Trace Elements and Mineralization:
The benefits of combining micro-XRF and SEM-EDS/WDS

Bruker Nano Analytics, Berlin, Germany
Webinar

Presenters

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Overview:
Trace Elements and Mineralization

- The motivation and analytical challenge
- Short introduction to the analytical techniques applied in this work
- Advantages of combining analytical techniques
  - Case Study 1: Au (Gold)
  - Case Study 2: Co (Cobalt)
  - Sample size and analytical solution
  - Spectroscopical overlaps and analytical considerations
- Summary and Conclusion

Overview:
Trace Elements and Mineralization

The motivation and analytical challenge:

- In many economic deposits the element or mineral of interest is a trace component.
- The ability to identify or even extract these elements and minerals depends on how they occur.
- Such information is important to understand the genesis of the deposit as well as the mineral and metallurgical processes to yield the maximum recovery.
- The analytical questions and samples to be studied cover a wide range in terms of sample and relevant mineral sizes; in addition, occasional spectroscopical challenges such as element overlaps might hinder the evaluation.

The examples shown will highlight the difference between a trace element and trace mineral characterization as well as the multiple analytical tools for the ultimate project goal.

Overview:
Analytical techniques

Benchtop micro-XRF:
Micro-XRF is spatially resolved X-ray fluorescence analysis. The high spatial resolution is achieved by using a focusing polycapillary x-ray optic. Generated fluorescent signal is analyzed using one or two SDDs.

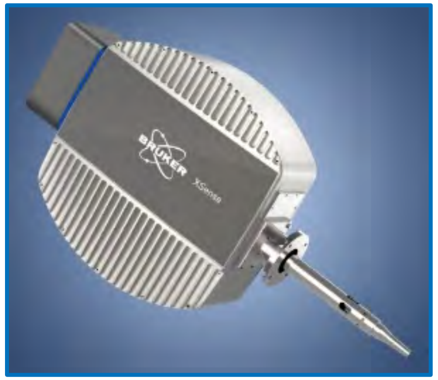
Scanning electron microscope (SEM) and analytical add-on options
The SEM is a well-known analytical technique based on electron beam spatially resolved imaging and elemental composition analysis using Energy Dispersive Spectrometers (EDS). Additional options such as wavelength dispersive spectrometers (WDS) as well as focused X-ray beam sources have been added to complement the analytical capabilities.

Micro-XRF **M4 TORNADO PLUS**

SEM-EDS: **QUANTAX**

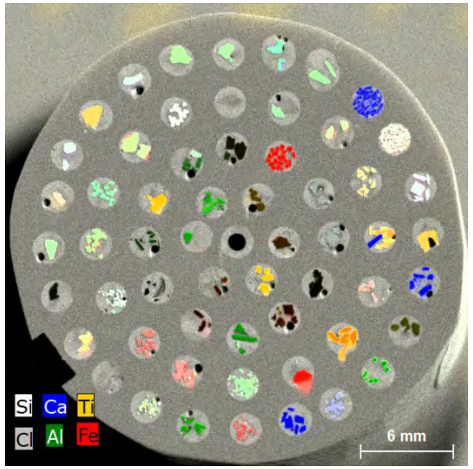
Micro-XRF: **XTrace**

SEM-WDS: **XSense**

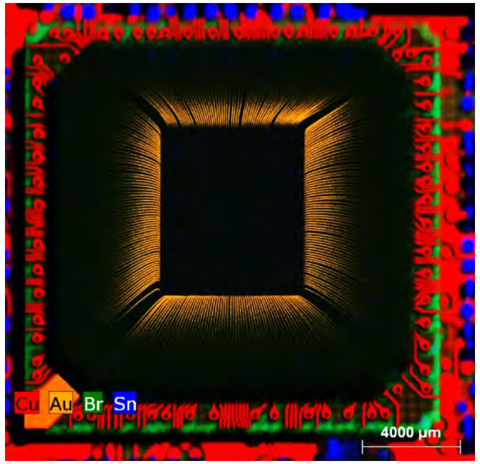


Overview:
Micro-XRF as an analytical technique

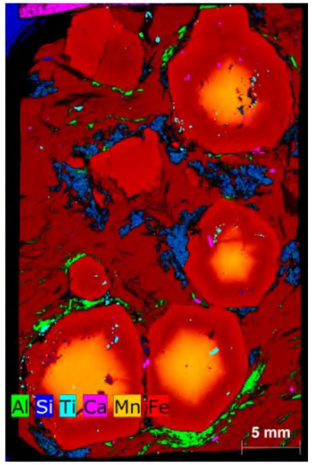
Main analytical advantages of micro-XRF



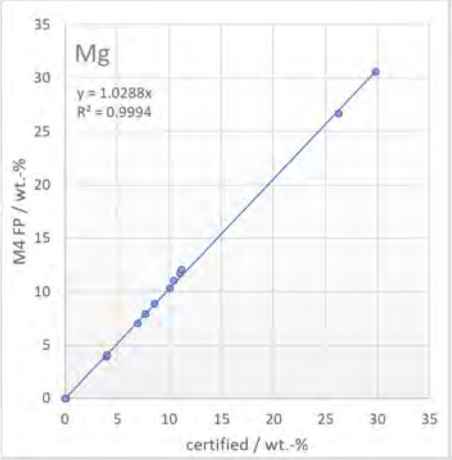
No sample preparation



Information from the depth of the sample



Trace element sensitive



Reference samples free and standard supported quantify-cation options

Micro-XRF **M4 TORNADO PLUS**

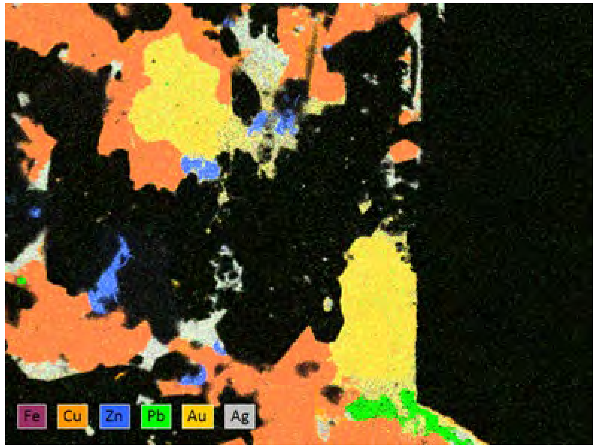
Micro-XRF: **XTrace**

Analytical differences:

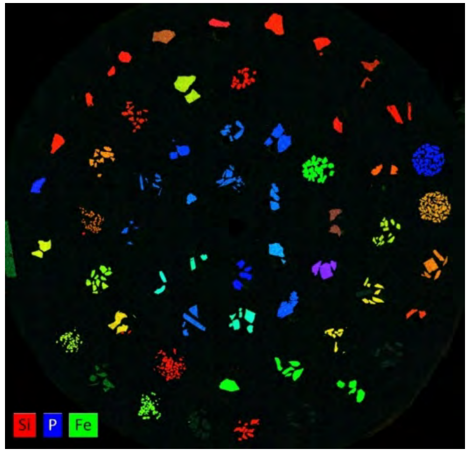
- **M4 TORNADO PLUS** as a benchtop instrument allows faster scan of lager samples and heavier sample (up to 30 cm and 7 kg) at higher resolution
- **XTrace** as and ad-on techniques allows to combine the advantages of micro-XRF with the associated SEM options (high spatial resolution of the E-Beam and resolution of the WDS)

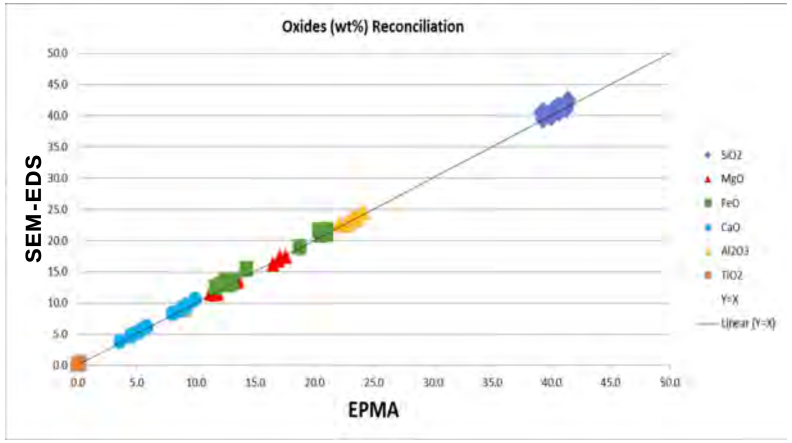
Scanning Electron Microscopy (SEM) and analytical options

Analytical advantages of SEM-EDS and SEM-WDS relevant for this work



High spatial resolution





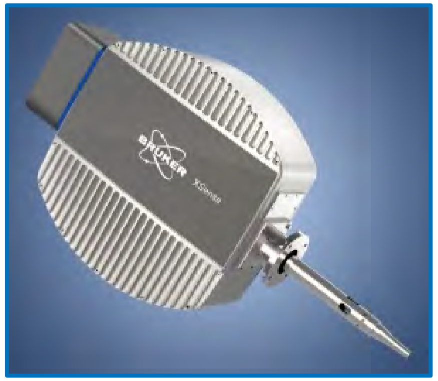
Multiple quantification options: standardless and standard-based

SEM-EDX: **QUANTAX**

121 eV*

4 eV**

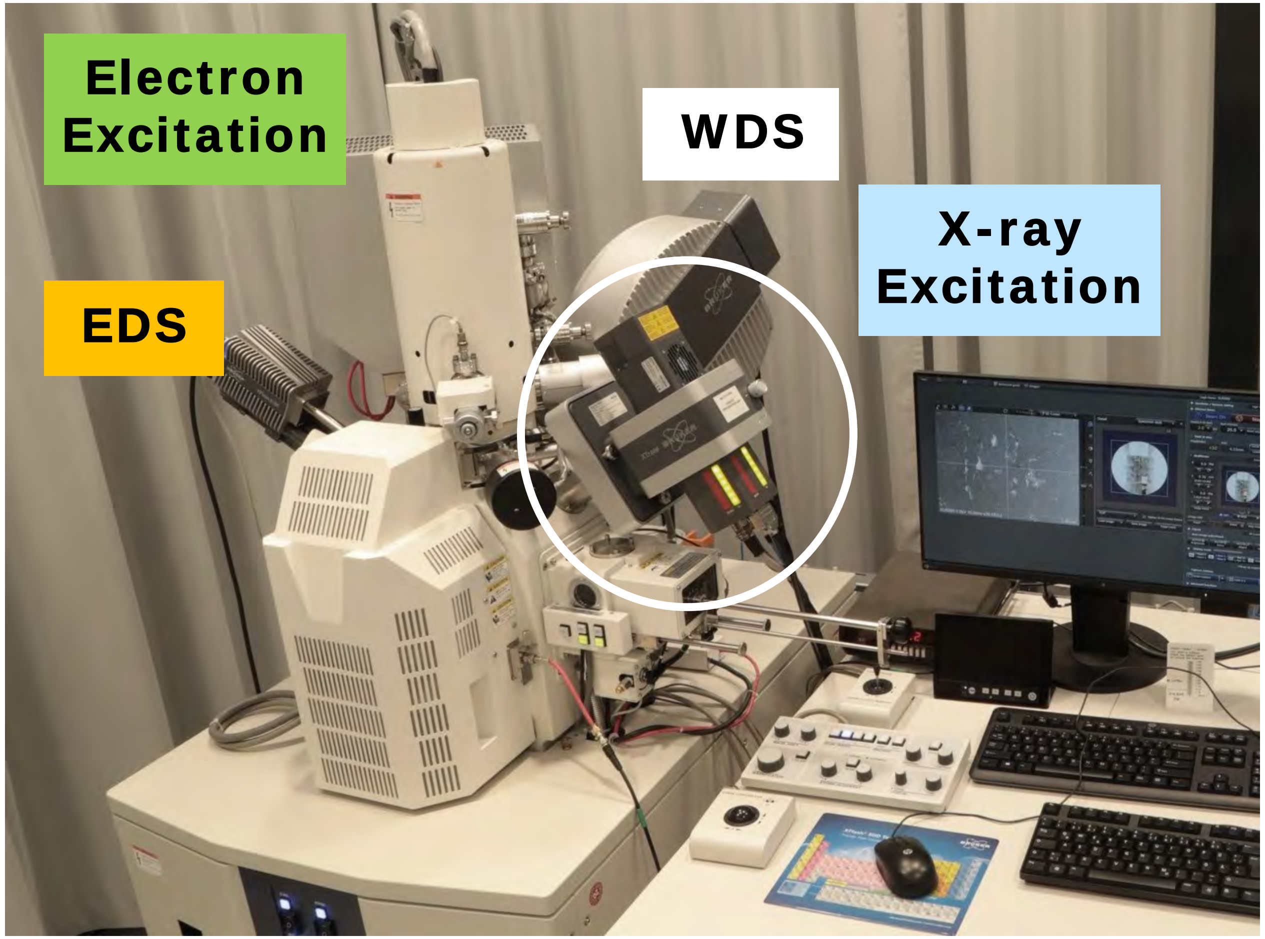
SEM-WDS: **XSense**

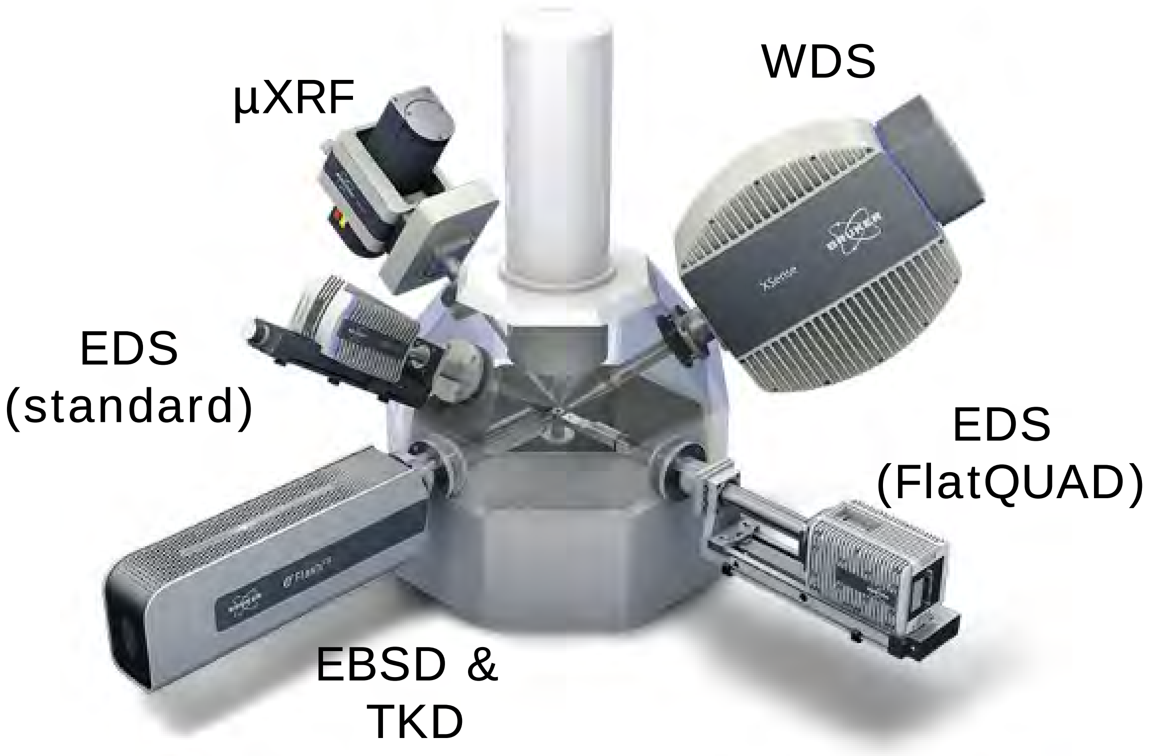


SEM-EDS-WDS: Analysis based on the sample interaction with an electron beam source from the SEM and the resultant X-rays that are detected using either and SDD or and WDS.

* For 121 eV for Mn Ka (equivalent to 73 eV for a Si Ka), ** for Si Ka

SEM and analytical options:
Electron and Photon Excitation for micro-XRF and EDS/WDS





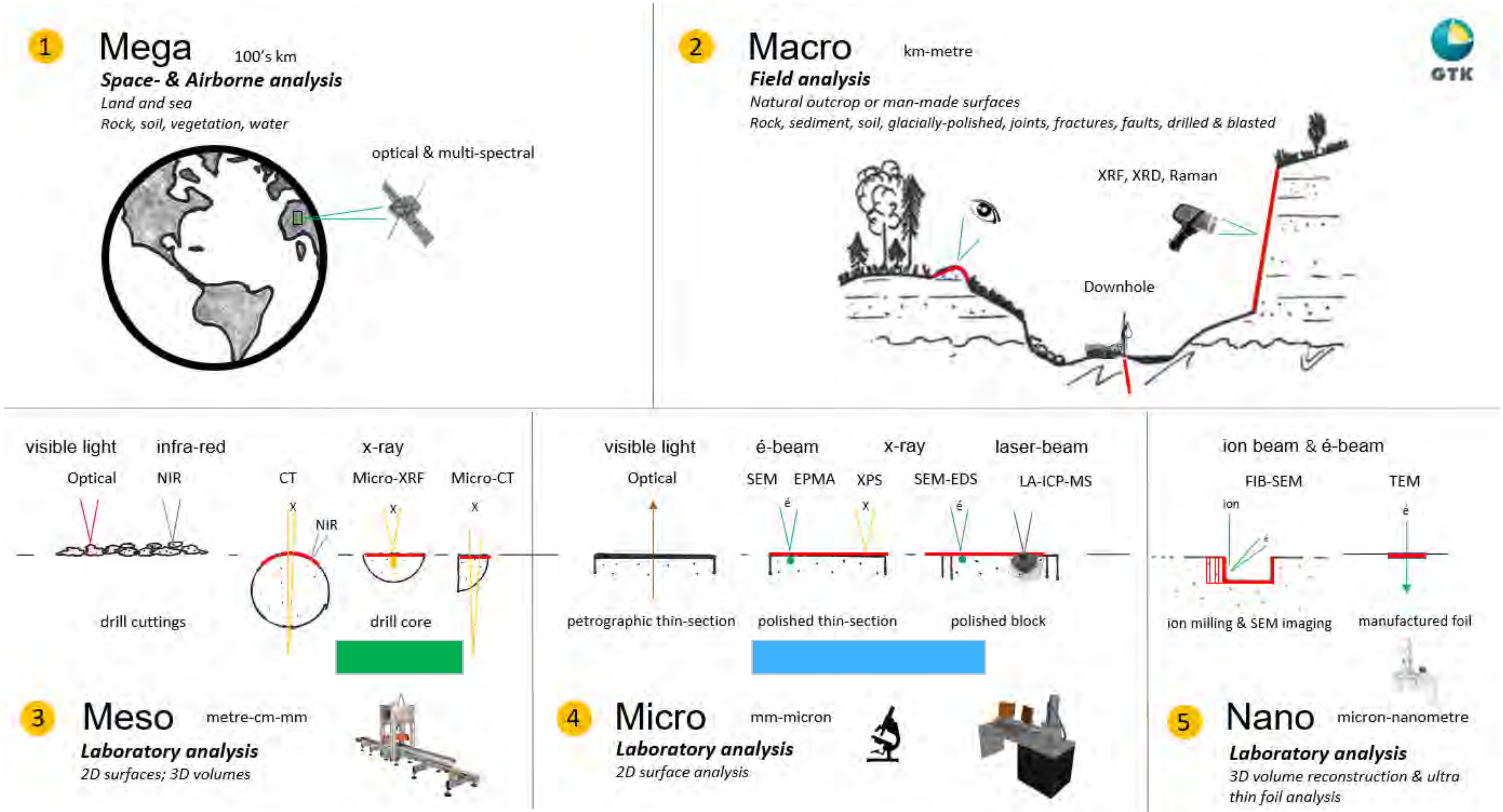
Analytical Parameters and Conditions

SEM-EDS vs. SEM-WDS vs. micro XRF

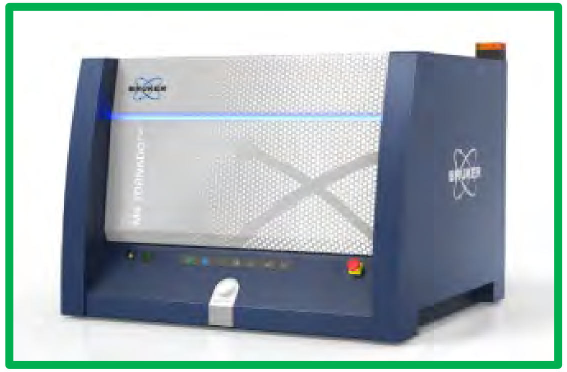
Parameter	EDS: E-beam (SEM-EDS)	WDS: E-beam (SEM-WDS)	Micro-XRF (SEM-XRF-EDS or benchtop)
Analyzed Volume	Ø: few µm Information depth: µm; (depending primarily on electron energy)	Ø: few µm Information depth: µm; (depending primarily on electron energy)	Ø: 15-30 µm Information depth: µm to mm; (depending on analysed element and matrix)
Detectable Elements	Atomic number Z ≥ 4 (beryllium)	Atomic number Z ≥ 4 (beryllium)	Atomic number Z ≥ 6 (carbon)
Energy range	K- L –M – Lines (up to 20 keV)	70 eV – 3.6 keV (L- M- Lines)	K- L –M – Lines (up to 40 keV)
Concentration Range	Down to 1000 ppm	Down to 100 ppm	Down to 5 ppm
Quantification	Standard less and Standard based	Standard based	Standard less and standard based
Data collection	Simultaneously	Sequentially	Simultaneously
Sample Preparation	Sample needs to be electrically conductive (commonly carbon-coated), polishing required	Sample needs to be electrically conductive (commonly carbon-coated), polishing required	Electrical Conductivity not required, samples doesn´t need to be polished
Sample size / weight	Usually 5 to 10 cm (depends on SEM)	Usually 5 to 10 cm (depends on SEM)	5 to 10 cm (depends on SEM) up to 30 cm and 7 kg for benchtop instrument
Spectroscopic resolution	Down to 121 eV for Mn Ka	~ 4 eV for Si Ka	better than 145 eV for Mn Ka (depending of detector even down to 121 eV)

Overview:

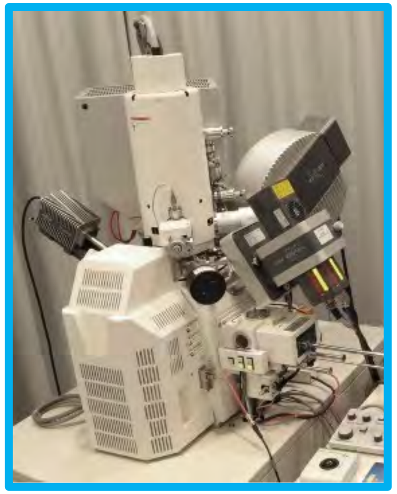
Characterization Workflow of a multiscale approach



Micro-XRF **M4 TORNADO PLUS**



SEM-EDS-Micro-XRF-WDS



Butcher AR (2020) Upscaling of 2D mineralogical information to 3D volumes for geoscience applications using a multi-scale, multi-modal and multi-dimensional approach. ***EMAS 2019***, *Conference Proceedings Volume, Trondheim*, 19-23 May 2019.

Trace Elements and Mineralization:

Case Study 1 – Gold (Au)

Analyzing Large Samples: Drill Core (Micro-XRF)

Overview:
Analysis for Gold

Gold can occur as a native element (mineral) or as high concentrations in a mineral (electrum, calaverite). Gold can also occur as a trace element in the structure of other minerals, for example **arsenopyrite**.

Electrum: Au = 70 to 95 wt%

Arsenopyrite: Au = 50 ppm (0.005 wt%)

For example: if a sample has 58 ppm

If the gold is in the form of Native Gold or Au-bearing mineral, then then elemental or mineralogical hyper-mapping (microXRF or SEM-EDS or AMICS) will detect the gold.

If the gold is included in arsenopyrite then it is unlikely that the gold will be detected.

Note: The arsenopyrite will be detected, however, point analysis with the microXRF would be required to determine if the arsenopyrite contains any gold.

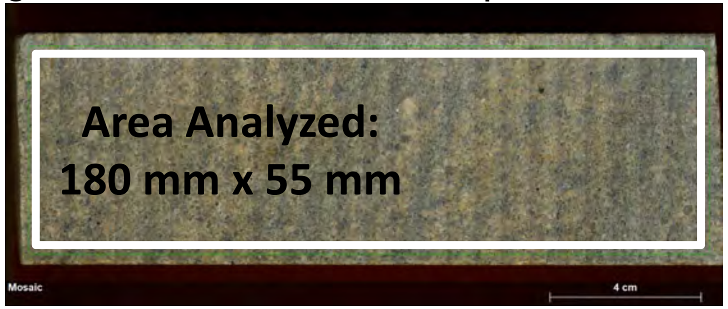
Case Study: Gold (Au)

Drill Core/Rock Samples: Hyperspectral Datasets

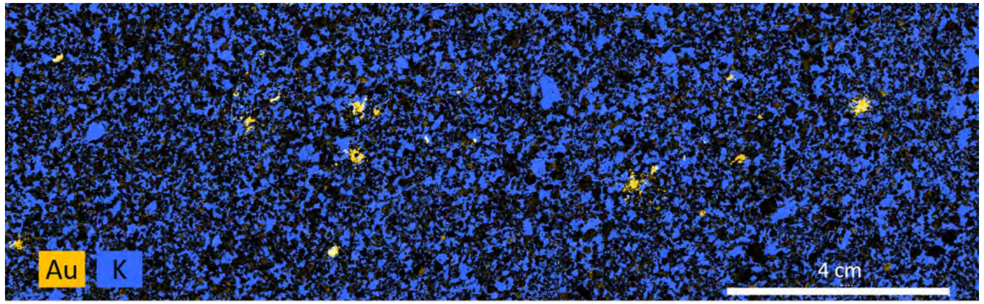
In the following examples for different Au deposits we will show the ability to identify Gold-bearing minerals and to focus on obtaining the most information possible.

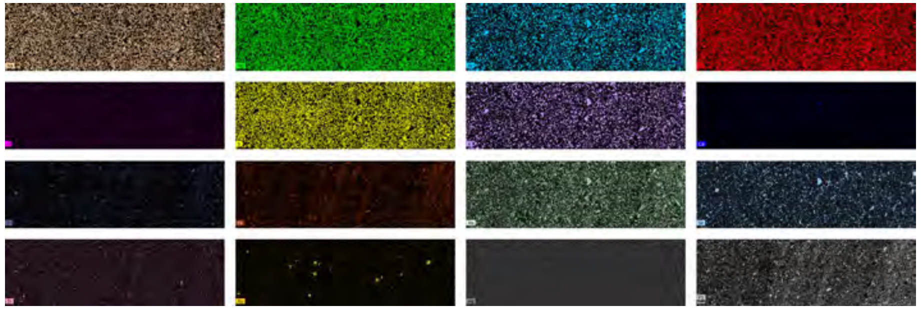
Micro-XRF images:
Top: optical mosaic, red box is the area of analysis (18 cm x 4 cm);
Middle: combined elemental map of K (blue) and Au (orange)
Bottom: AMICS mineralogy map

Optical

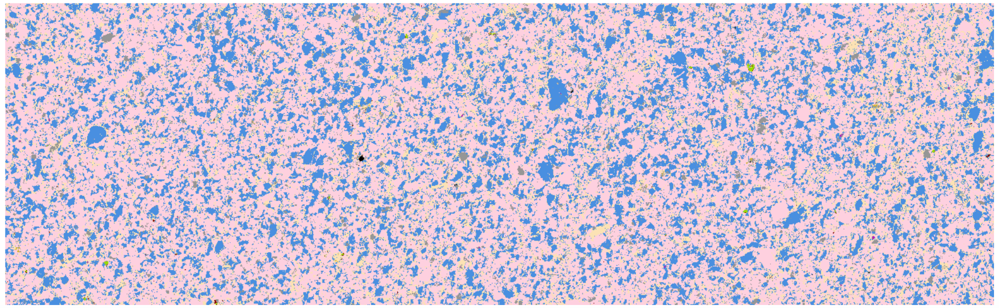


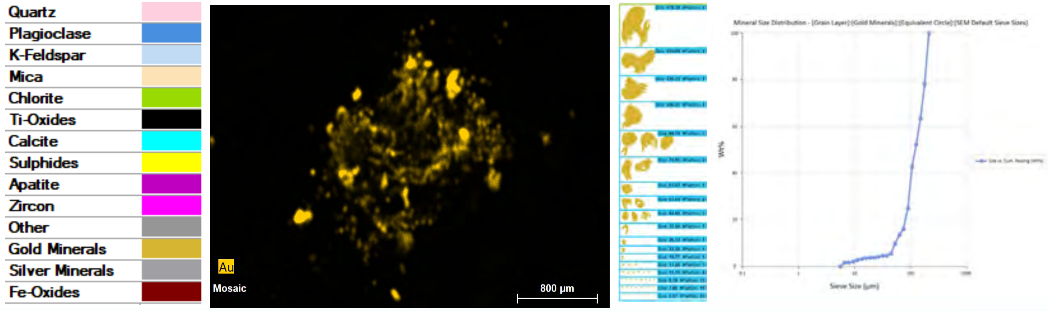
Elemental



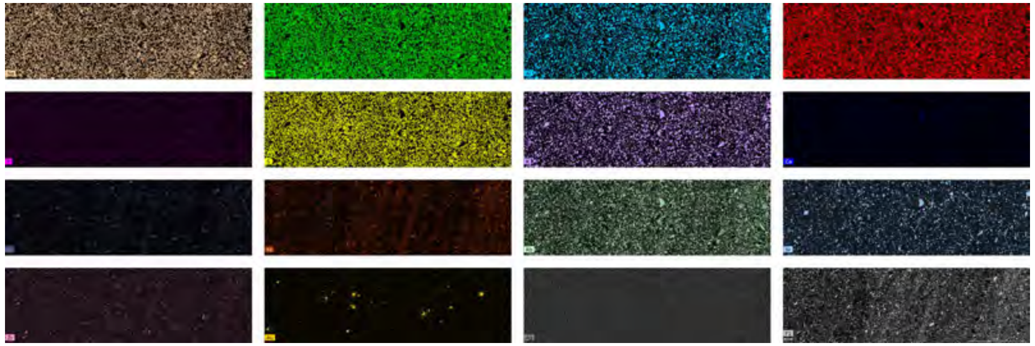


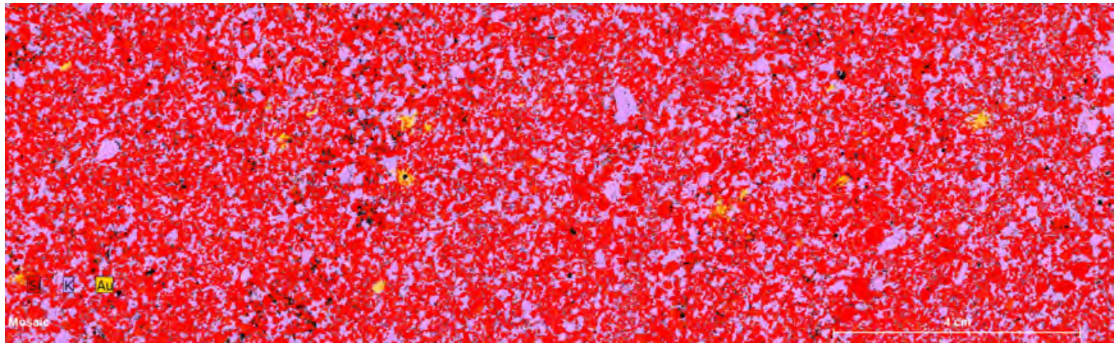
Mineralogical





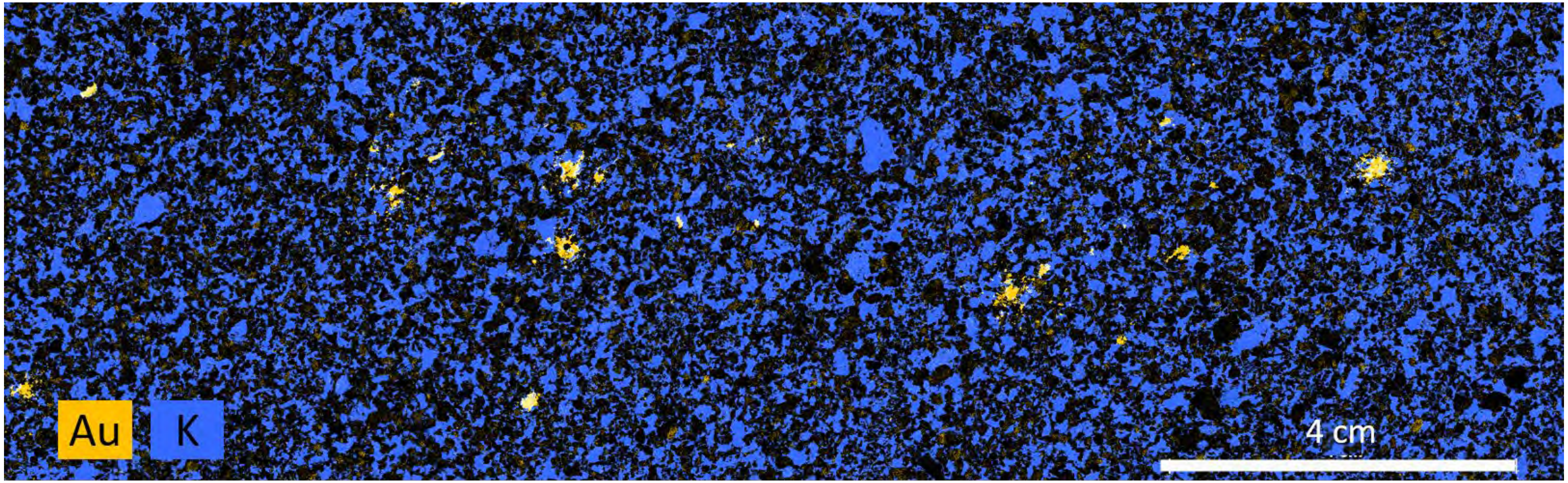
Case Study 1: Gold (Au)
Analysis of Drill Core: Elemental Maps



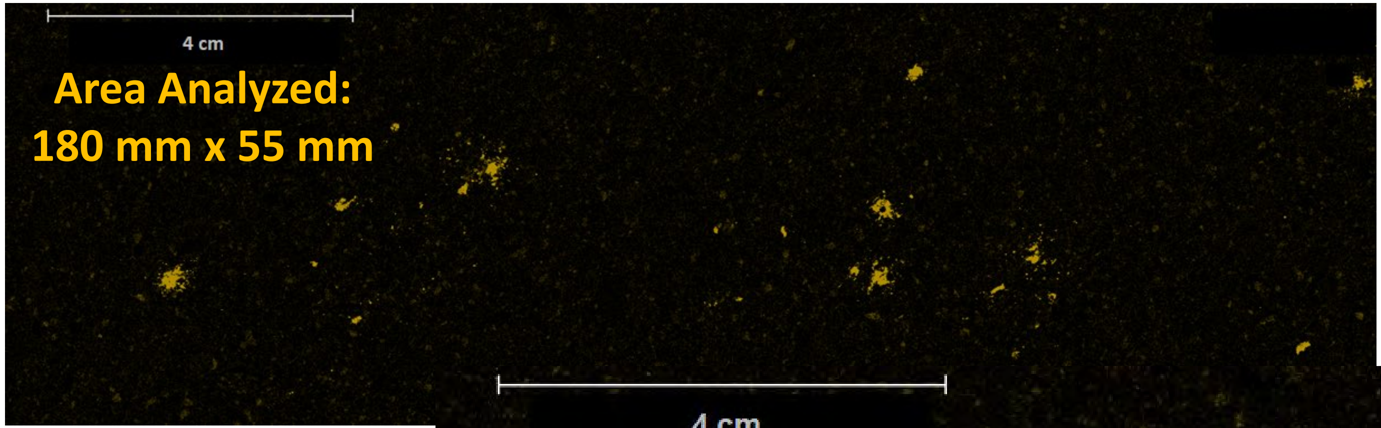


Drill Core Mapped at 20 micrometers pixel spacing

Area Analyzed: 180 x 55 mm

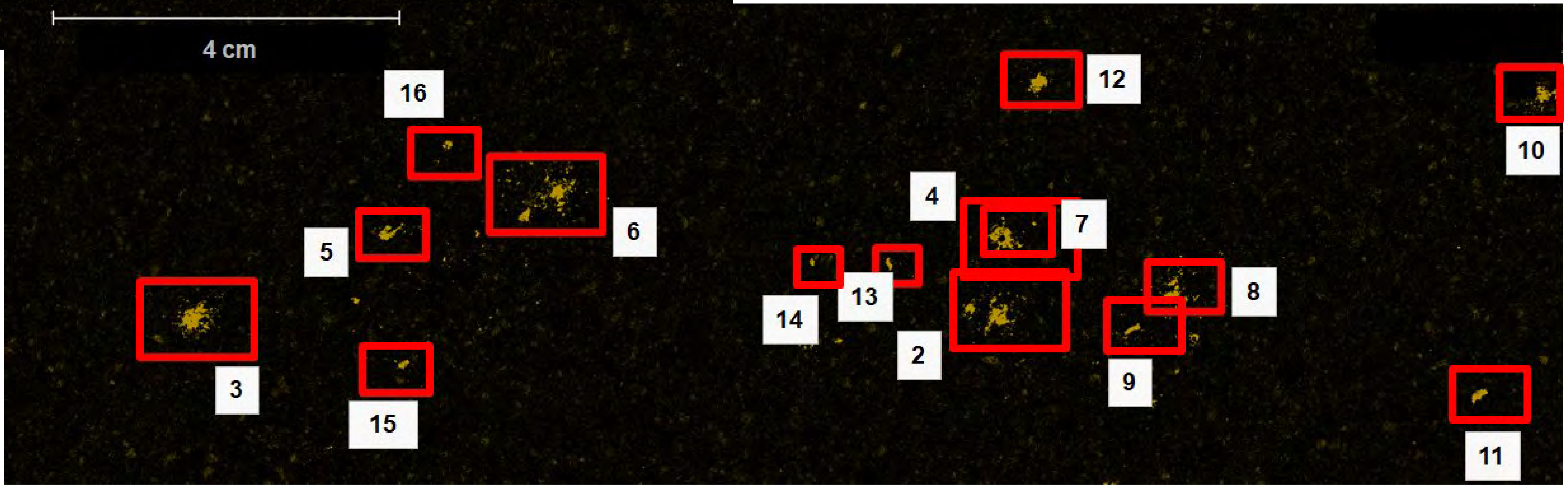


Case Study 1: Gold (Au)
Analysis of Drill Core: Elemental Maps



Left: Au Elemental Intensity Map.

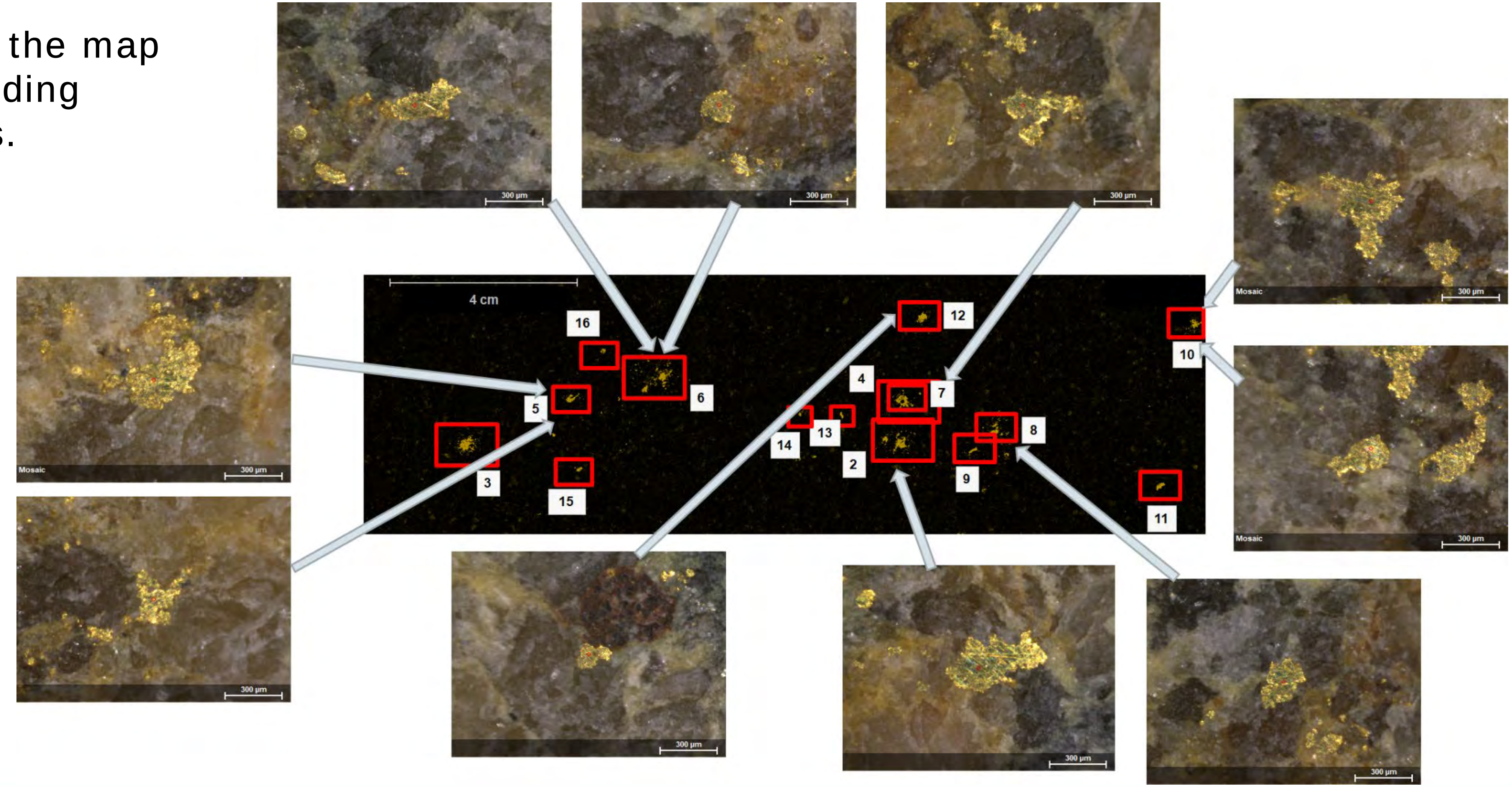
Bottom: Au Elemental Intensity Map with selected areas for higher resolution mapping.



Case Study 1: Gold (Au)

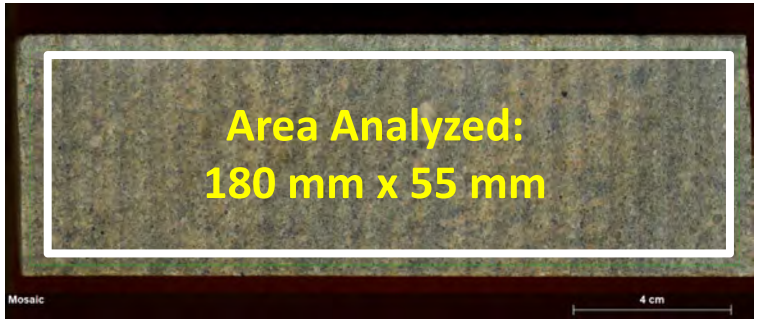
Analysis of Drill Core: Gold Identification

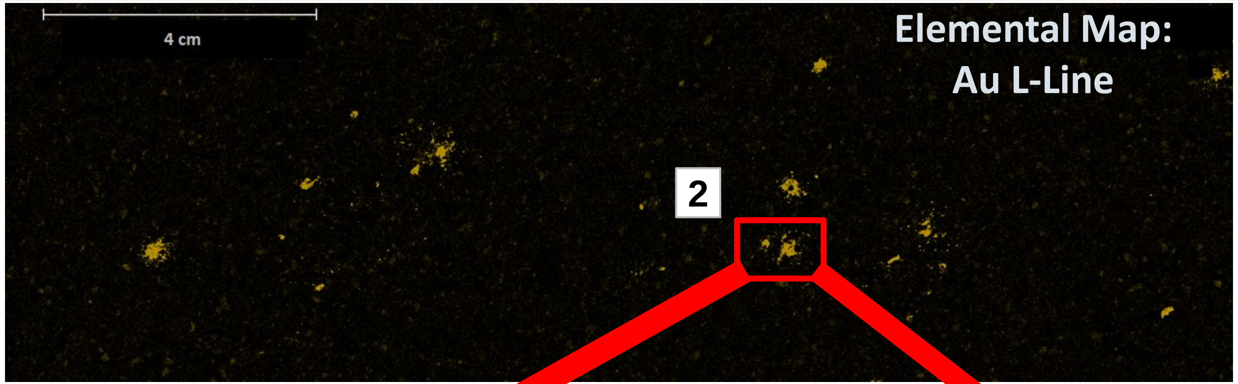
Gold grains in the map and corresponding optical images.

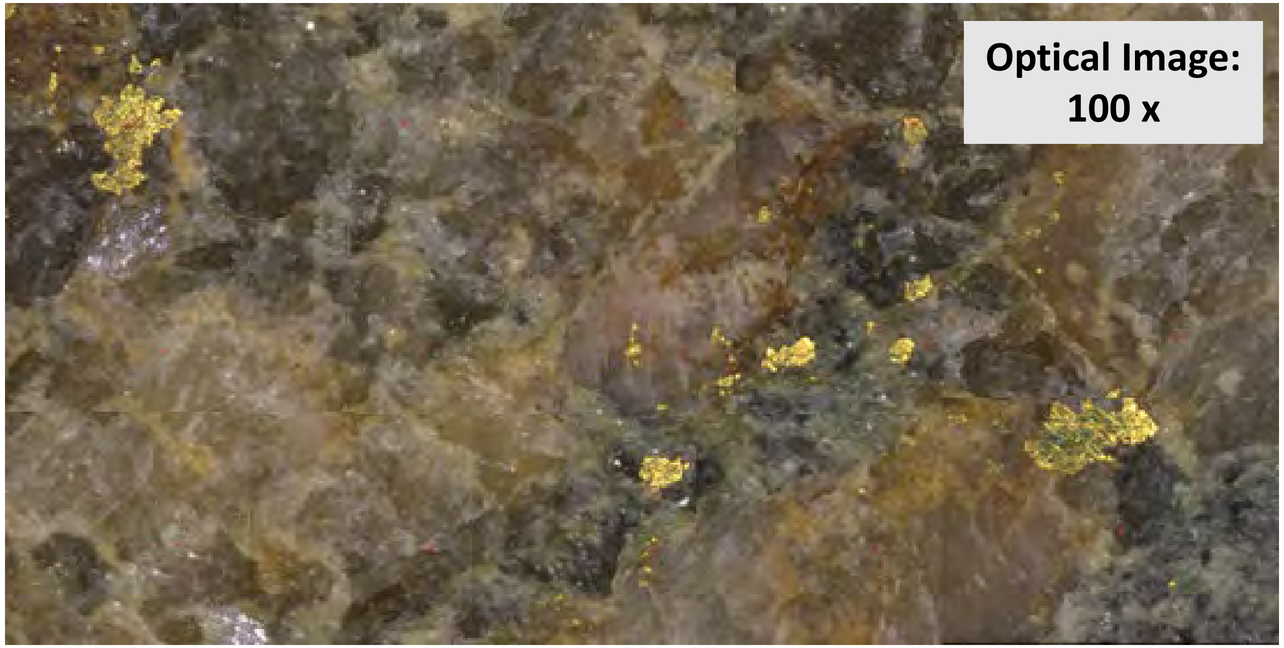


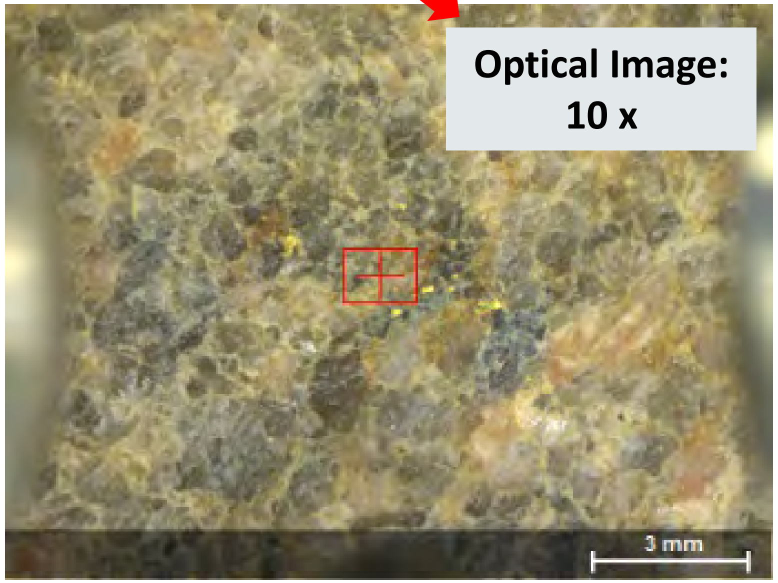
Case Study 1: Gold (Au)

Analysis of Drill Core: Gold Grains Identification









Case Study 1: Gold (Au)
Analysis of Drill Core: Gold Grains Analysis

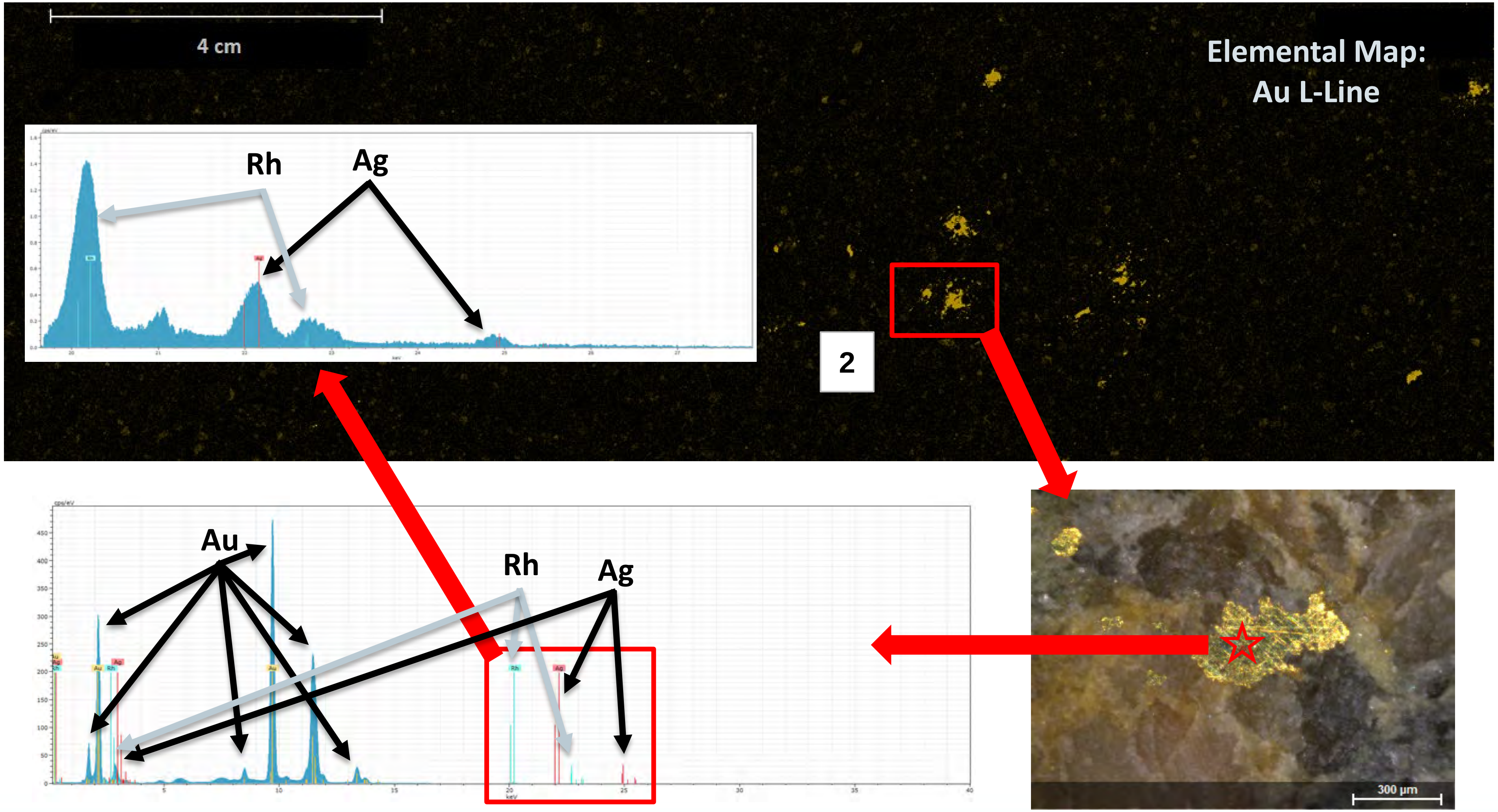
Identified Elements in the "large" gold grain from Map 02

Grain Size:
300-400 µm

Showing the Au and Ag peaks.

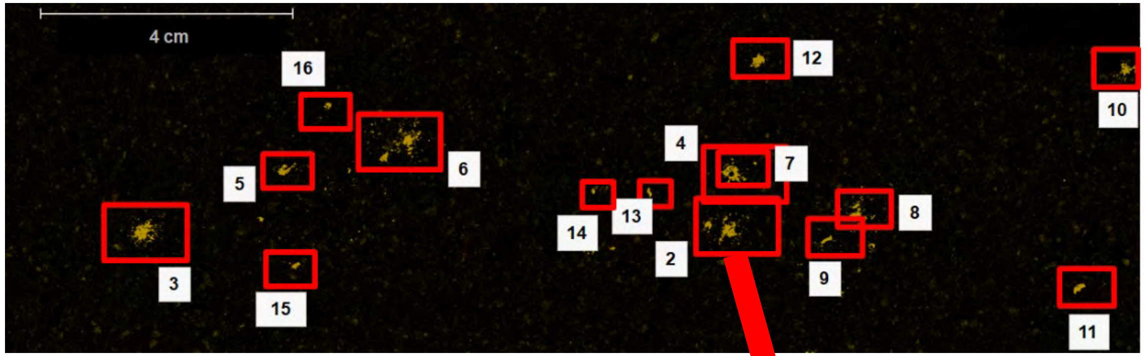
Rh

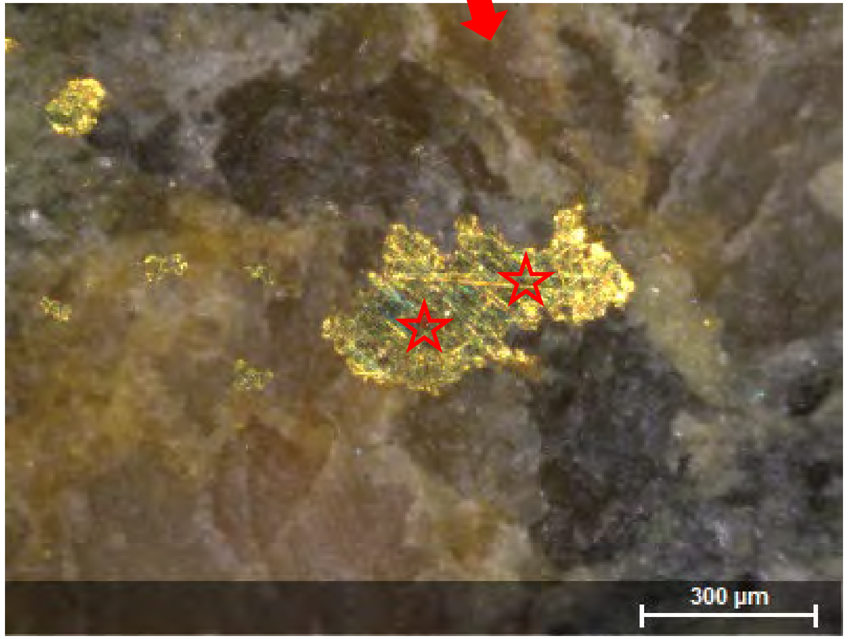
Mineral → **Electrum**



Case Study 1: Gold (Au)

Gold Grains Analysis: Elemental Composition





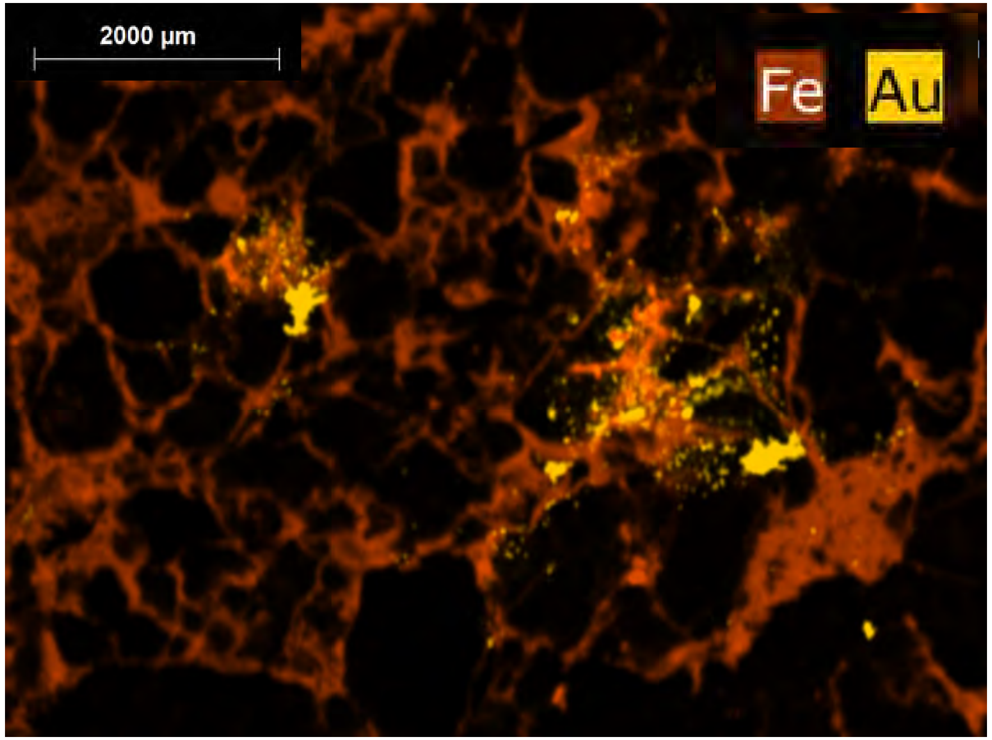
Normalized FP quantification of the different gold grain in the sample.

Au 95.8 ± 0.7 wt. %
Ag 4.2 ± 0.7 wt. %

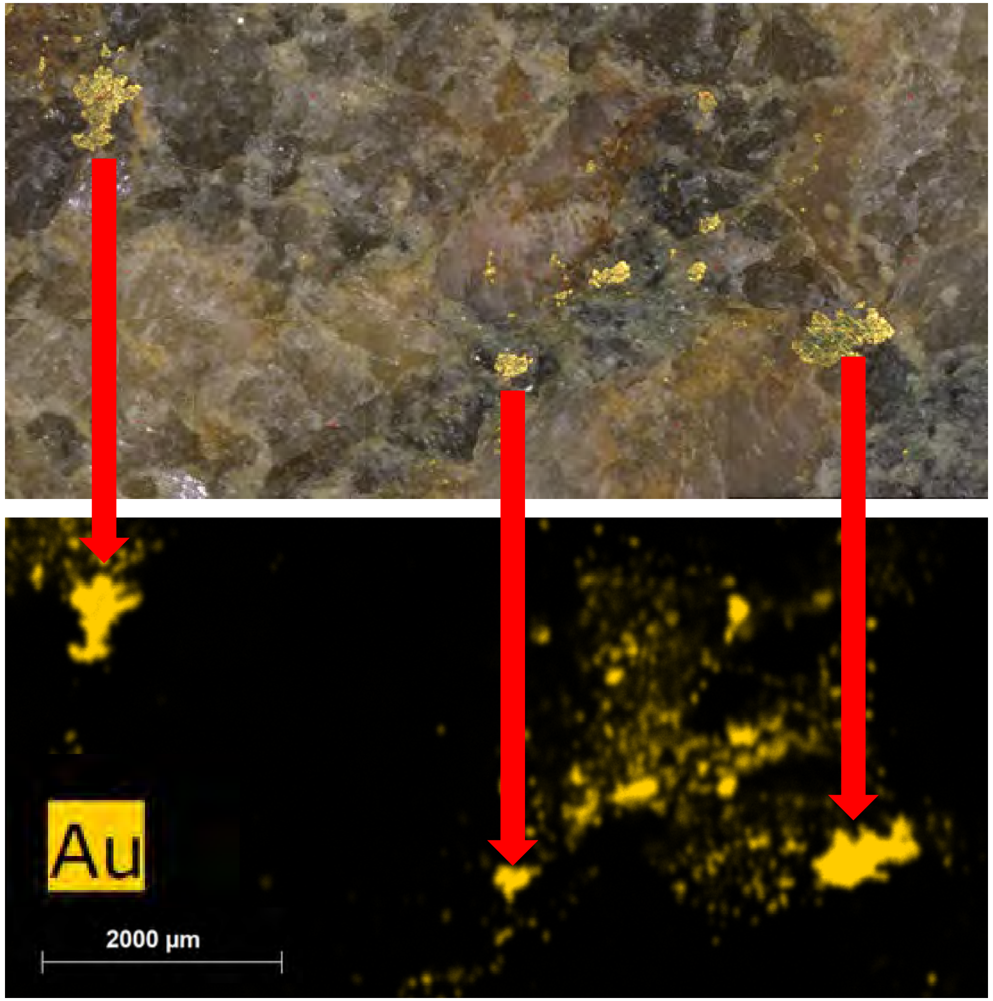
Spectrum	Ag	Au
Au-Map02-Grain01- 1.spx	4.3	95.7
Au-Map02-Grain01- 2.spx	4.2	95.8
Au-Map05-Grain01- 1.spx	3.3	96.7
Au-Map05-Grain01- 2.spx	2.2	97.8
Au-Map05-Grain02- 1.spx	3.8	96.2
Au-Map06-Grain01- 1.spx	4.3	95.7
Au-Map06-Grain01- 2.spx	4.7	95.3
Au-Map06-Grain02- 1.spx	3.8	96.2
Au-Map07-Grain01- 1.spx	4.9	95.1
Au-Map08-Grain01- 1.spx	4.7	95.3
Au-Map10-Grain01- 1.spx	4.6	95.4
Au-Map10-Grain02- 1.spx	4.7	95.3
Au-Map10-Grain03- 1.spx	4.3	95.7
Au-Map10-Grain04- 1.spx	4.5	95.5
Au-Map12-Grain01- 1.spx	4.1	95.9
Mean value:	**4.2**	**95.8**
Std. Abw.:	**0.7**	**0.7**
Std. Abw. rel. [%]:	**16.5**	**0.7**
Conf. interval:	**0.2**	**0.2**

Case Study 1: Gold (Au)

Micro-XRF: High Resolution Map Area 02

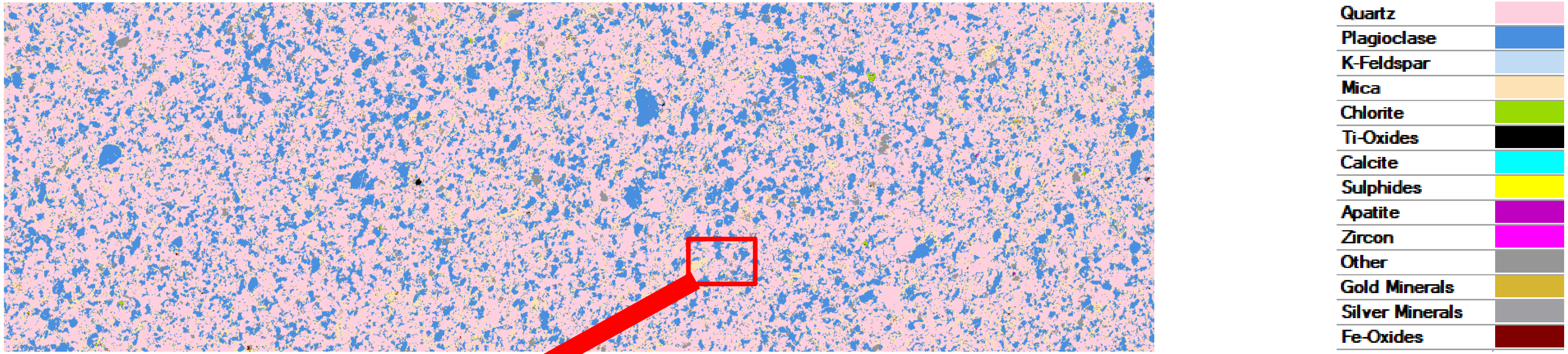


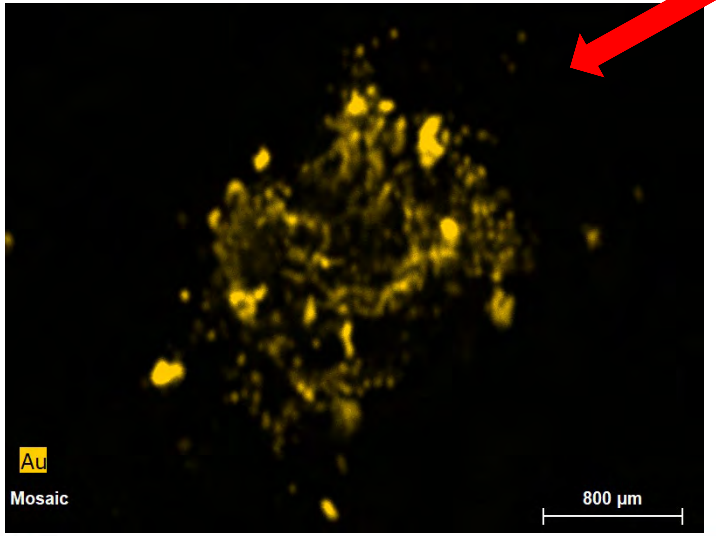
Selected areas mapped at 5 micrometers pixel spacing

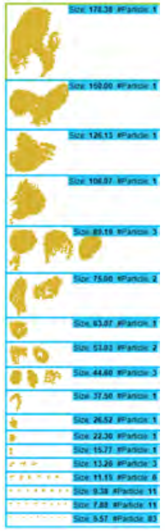


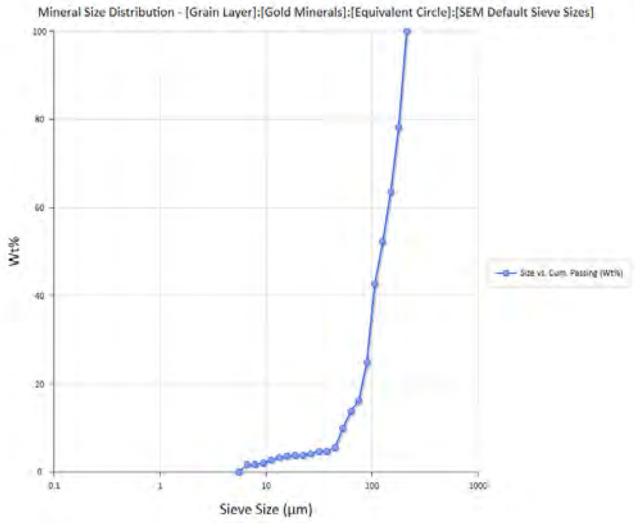
Automated Mineralogy (AMICS)

Analysis of Drill Core







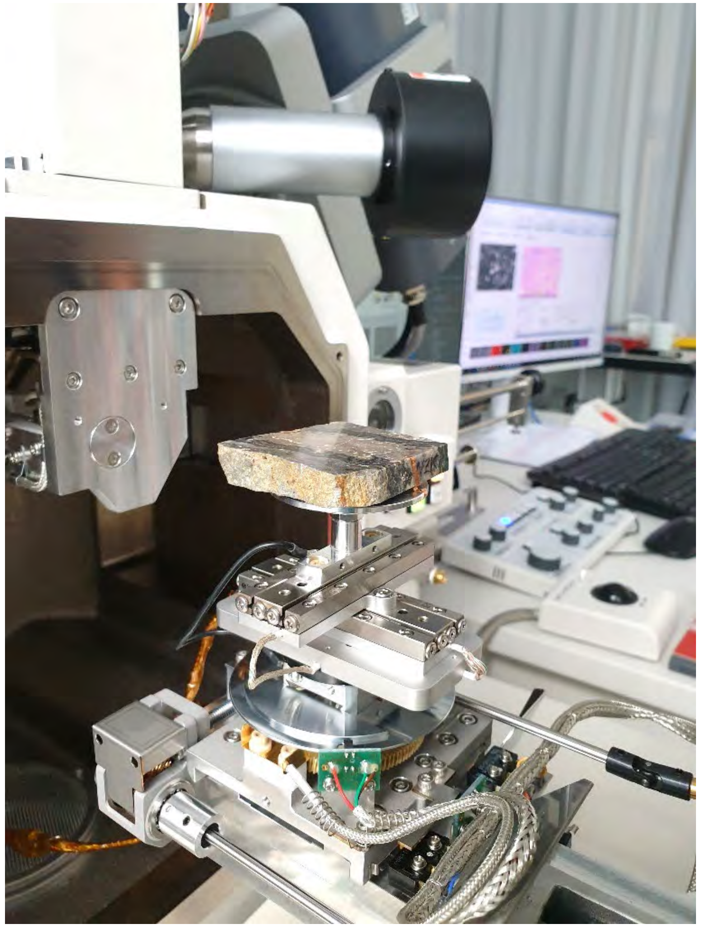


Trace Elements and Mineralization:
Case Study 1 – Gold (Au)

Analyzing Large Samples: Rock Sample (Micro-XRF and SEM)

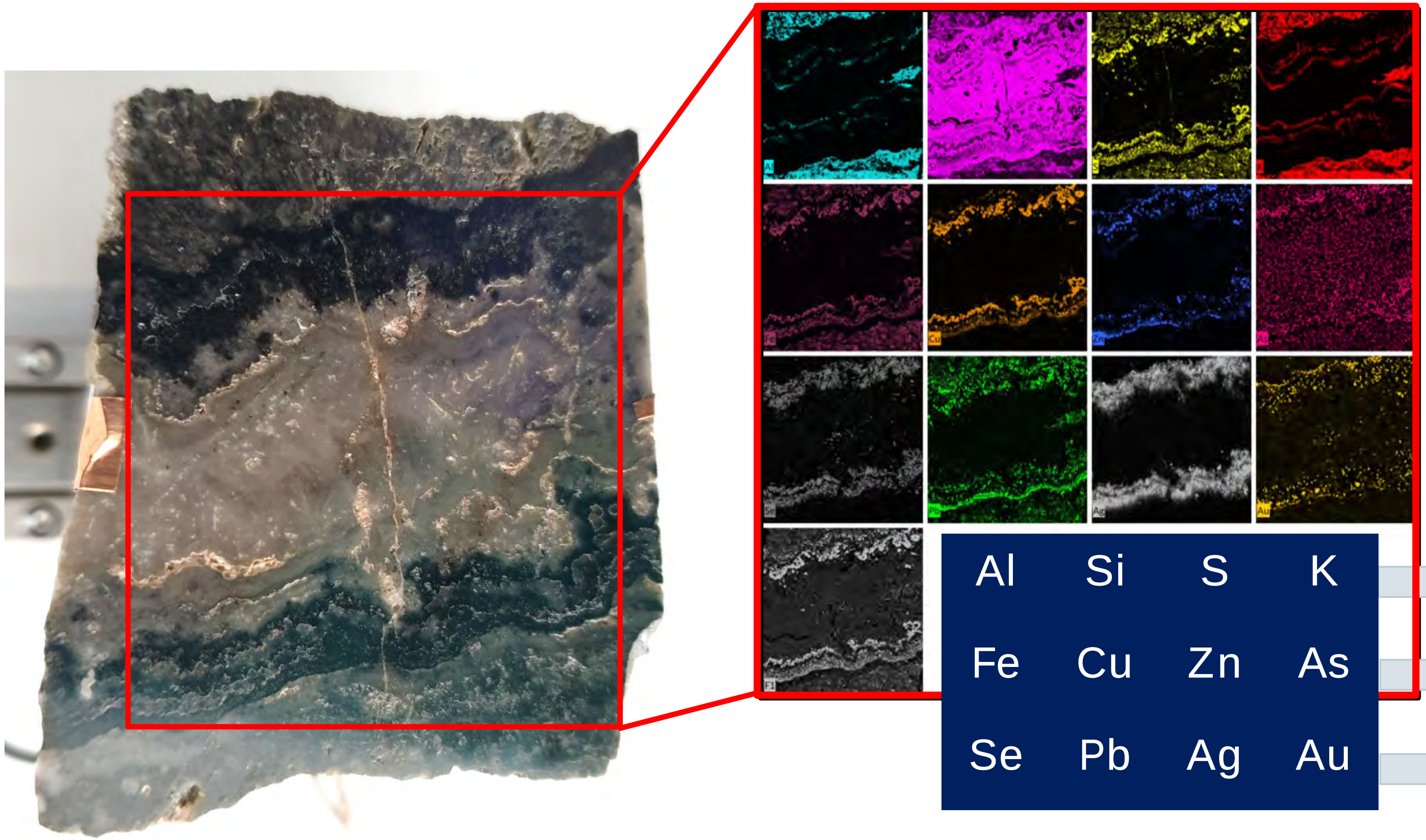
Case Study 1: Gold (Au)
Epithermal Gold

Mineral	Formula
Native Gold	Au
Native Silver	Ag
Sulphides	
Pyrite	FeS_2
Chalcopyrite	$CuFeS_2$
Galena	PbS
Sphalerite	ZnS
Gangue Mineralogy	
Quartz	SiO_2
Adularia	$KAlSi_3O_8$



SEM Micro-XRF Analysis: Epithermal Au

Large Area Mapping



Beam:	X-ray
High Voltage:	50 kV
Anode Current:	600 µA
Analytical Spacing:	100 µm
Dwell Time:	64000 µs (64 ms)
Analytical Area:	4.5 x 4.5 cm
Total Analytical Time:	188 minutes
Spot Size:	25 µm
Interaction Depth:	10 – 100 µm

Host Rock Elements: Al, Si, K

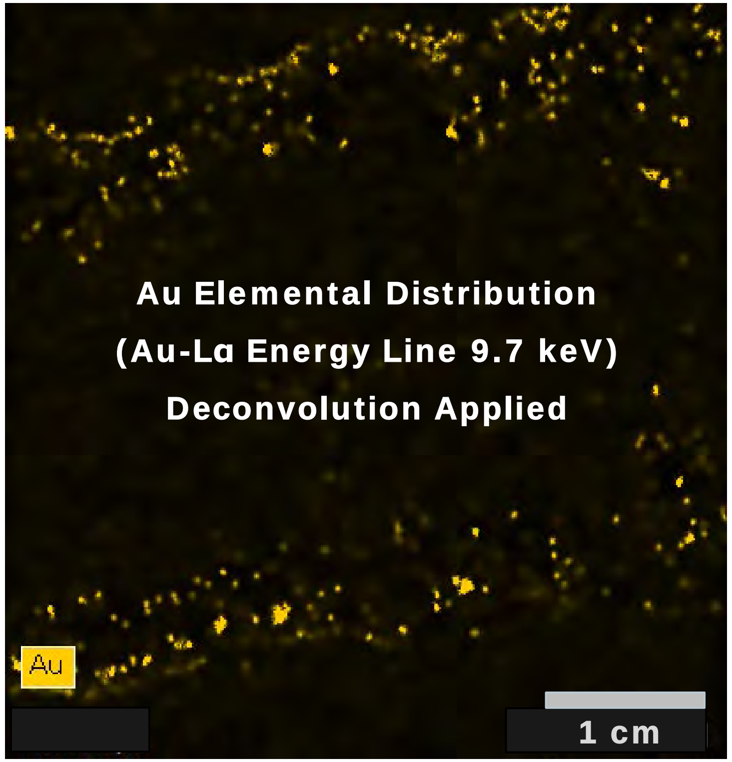
Mineralization: S, Fe, Cu, Zn, As

Economic Mineralization: Au, Ag, Se

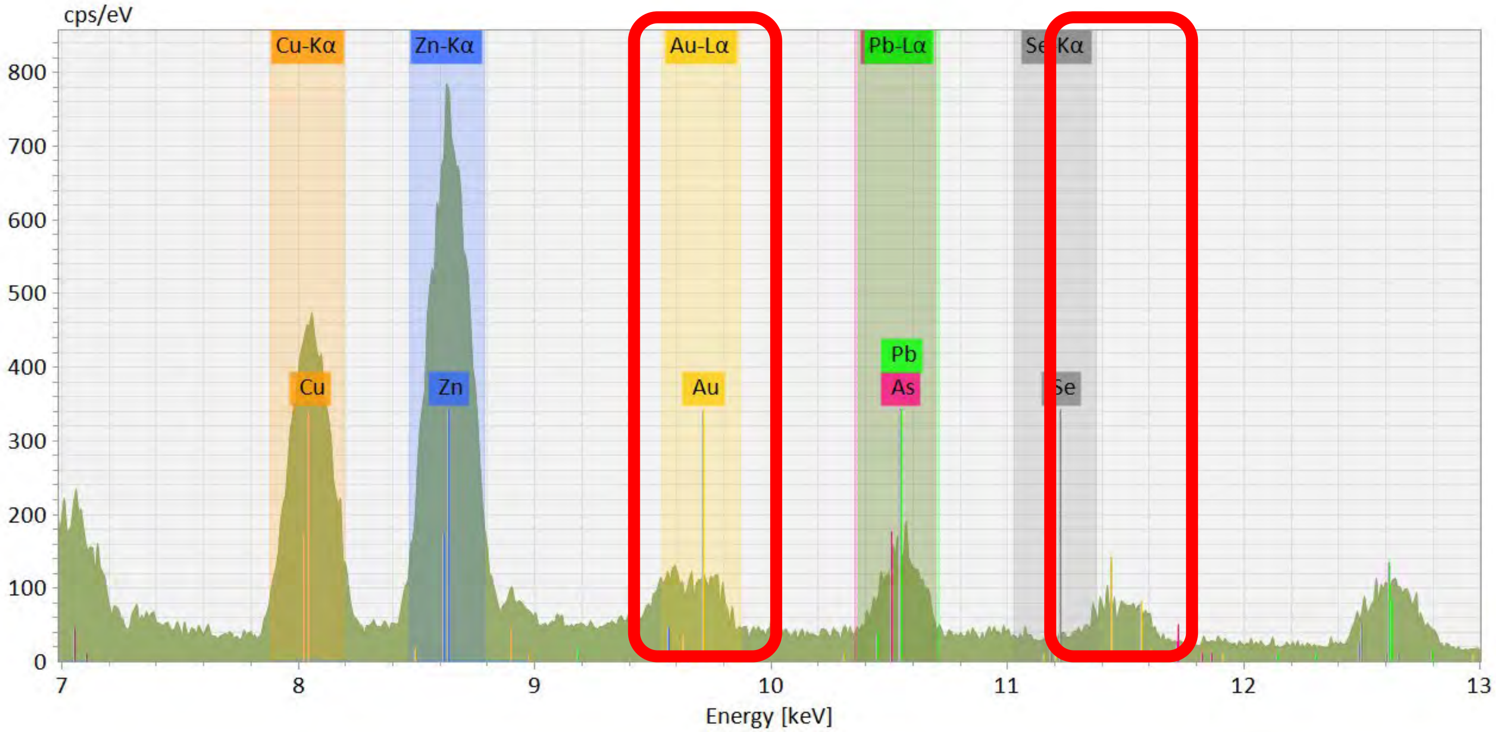
Epithermal Gold-bearing rock sample from Karangahake, New Zealand

Micro-XRF on SEM

Identifying Gold (Au) in the Sample



Maximum Pixel Spectrum

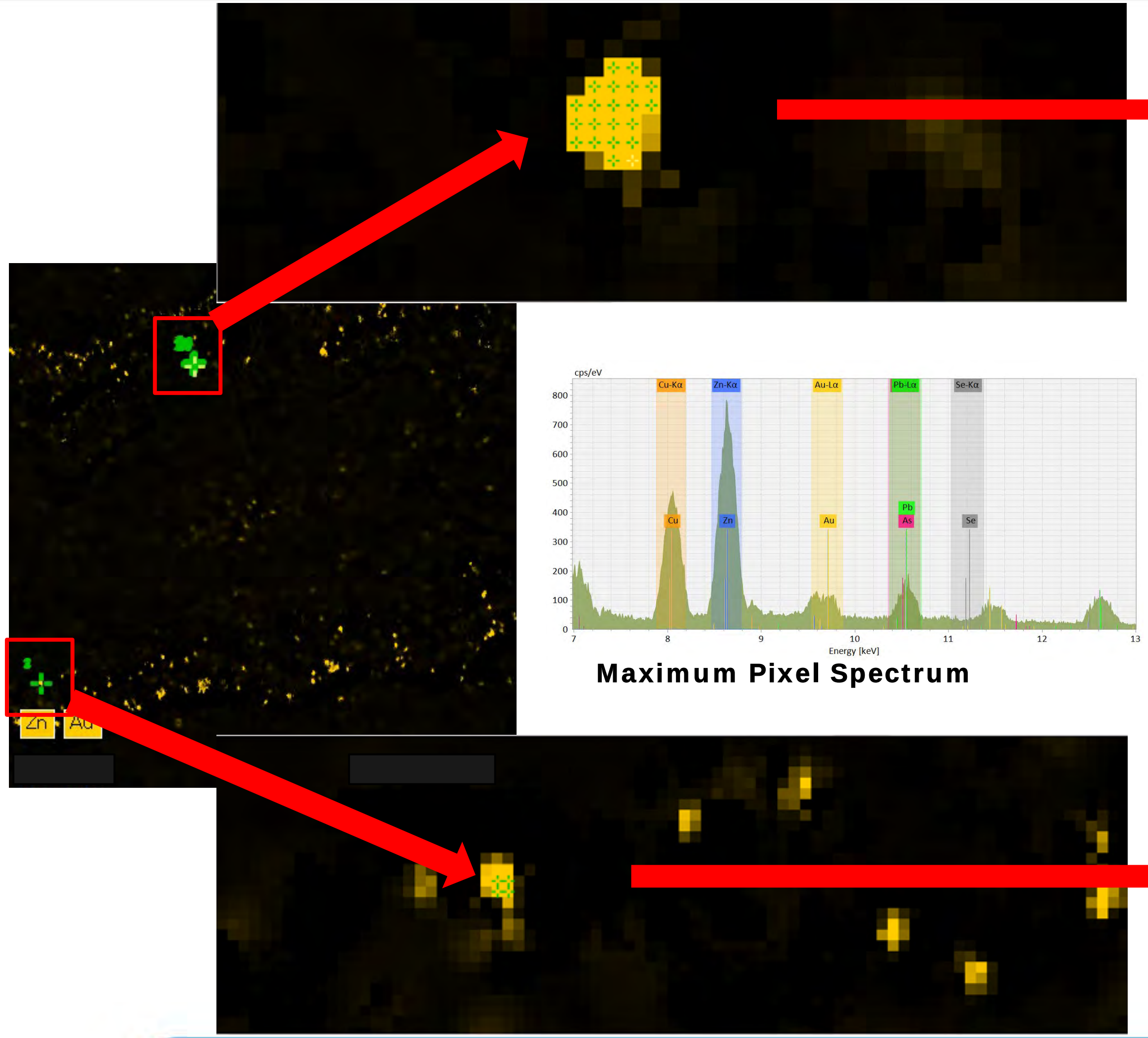


Distinct and clear Au: Au-Lβ X-ray energy Lines.

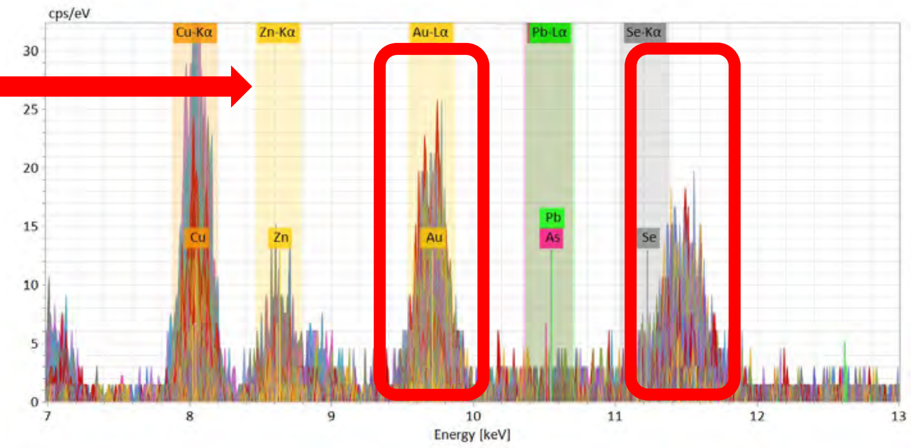
Presence of Au in the sample is confirmed. But is it identified correctly?

Micro-XRF on SEM

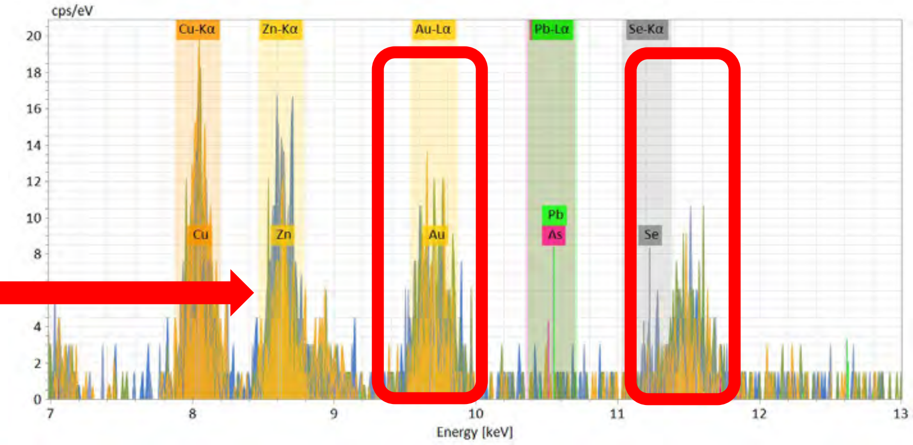
Identifying Gold (Au) in the Sample



Maximum Pixel Spectrum

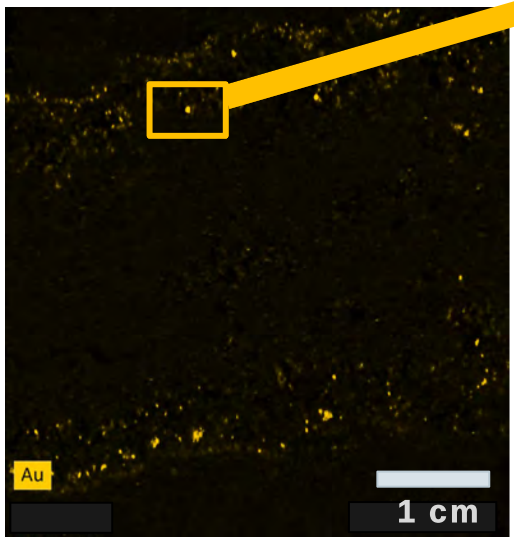


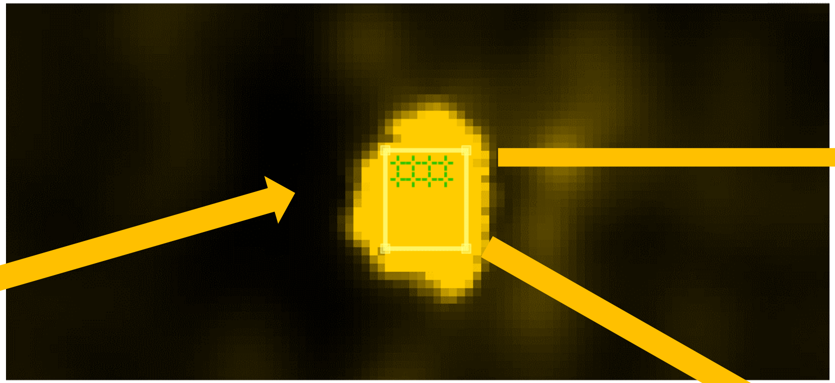
Distinct and clear Au-Lα and Au-Lβ X-ray energy Lines.
Presence of Au in the sample confirmed.

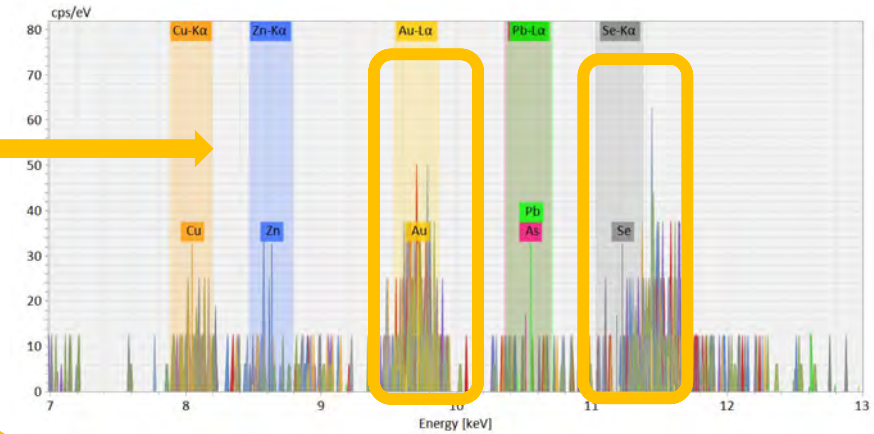


Micro-XRF on SEM (X-ray Beam)

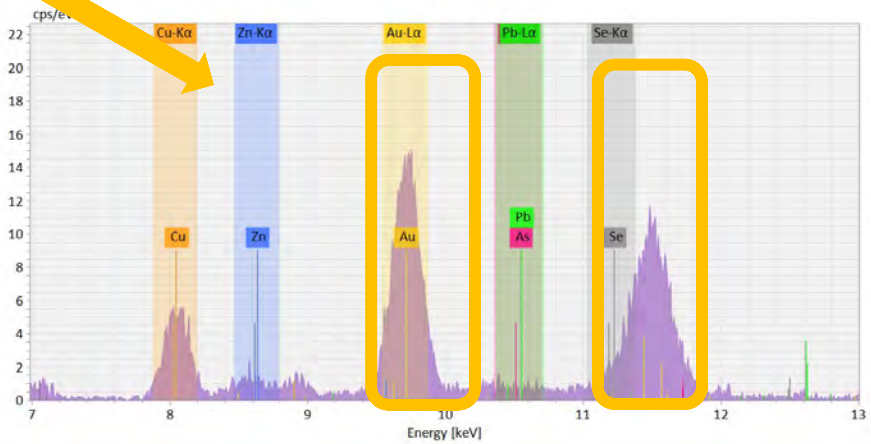
Identifying Gold (Au) in the Sample







Individual Points Spectra – Low Counts



Summed points within Grain – High Counts, clear and confirmed elemental peaks

Distinct and clear Au-Lα and Au-Lβ X-ray energy Lines. Presence of Au in the sample confirmed

Mining and Exploration Applications:
Epithermal Gold

Micro-XRF hypermaps successfully identify the presence and location of Au Grains within the sample.

The sample can be analyzed with no carbon coat and at low vacuum.

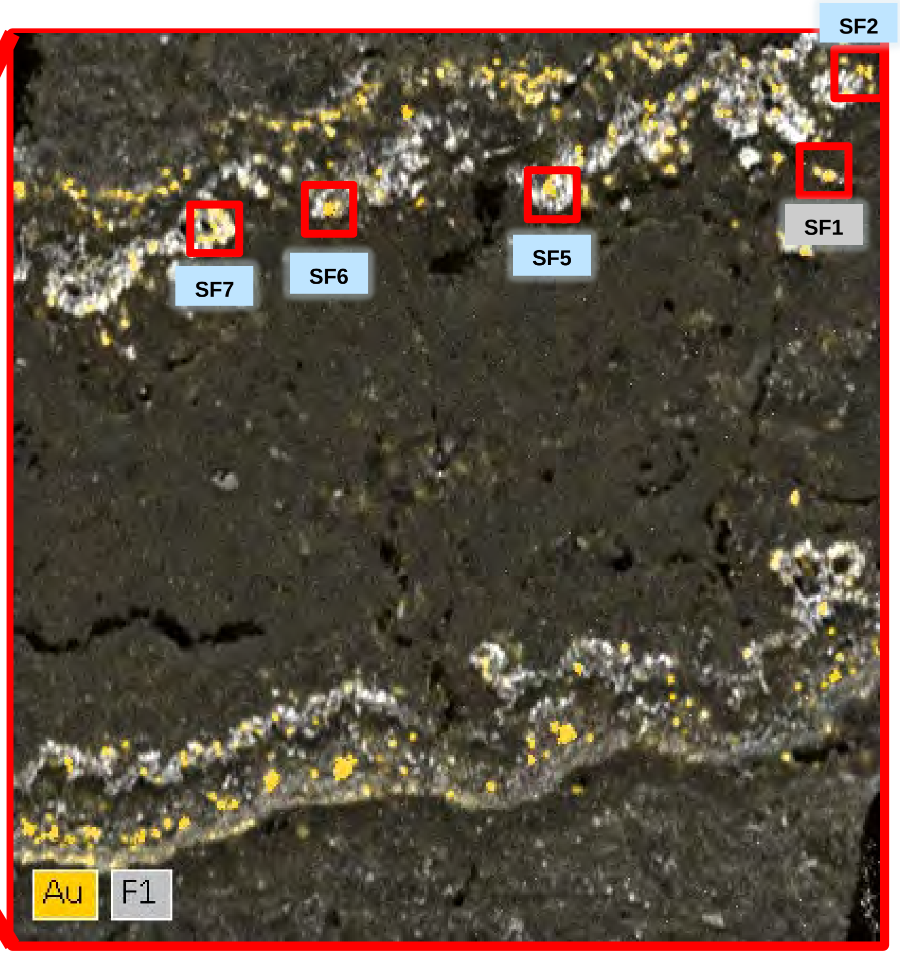
- Follow-up analyses can be achieved by switching to e-beam SEM analyses (requires sample coating and high vacuum)

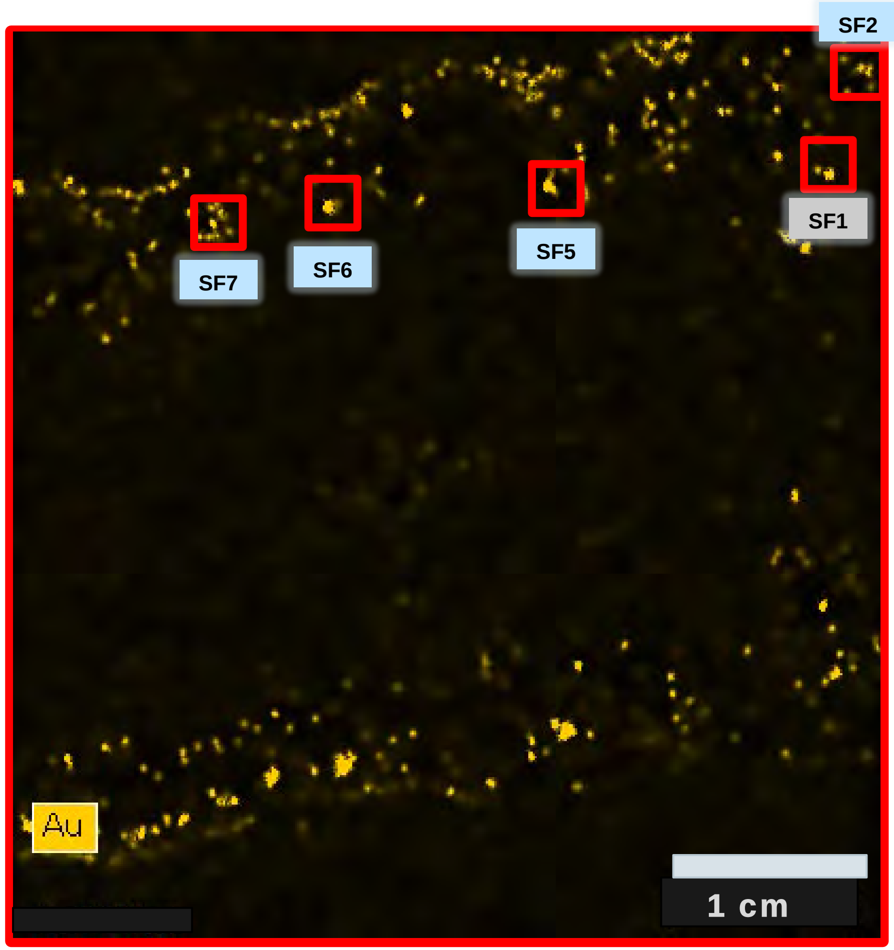
Or

- Selecting specific areas in the sample for further sample preparation prior to analyze

Micro-XRF on SEM (X-ray Beam)

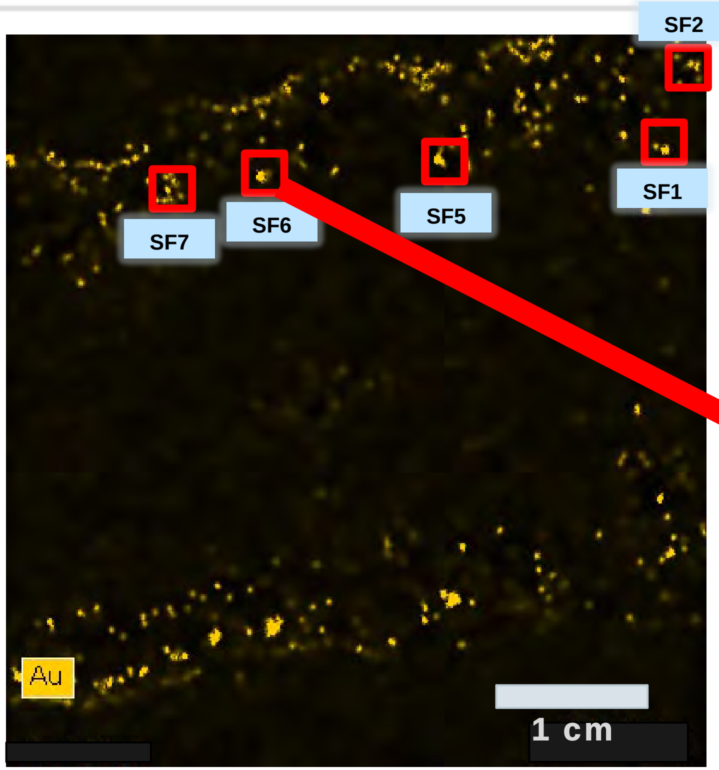
Identifying Gold (Au) in the Sample

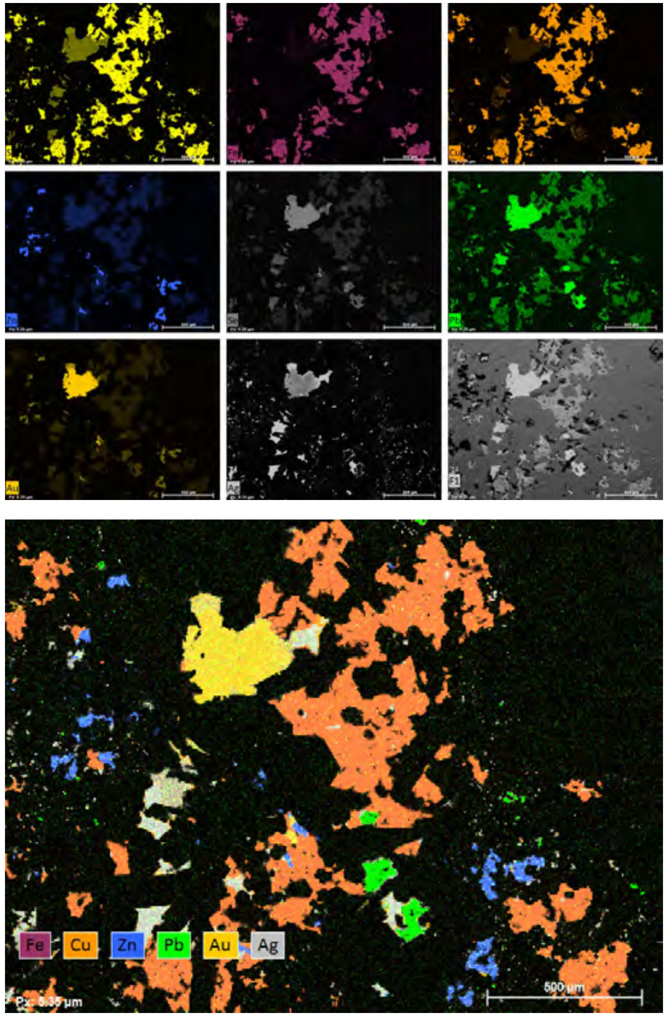




SEM-EDS (e-beam)

Identifying Gold (Au) in the Sample





Single Field 6

Large Gold Grain;

Associated with Silver

Other mineralization:

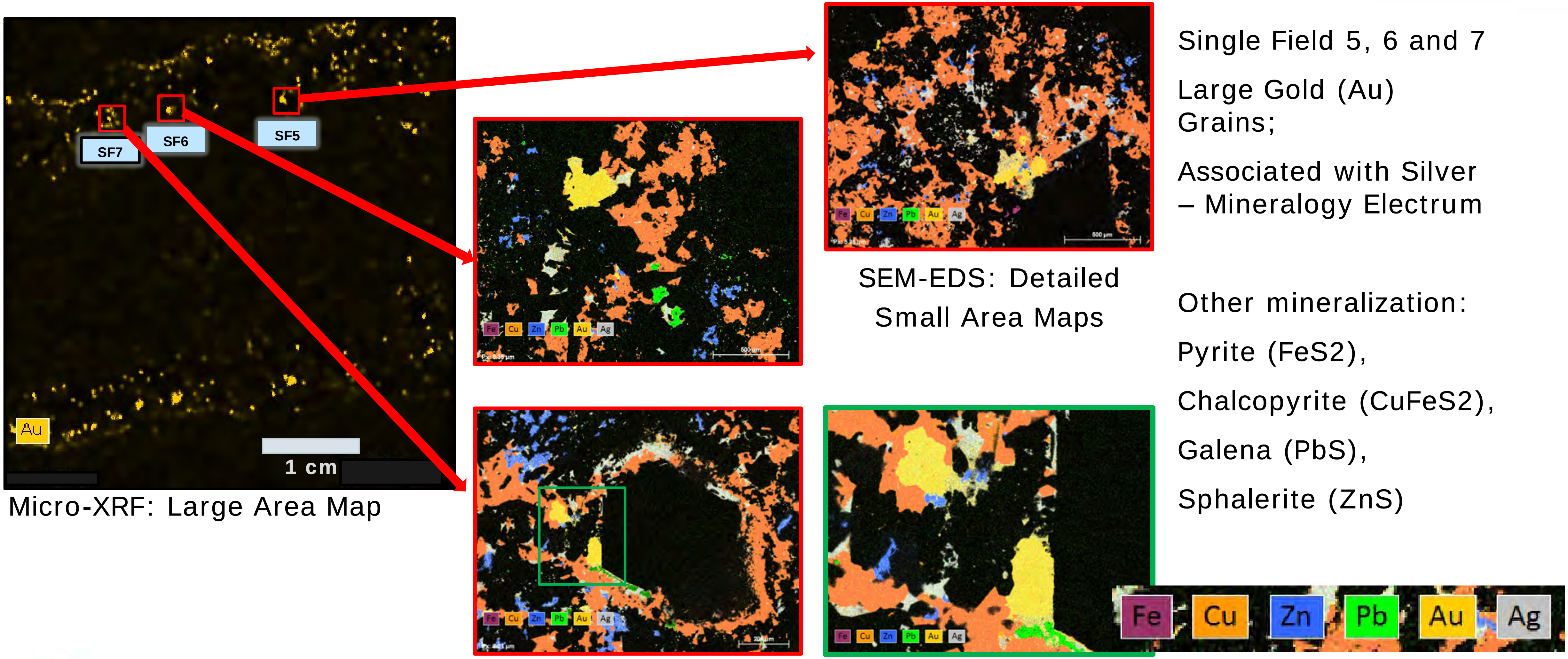
Pyrite (FeS_2),

Chalcopyrite ($CuFeS_2$),

Galena (PbS),

Sphalerite (ZnS)

SEM-EDS (e-beam)
Identifying Gold (Au) in the Sample



Micro-XRF: Large Area Map

SEM-EDS: Detailed Small Area Maps

Single Field 5, 6 and 7

Large Gold (Au) Grains;

Associated with Silver – Mineralogy Electrum

Other mineralization:

Pyrite (FeS_2),

Chalcopyrite ($CuFeS_2$),

Galena (PbS),

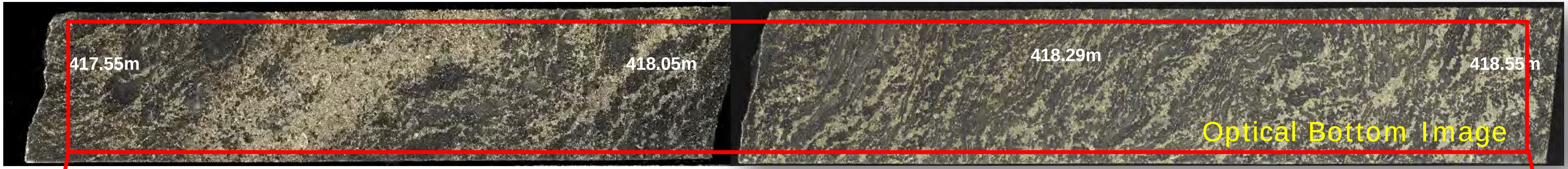
Sphalerite (ZnS)

Trace Elements and Mineralization:
Case Study 1 – Cobalt (Co)

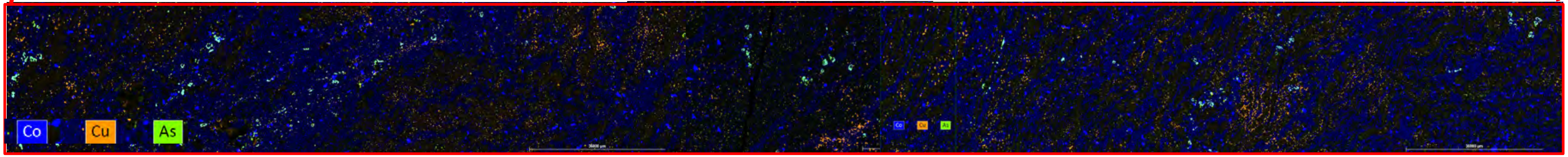
Analyzing Large Samples: Drill Core (Micro-XRF)

Case Study 2: Cobalt (Co)
Battery Elements

In-situ non-destructive analysis Drill Core – 1 meter section



Stitched elemental Map – Co (Blue), Cu (Orange), and As (Green)



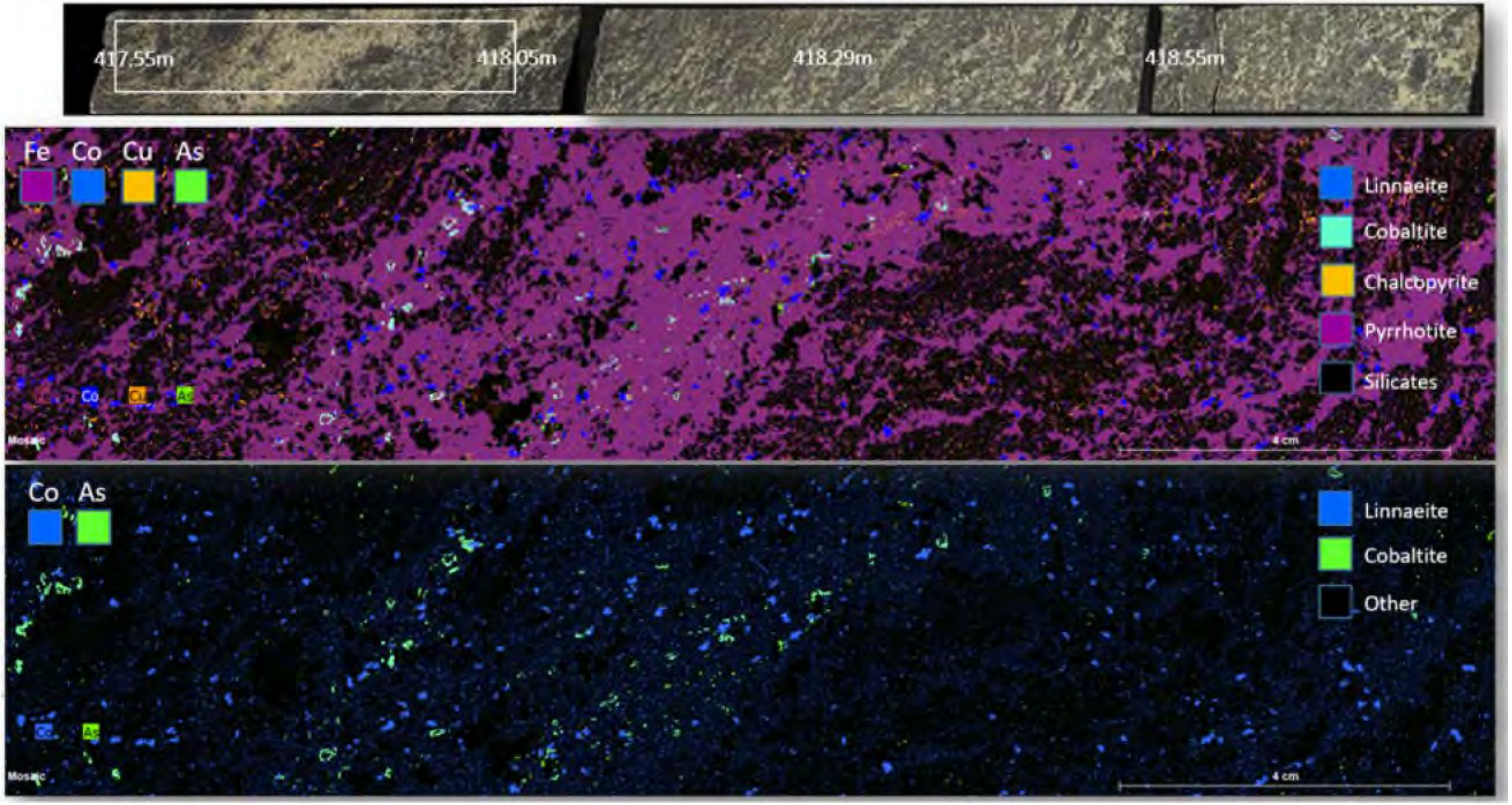
Centimeter-scale elemental mapping of cobalt mineralisation in drill hole PAL0163 by micro-XRF (directly onto a cut surface of a drill core), to reveal the spatial distribution of mineral species and their relationship to the micro-structural fabric.

Case Study 2: Cobalt (Co)

Battery Relevant Elements

Ore mineralogy, petrogenesis and metallurgy

Centimeter-scale elemental mapping of cobalt mineralisation in drill hole PAL0163 by micro-XRF (directly onto a cut surface of a drill core), to reveal the spatial distribution of mineral species and their relationship to the micro-structural fabric.



Case Study 2: Cobalt (Co)

Battery Elements

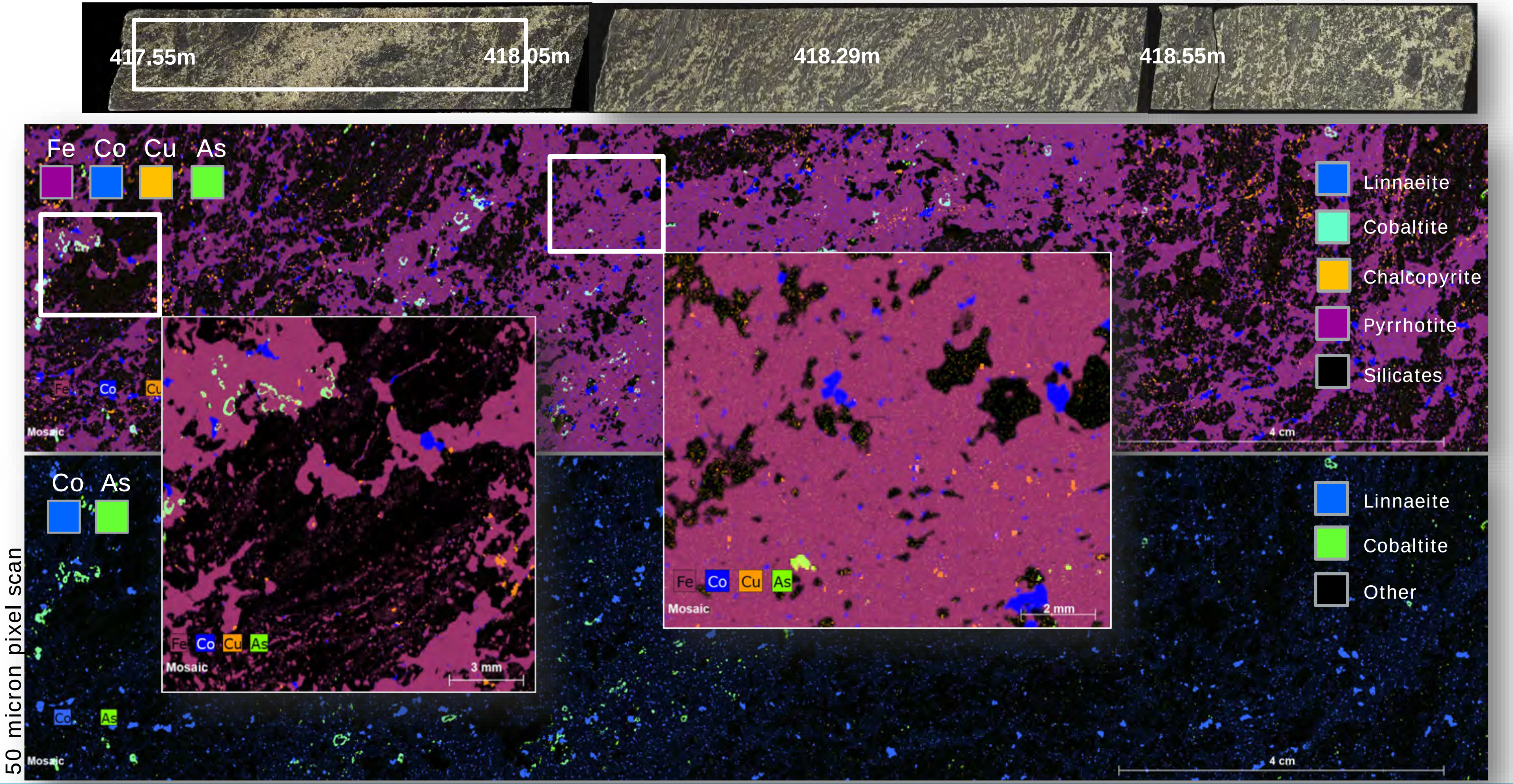
Identification of key elements of interest

Overlayed Mixed Element images can lead to mineral identification

High resolution scans can identify textures and associations

PAL0163 – 417.55m

Extreme Detail

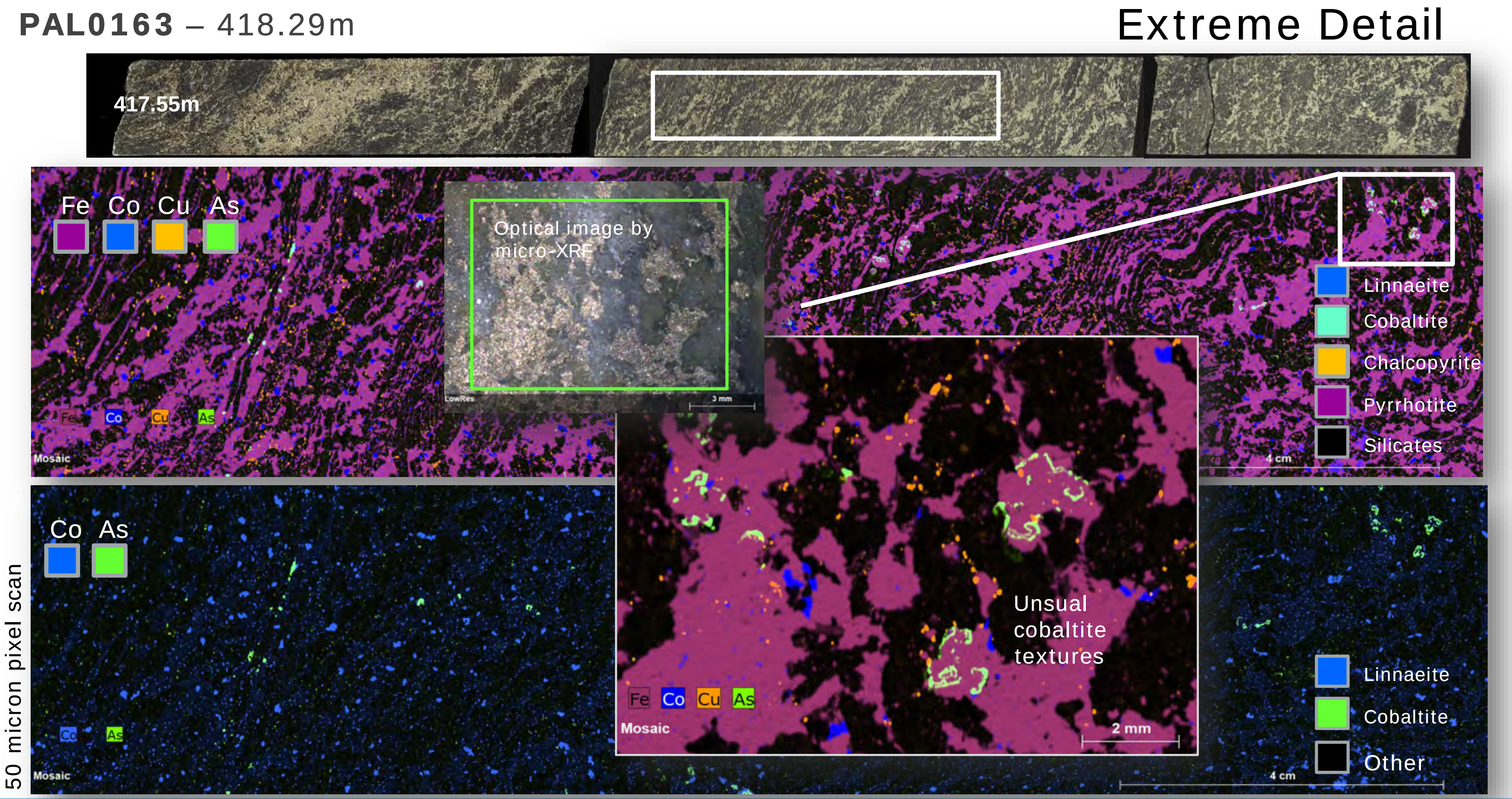


Case Study 2: Cobalt (Co)
Battery Elements

Identification of key elements of interest

Overlayed Mixed Element images can lead to mineral identification

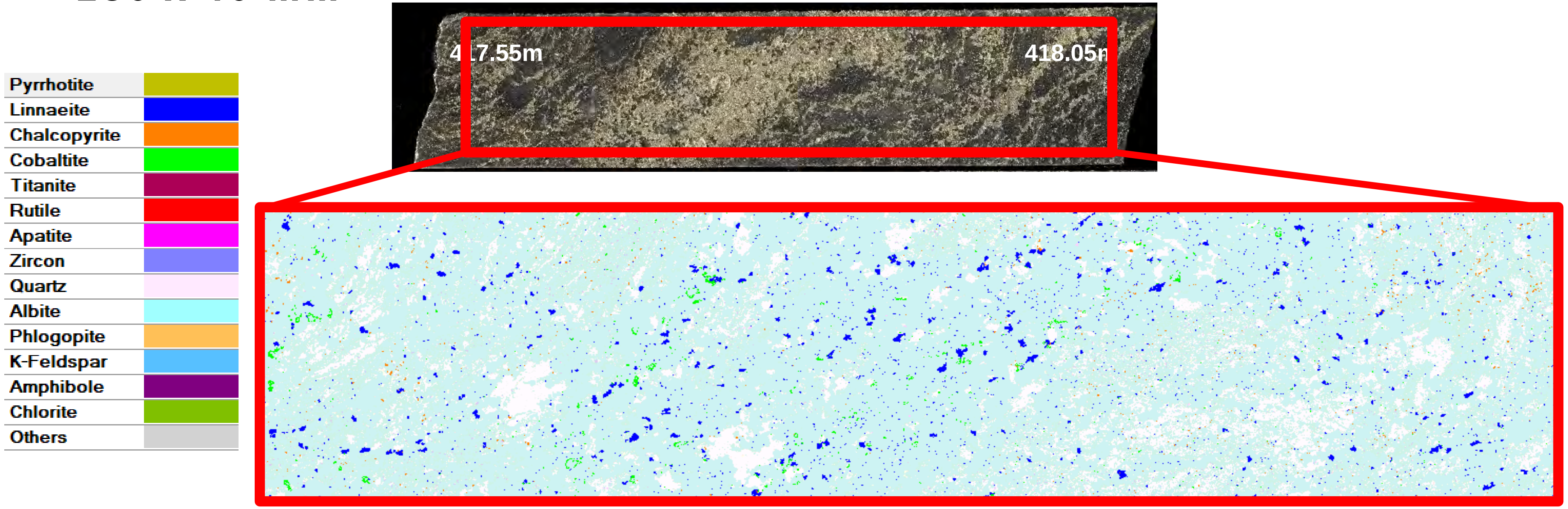
High resolution scans can identify textures and associations



Case Study 2: Cobalt (Co)
Automated Mineralogy (AMICS)

Scan

180 x 40 mm



Linnaeite ($Co^{+2}Co^{+3}{}_2S_4$)

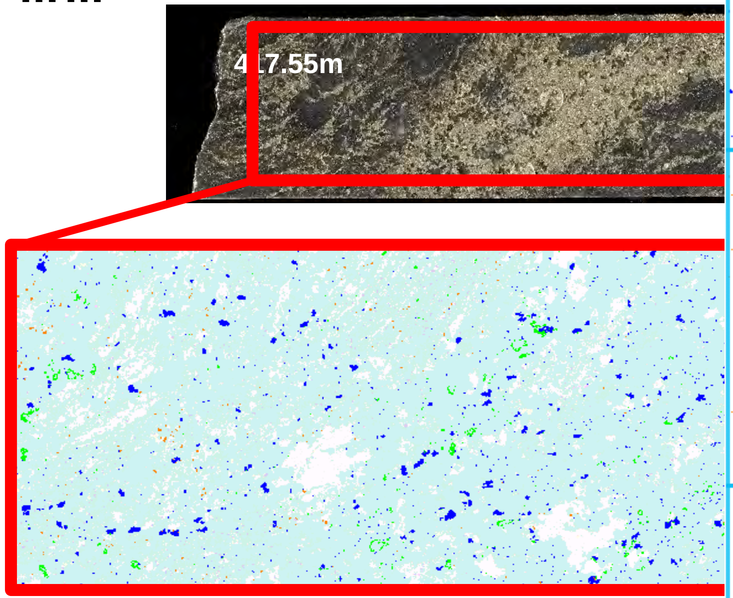
Cobaltite (CoAsS)

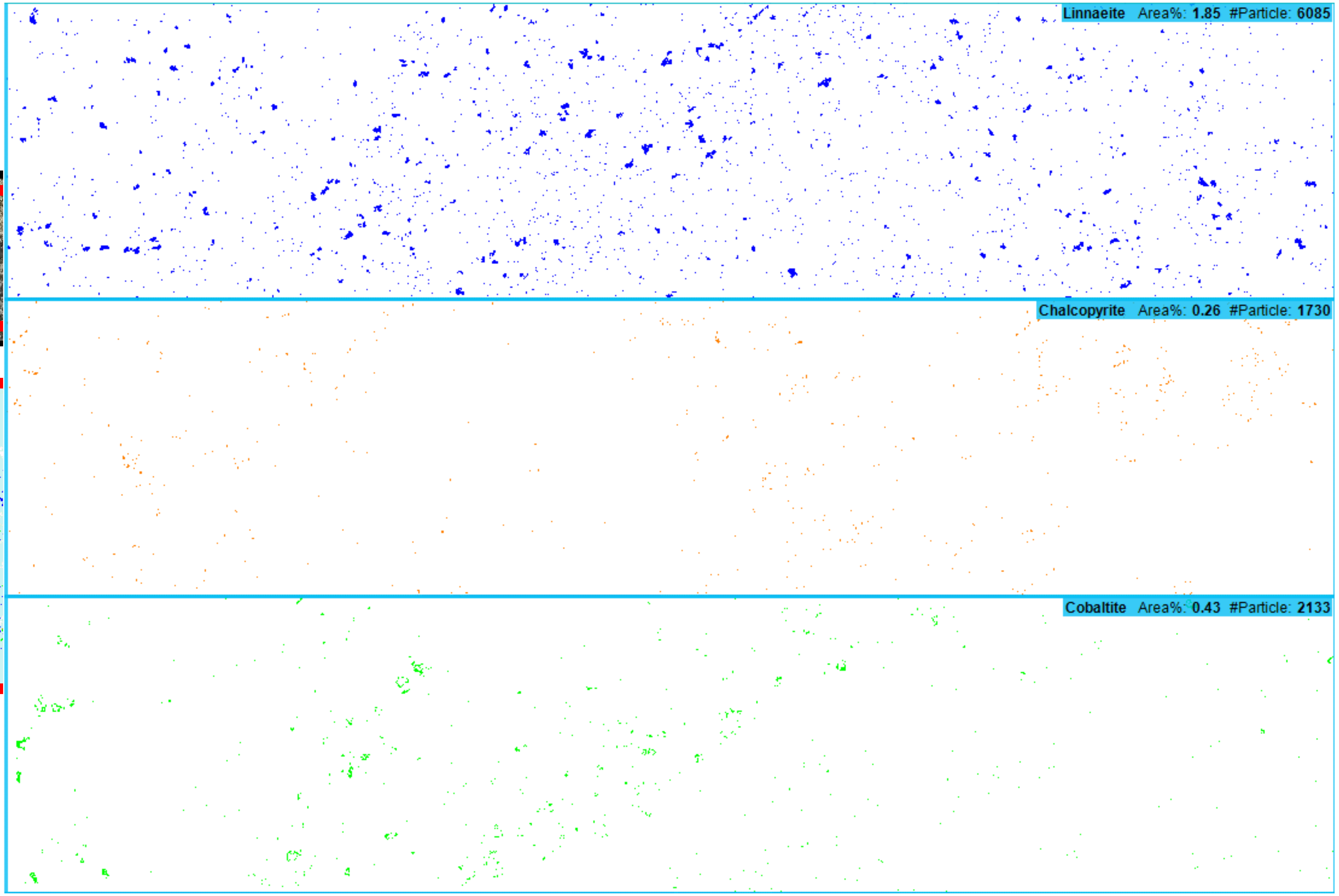
Case Study 2: Cobalt (Co)
Automated Mineralogy (AMICS)

Scan

180 x 40 mm

Mineral	
Pyrrhotite	
Linnaeite	
Chalcopyrite	
Cobaltite	
Titanite	
Rutile	
Apatite	
Zircon	
Quartz	
Albite	
Phlogopite	
K-Feldspar	
Amphibole	
Chlorite	
Others	





Linnaeite ($Co^{+2}Co^{+3}{}_2S_4$)

Cobaltite (CoAsS)

Case Study 2: Cobalt (Co)

Grain Size Distribution - Linnaeite (Co_3S_4)

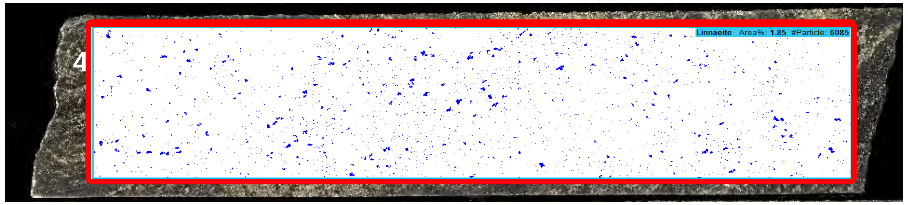
Scan

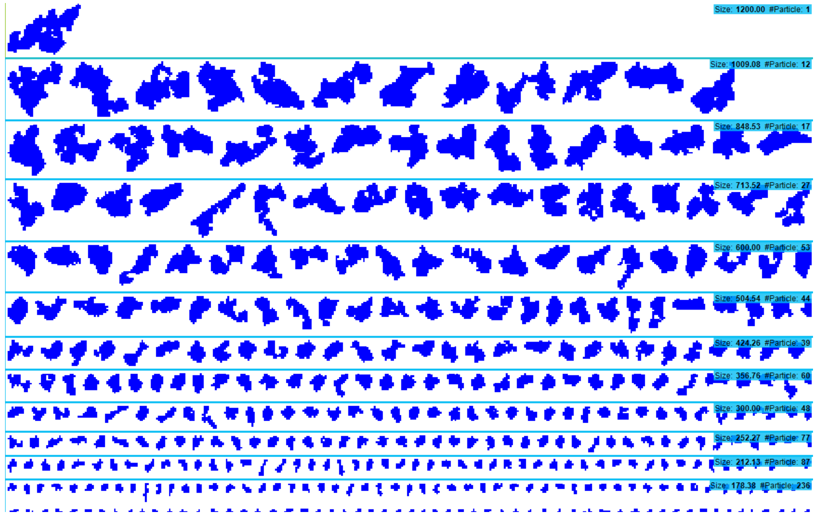
180 x 40 mm

Pyrrhotite	
Linnaeite	
Chalcopyrite	
Cobaltite	
Titanite	
Rutile	
Apatite	
Zircon	
Quartz	
Albite	
Phlogopite	
K-Feldspar	
Amphibole	
Chlorite	
Others	

Linnaeite ($Co^{+2}Co^{+3}{}_2S_4$)

Cobaltite (CoAsS)





AMICS Mineralogy

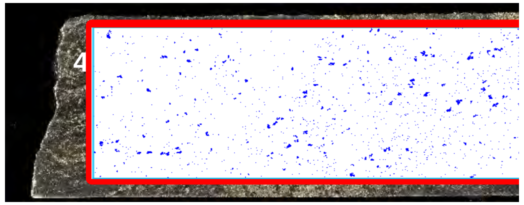
Case Study 2: Cobalt (Co)

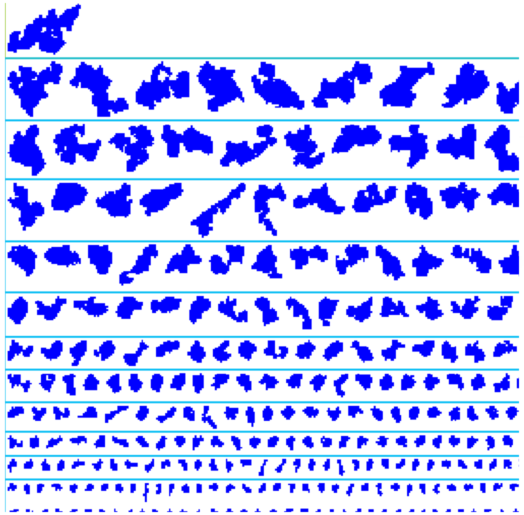
Grain Size Distribution - Linnaeite (Co_3S_4)

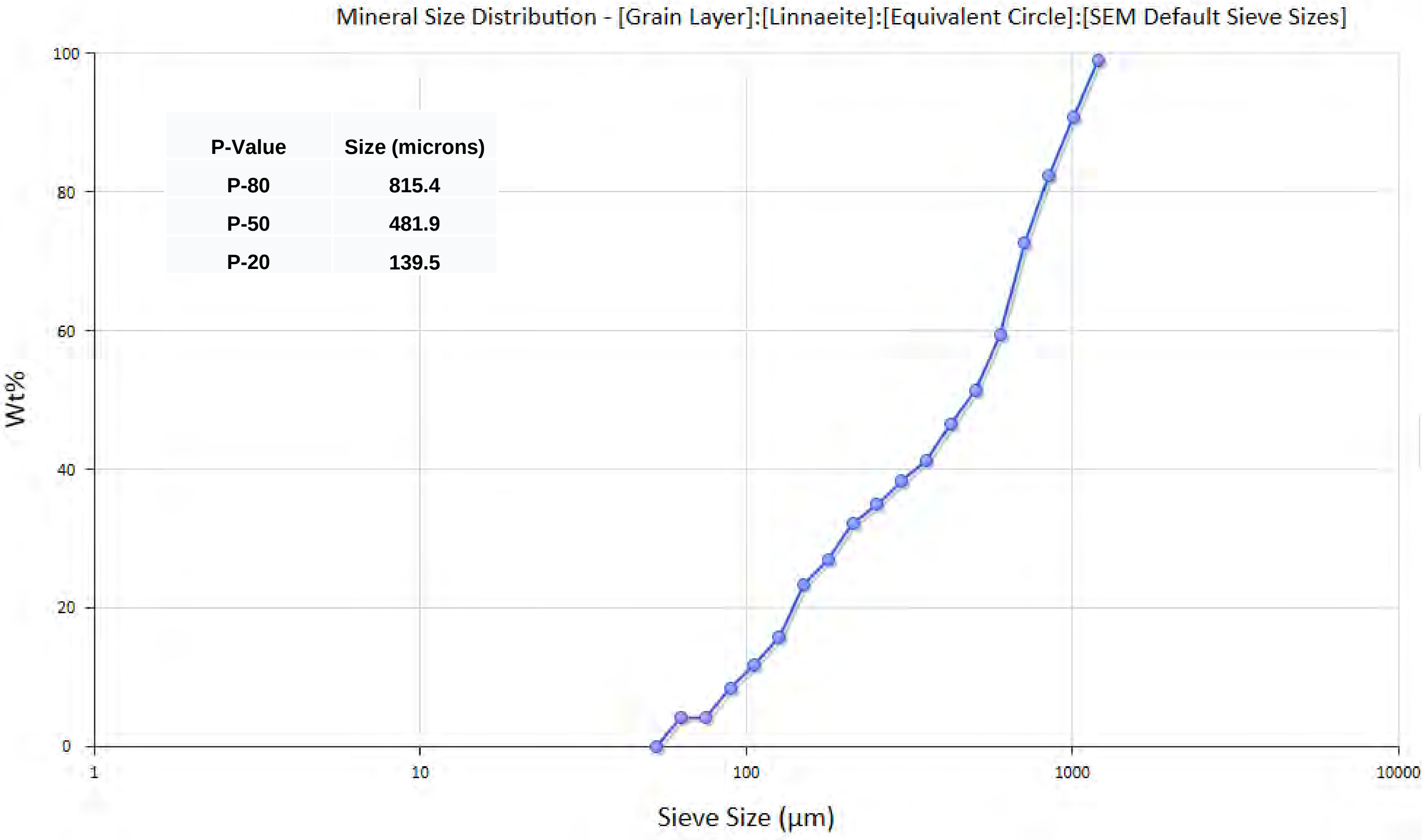
Pyrrhotite	
Linnaeite	
Chalcopyrite	
Cobaltite	
Titanite	
Rutile	
Apatite	
Zircon	
Quartz	
Albite	
Phlogopite	
K-Feldspar	
Amphibole	
Chlorite	
Others	

Linnaeite ($Co^{+2}Co^{+3}{}_2S_4$)

Cobaltite (CoAsS)







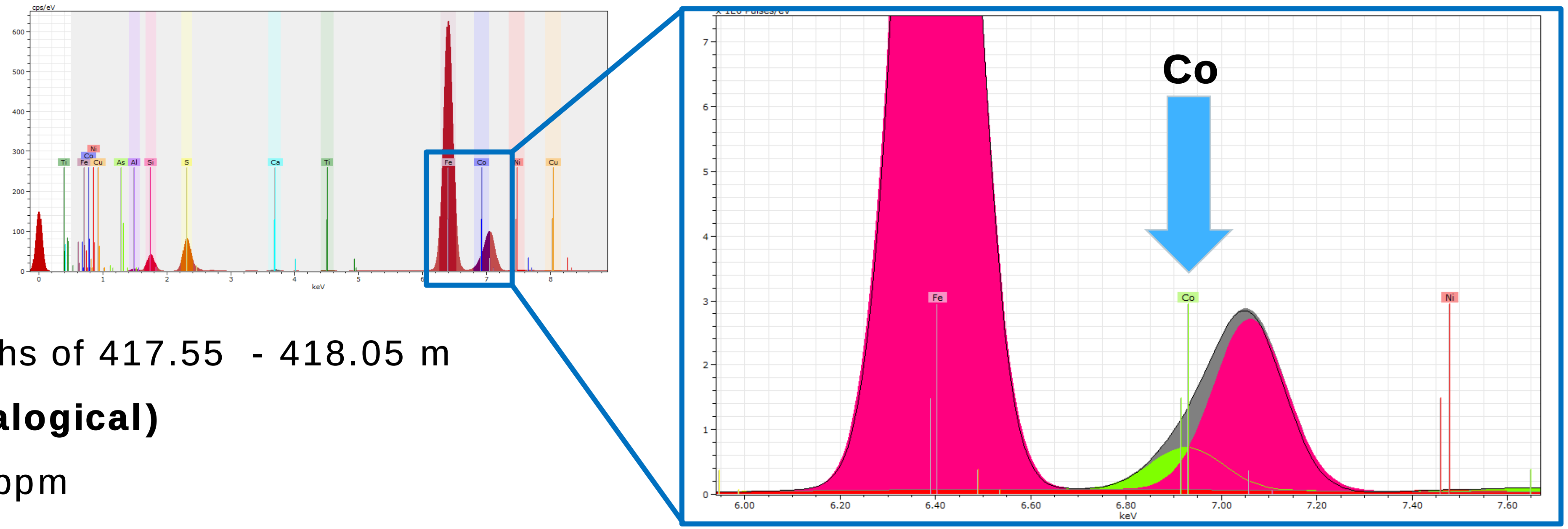
P-Value	Size (microns)
P-80	815.4
P-50	481.9
P-20	139.5

AMICS Mineralogy

Case Study 2: Cobalt (Co)

Co Concentration

Assay
Calculations
Comparison



Cobalt content at the depths of 417.55 - 418.05 m

Back Calculated (Mineralogical)

Co concentration → 9340 ppm

Total Spectrum (Whole Rock)

Co concentration → 10400 ppm

Cobalt content at the depths of 417.6 - 418.6 m:

Chemical assay

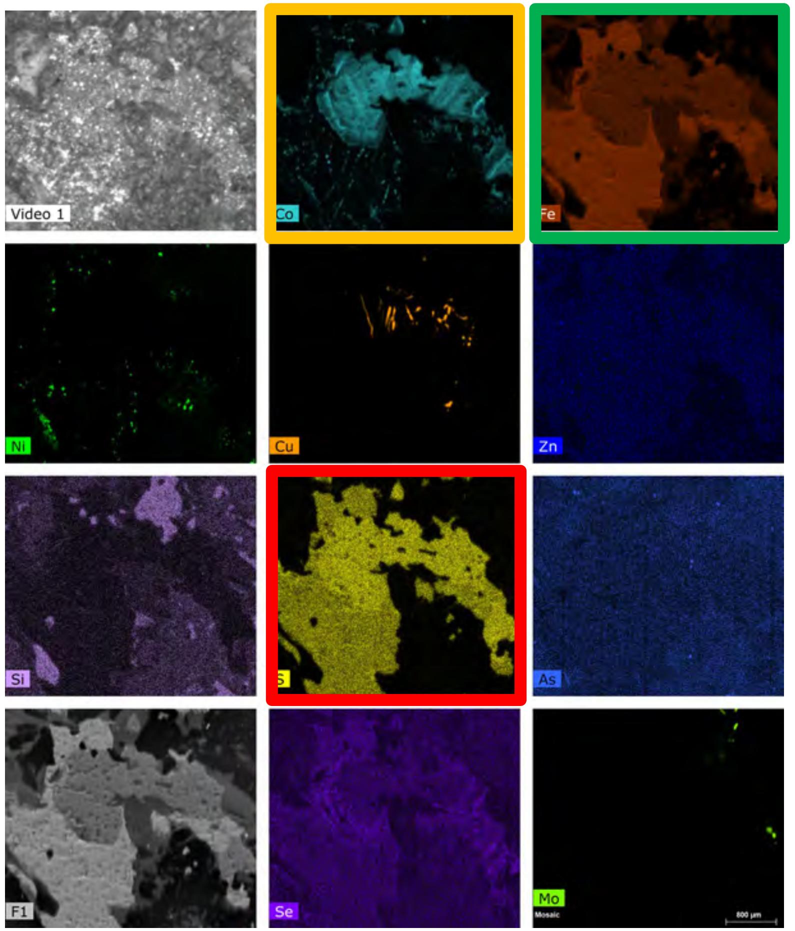
Co concentration → 9769.3 ppm
(reported by Mawson Oy)

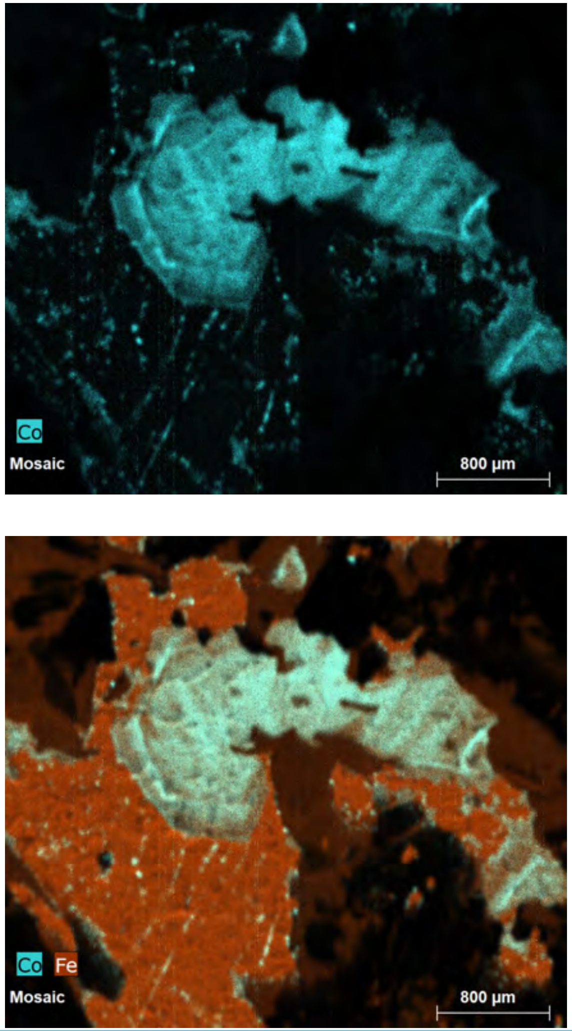
Total Spectrum (Whole Rock)

Micro XRF: Co 1.04 wt. %

Case Study 2: Cobalt (Co)

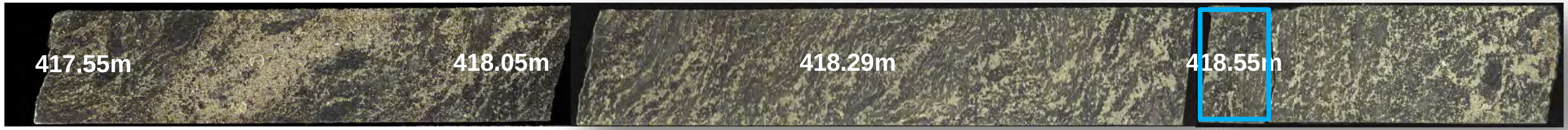
Identification of Co-in-pyrite





Automated Mineralogy (AMICS):
Micro-XRF vs SEM

PAL0163 – 418.29m



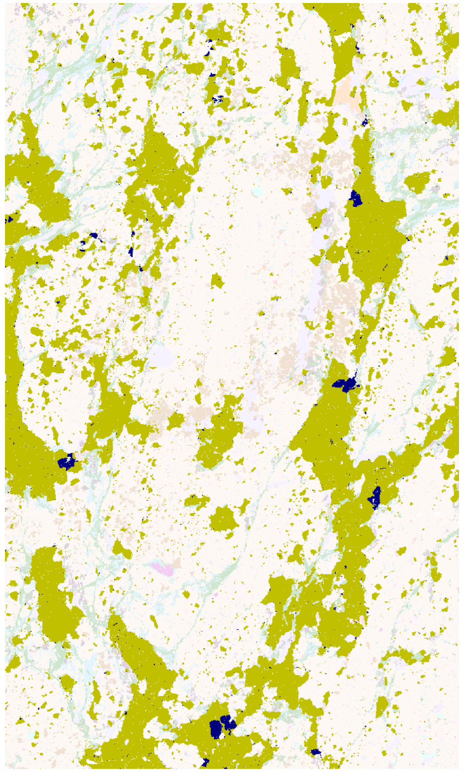
Thin Section of Co-Ore showing the Sulphide phases.

Automated Mineralogy (AMICS) possible with both Micro-XRF and SEM.

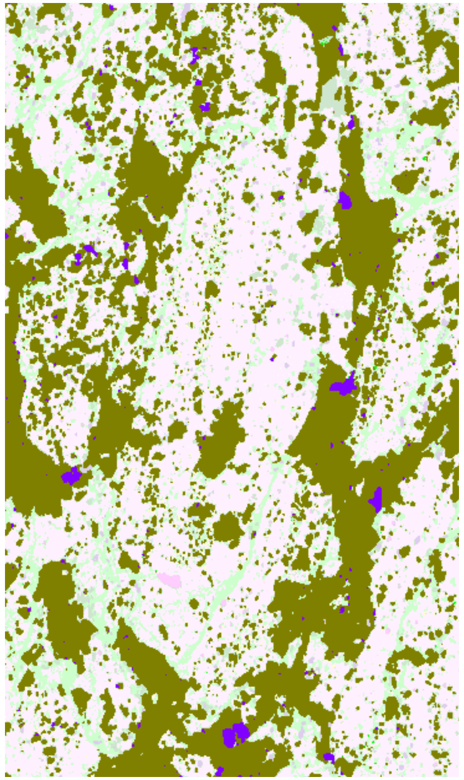
Principally Pyrrhotite and Cobaltite

Optical

SEM

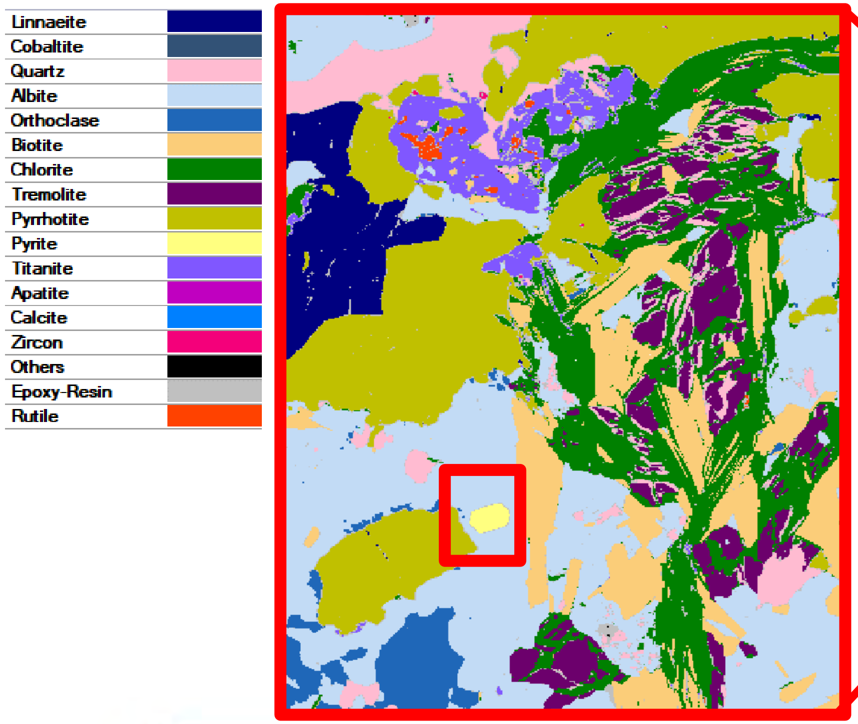


Micro-XRF

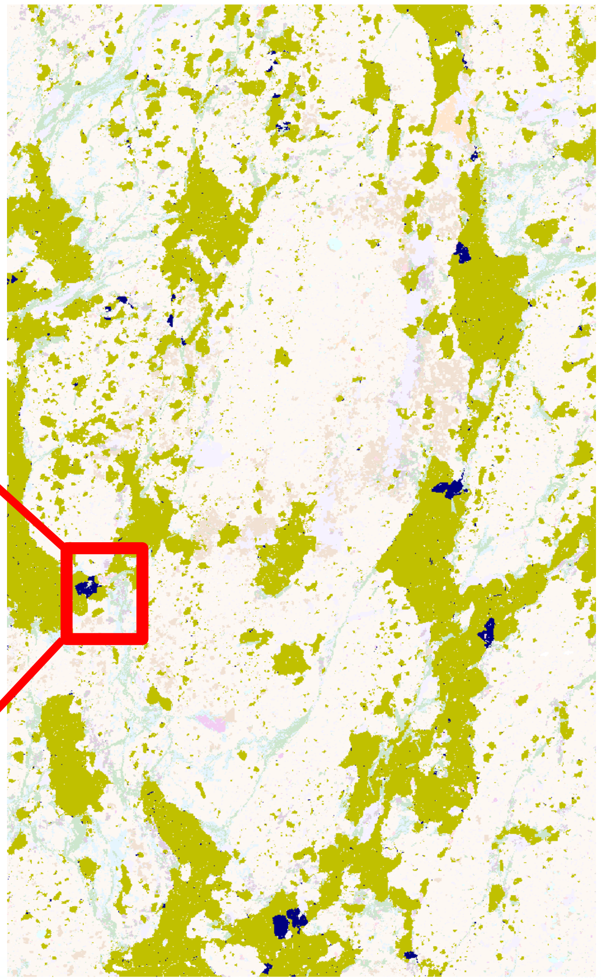


Automated Mineralogy (AMICS):
Micro-XRF vs SEM

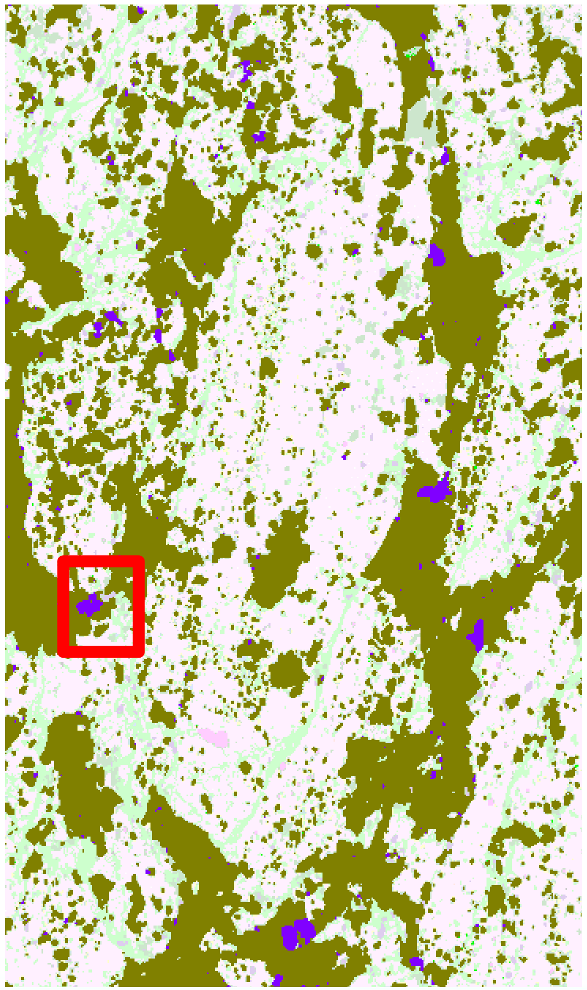
Automated Mineralogy (AMICS) possible with both Micro-XRF and SEM. Difference primarily in resolution. Thin Section of Co-Ore showing the Sulphide phases. Principally Pyrrhotite and Cobaltite



SEM



Micro-XRF

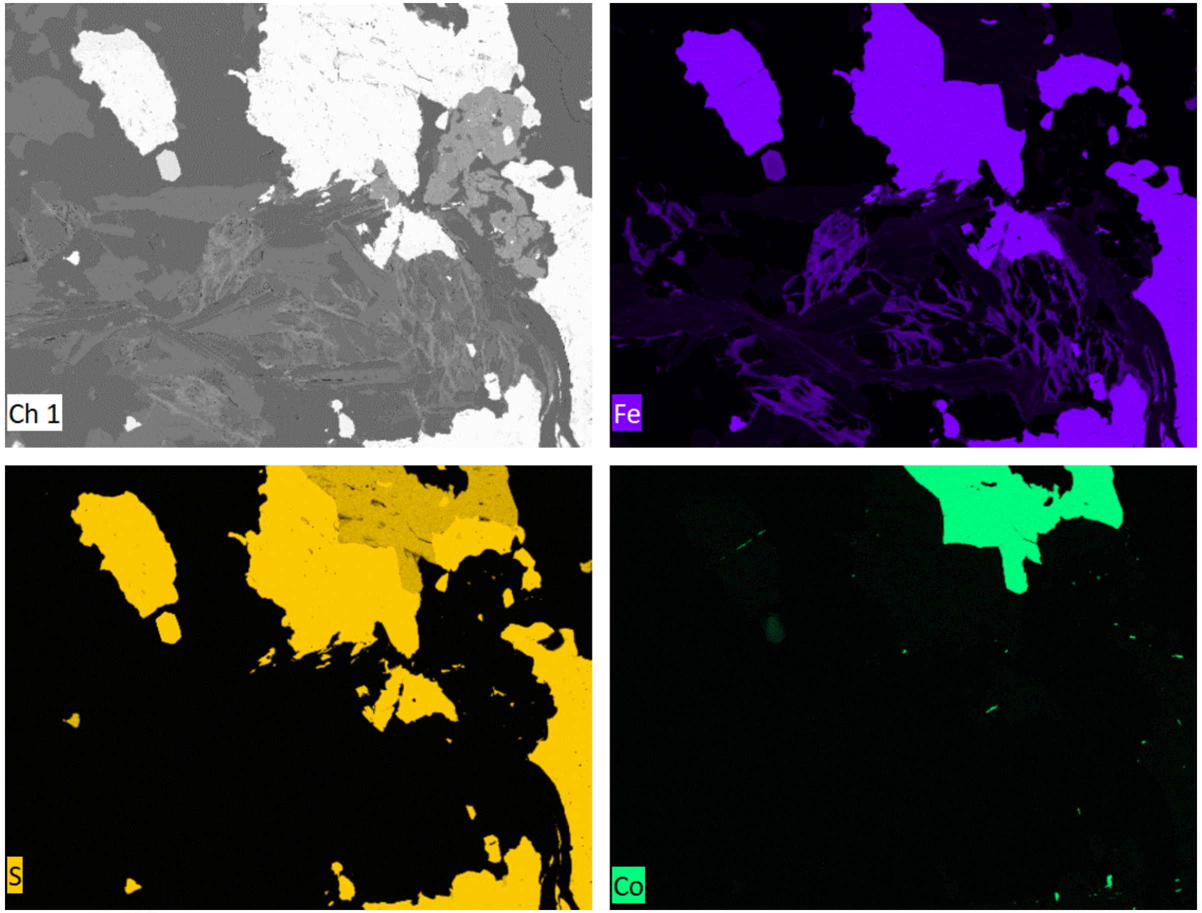


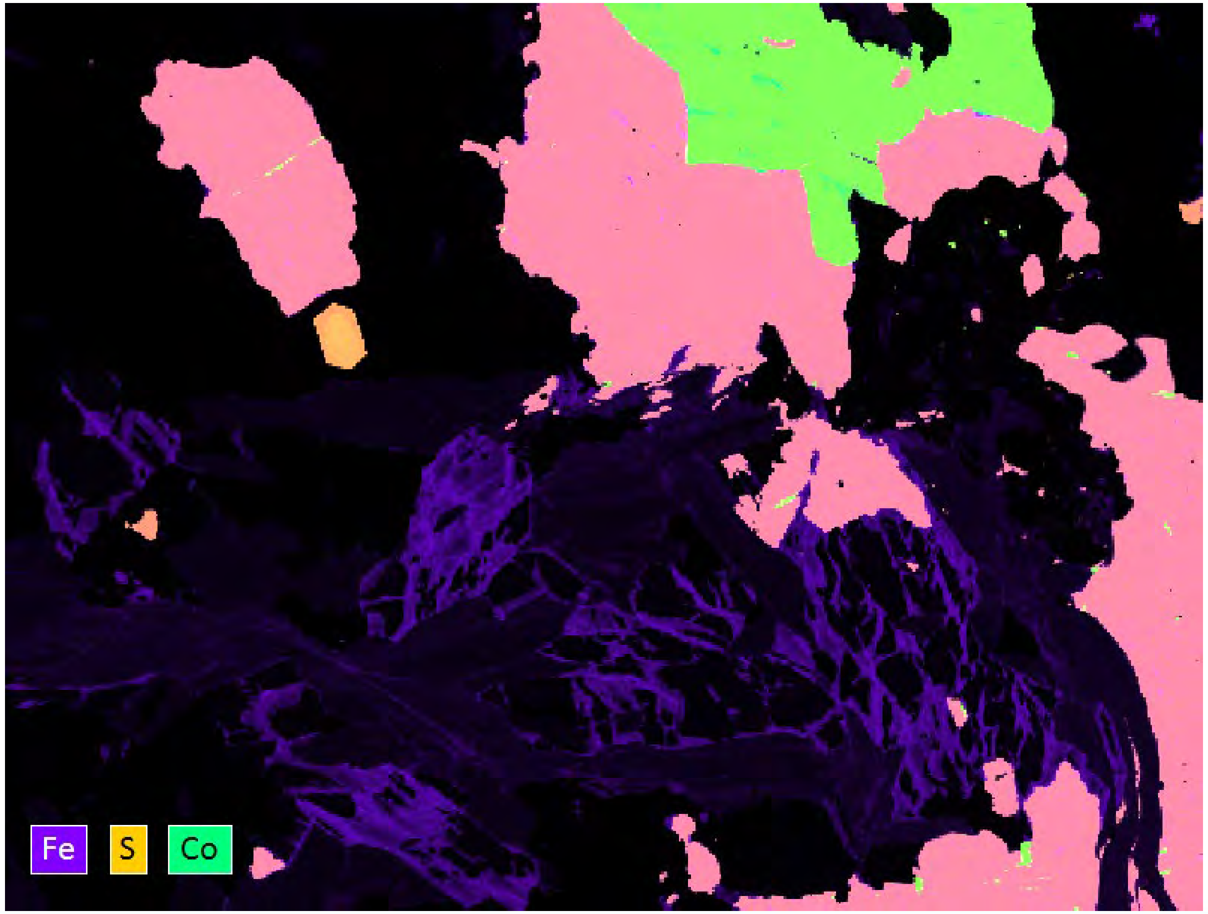
SEM-EDS Analysis:
Co-in-Pyrite

Analysis of small (<100 µm) Co-bearing pyrite grain.

Left: Individual Element intensity maps (BSE, Fe, S, and Co);

Right: Combined elemental maps: Fe,

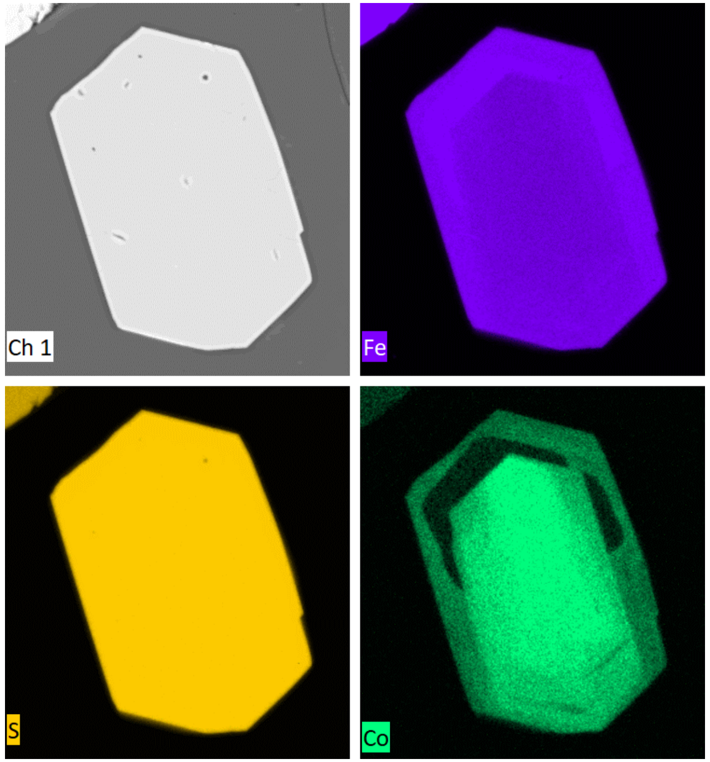




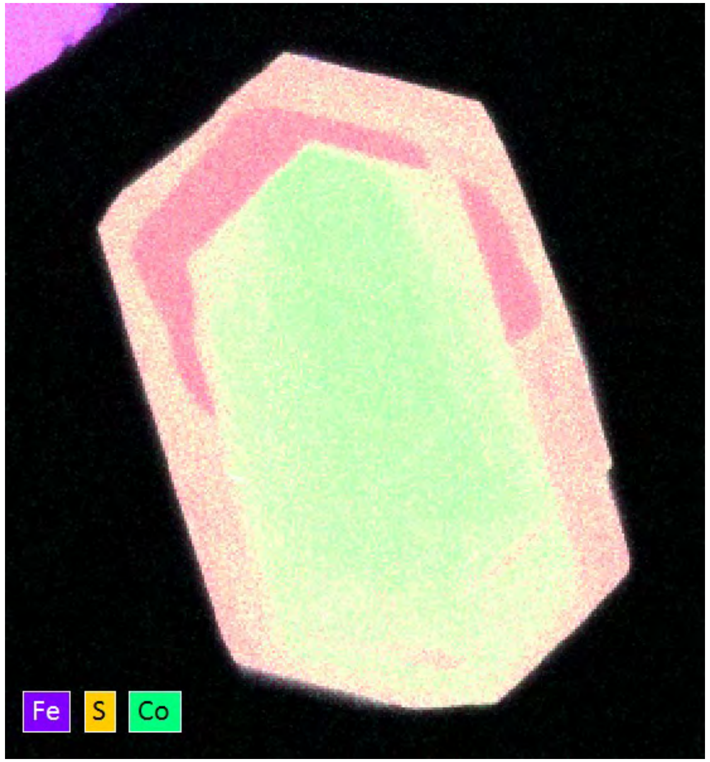
SEM-EDS Analysis:
Co-in-Pyrite

Analysis of small (<100 µm) Co-bearing pyrite grain.

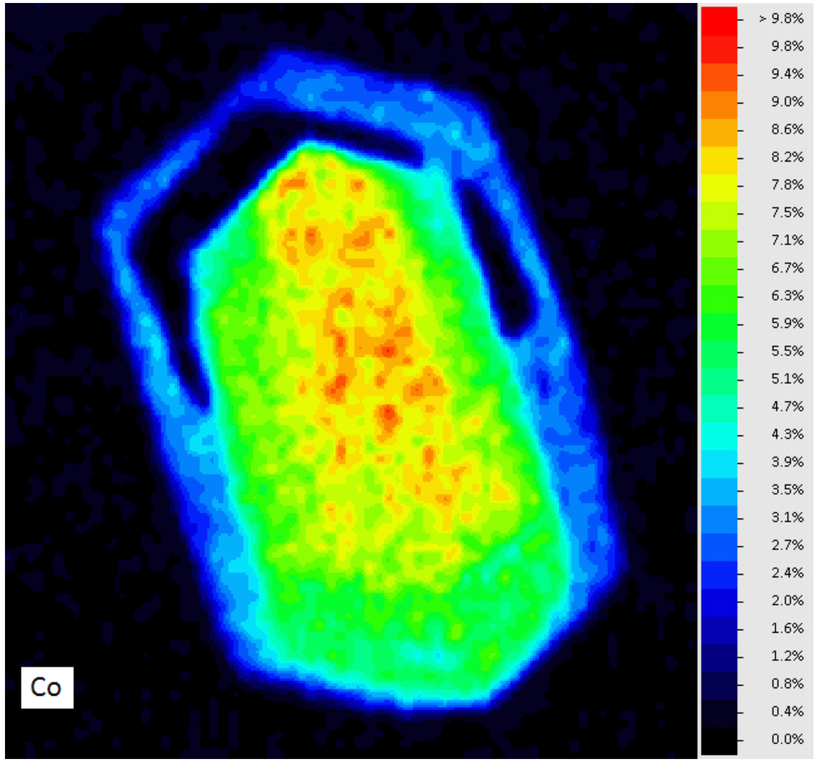
Left: Individual Element intensity maps (BSE, Fe, S, and Co)



Middle: Combined elemental maps: Fe, S, and Co

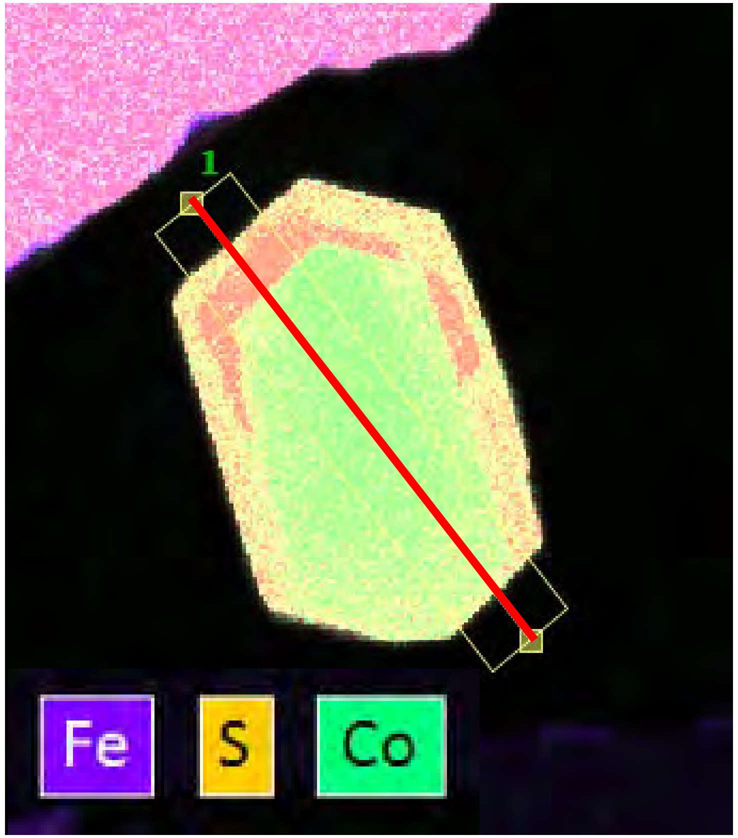


Right: Quantified Co Map

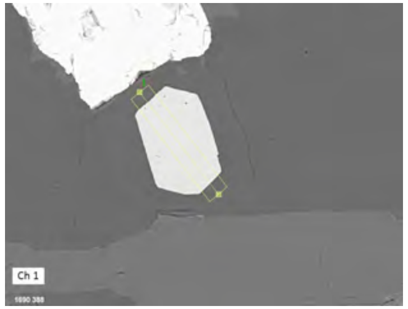


SEM-EDS Analysis:
Co-in-Pyrite

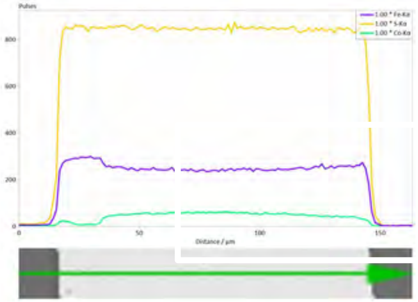
Left: Position of Line Scan on combined elemental maps: Fe, S, and Co

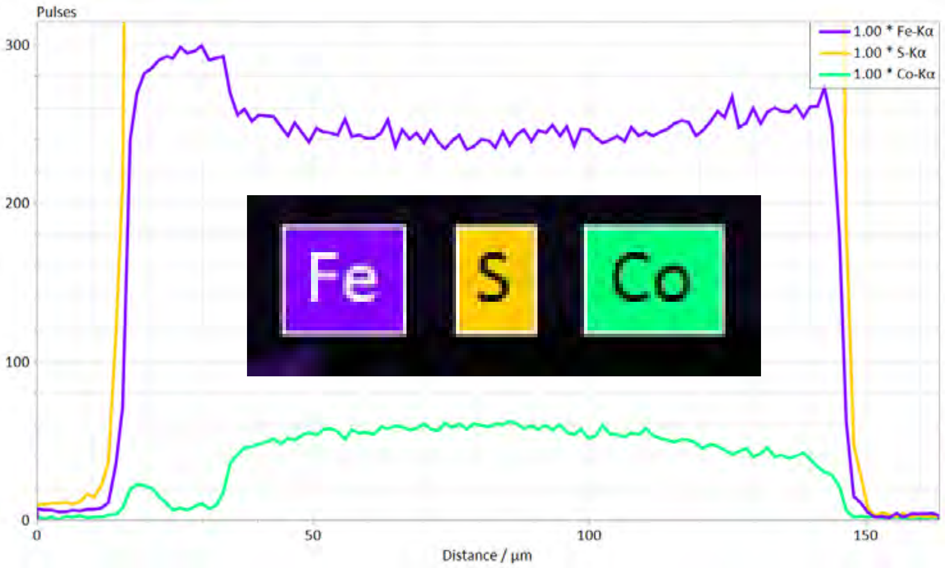


Top Middle: BSE Image



Top Right: Line Scan of Fe, S, and Co



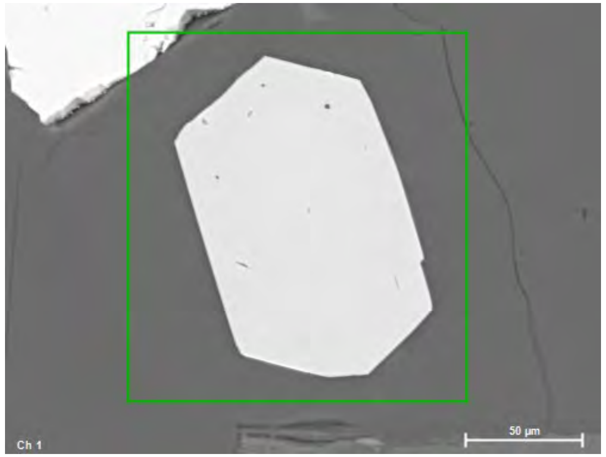


Benefits: Understanding crystal growth and compositional changes and thus petrological implications and mineralization.

Bottom Right: Zoom of Line Scan of Fe and Co

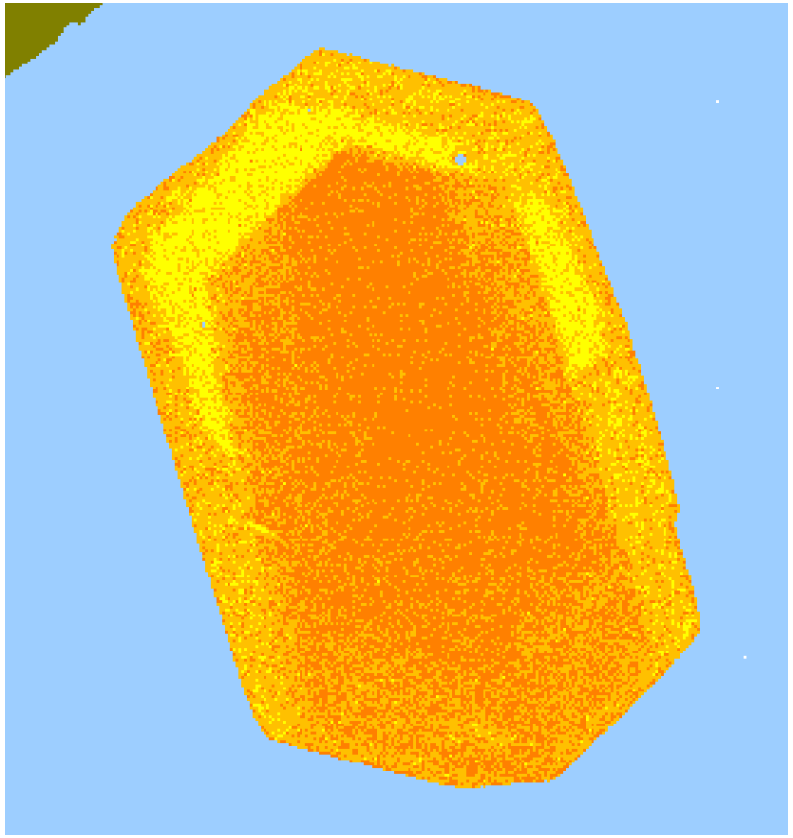
SEM-EDS Analysis:
Automated Mineralogy (AMICS)

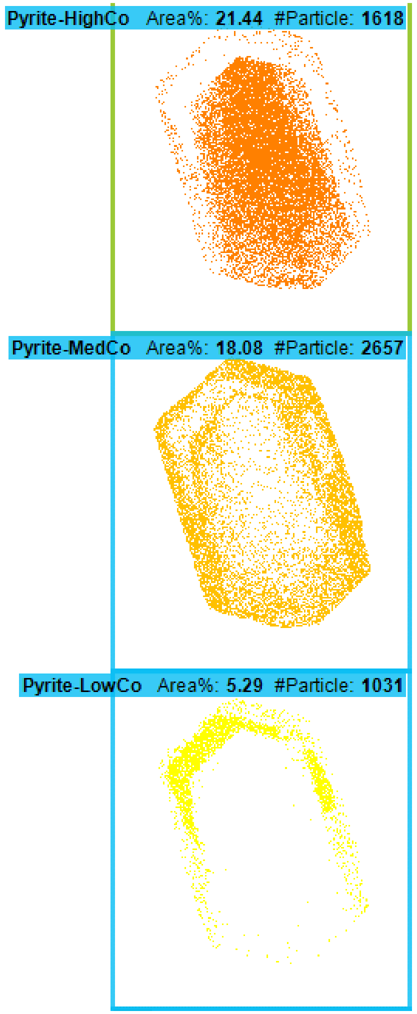
Left: BSE Image



Pyrite-HighCo	
Pyrite-MedCo	
Pyrite-LowCo	
Pyrrhotite	
Other	

Middle: AMICS mineralogical map showing the different pyrite classifications based on Co concentrations





Benefits:
Ability to add accurate Co deportment to metallurgical calculations

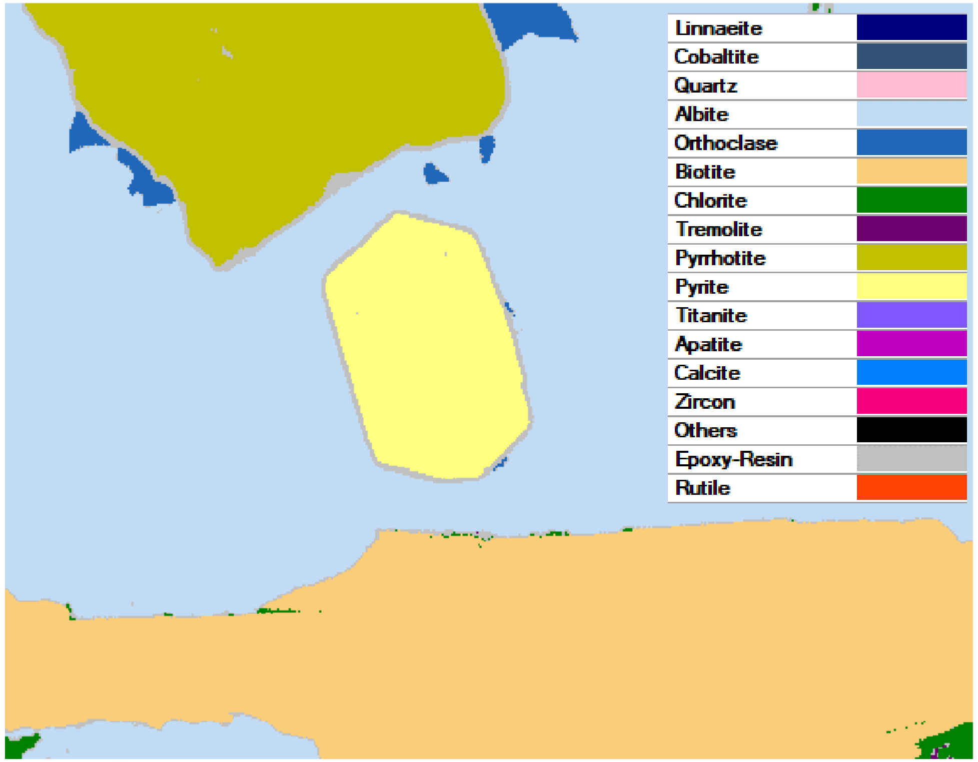
Right: Individual zones of pyrite grain based on Co-concentrations.

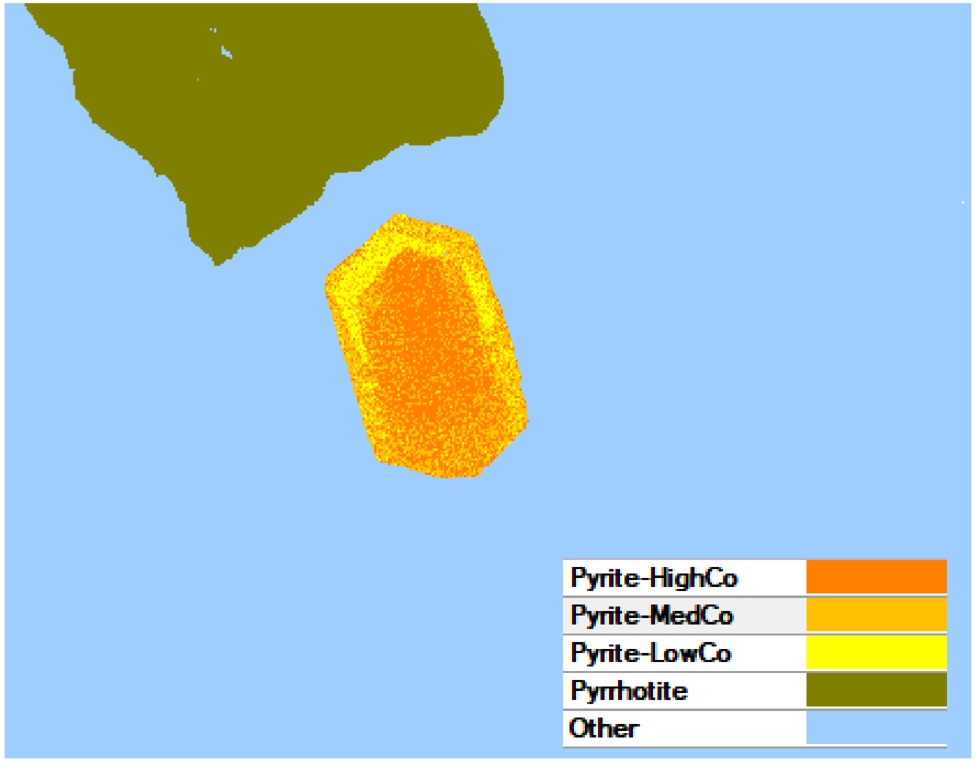
SEM-EDS Analysis:
Automated Mineralogy (AMICS)

Left: AMICS mineralogical map showing general mineral classifications. Note that Pyrite has a single classification.

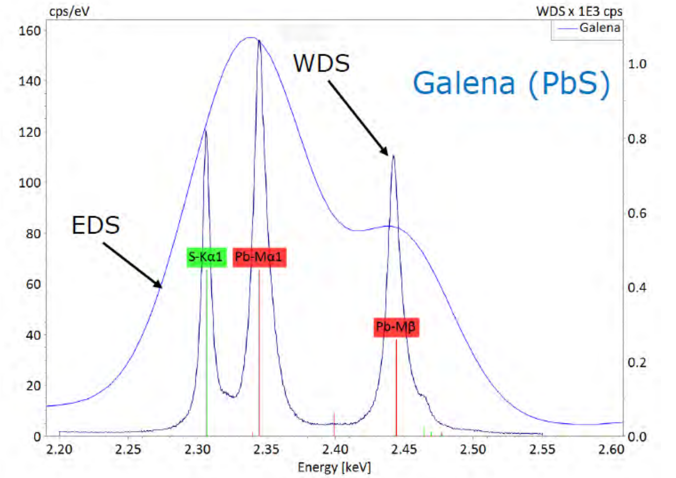
Right: AMICS mineralogical map showing the different pyrite classifications based on Co concentrations.

Benefits:
Ability to add accurate Co deportment to metallurgical calculations





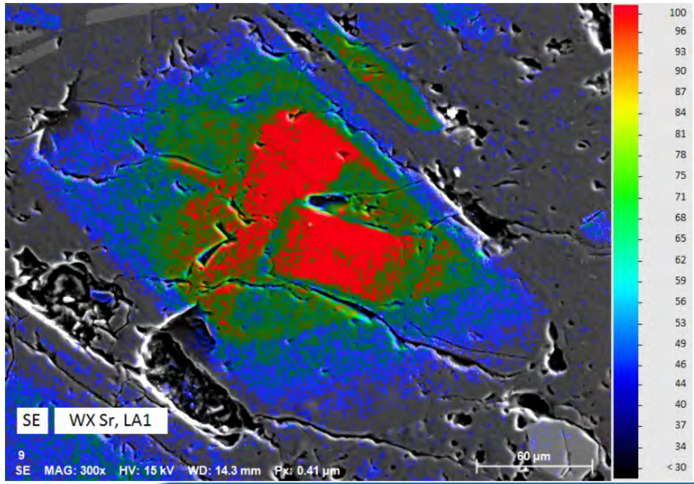
SEM-WDS Analysis:
Trace Element Distribution in Pyrite



Δ S-Kα – Pb-Mα: 38 eV

Resolution of WDS compared to EDS:

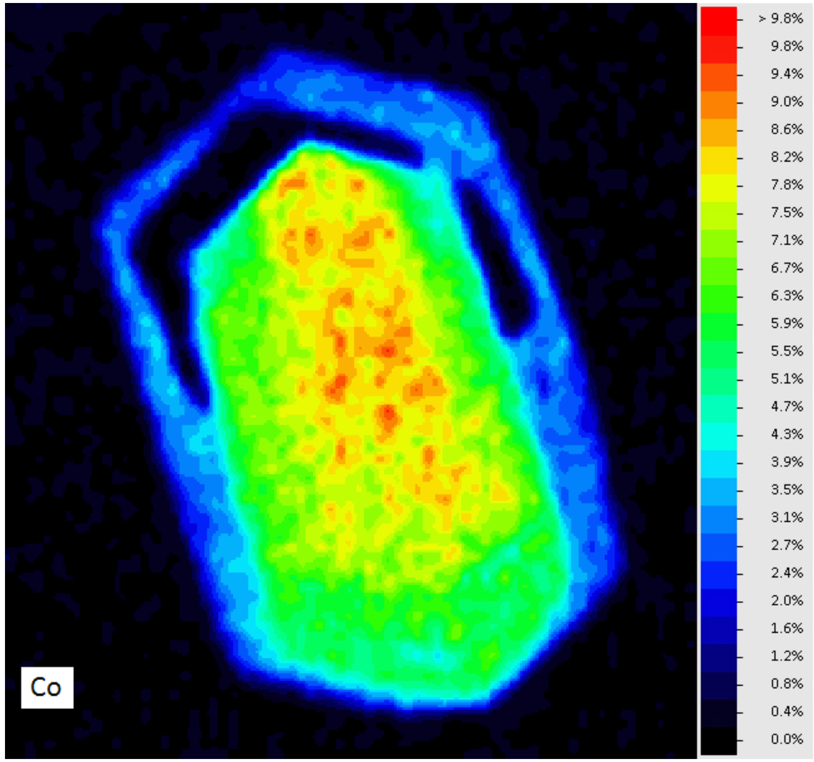
Pb vs S



WDS map of Sr in Plagioclase

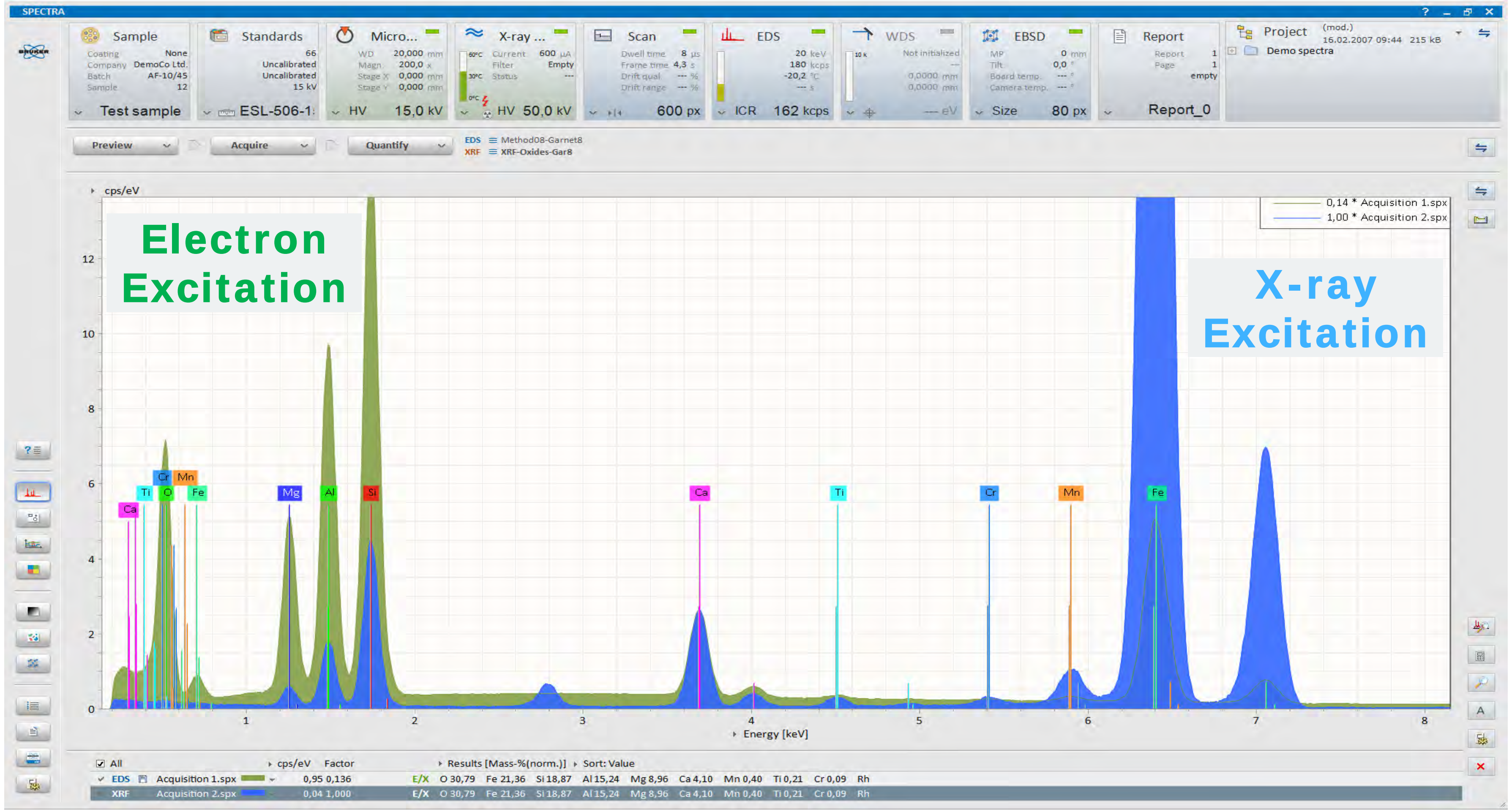
Future Work

WDS allows to improve EDS Co identification, especially in Fe-bearing minerals (Pyrite).
Better assessment of Co contained in Pyrite.



Energy Dispersive Spectra

Comparison: Electron vs. X-ray Excitation



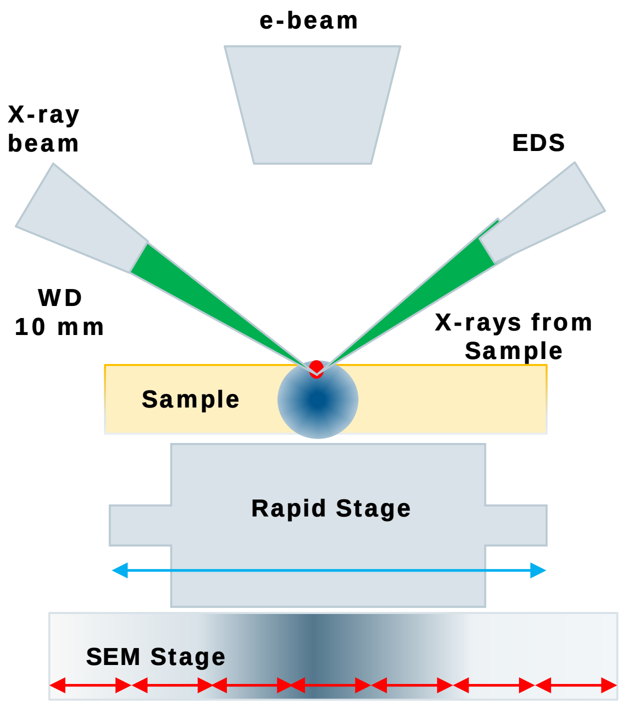
The garnet has:
40 wt% SiO2 and
20 wt% FeO.

The different spectrum profiles are obvious. For example, the e-beam spectra (in green) the lighter elements are more intense.

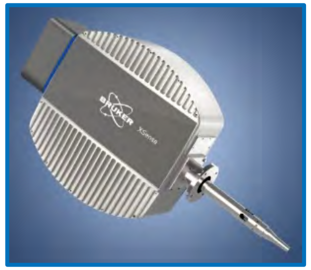
Whereas for the heavier elements the X-ray spectrum (in blue) has a significantly more intense signal.

Introduction
Terminology

Exiting with X-rays



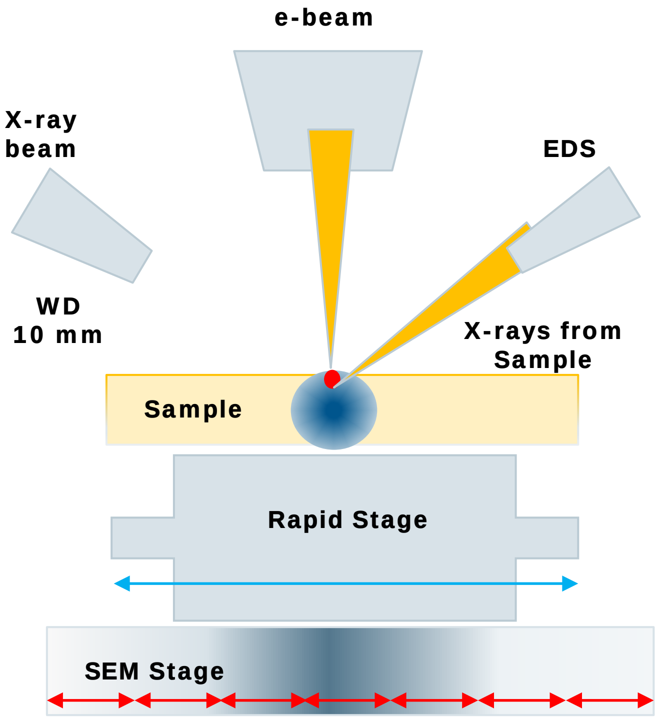
SEM-EDS: Analysis based on the sample interaction with an electron beam source from the SEM and the resultant X-rays that are detected using an EDS (simultaneous element detection)



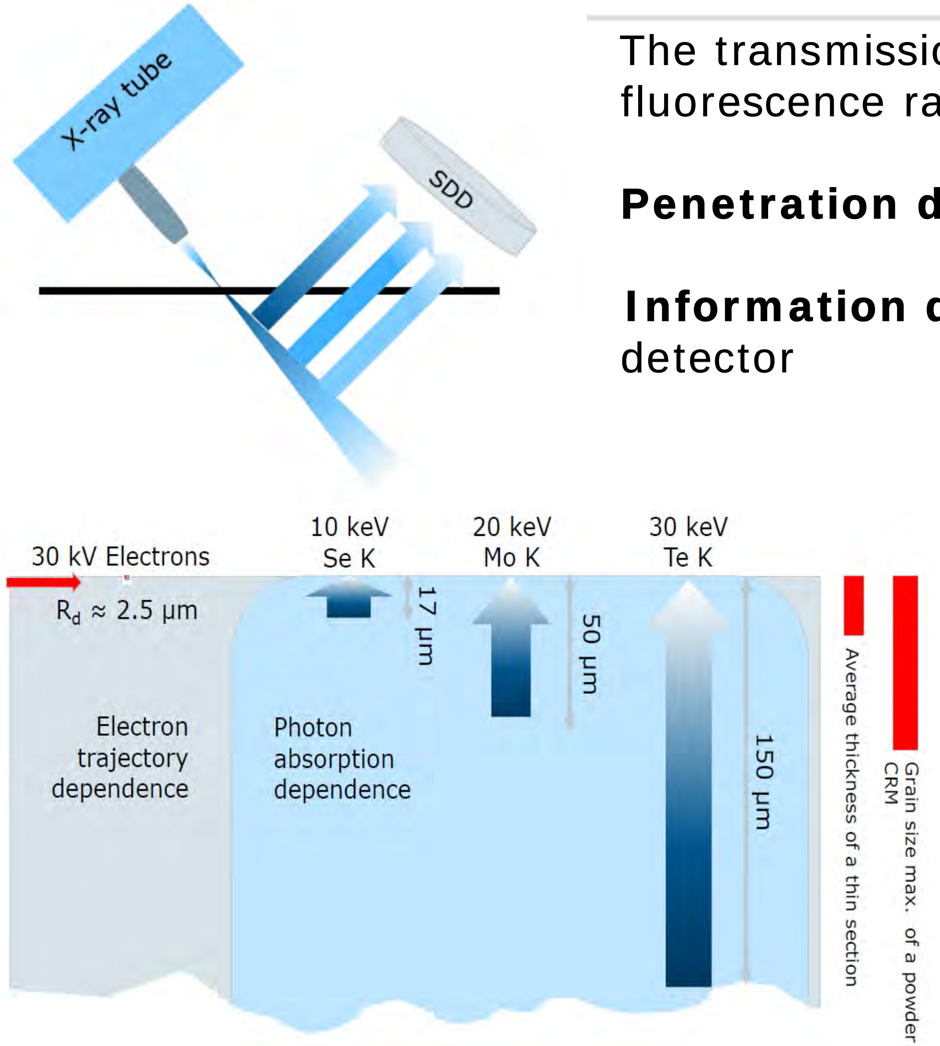
SEM-WDS: Analysis based on the sample interaction with an electron beam source from the SEM and the resultant X-rays that are detected using a WDS (sequential element detection)

SEM-XRF-EDS: Micro-XRF on SEM (XTrace): Analysis based on the sample interaction with an X-ray beam source from the Micro XRF attached to the SEM and the resultant X-rays that are detected using an EDS (simultaneous element detection)

Exiting with electrons



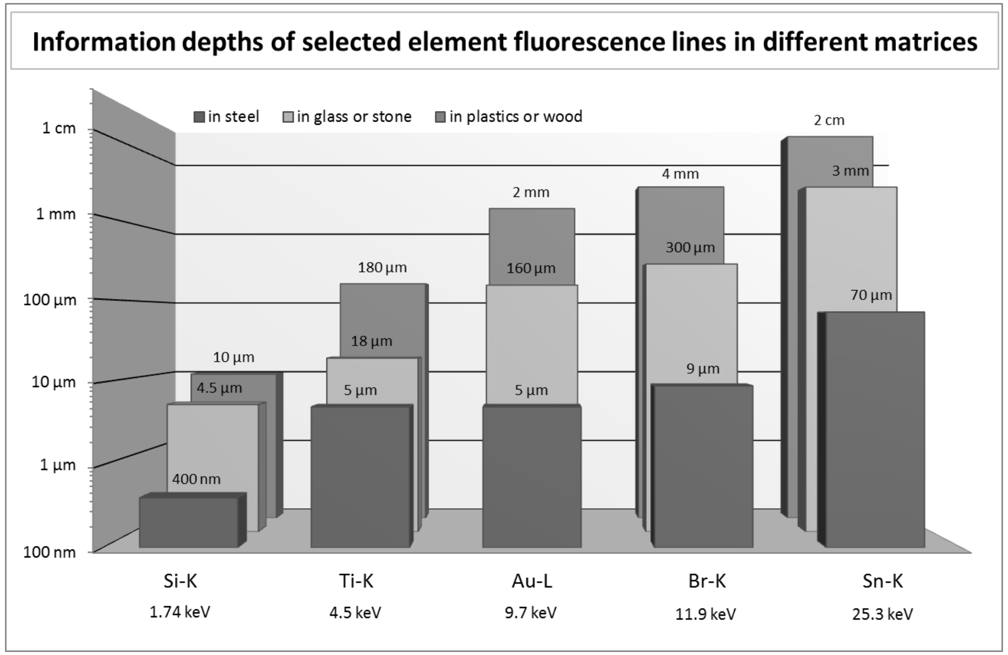
Spatial Resolution and Analyzed Volume:
Transmission and Attenuation



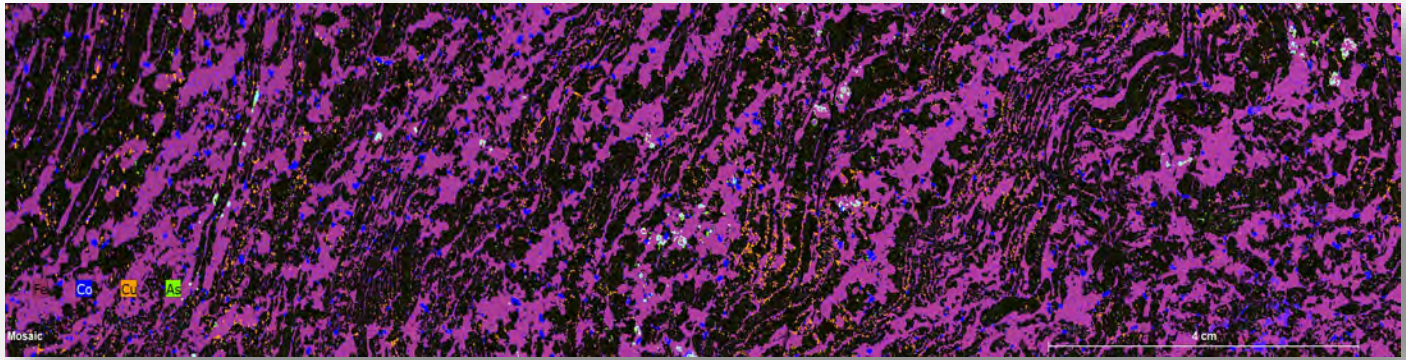
The transmission of X-rays is important for excitation of samples as well as for the fluorescence radiation.

Penetration depth: the depth that can still be excited

Information depth: the depth from which fluorescence X-rays can still reach the detector

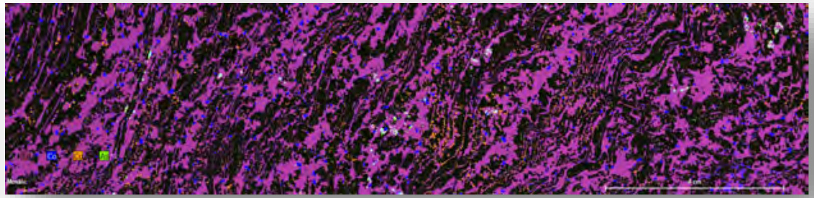


In-situ non-destructive Micro-XRF analysis:
Analytical Conditions



50 micron pixel scan

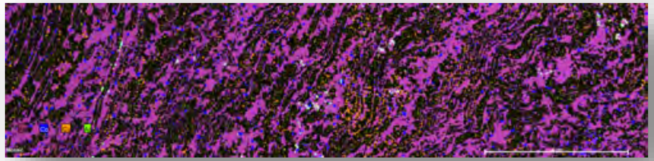
Less than 9 hours
total measurement
time



100 micron pixel scan

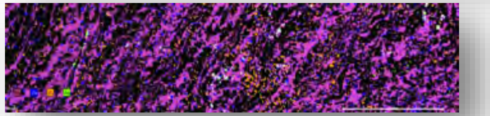
Less than 3 hours total measurement time

Demonstration of variable resolution



200 micron pixel scan

Less than 1 hour total measurement
time



500 micron pixel scan

Less than 1 hour total measurement
time

- Linnaeite
- Pyrrhotite
- Silicates
- Chalcopyrite

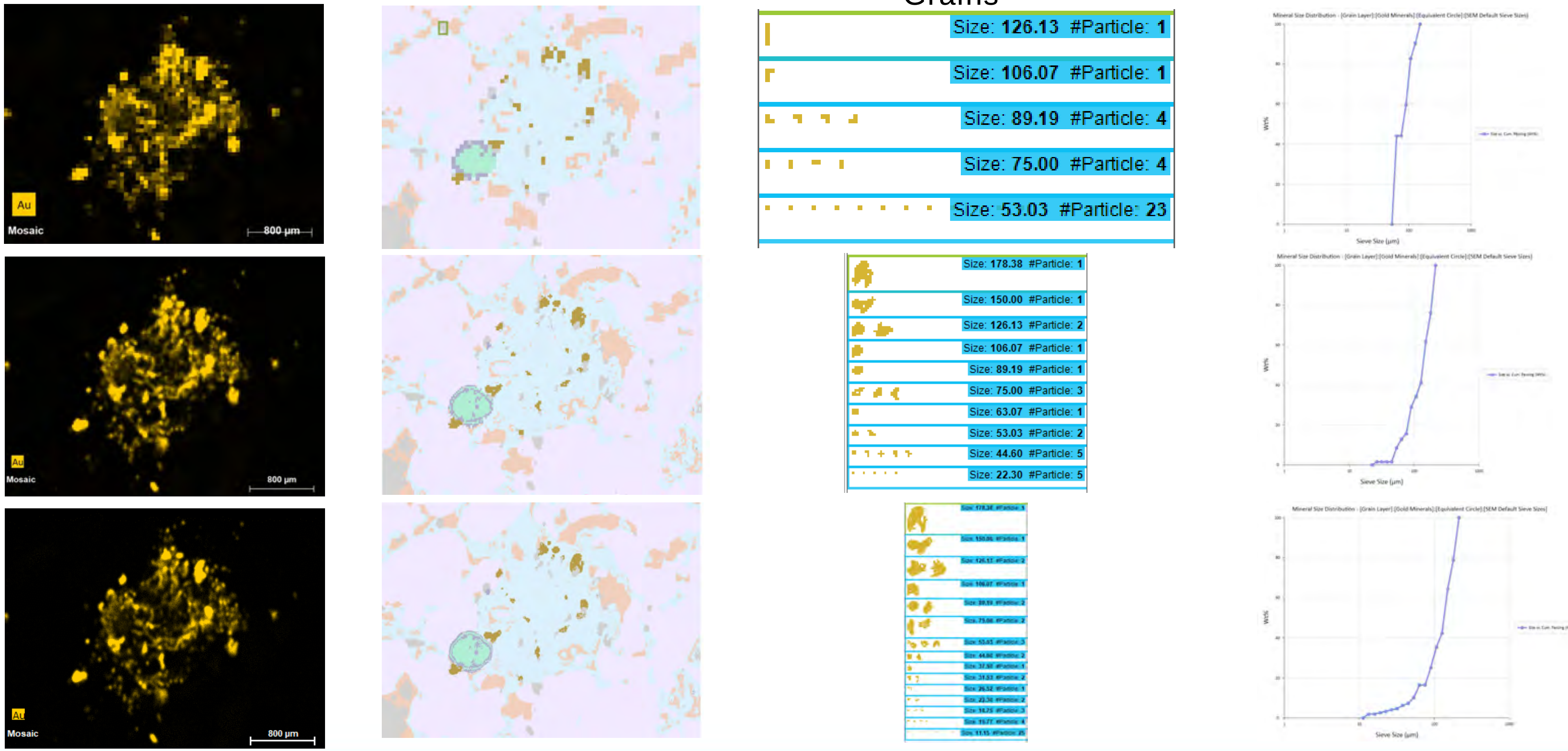
In-situ non-destructive Micro-XRF analysis:
Analytical Conditions: Pixel Spacing

Element Map: Au | Mineralogy | Individual Gold Grains | Gold Grain Size Distribution

50 microns

20 microns

10 microns



Summary and Conclusions:
Analytical Benefits

Micro-XRF Benefits:

- Lower detection limits (down to 10 ppm)
- Detection of High Energy X-ray Lines (Full Spectrum Range up to 40 kV)
- Micrometer scale measurement over large area
- Ideal for Low kV or Beam Sensitive samples
- Minimal Sample Preparation Required, No charging effects
- Fast elemental X-ray mapping over large areas

SEM-EDS-WDS Benefits:

- Higher Beam Resolution
- Smaller sample interaction area
- Improved element resolution when using WDS

Summary and Conclusions:
Applications

- In many applications, e.g., geology and mining, the element or mineral of interest is a trace component. Thus, the ability to analytically identify them can be important but challenging.

- Combining micro-XRF and SEM analytical information (either as two sperate systems or as one combined system) greatly enhances the sample information, specifically in relation to sample size, analytical resolution, element detection, and sample preparation.

- Accordingly, the benefits of each system can be applied to relevant samples, improving analytical and project workflows.

- This includes both elemental and mineralogical information through the relevant software (ESPRIT, M4, or AMICS).

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Questions and Answers

Are There Any Questions?

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

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