mode

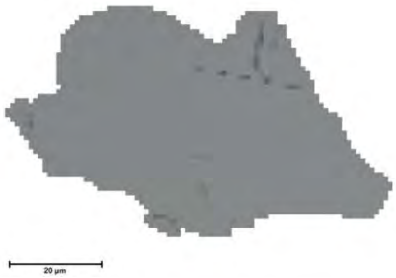
# Particle Segementation Example

## Differentate of Quartz, Albite, K-Feldspar and Pyrrhotite

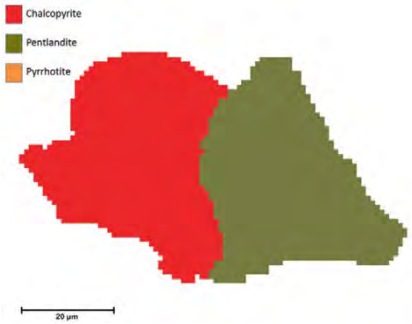


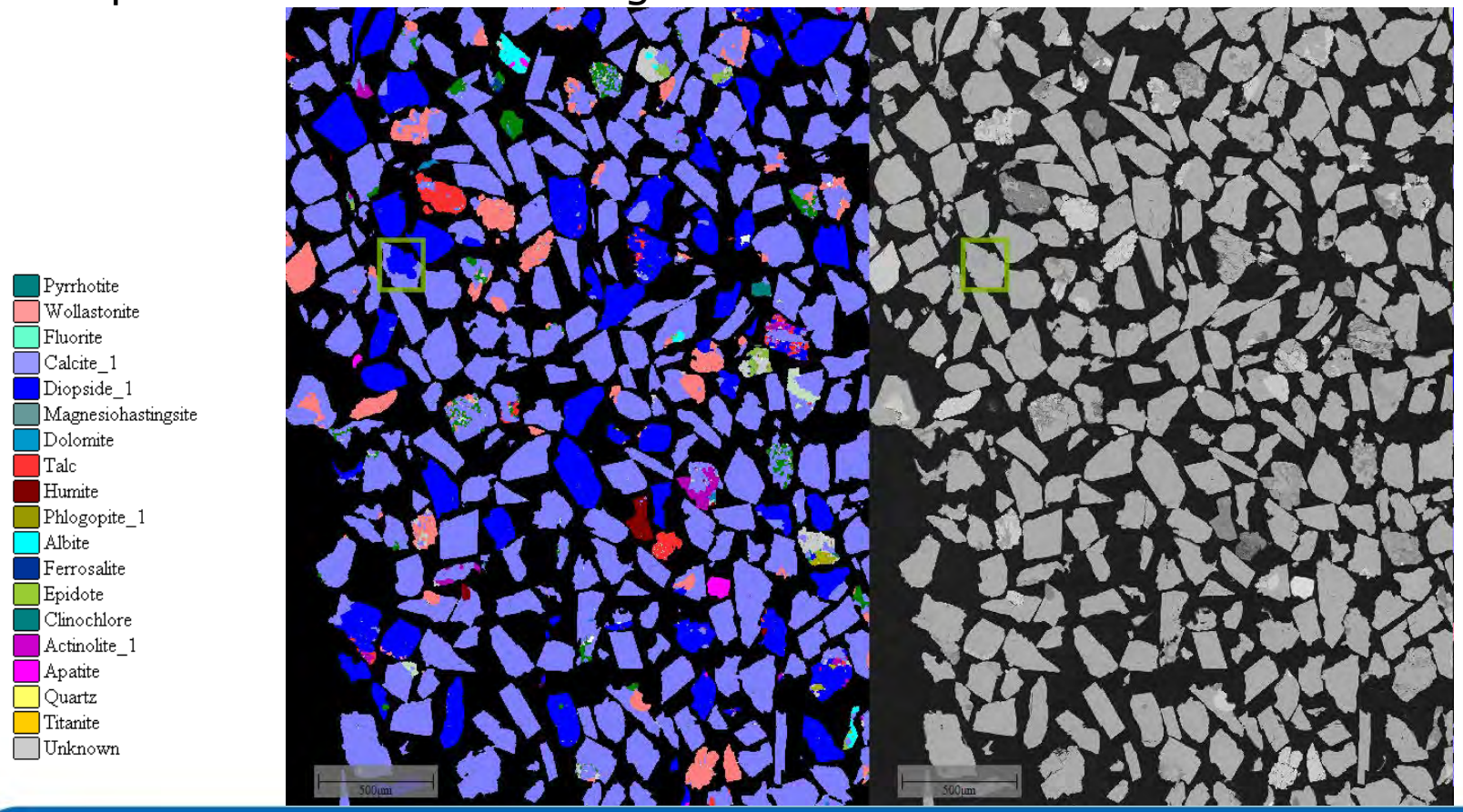




# Particle Segementation Example
## Calcite / Diopside

Mirror View of Sample

- In this wollastonite  sample calcite and diopside is well differentiated despite their similar BSE signal



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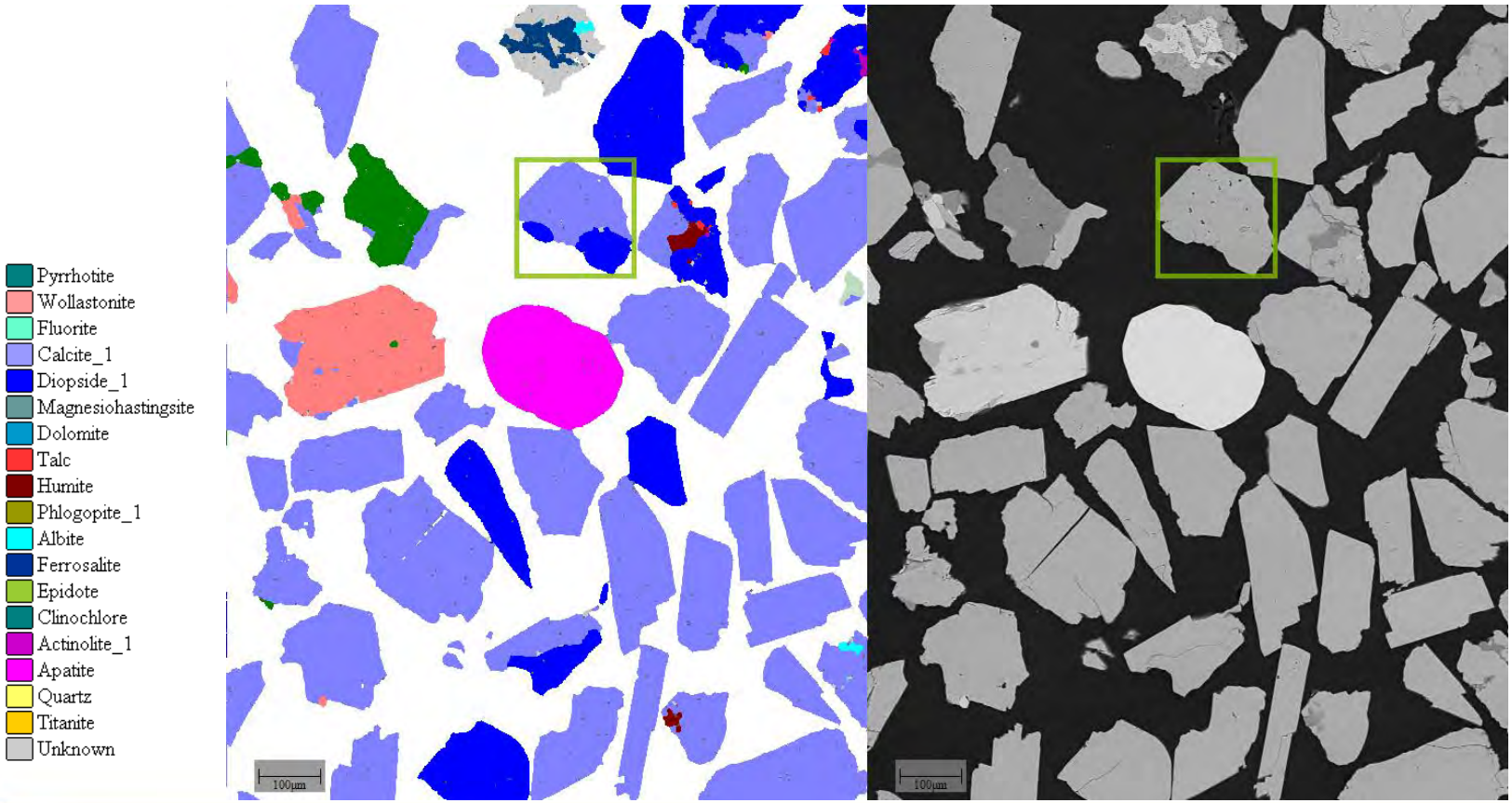

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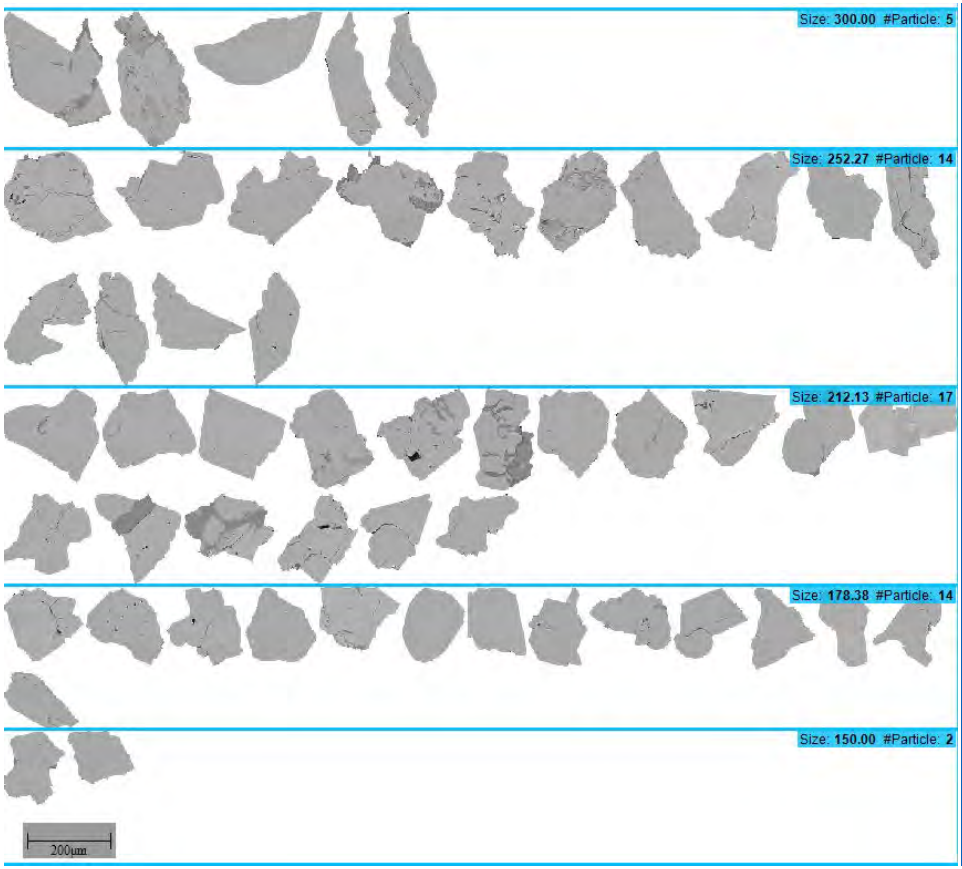
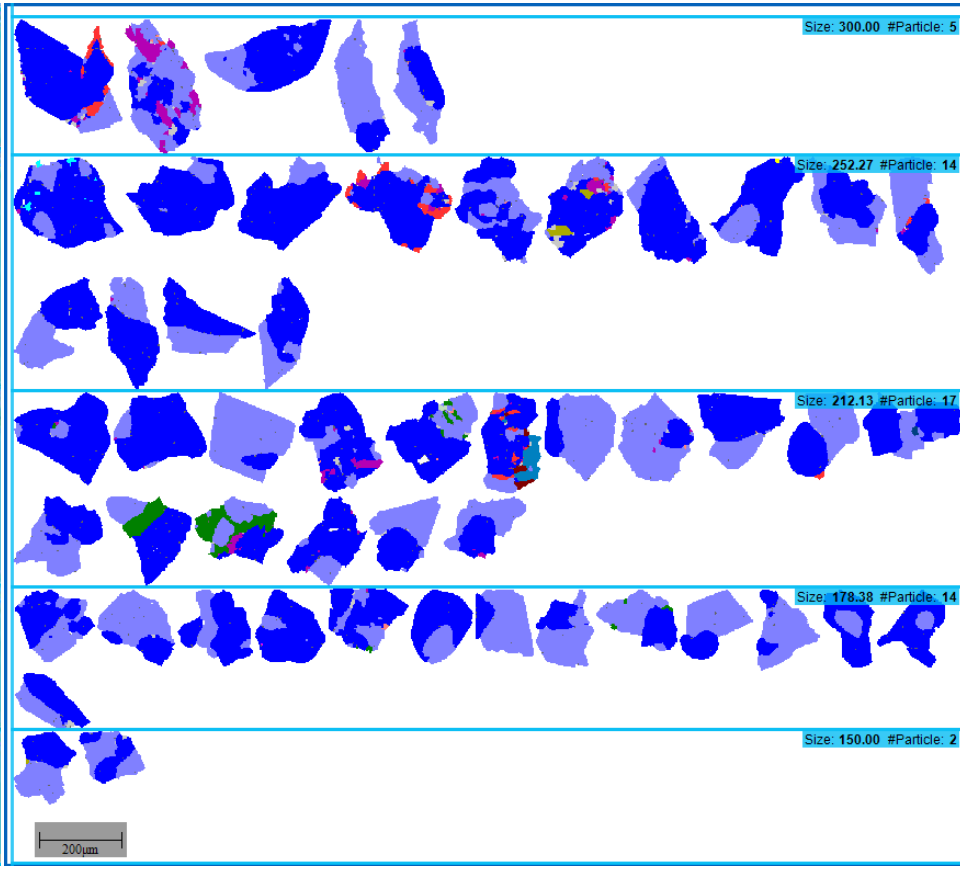
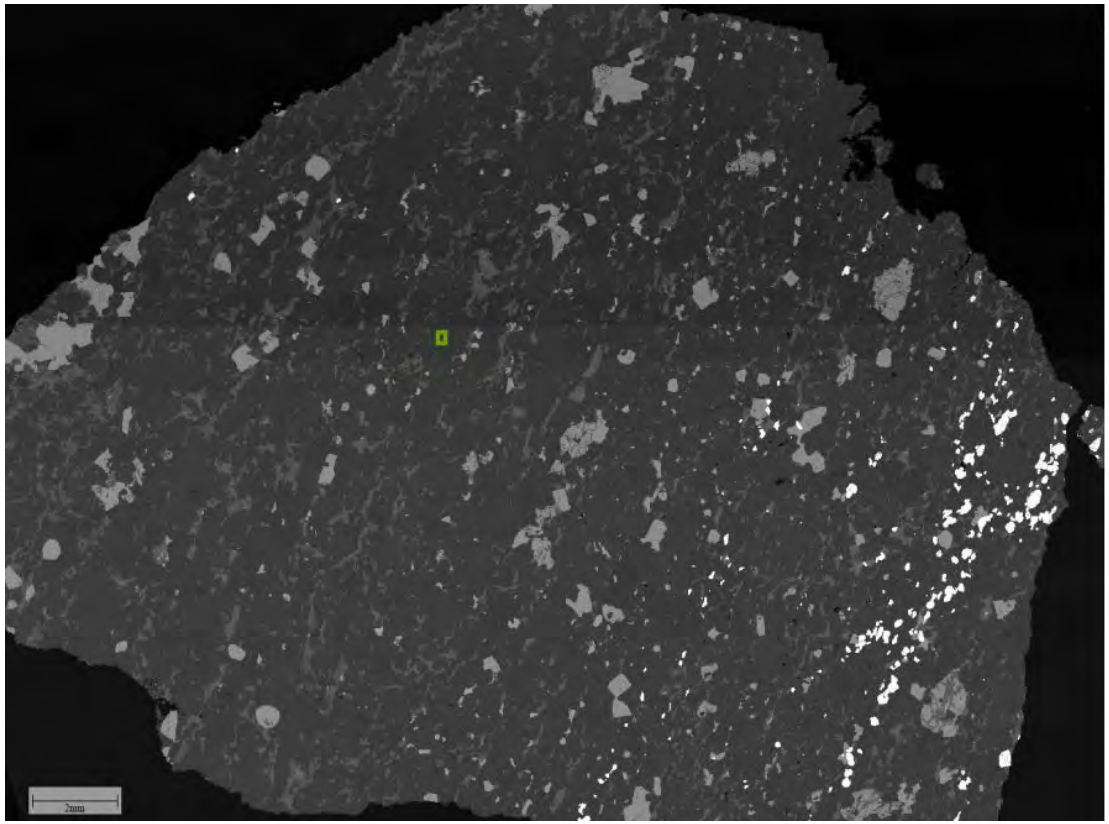



Calcite_1
Diopside_1

# Granite Sample

## Methods of sample investigation and reporting



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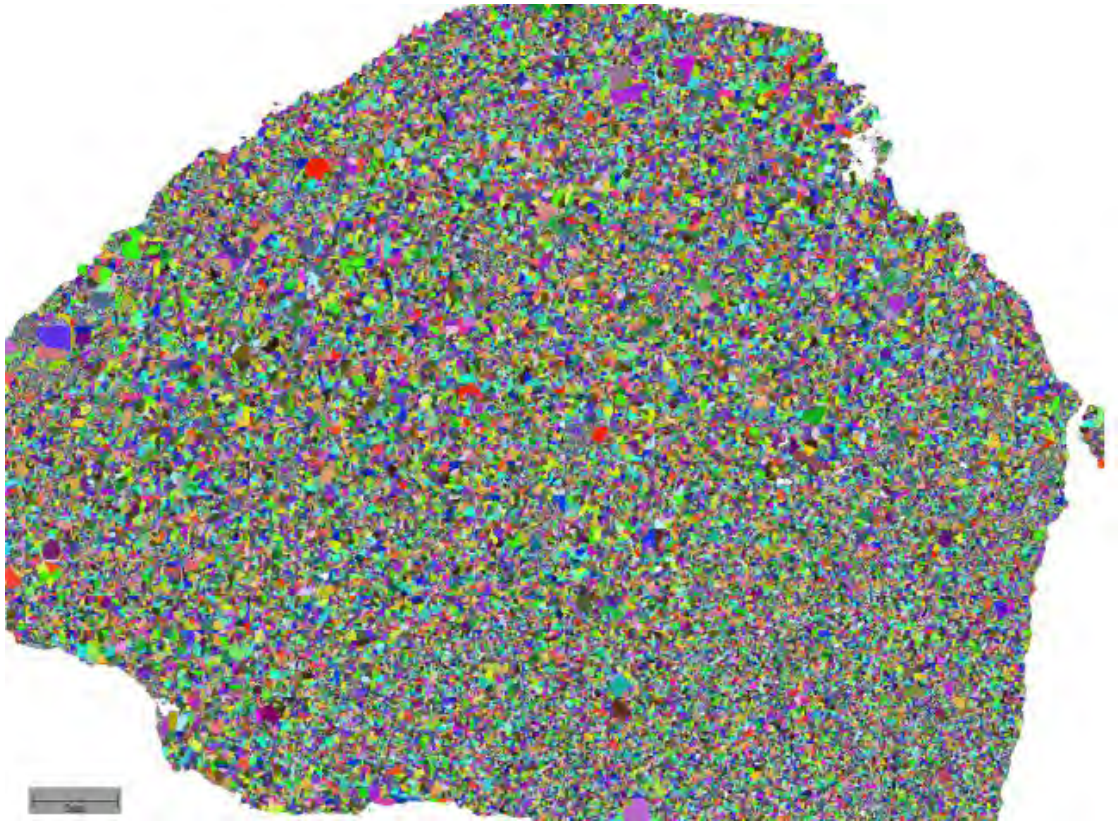

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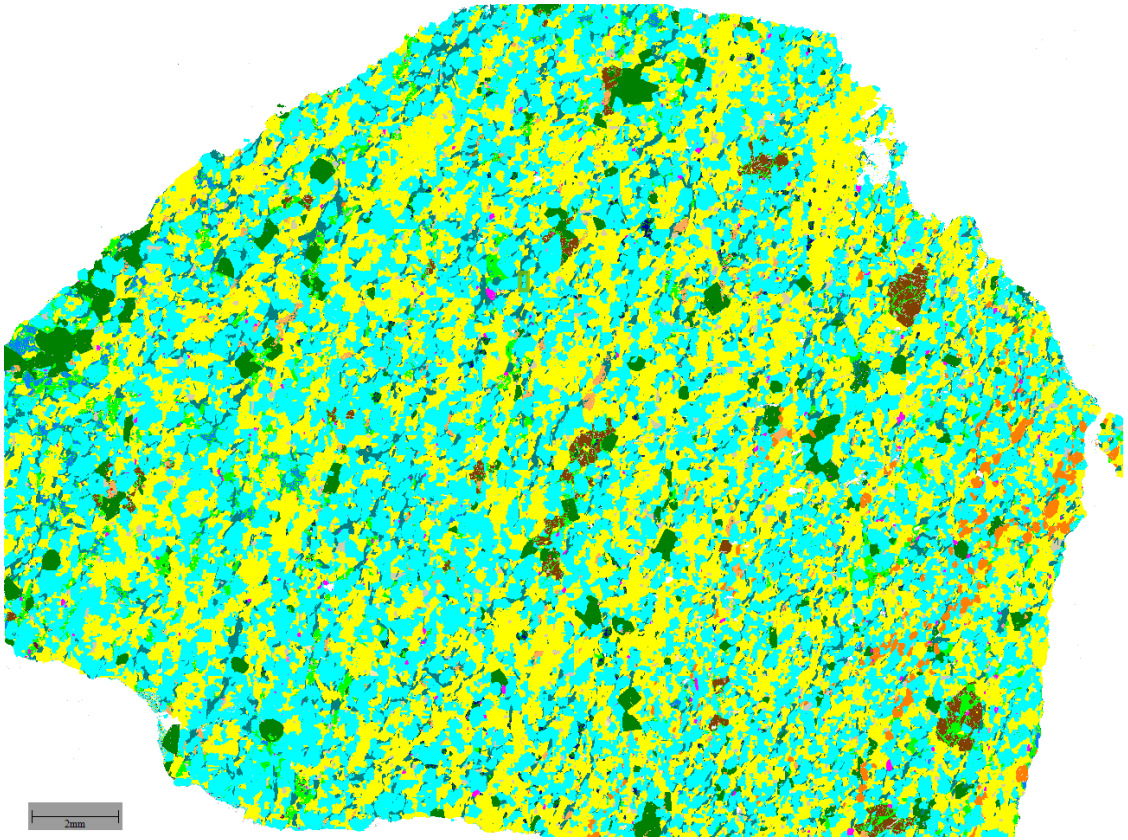

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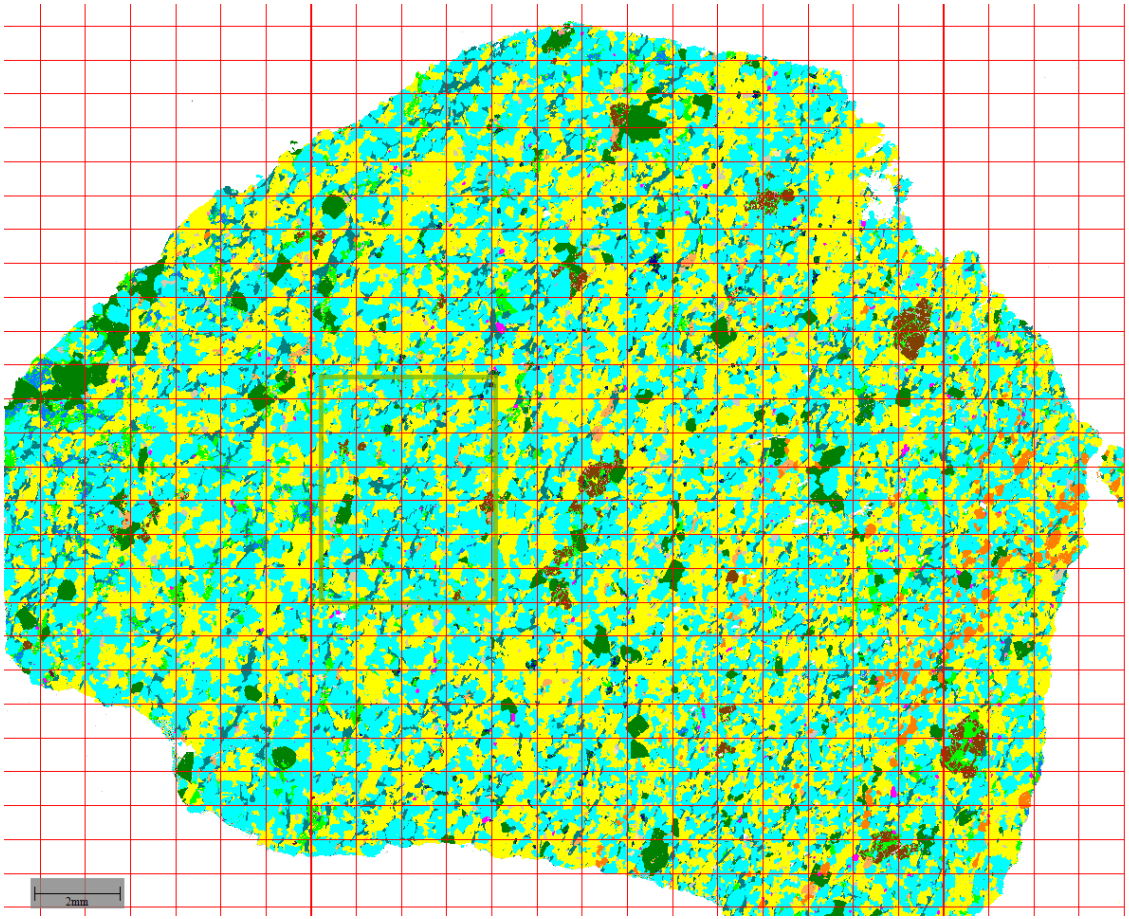

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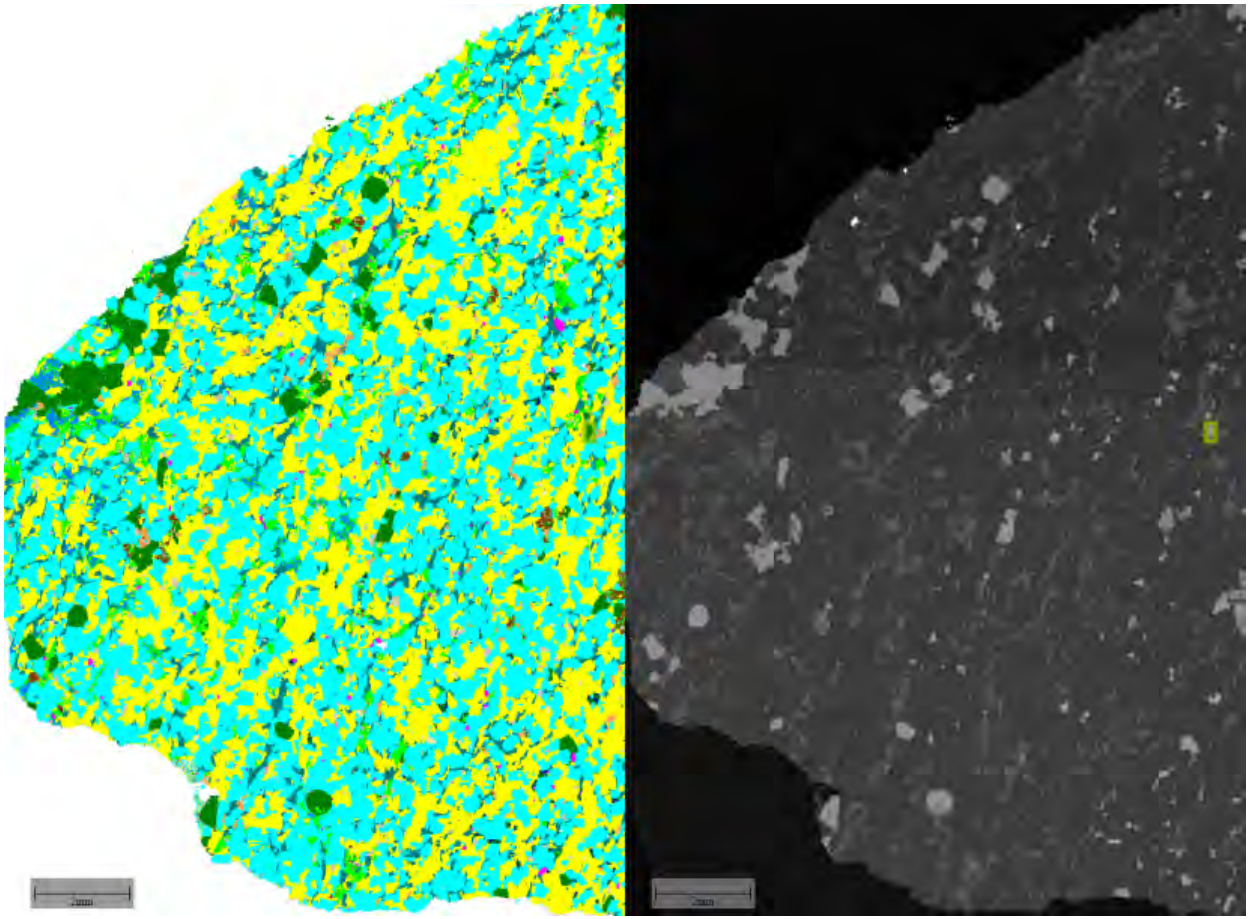

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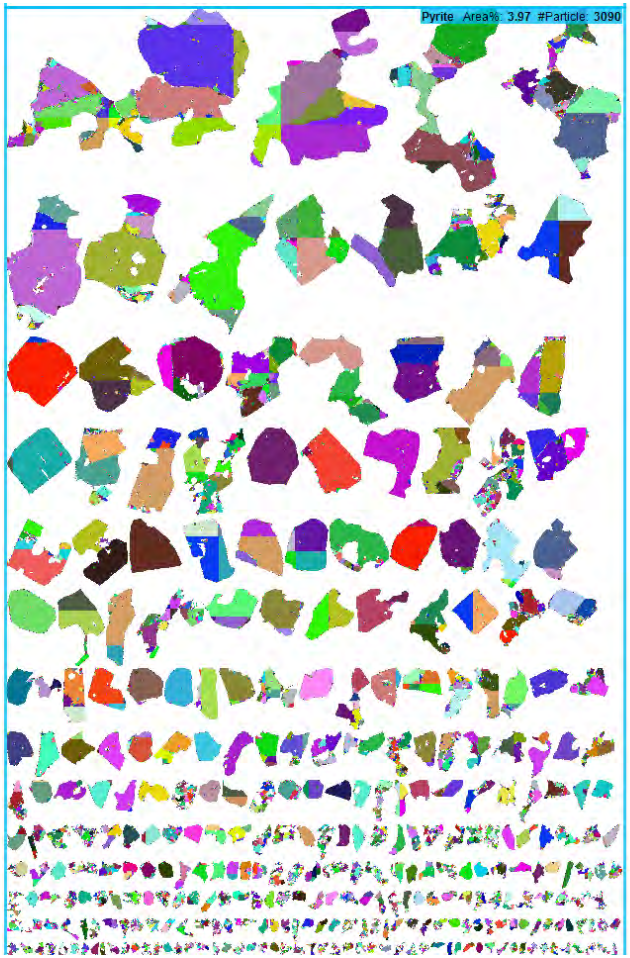


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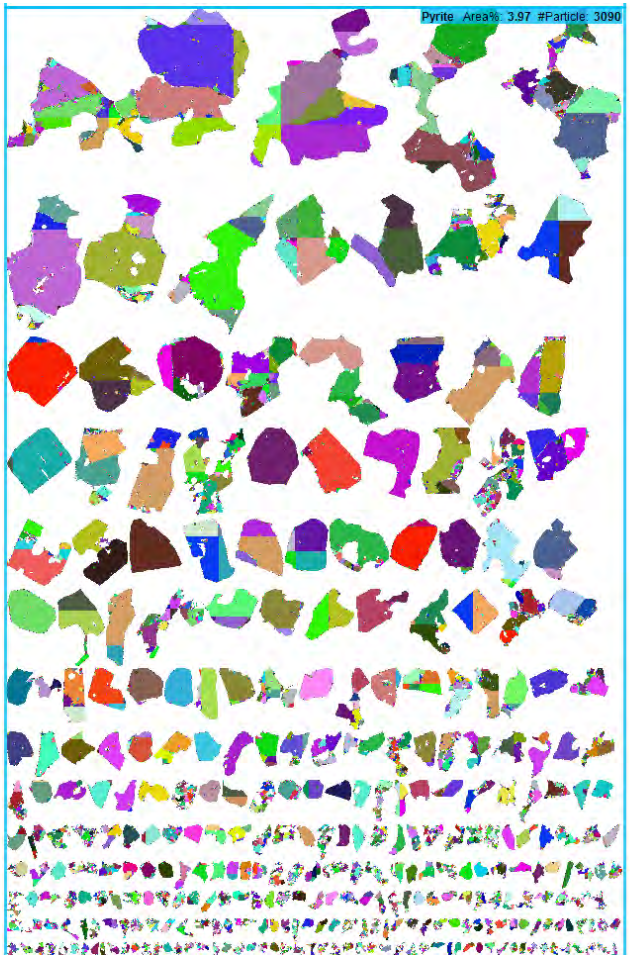


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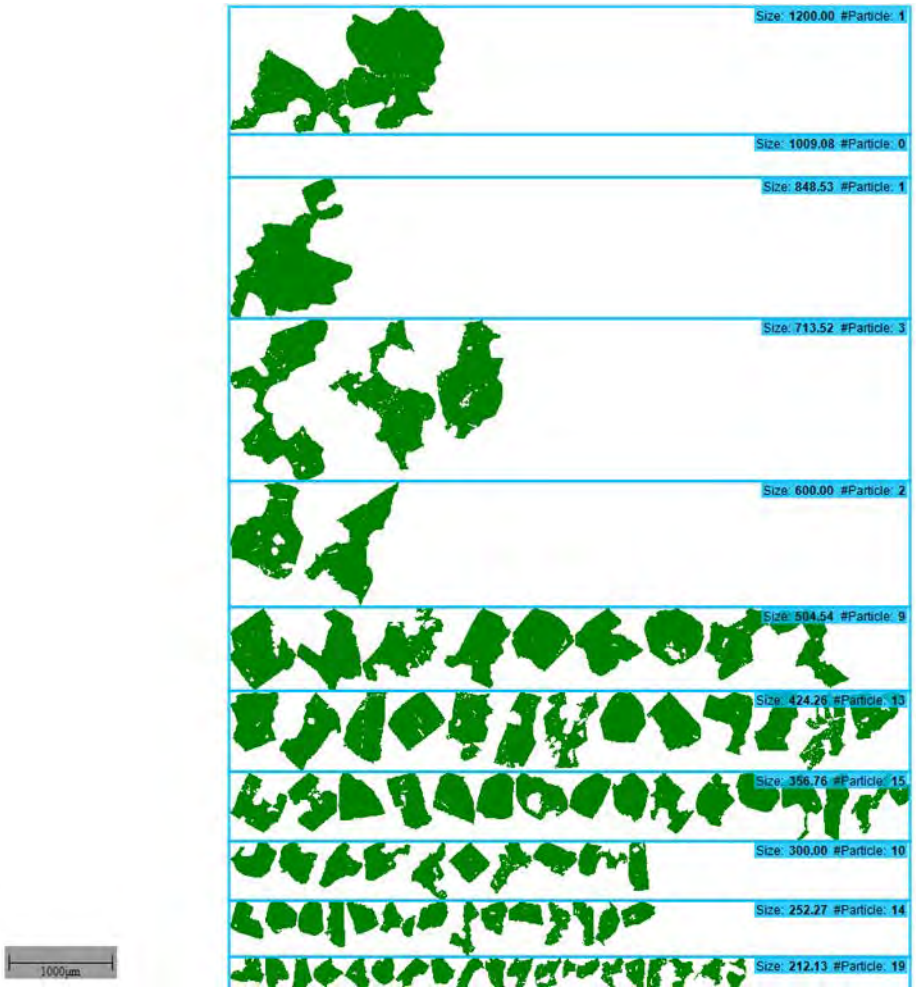

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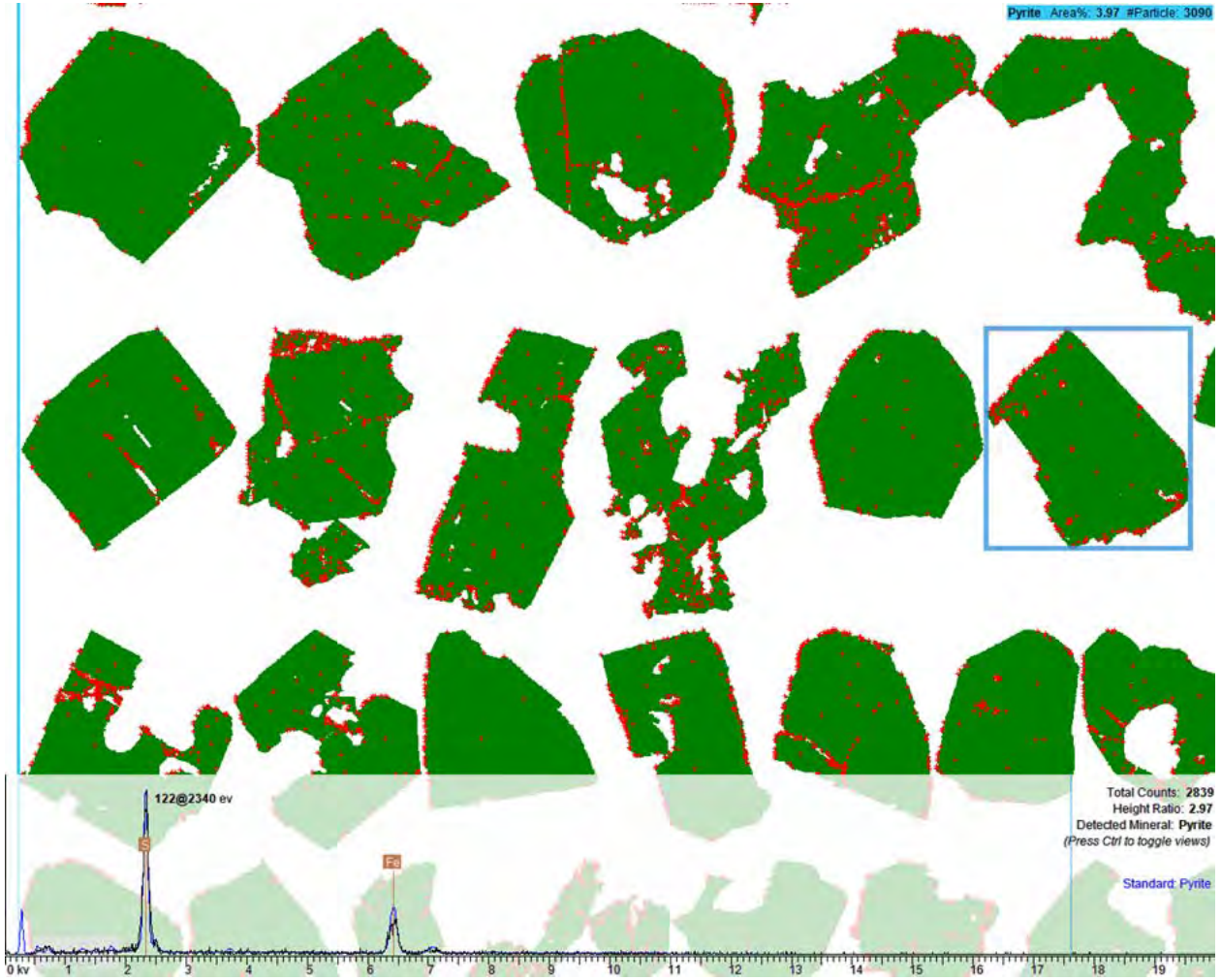

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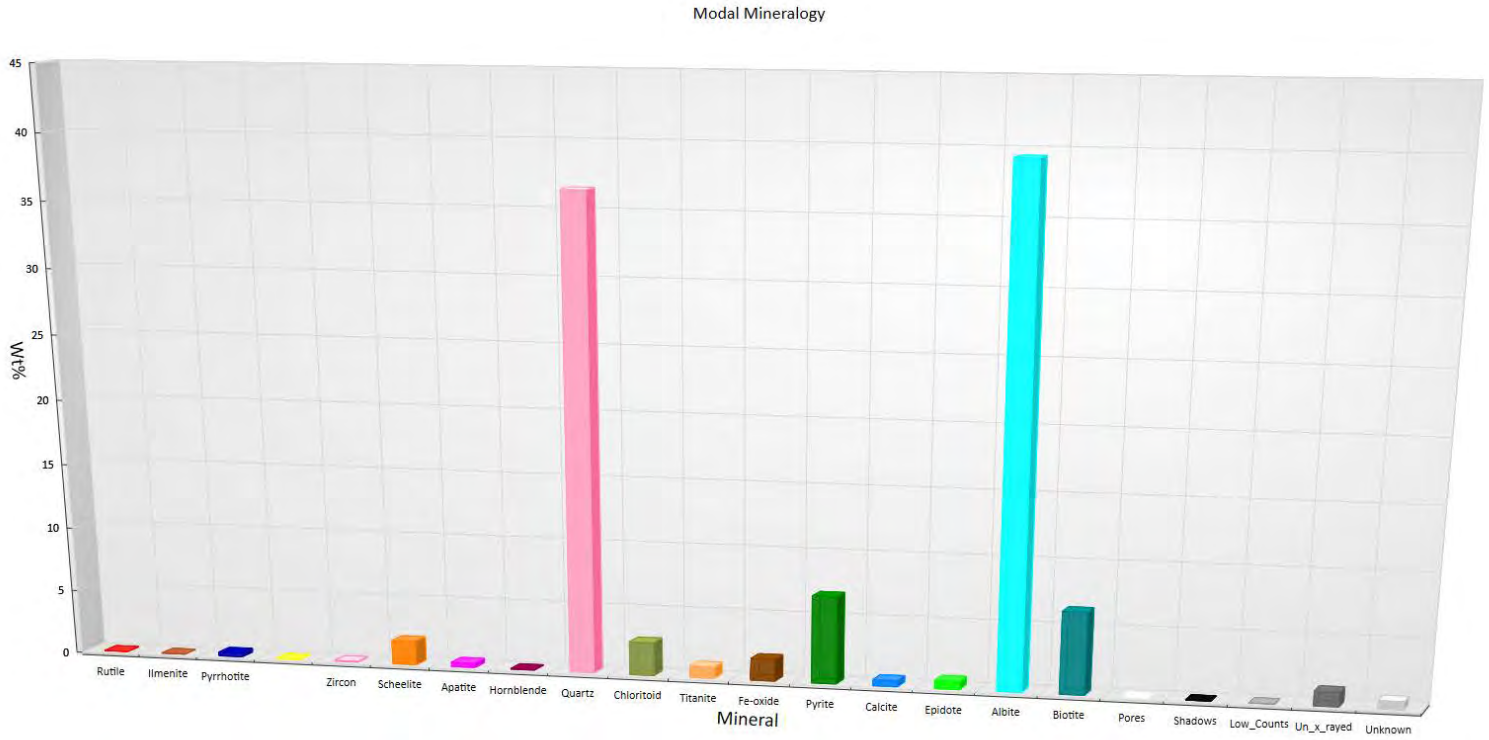

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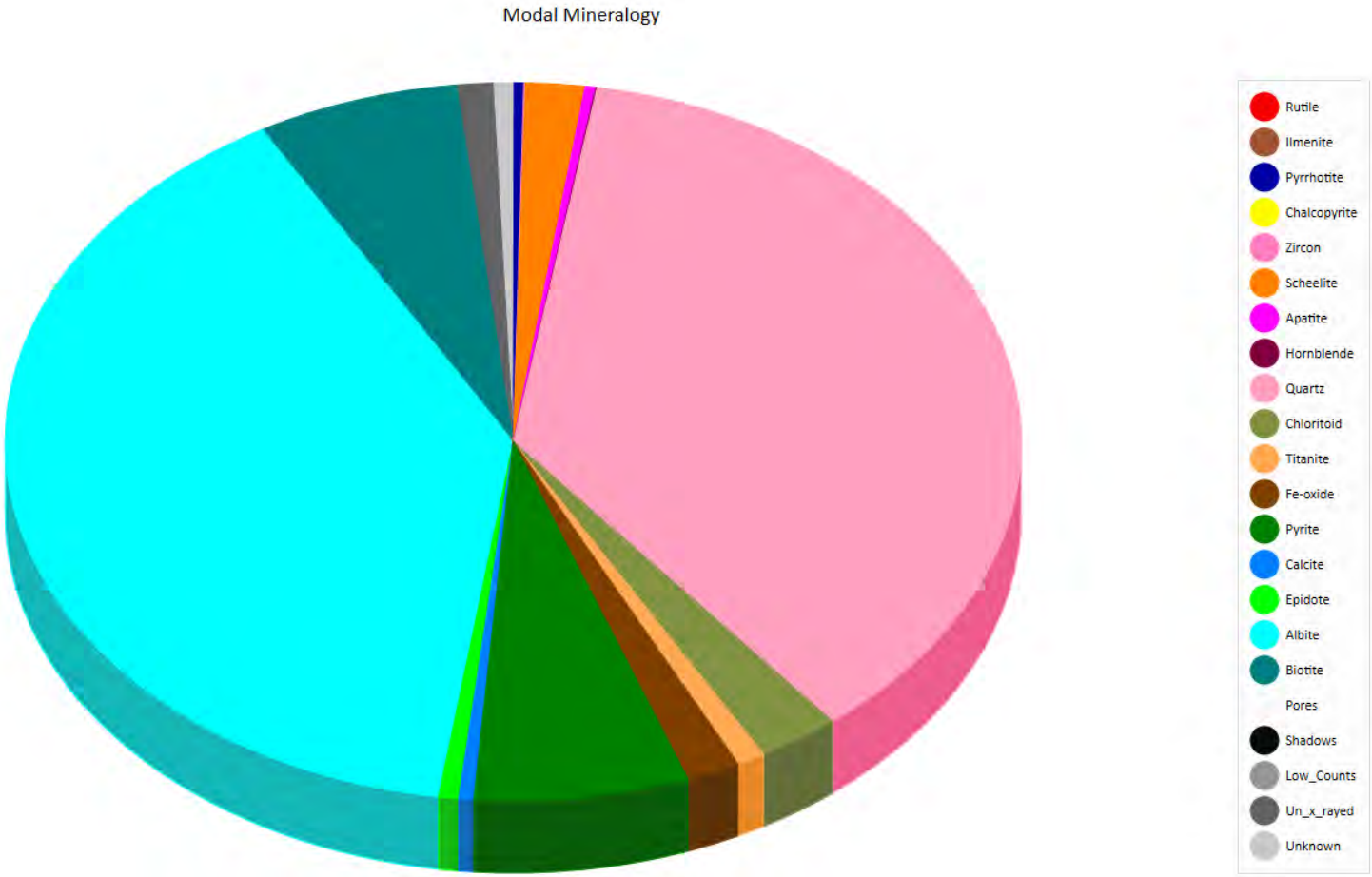
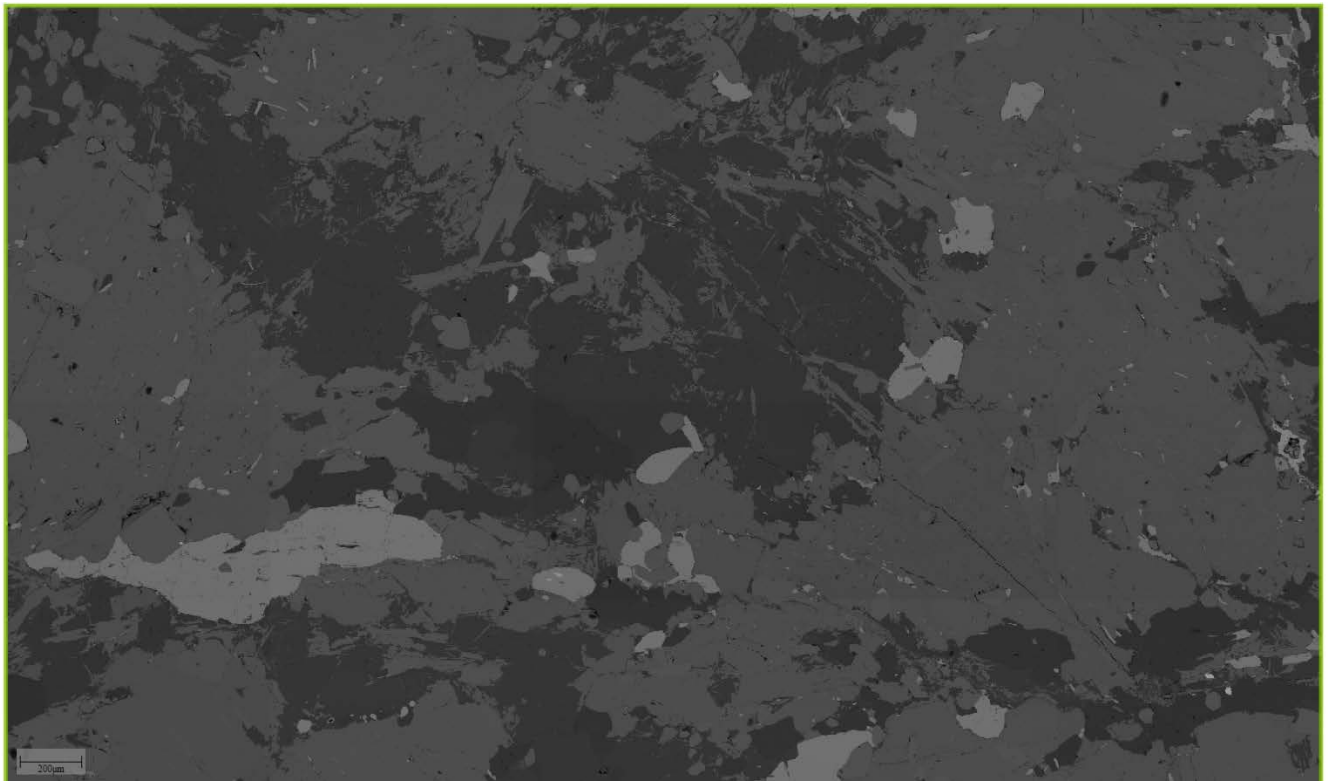


# Thin section: Ferrodiorite



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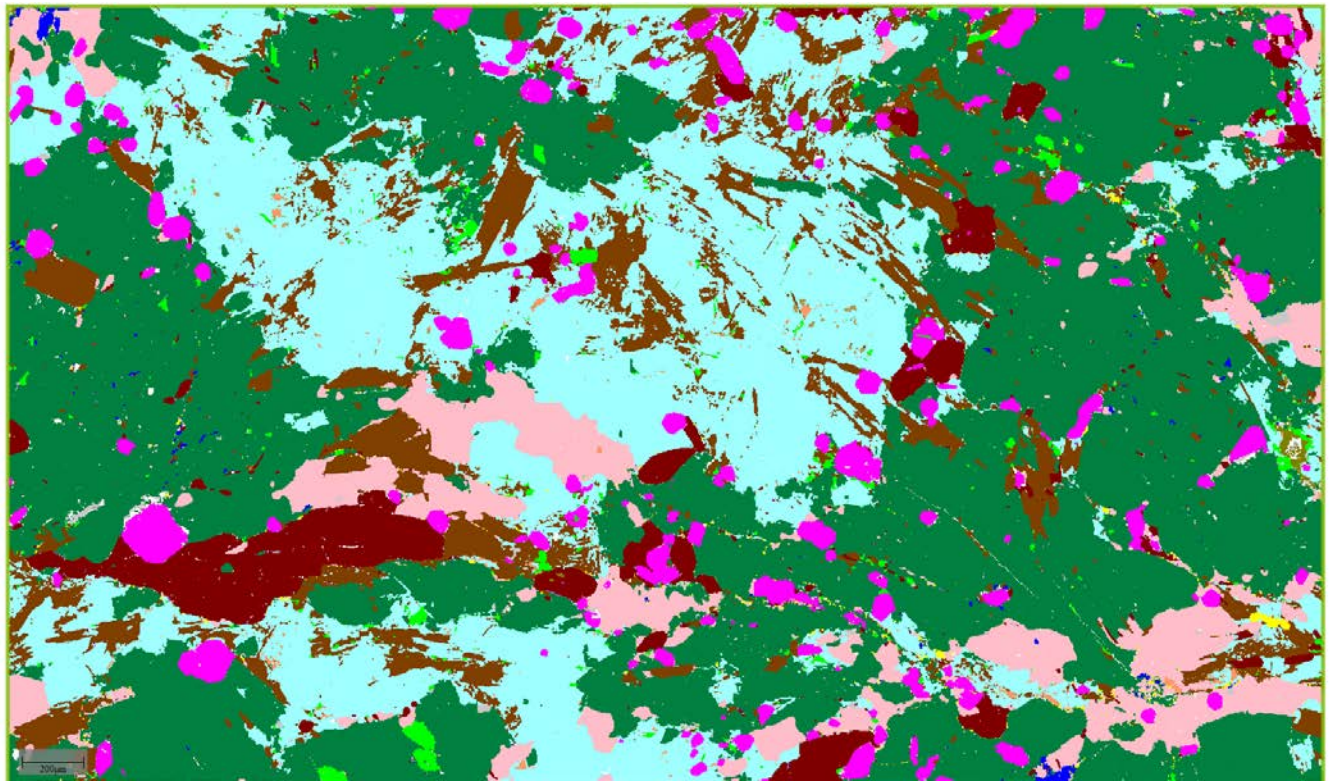
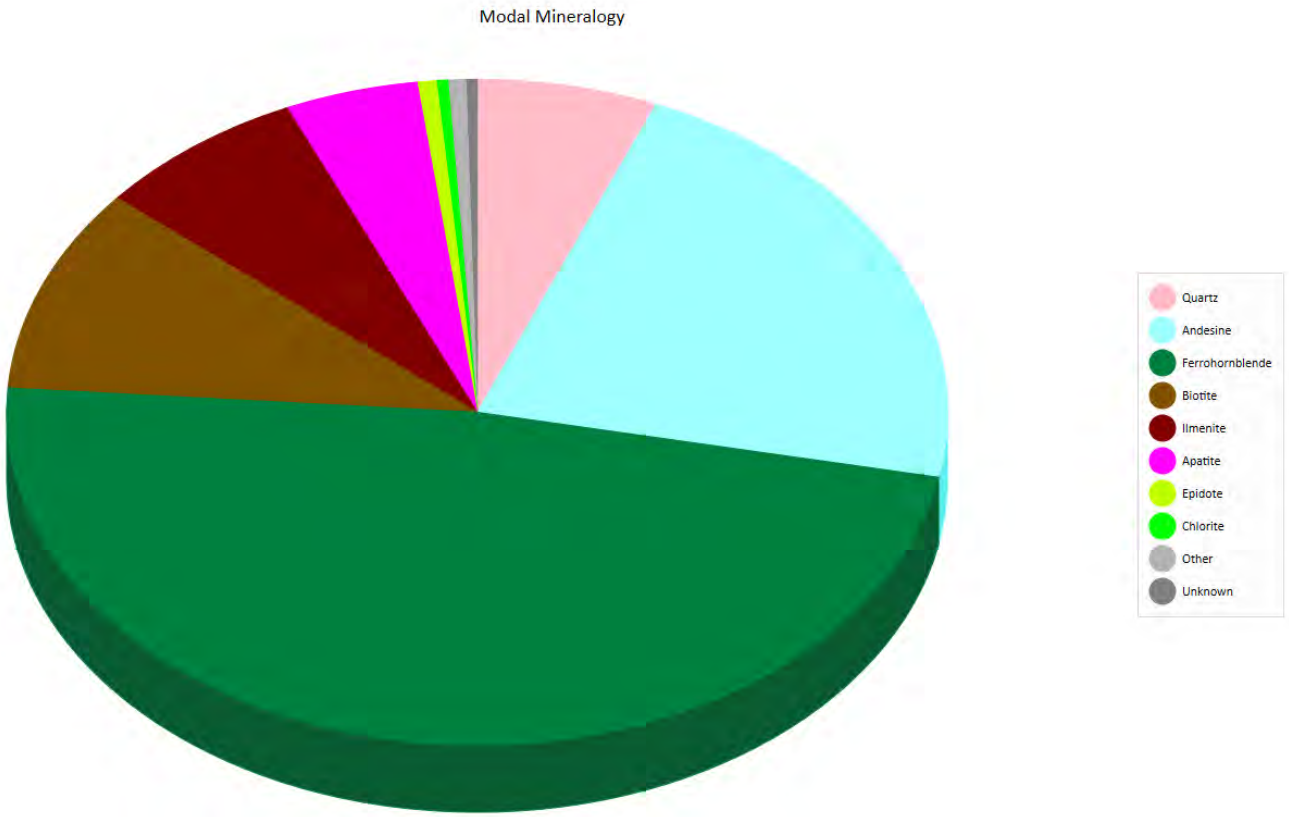


# Thin section: Ferrodiorite

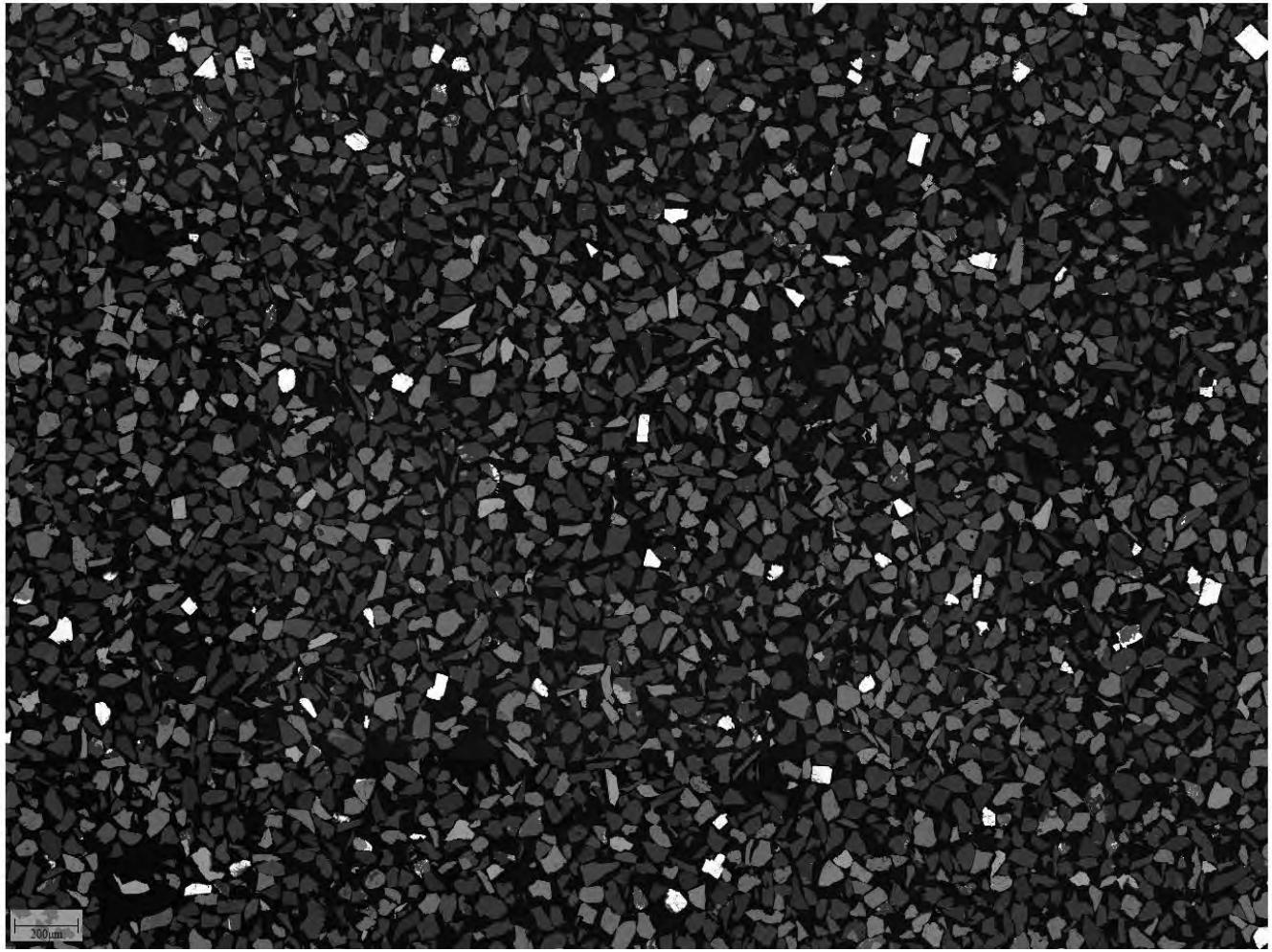
**Modal Mineralogy**

| | Name | Wt% | Area% | Area (µ2) | Particle Num... | Grain Number | Relative Error |
|---|---|---|---|---|---|---|---|
| | <all> | <all> | <all> | <all> | <all> | <all> | <all> |
| 1 | Quartz | 6.20 | 7.32 | 784575.10 | 1 | 931 | 1.87 |
| 2 | Andesine | 21.93 | 25.37 | 2721339.45 | 1 | 1067 | 1.87 |
| 3 | Ferrohomble... | 48.03 | 46.09 | 4942962.19 | 1 | 666 | 1.87 |
| 4 | Biotite | 9.97 | 9.74 | 1044473.43 | 1 | 2051 | 1.87 |
| 5 | Ilmenite | 7.24 | 4.74 | 508612.79 | 1 | 467 | 1.87 |
| 6 | Apatite | 4.58 | 4.44 | 476034.98 | 1 | 205 | 1.87 |
| 7 | Epidote | 0.66 | 0.60 | 63998.02 | 1 | 403 | 1.87 |
| 8 | Chlorite | 0.39 | 0.38 | 40686.61 | 1 | 547 | 1.87 |
| 9 | Other | 0.61 | 0.58 | 62555.11 | 1 | 712 | 1.87 |
| 10 | Unknown | 0.39 | 0.74 | 79395.40 | 8 | 2864 | 0.00 |

# Thin section: Ferrodiorite



# Sulfide sample




Measurement all phases and minerals: 30min

Image resolution
1.6 µm/pixel
~7000 particles

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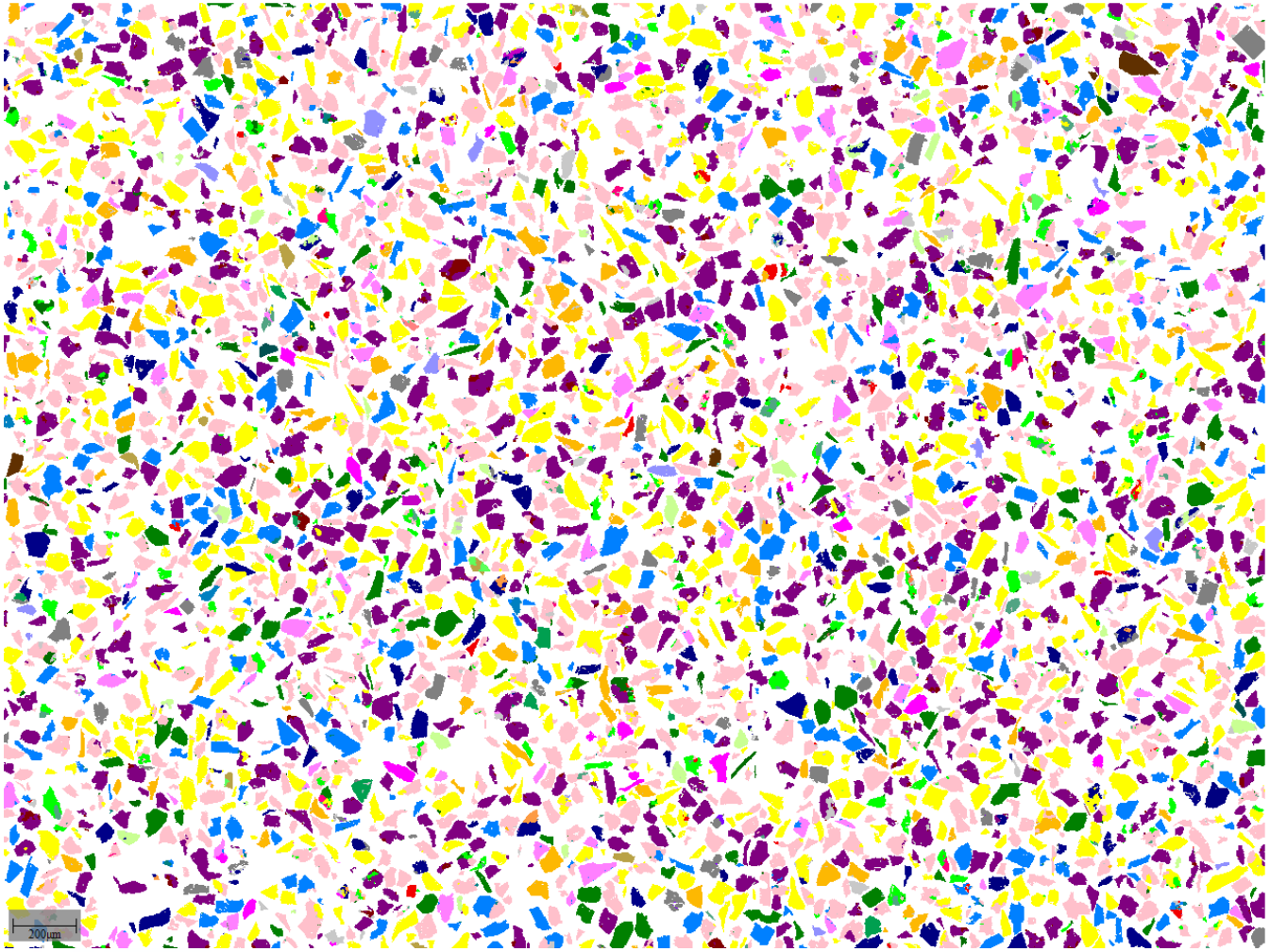
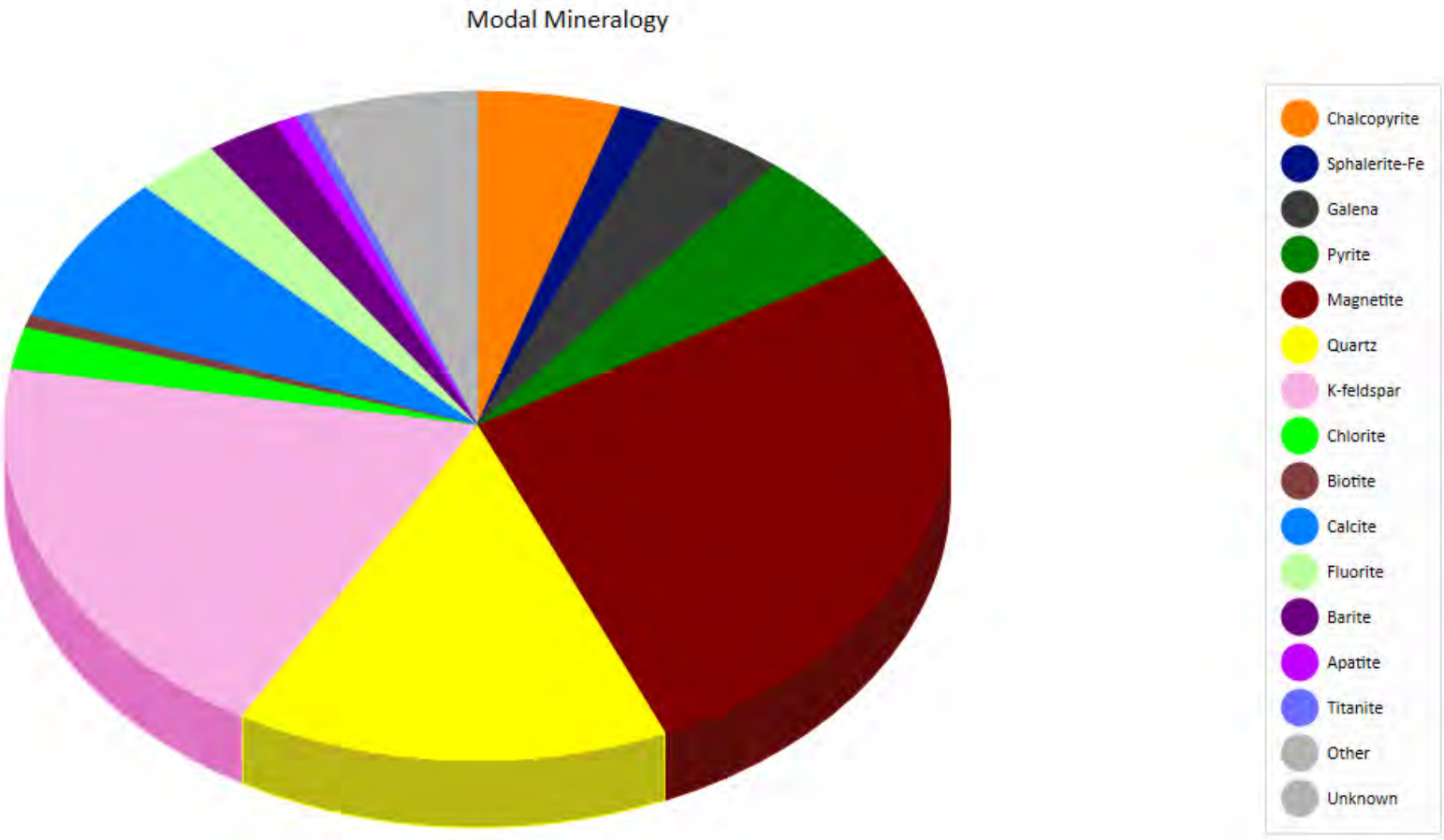



Measurement all phases and minerals: 30min

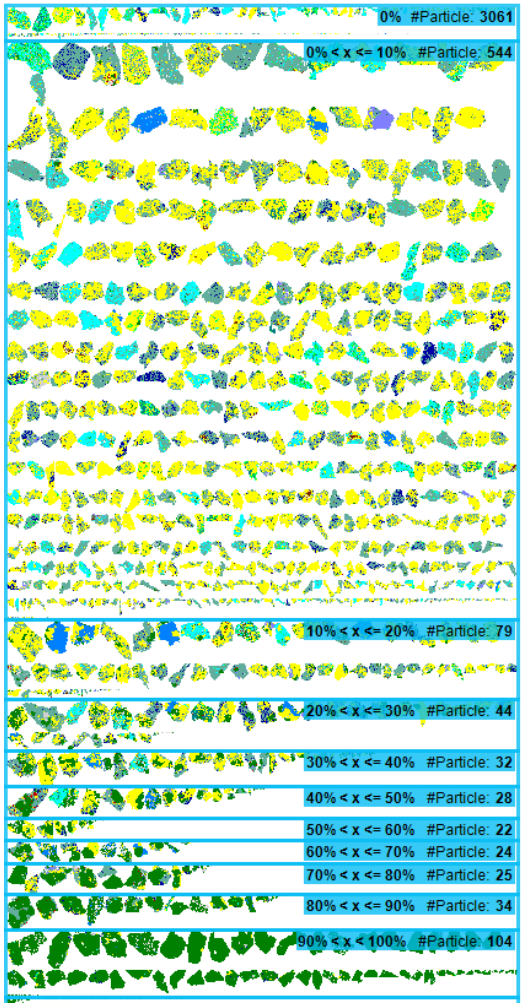
Image resolution
1.6 µm/pixel
~7000 particles

- Chalcopyrite
- Sphalerite-Fe
- Galena
- Pyrite
- Magnetite
- Quartz
- K-feldspar
- Chlorite
- Biotite
- Calcite
- Fluorite
- Barite
- Apatite
- Titanite
- Other
- Unknown

# Sulfide sample



# Mineral Liberation Example
## Particle Display





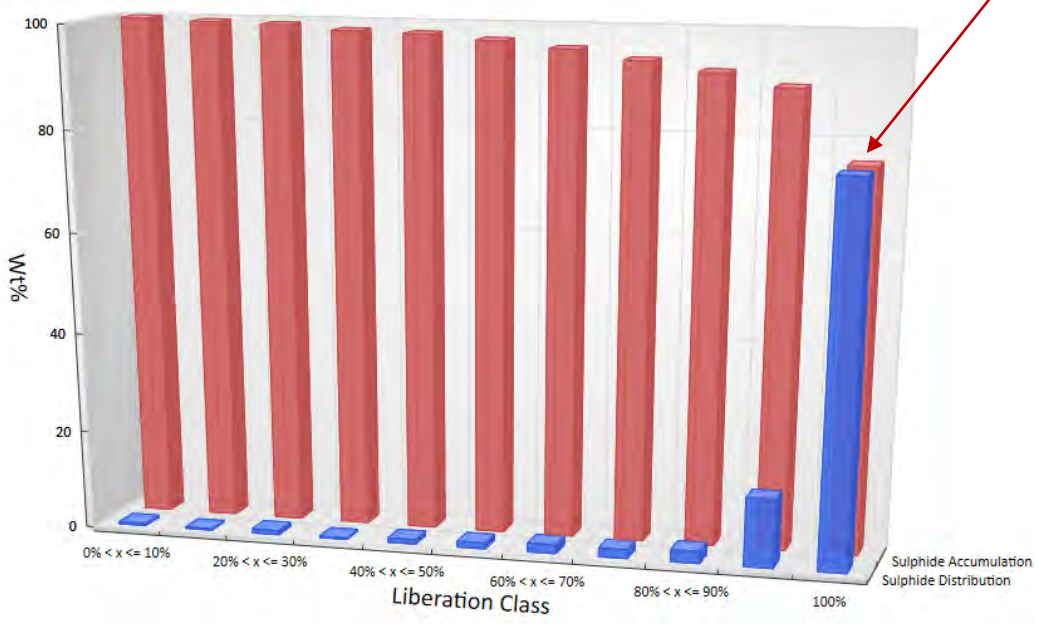
- Particle Grid Display (Sulphides) for visual inspection of data
- Particles for each liberation class (0%-10%, 10%-20%, 20%-30% etc.

# Mineral Liberation Example
## Tables and Charts

Data in tabular format or graph format

| Classes | 0% | 0% < x <= 10% | 10% < x <= 20% | 20% < x <= 30% | 30% < x <= 40% | 40% < x <= 50% | 50% < x <= 60% | 60% < x <= 70% | 70% < x <= 80% | 80% < x <= 90% | 90% < x < 100% | 100% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Particle Count | 2988 | 47 | 8 | 8 | 3 | 5 | 6 | 6 | 6 | 6 | 33 | 240 |
| Sulphide Distribution | 0 | 0.5 | 0.3 | 0.9 | 0.3 | 0.9 | 1.2 | 1.8 | 1.8 | 2.5 | 13.9 | 75.8 |
| Sulphide Accumulation | 0 | 100.0 | 99.5 | 99.2 | 98.4 | 98.1 | 97.1 | 95.9 | 94.1 | 92.2 | 89.8 | 75.8 |

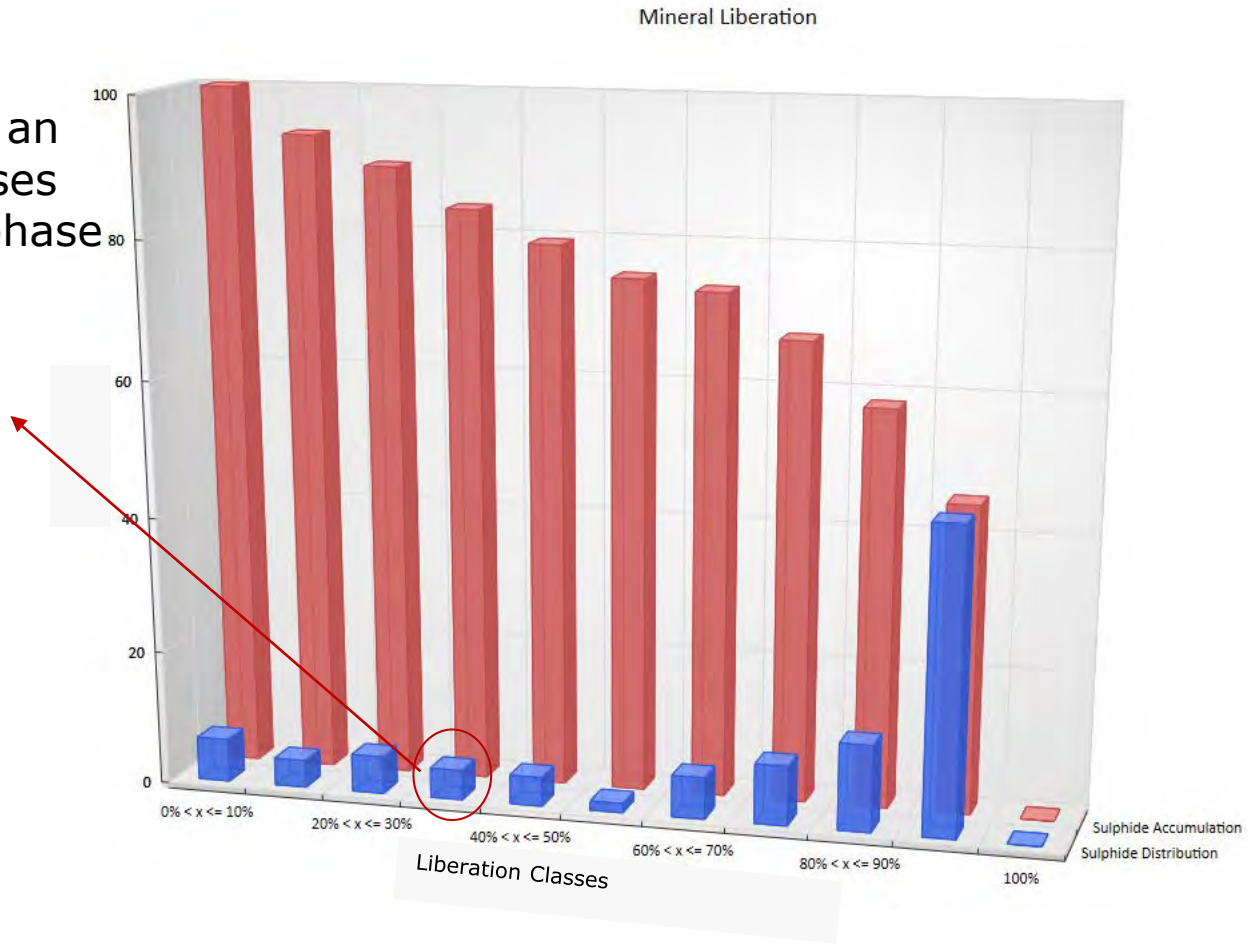
As can be seen, 100% liberated class contain 240 particles, and make up 75.8 % of all of the Sulphide bearing particles.



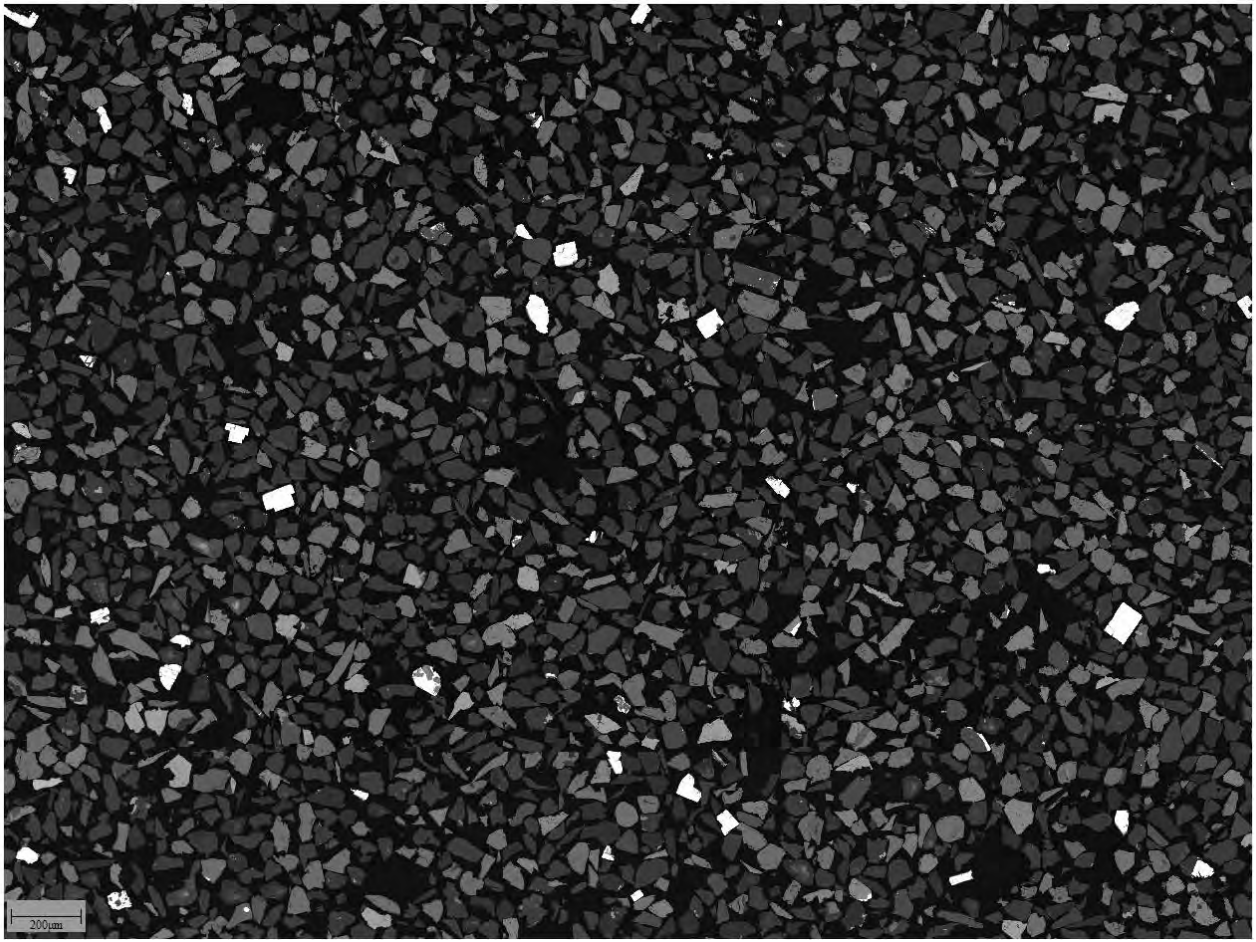
# Mineral Liberation Example
## Tables and Charts

Modal data for each liberation class gives an indication of the phases associated with the phase of interest

| Classes | 30% < x <= 40% |
|---|---|
| Sulphide | 35.2 |
| Arsenopyite | 0.4 |
| Quartz | 31.1 |
| Alkali Feldspar | 2.2 |
| Calcite-Mn | 2.2 |
| Illite | 23.5 |
| Muscovite/Sericite | 1.9 |
| Other Clay | 0.4 |
| Clinochlore | 0.2 |
| Ti-oxide | 1.1 |
| Mn-oxide | 0.3 |
| Other | 1.6 |



# Sulfide sample: Bright Phase Search




Measurement for only bright phases shortens measurement time to 14min

Image resolution
0.7 µm/pixel
25 fields

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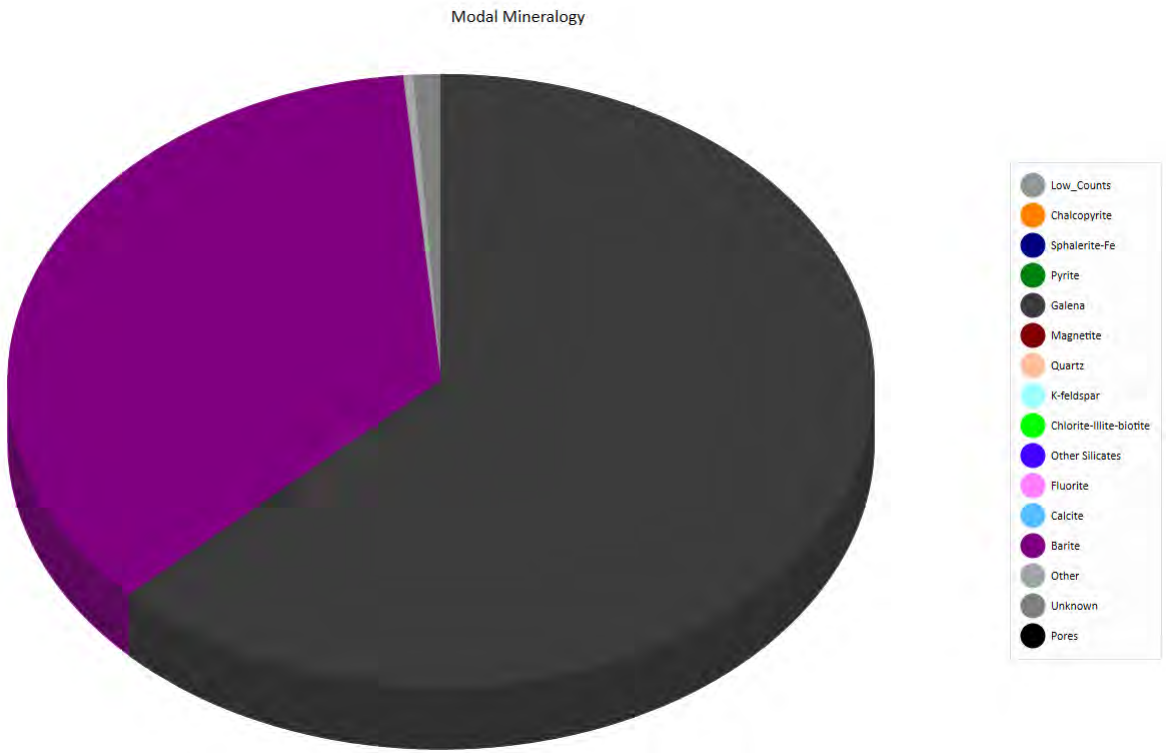


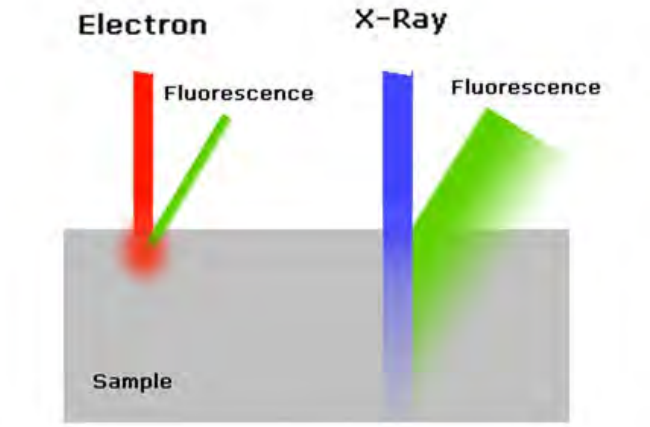
# AMICS for QUANTAX EDS
## Summary

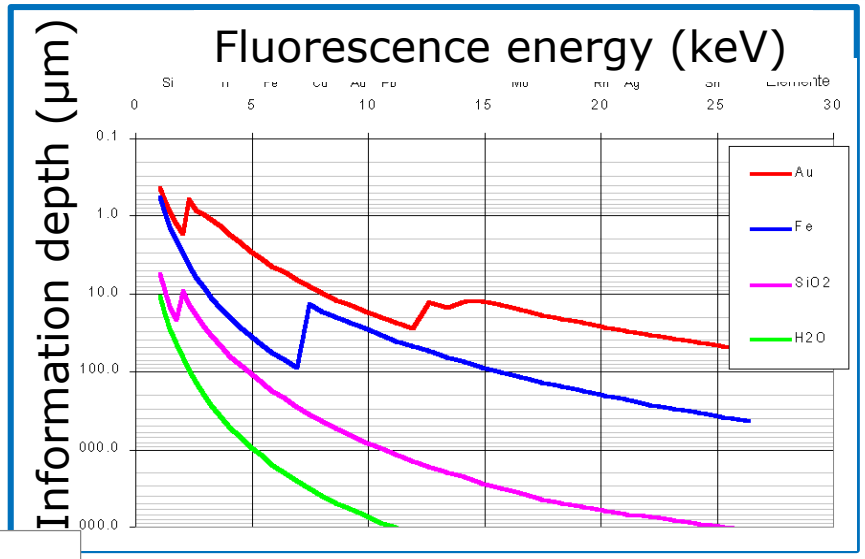
- Minerals with similar BSE intensities such as Chalcopyrite-Pentlandite can be effectively distinguished with AMICS's unique advanced segmentation
- Likewise, silicate minerals often have very similar BSE intensities but phases such as Quartz, Albite and different Plagioclase minerals can be reliable differentiated with AMICS's advanced segmentation technology.
- A number of predefined calculations are available that can be displayed in tabular or chart formats
- The software is intuitaive and easy to use

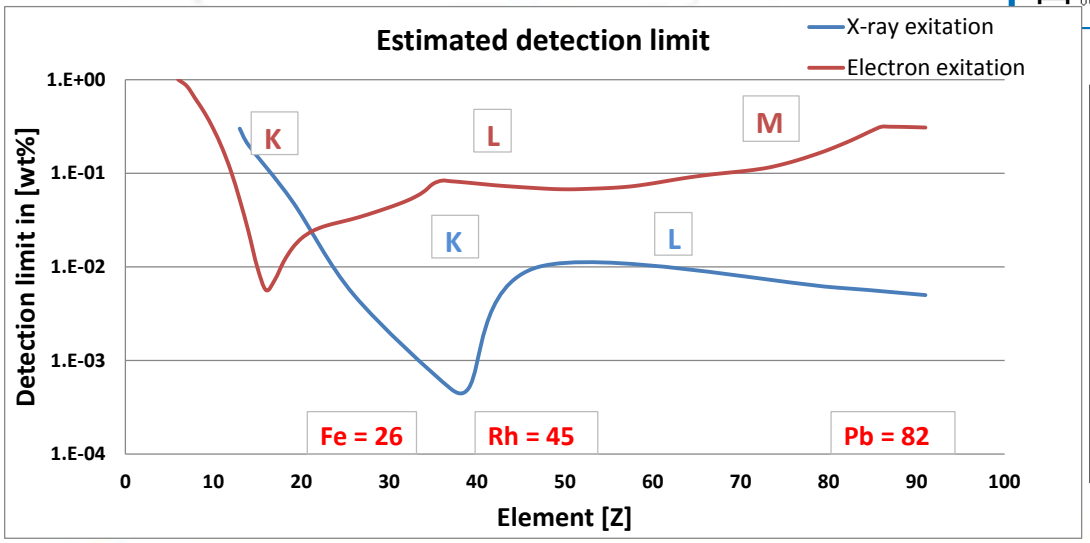
# AMICS for M4 TORNADO – Micro-XRF

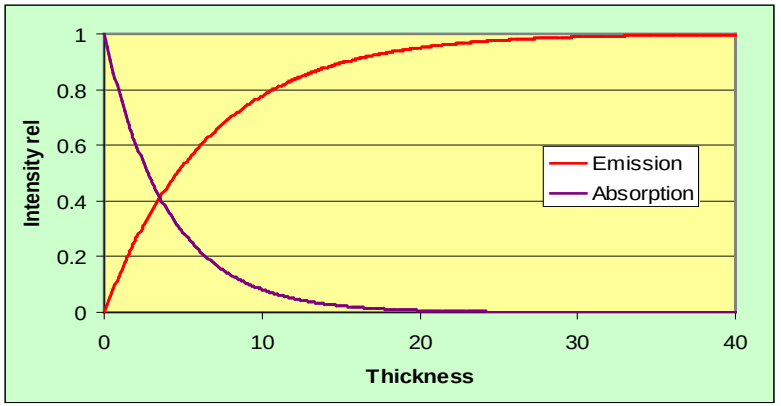
# Advanced Mineralogy by Micro-XRF
## Brief Introduction to Micro-XRF

Differences in excitation and LOD:



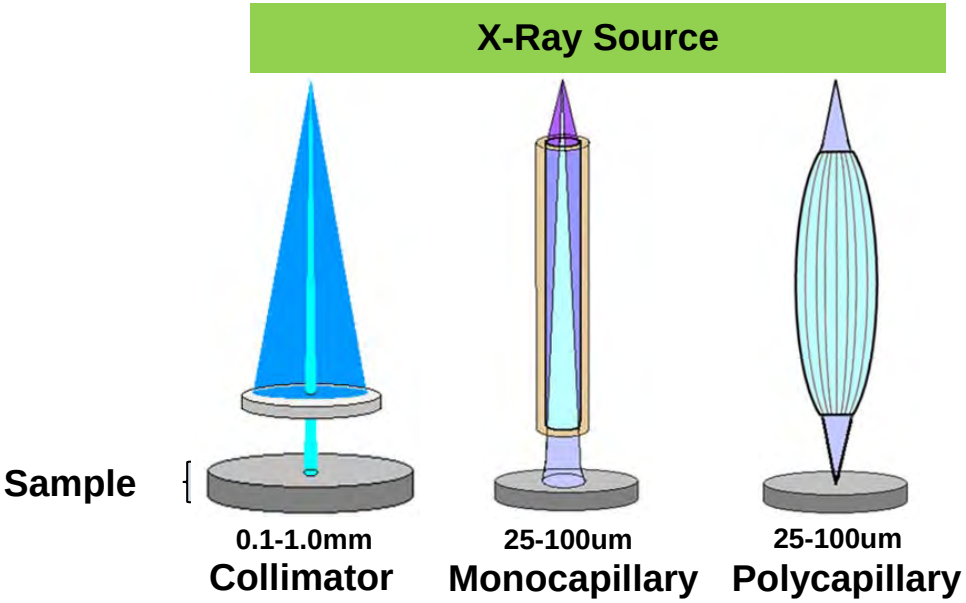



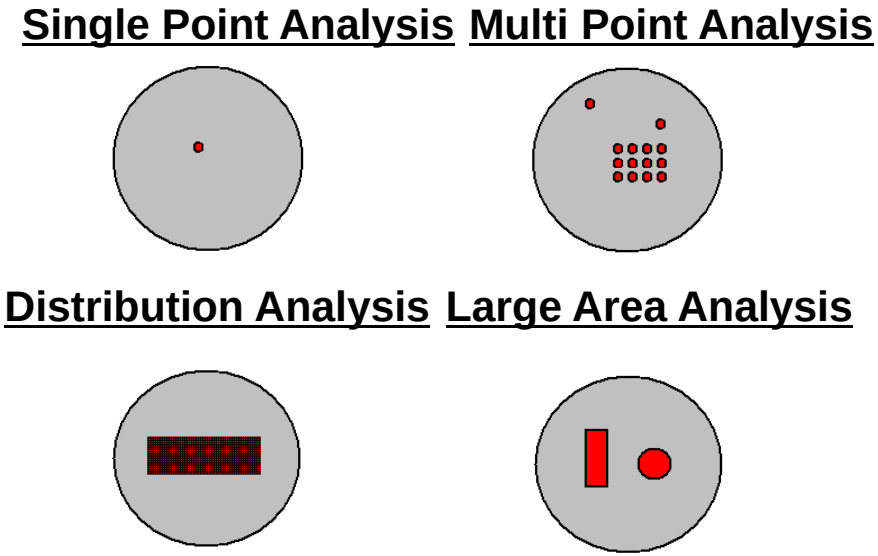
# Advanced Mineralogy by Micro-XRF
## Brief Introduction to Micro-XRF

### X-Ray spatial resolution by optic

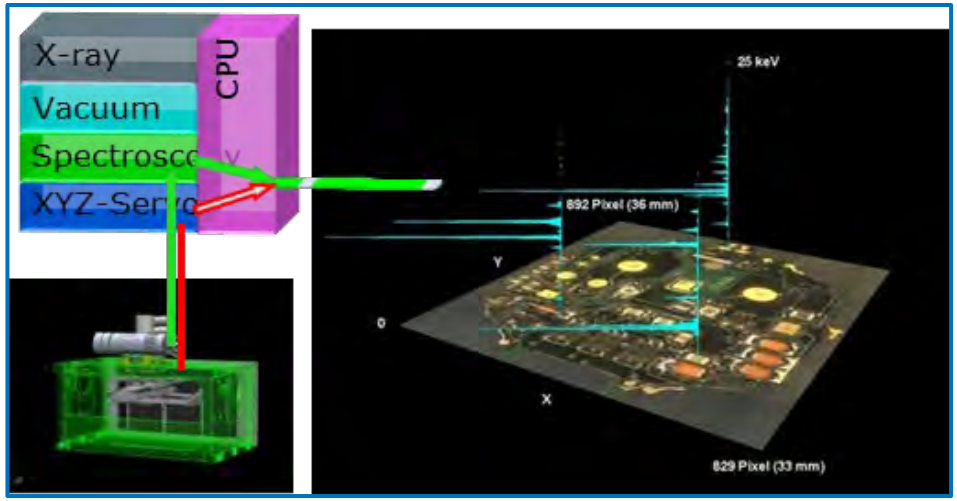



| Optics | Brilliance / norm. for area |
|---|---|
| Collimator | 1 |
| Monocapillary | ≈ 10 |
| Polycapillary | ≈ 10000 |

### Analysis types



# Advanced Mineralogy by Micro-XRF
## The µXRF Instrument – M4 TORNADO$^{AMICS}$




- Large, vacuum chamber, pump down < 2 min, allowing detection to Na
- Fast 100 mm/s stage for "on-the-fly" distribution analysis with 20 x 16 cm range and 4 µm resolution
- Dual mag optical microscopes for sample view and positioning
- < 20 µm spot size at Mo Kα and high excitation intensity with capillary optic
- Dual SDD in 30 or 60 mm² with < 145 eV @ Mn Kα
- Hypermap 4D data storage
- Little or no sample preparation

# Comparison of AMCIS on Micro-XRF to EDS on SEM

## Application Examples

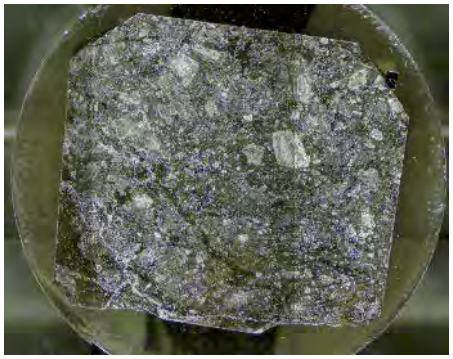
# Advanced Mineralogy by Micro-XRF

## Fine alteration textures and intergrowths of Cu/Au Porphyry

Step Size: 100 µm
Time: 1h15m (single detector)

µ-XRF + AMICS

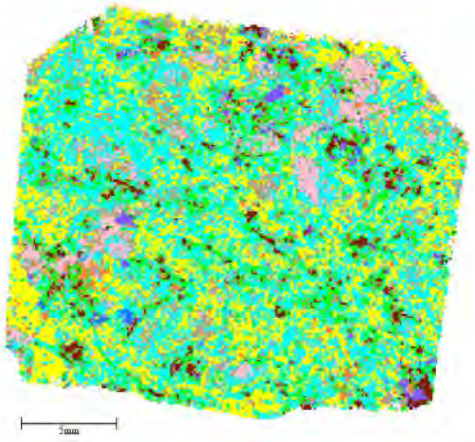
M4 TORANDO

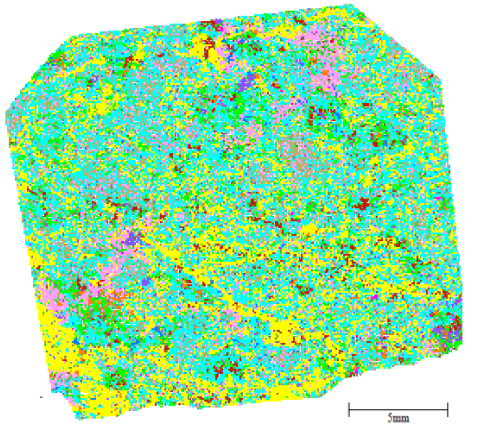


SEM/EDS + AMICS

HHT S3500 / XFlash® 6|10

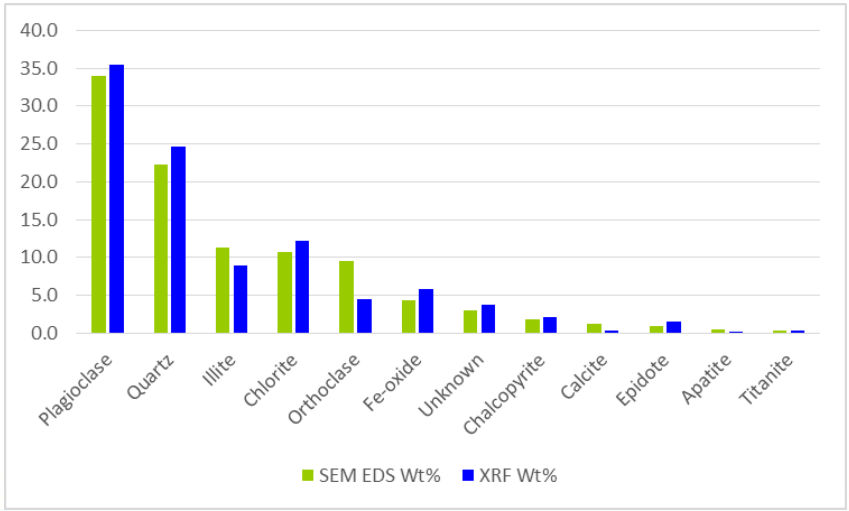
Step Size: 100 µm
Time: 1h28m (single detector)





| |
|---|
| Quartz |
| Plagioclase |
| Orthoclase |
| Illite |
| Chlorite |
| Apatite |
| Chalcopyrite |
| Pyrite |
| Fe-oxide |
| Calcite |
| Epidote |
| Titanite |
| Unknown |

Modal by Wt%

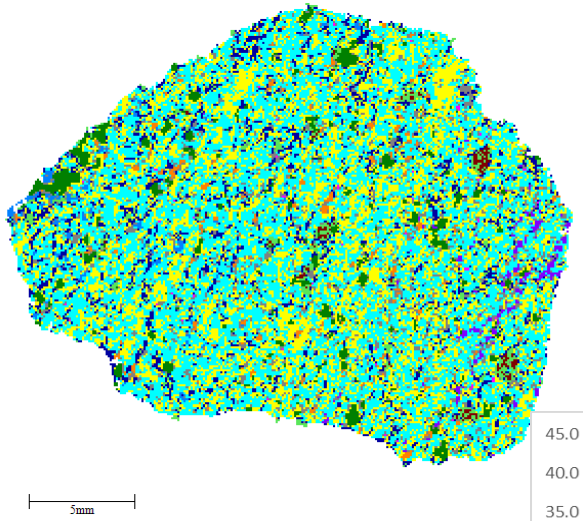


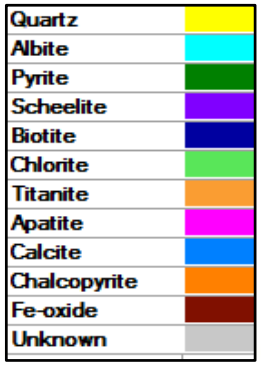

| |
|---|
| Quartz |
| Plagioclase |
| Orthoclase |
| Illite |
| Chlorite |
| Apatite |
| Chalcopyrite |
| Pyrite |
| Fe-oxide |
| Calcite |
| Epidote |
| Titanite |
| Unknown |

# Advanced Mineralogy by Micro-XRF
## Quartz, albite & pyrite with little alteration

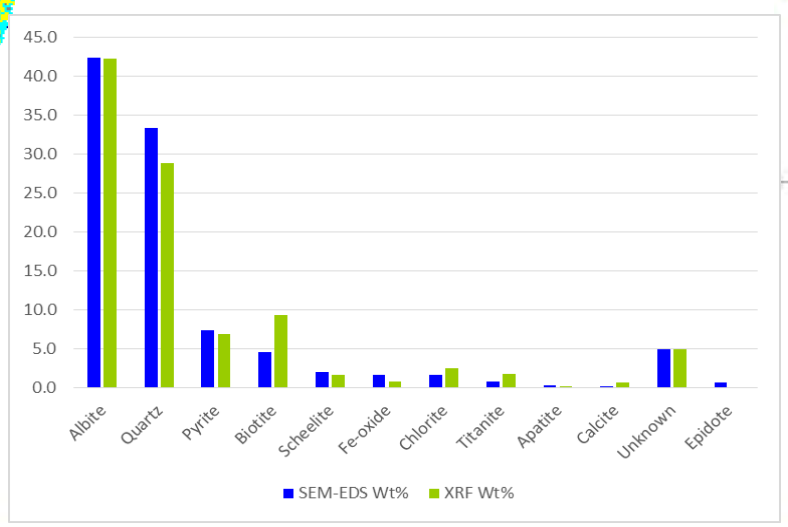
Step Size: 100 µm
Time: 1h4m (single detector)

M4 TORNADO$^{AMICS}$



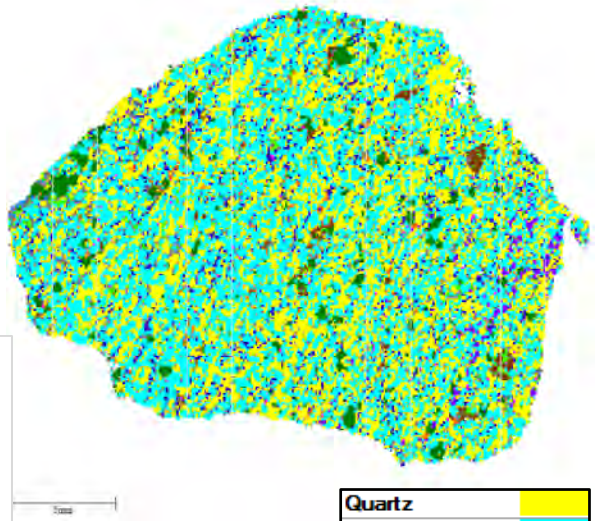

Modal by Wt%

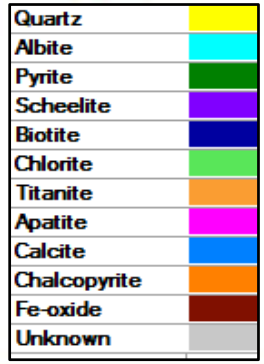



Step Size: 100 µm
Time: 1h26m (single detector)

SEM/EDS + AMICS

Hitachi S3500 / XFlash® 6|10





# Advanced Mineralogy by Micro-XRF
## Carbonatite with REE

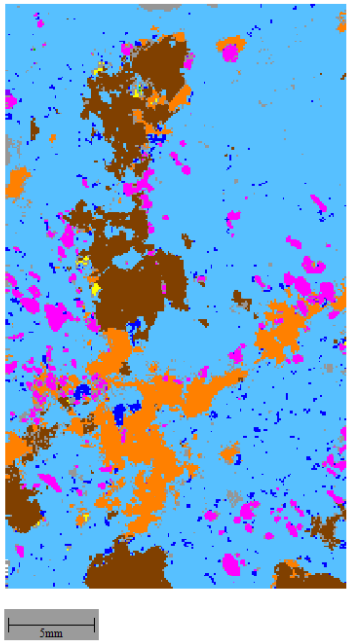
M4 TORNADO$^{AMICS}$

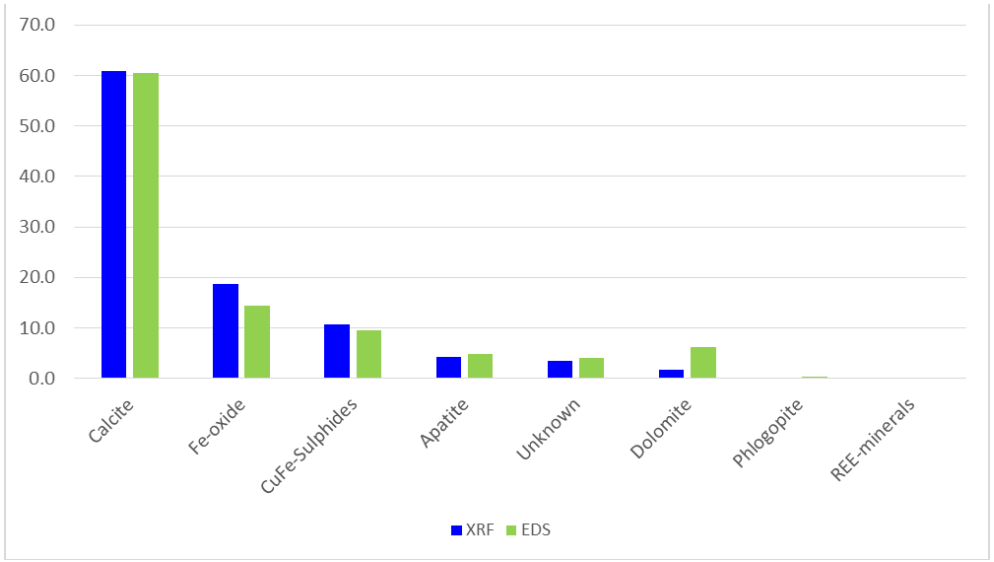
Step Size: 100 µm
Time: 2h17m (single detector)

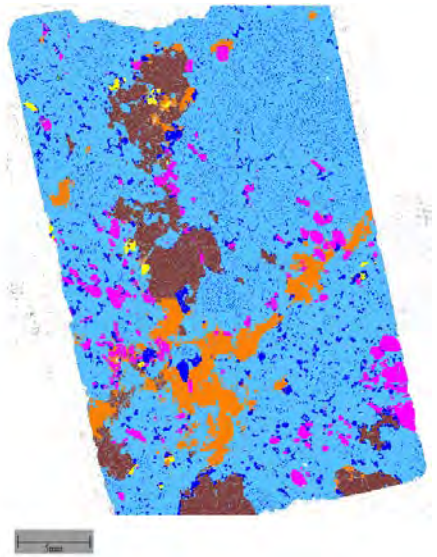
SEM/EDS + AMICS

Image resolution: 2.5µm
Time: 19h21m (single detector)

Hitachi S3500 / XFlash® 6|10



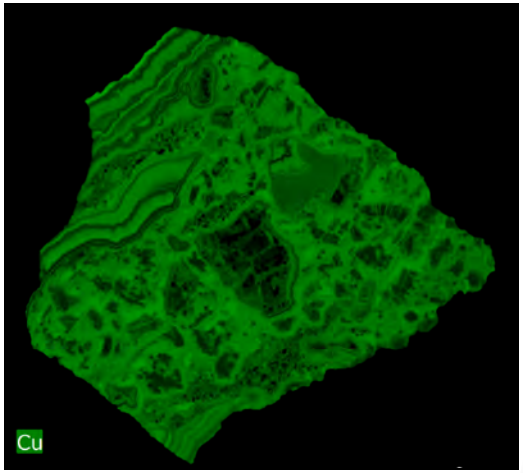

Calcite
Dolomite
CuFe-Sulphides
Fe-oxide
REE-minerals
Apatite
Phlogopite
Unknown

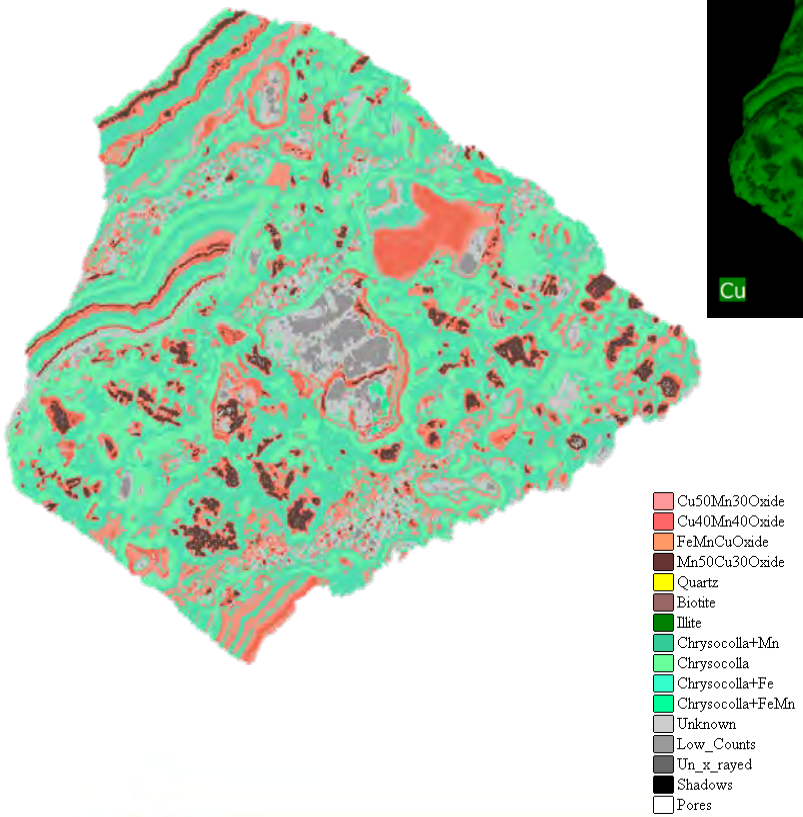
Calcite
Dolomite
CuFe-Sulphides
Fe-oxide
REE-minerals
Apatite
Phlogopite
Unknown

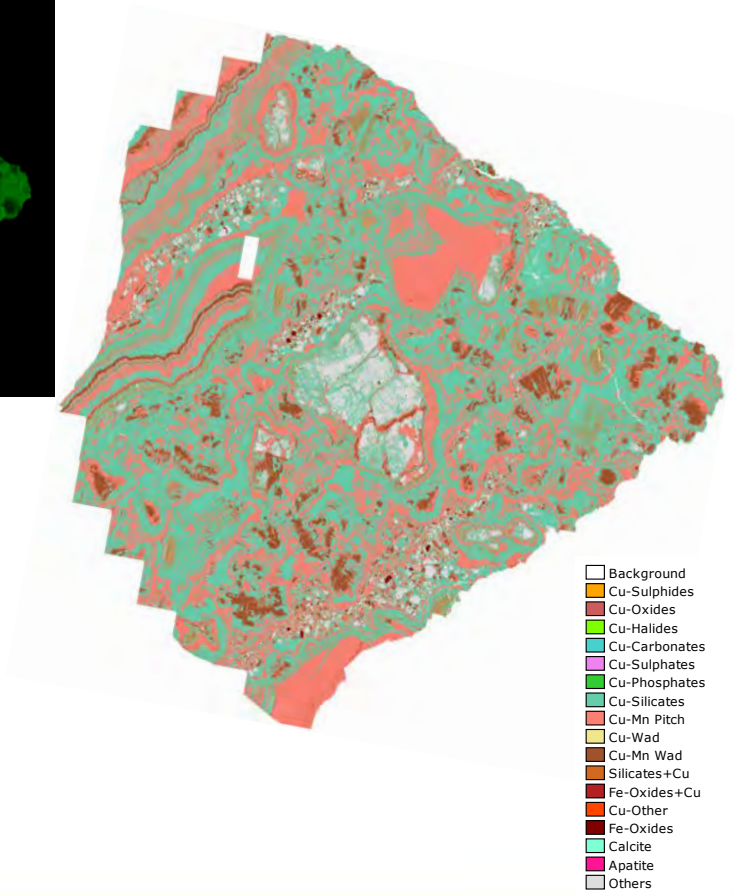
# Advanced Mineralogy by Micro-XRF
## QEMSCAN vs. M4 TORANDO: Exotic Cu

M4 TORNADO$^{AMCIS}$ Step Size: 20 µm
Time: ~3,5h (dual detectors)

QEMSCAN Step Size: 10 µm / 5 µm
Time: 4h45m / 1h6m (4 detectors)

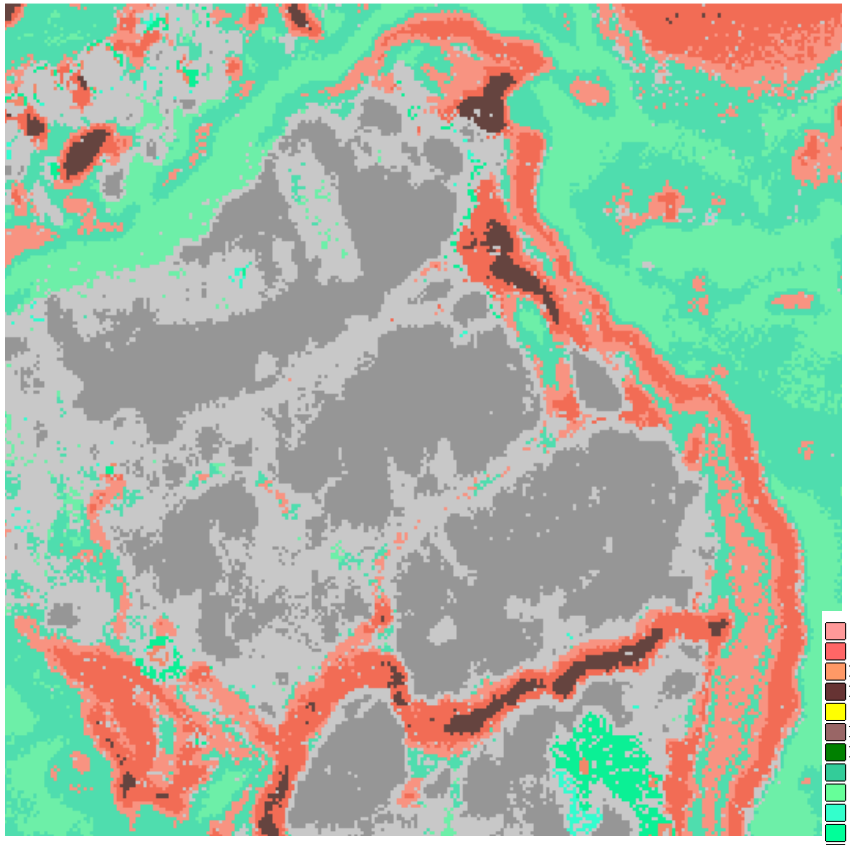


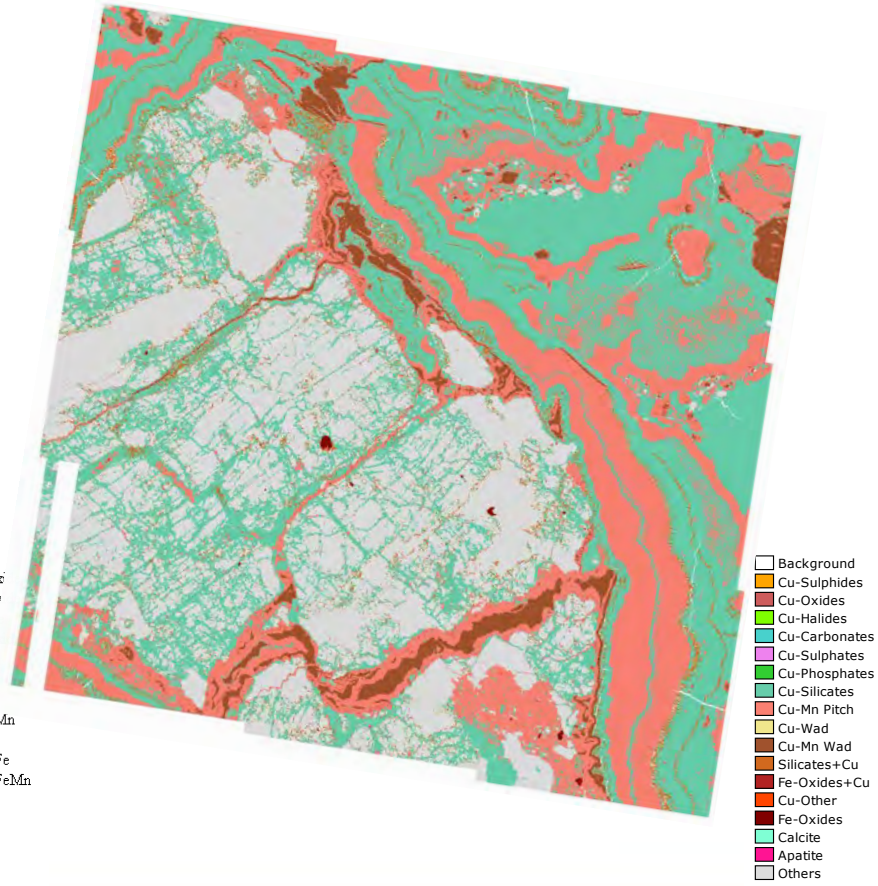



# Advanced Mineralogy by Micro-XRF
## QEMSCAN vs. M4 TORANDO: Exotic Cu

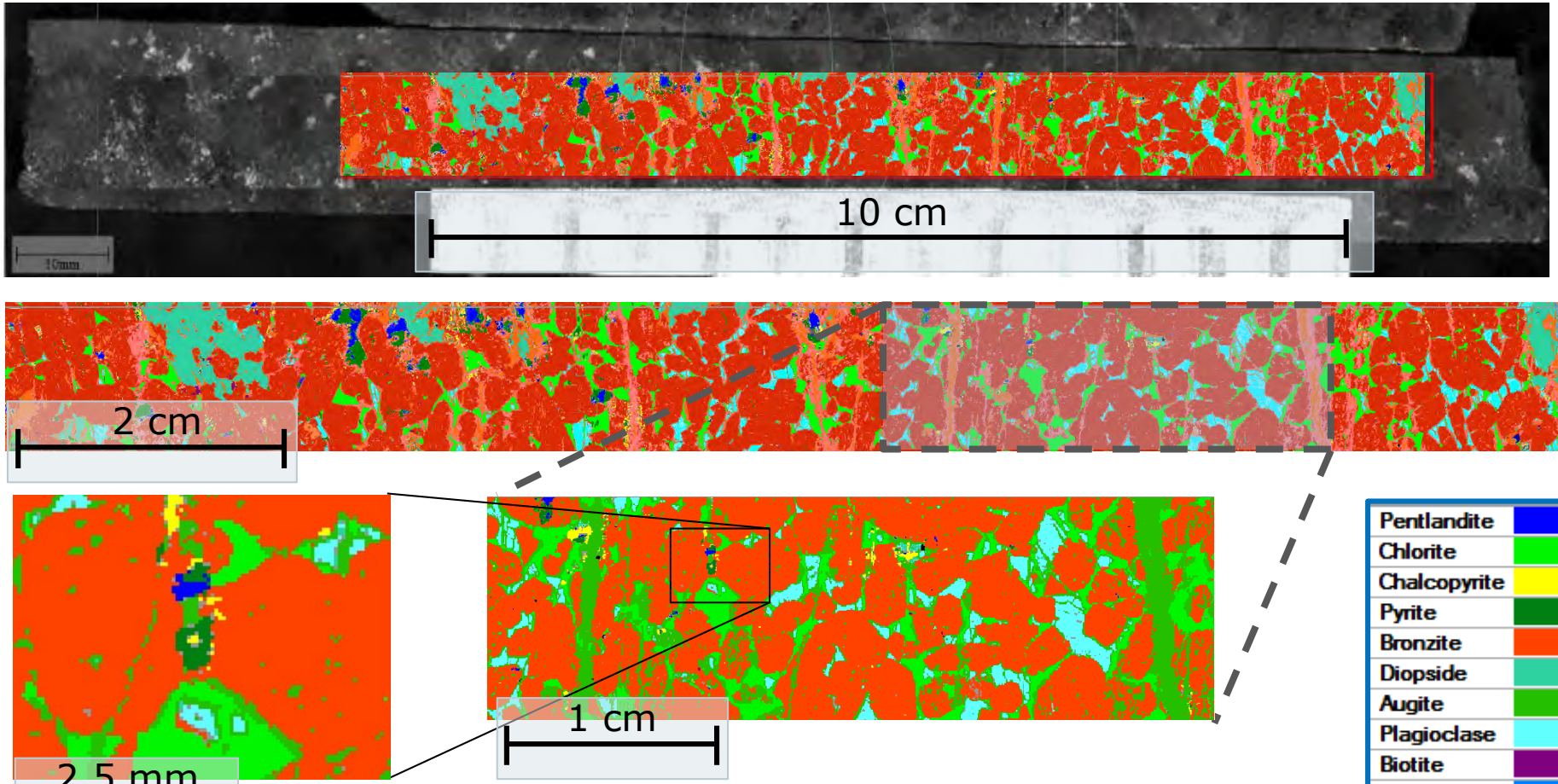
M4 TORNADO$^{AMCIS}$ Step Size: 20 µm
Time: ~3,5h (dual detectors)




QEMSCAN Step Size: 10 µm / 5 µm
Time: 4h45m / 1h6m (4 detectors)



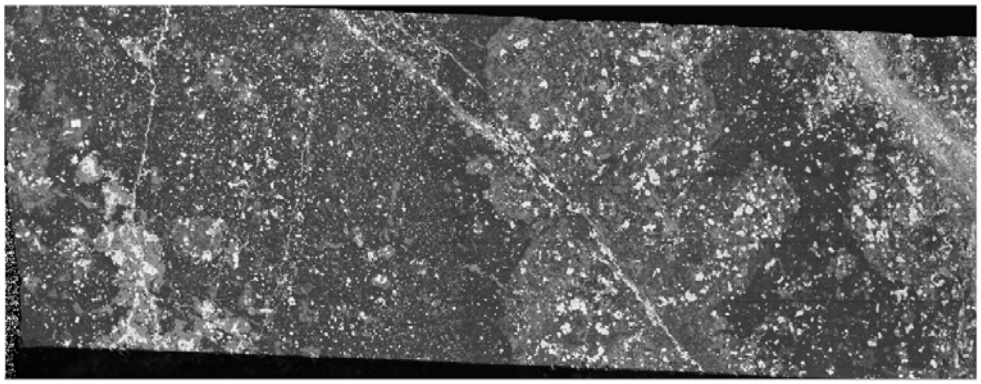
# Advanced Mineralogy by Micro-XRF
## Pyroxenite Drill Core

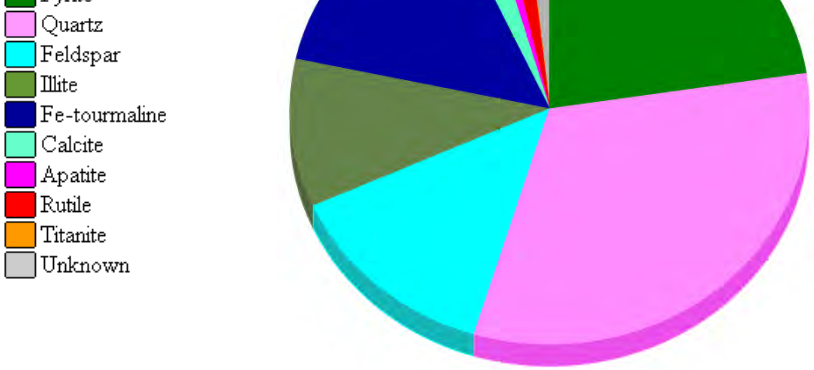


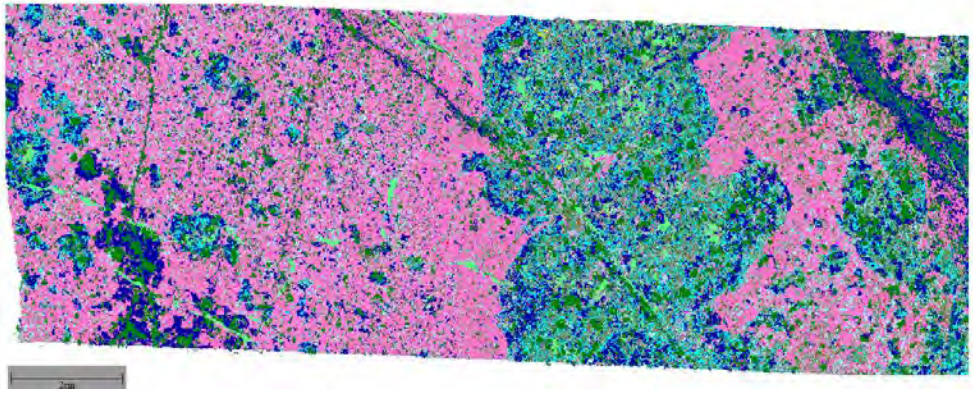

Step Size: 50 µm Area: 1.1 cm x 11.8 cm
Time: 13h20m (dual detectors)

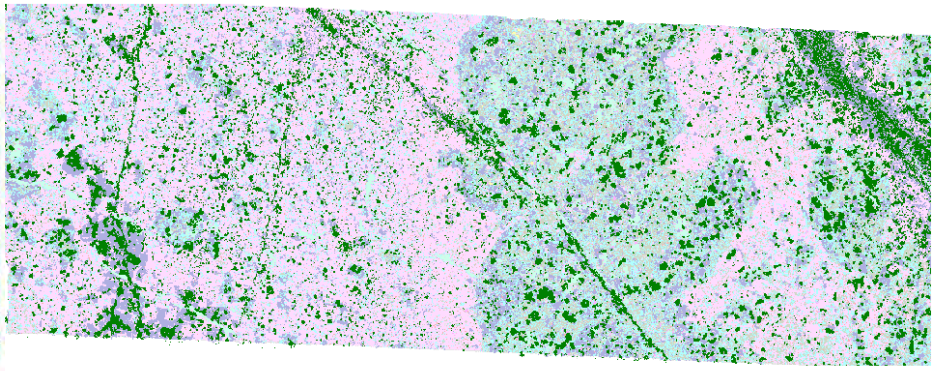
# Advanced Mineralogy by Micro-XRF
## Gold Deposit, Australia

Step Size: 100 µm
Time: 11h35m (single detector)





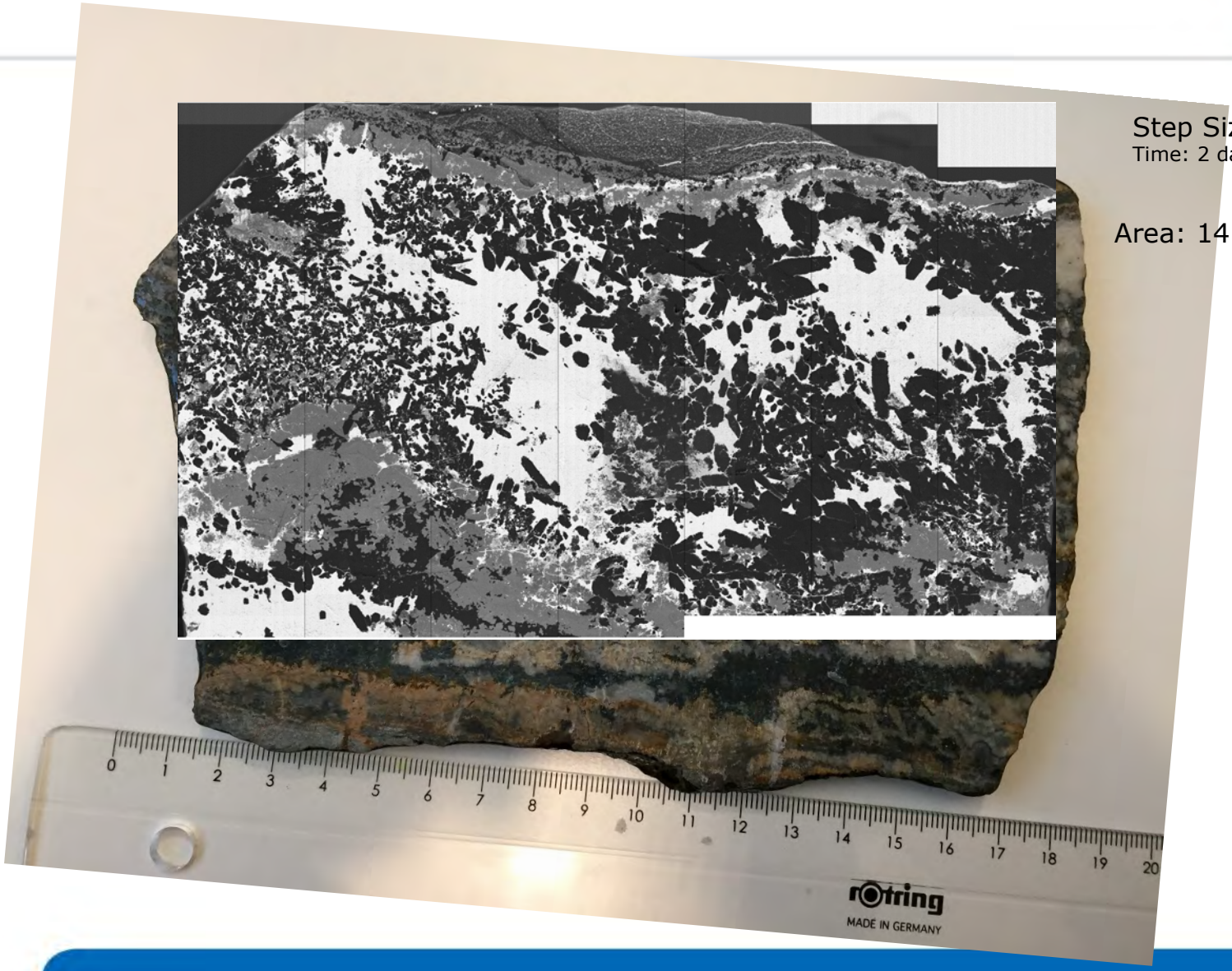



# Advanced Mineralogy by Micro-XRF
## Copper Deposit Champion Mine, MI, US


Step Size: 100 µm
Time: 2 days 21h (dual detectors)

Area: 14.5 cm x 10.1 cm

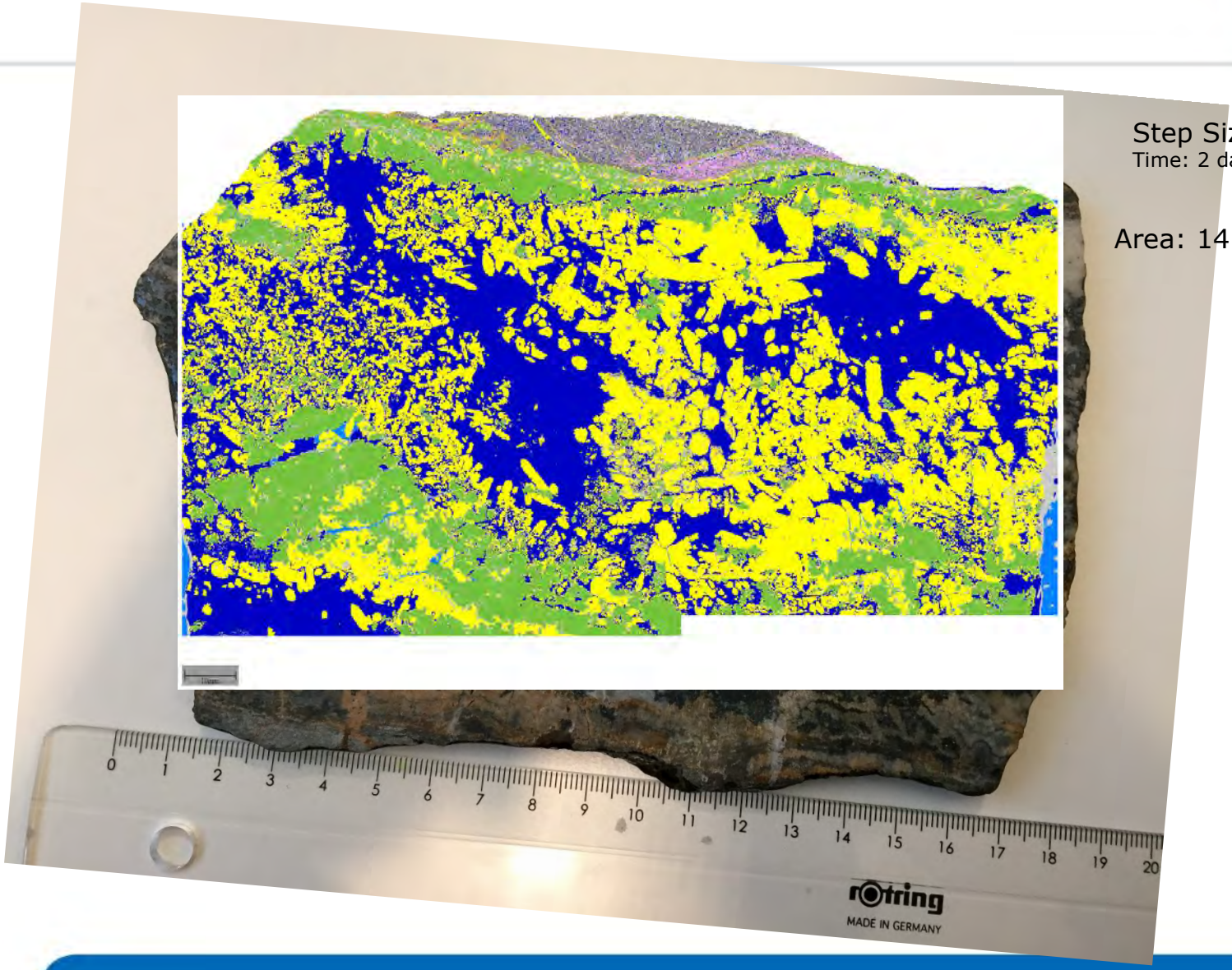
# Advanced Mineralogy by Micro-XRF
## Copper Deposit Champion Mine, MI, US



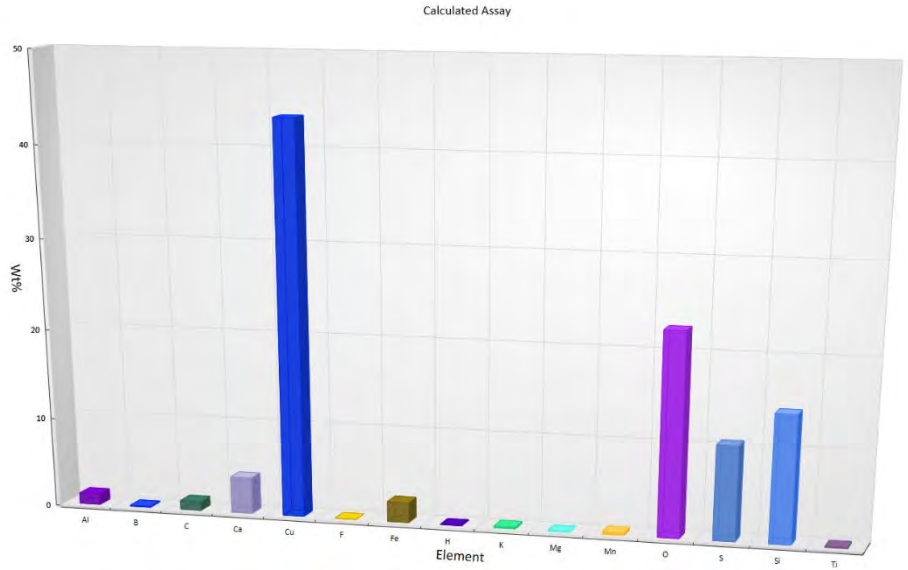

Step Size: 100 µm
Time: 2 days 21h (dual detectors)

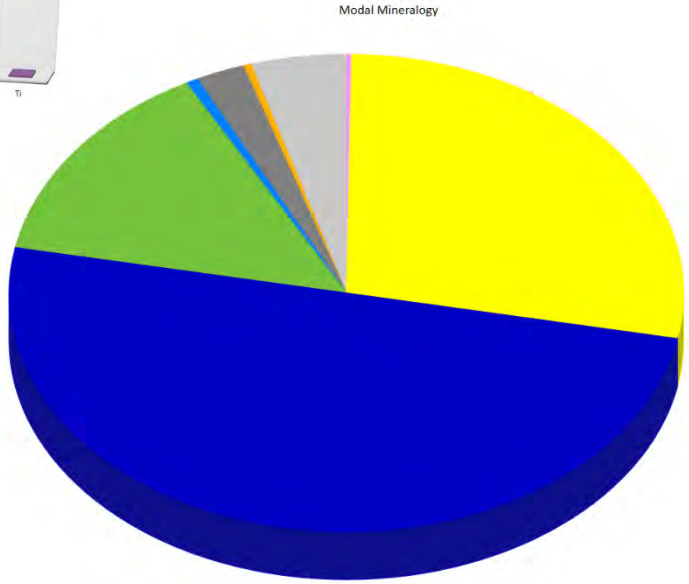
Area: 14.5 cm x 10.1 cm

# Advanced Mineralogy by Micro-XRF
## Copper Deposit Champion Mine, MI, US



# Advanced Mineralogy by Micro-XRF
## Copper Deposit Champion Mine, MI, US



# AMICS for M4 TORNADO
## Summary

- Can produce comparable results to SEM-EDS, MLA and QEMSCAN down to micron size scale
- Great tool for capturing the texture of an uncrushed sample (ore body development) not possible with SEM (on such large samples)
- Helps to make more informed decisions in selecting samples for time-consuming SEM-EDS analysis

# Demonstration

# Conclusion

AMICS

- Provides new powerful tools for automated mineralogy
- With SEM-EDS can provide detail analysis and mineral liberation information
- The world's first mineral analyzer based on Micro-XRF- M4 TORNADO$^{AMICS}$
- Complements SEM-EDS analysis in that it helps to make more informed decisions in selecting samples for time-consuming SEM-EDS analysis
- Same software for both SEM and Micro-XRF makes it easier to learn and use the system

# Q&A

## Are There Any Questions?

Please type in the questions you might have in the Q&A box and press *Send*.

# More Information

**For more information, please contact us:**

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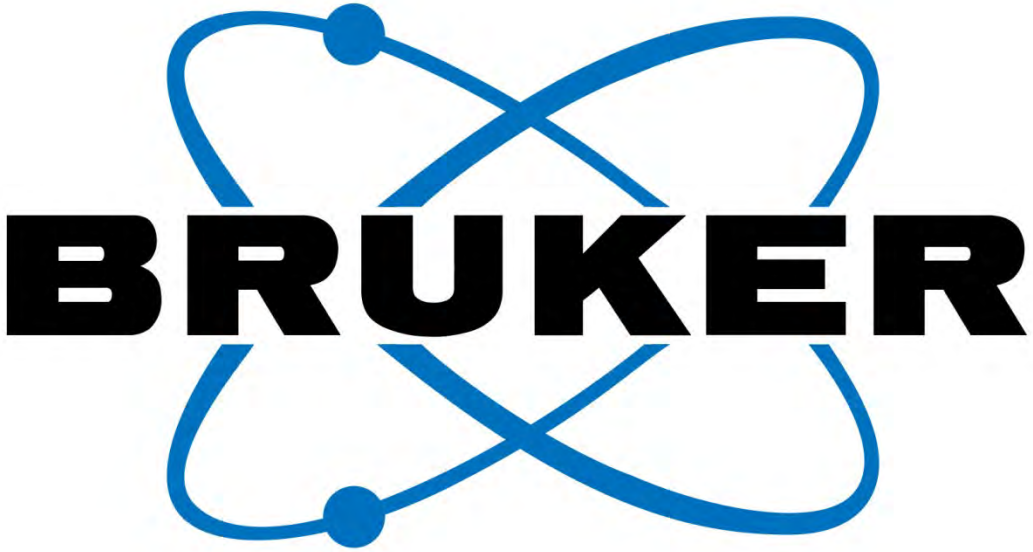
gertrudia.gloy@bruker.com

info.bna@bruker.com

https://www.bruker.com/AMICS




Innovation with Integrity