Evaluating Greenfield and Brownfield Mining Exploration Projects using Micro-XRF

Entendimento e Avaliaco de Projetos de Exploraco Greenfield e Brownfield usando Micro-XRF

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And

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Presenters

Camila Torres

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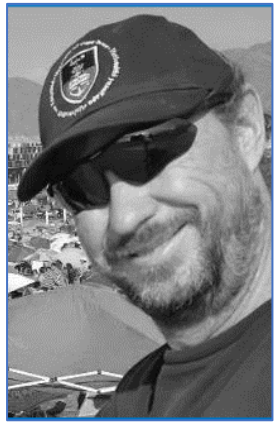

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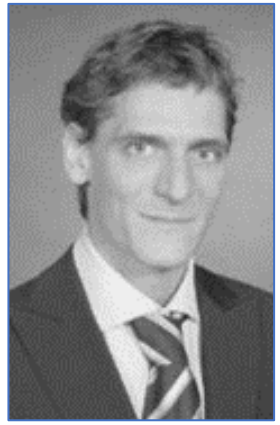

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Evaluating Greenfield and Brownfield Mining Exploration Projects using Micro-XRF

WEBINAR: Greenfield and Brownfield Mining Exploration Projects

Micro-XRF Imaging in Geological Sciences – Capabilities, Applications and Examples

Introduction

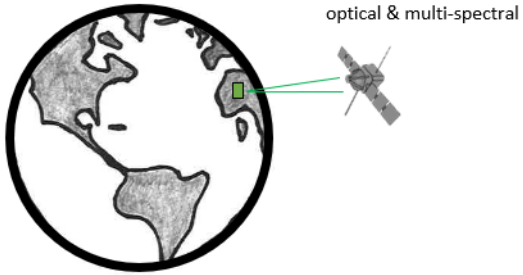
Overview:
Characterization Workflow of a multiscale approach

1 Mega 100's km

Space- & Airborne analysis

Land and sea

Rock, soil, vegetation, water

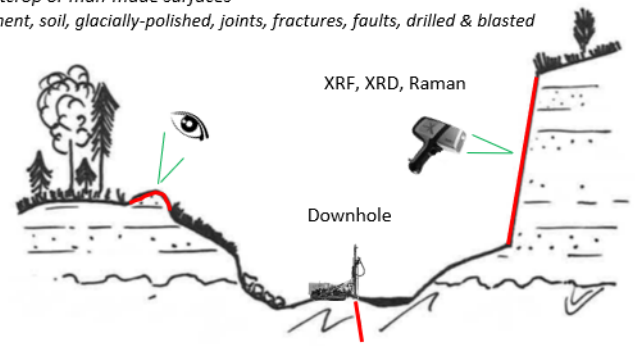


2 Macro km-metre

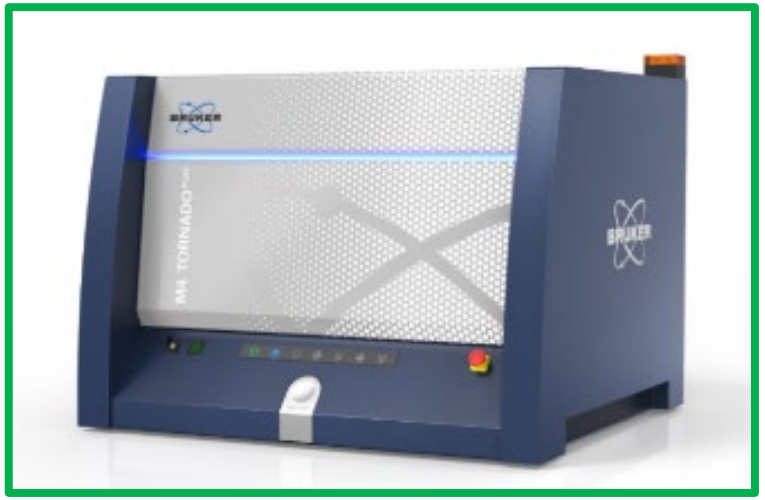
Field analysis

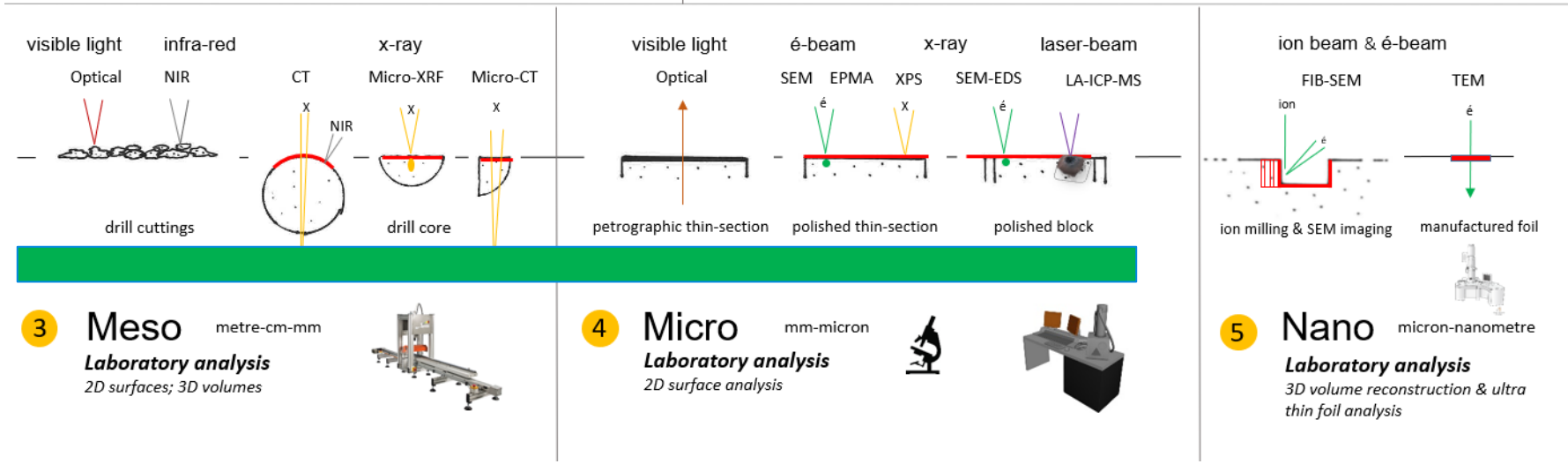
Natural outcrop or man-made surfaces

Rock, sediment, soil, glacially-polished, joints, fractures, faults, drilled & blasted



Micro-XRF **M4 TORNADO PLUS**





3 Meso metre-cm-mm

Laboratory analysis

2D surfaces; 3D volumes

4 Micro mm-micron

Laboratory analysis

2D surface analysis

5 Nano micron-nanometre

Laboratory analysis

3D volume reconstruction & ultra thin foil analysis

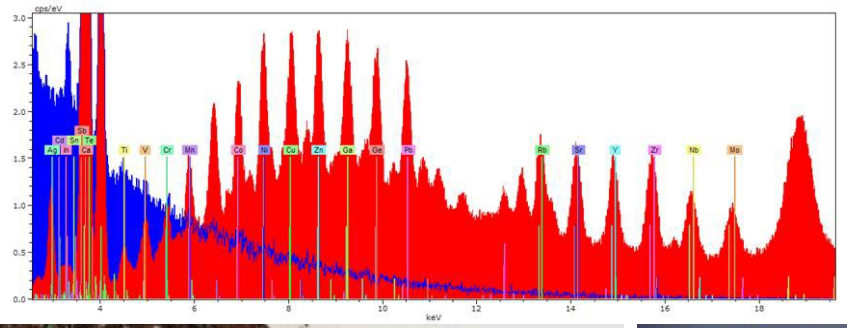
Micro-XRF **M6 JETSTREAM**

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.

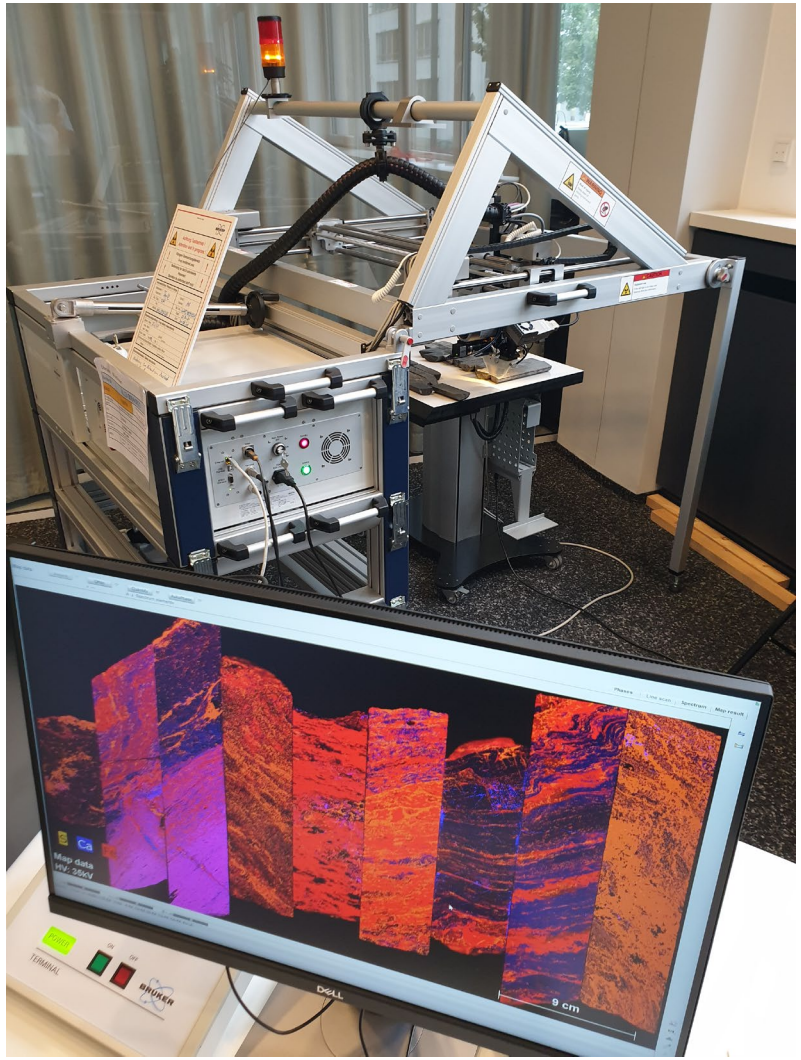
Micro-XRF Analysis: Introduction

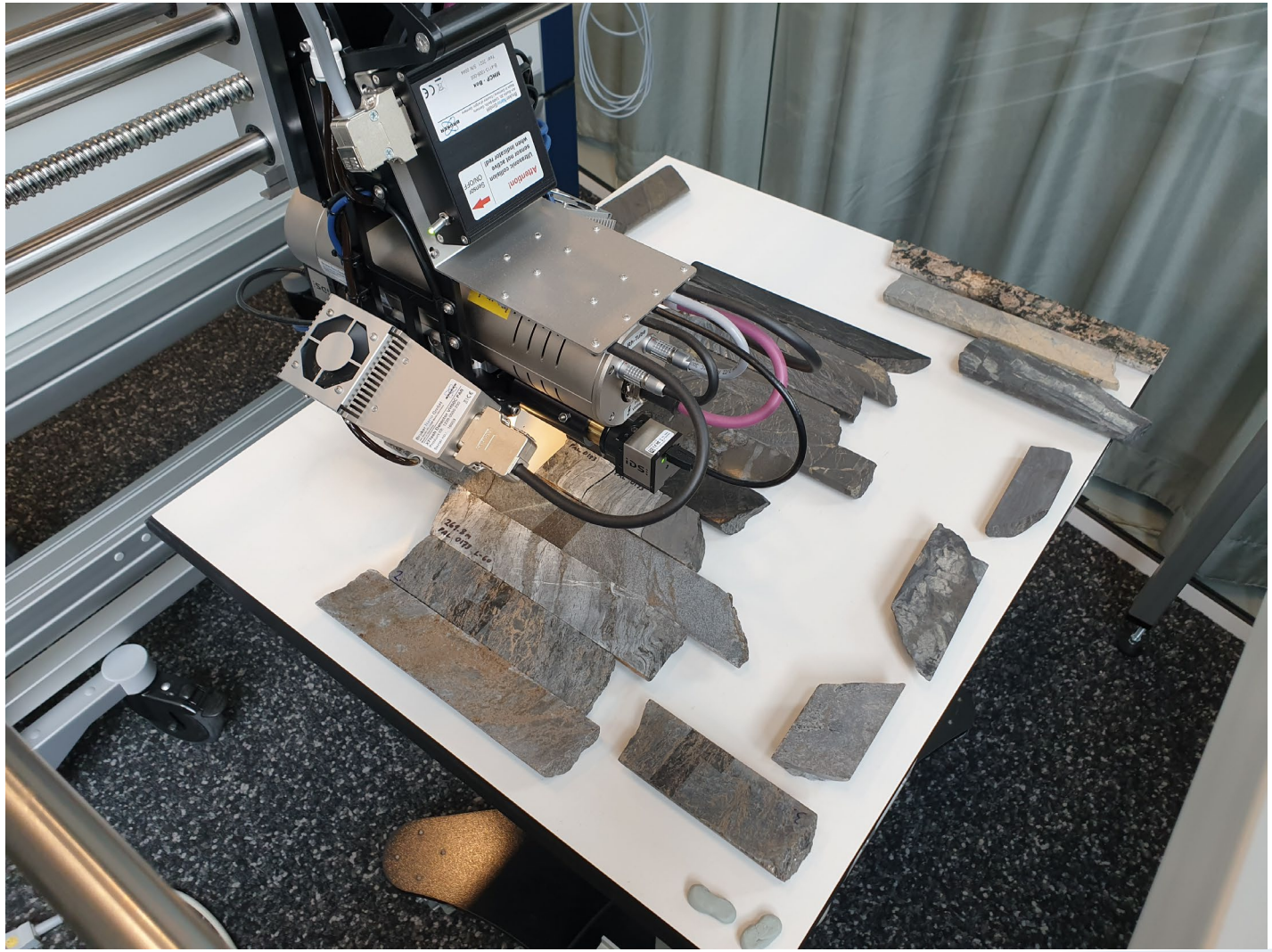
Micro-XRF is used across a wide variety of applications, including geological sciences. Its advantages are due to the minimal sample preparation required, the ability to analyze large samples at a micro scale, as well as quick and non-destructive data acquisition, including down to the trace element level.

- Little to no sample preparation
- Non-destructive
- Elemental information (Major and Trace elements)
- Small spot analysis
- Information from within the sample
- Meso-scale samples : Micro-scale information
- Quantification (down to ppm levels)
- Mineralogy / Automated Mineralogy



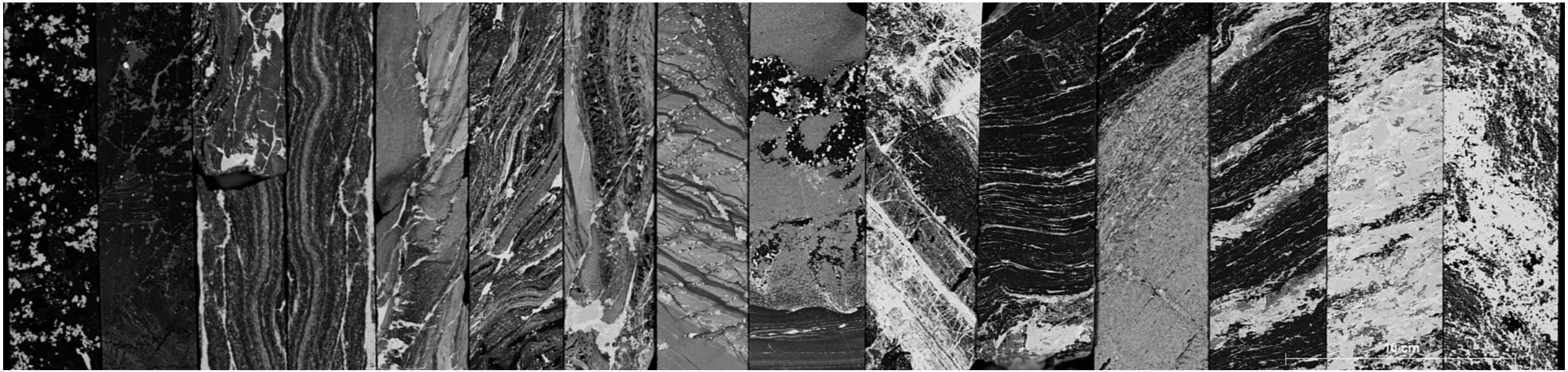
Examples:
Micro-XRF M6 JETSTREAM





Micro Information on the Macro Scale: Analysis of 15x Drill Cores

The single image below is comprised of 15 drill-cores from various localities around Finland.
Samples measured by M6 JETSTREAM

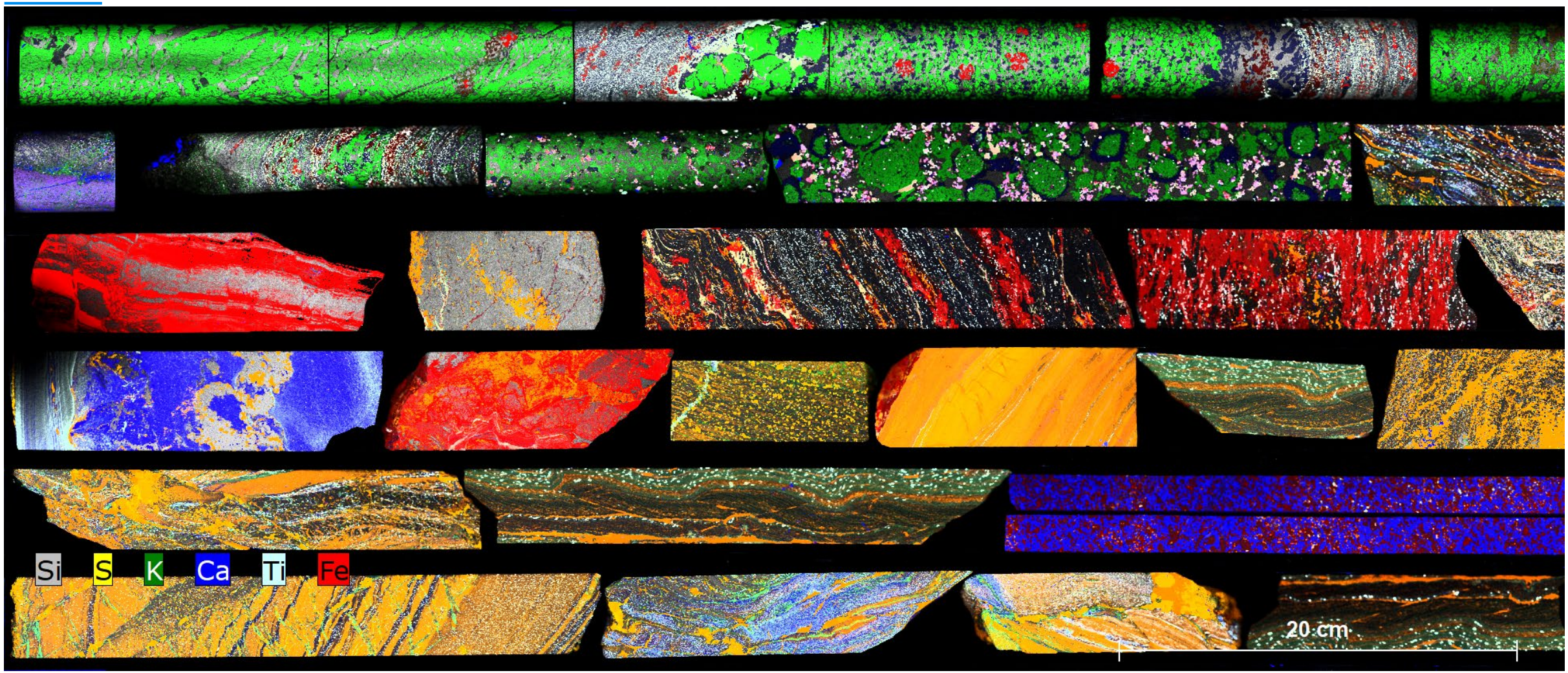


Black and White Image:
Total X-ray Intensity

Total Width 70cm

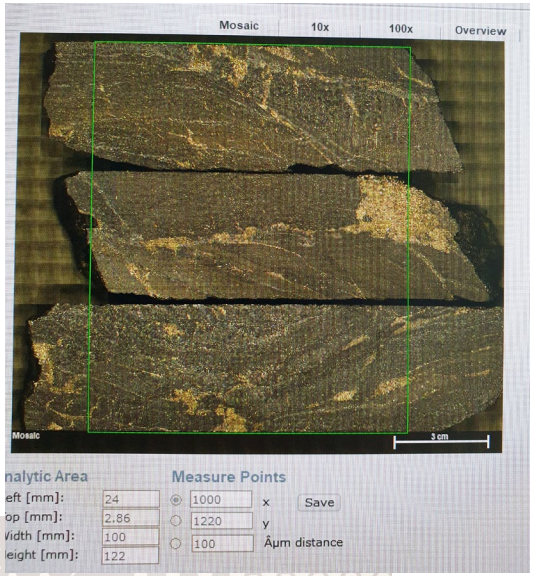
Color Image:
Multi-element Intensity Map

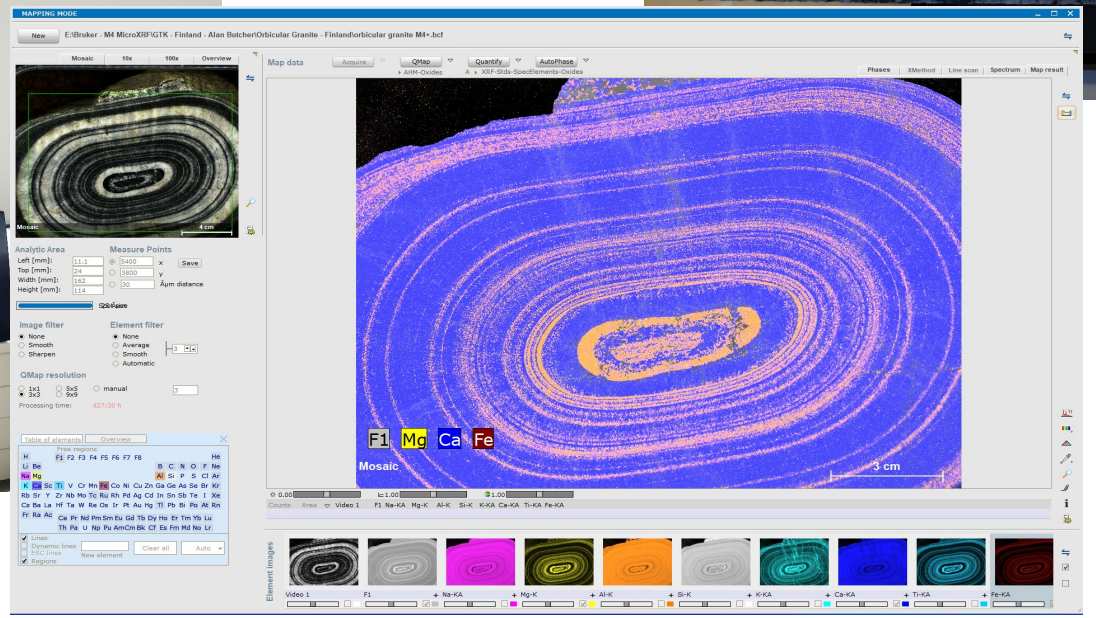
Examples:
Micro-XRF M6 JETSTREAM: Drill Core



Half Core vs Cylindrical Core

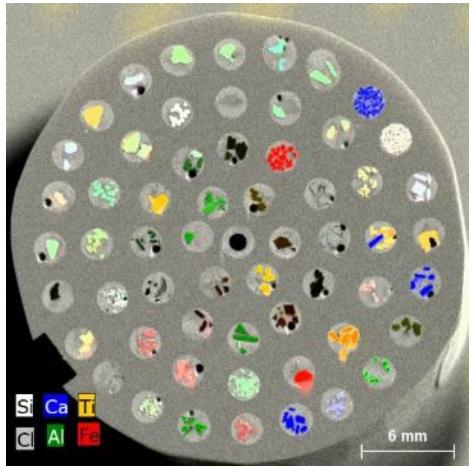
Examples:
Micro-XRF M4 TORNADO PLUS



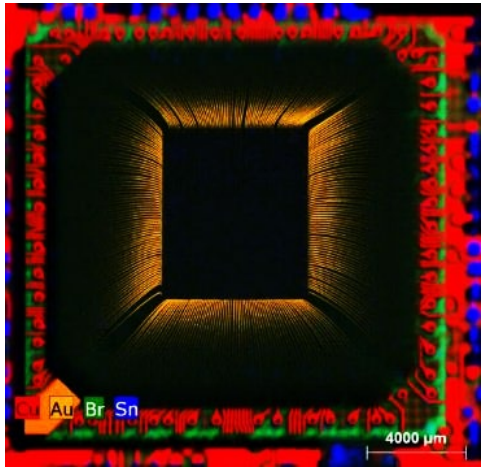


Overview:
Micro-XRF as an analytical technique

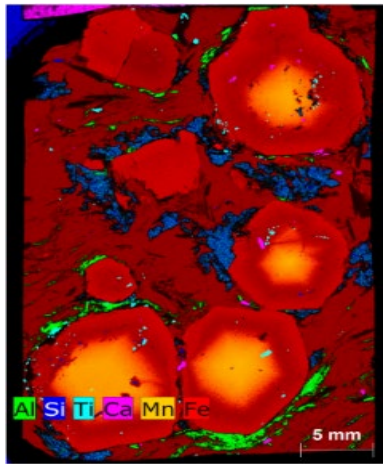
Main analytical advantages of micro-XRF



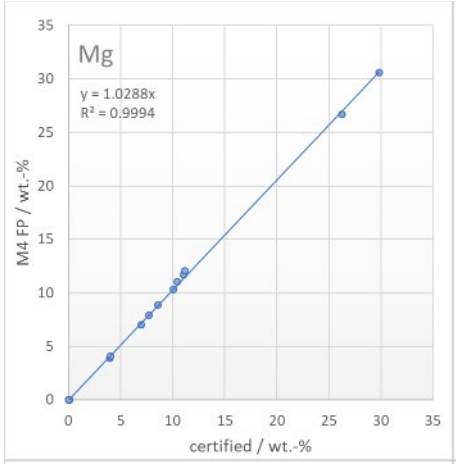
No sample preparation



Information from the depth of the sample



Trace element sensitive

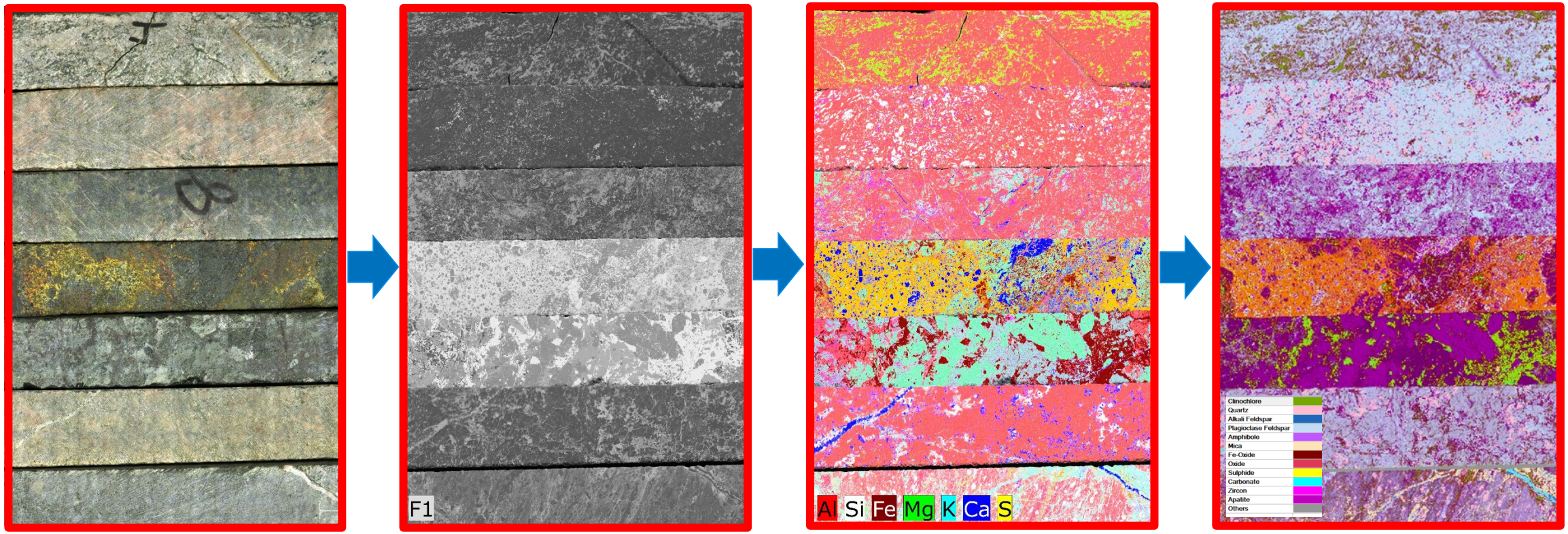


Reference samples free and standard supported quantification options

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

Analysis of Drill Core Samples: Workflow

Example of the Samples (7x Drill Cores) as analyzed in the microXRF M4 TORNADO.



Optical Image

Total X-ray Intensity Map

Overlaid Element X-ray Map

Mineralogical Map AMICS

Vale Base Metals South Atlantic

Evaluating Greenfield and Brownfield Mining Exploration Projects using Micro-XRF

Speaker: Camila Torres

Geosciences Long Term Planning

Mine Planning and Technical Services Base Metals

Sample Selection Process

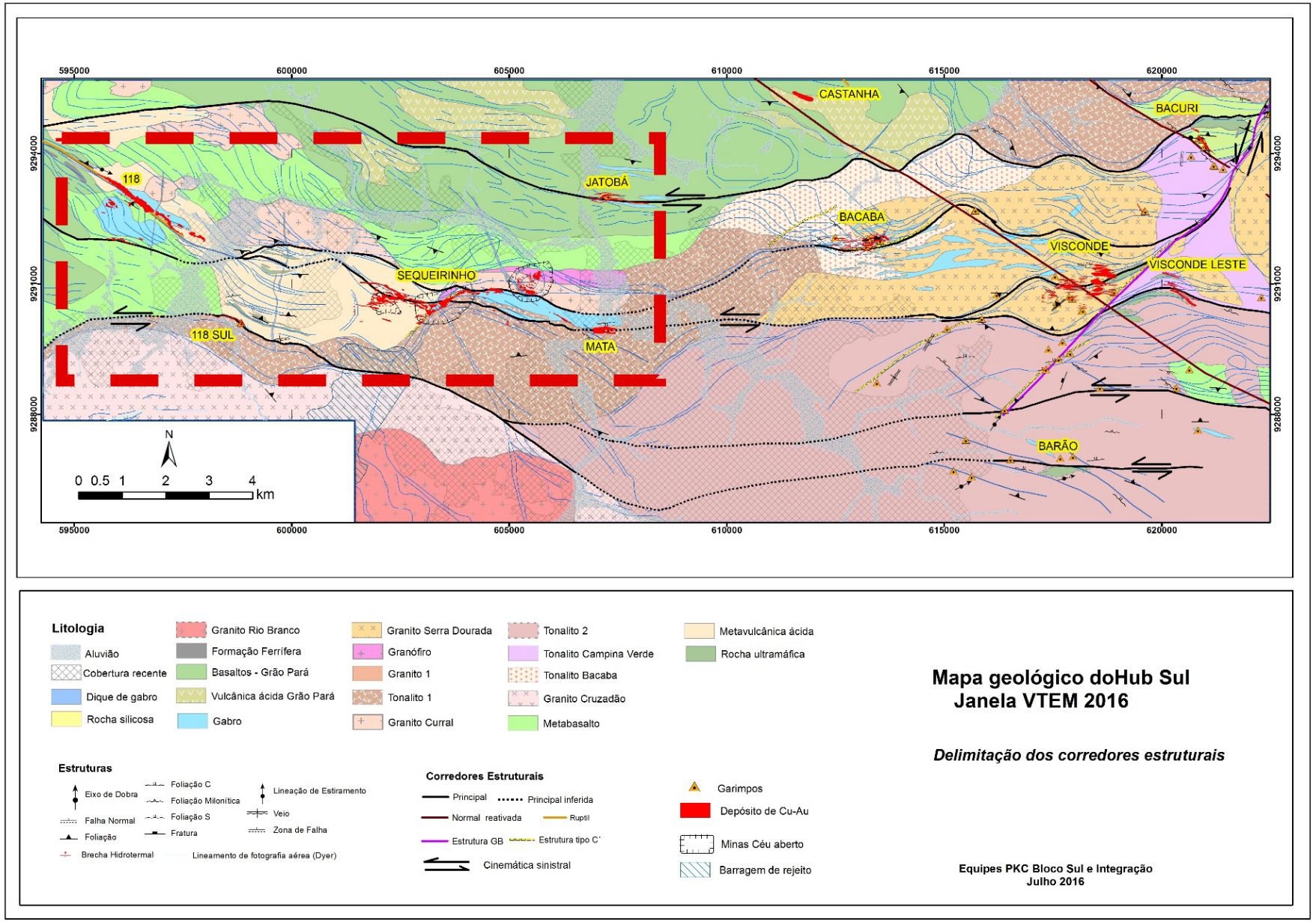
Type of samples to be analyzed: drill cores, pressed pallets, thick sections etc.;

Main target: spatial distribution for the mineralogical characterization (West Sossego as a whole deposit characterization, polygon characterization etc.;

Time for preliminary results: how long is needed for a robust data collection?

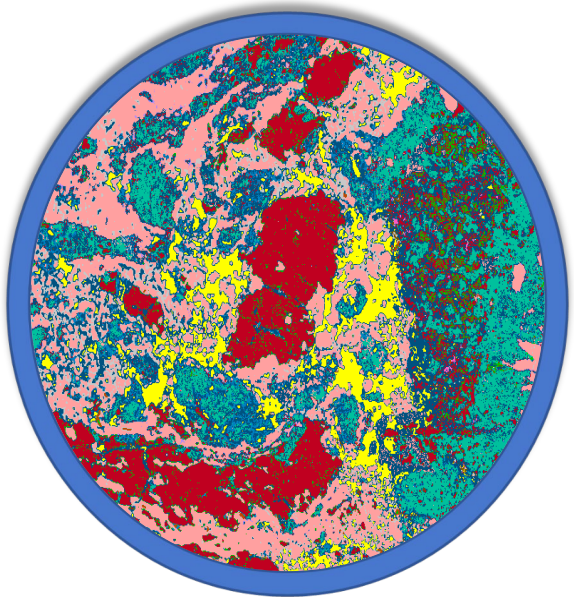
Sossego Complex

Sossego Complex Geology

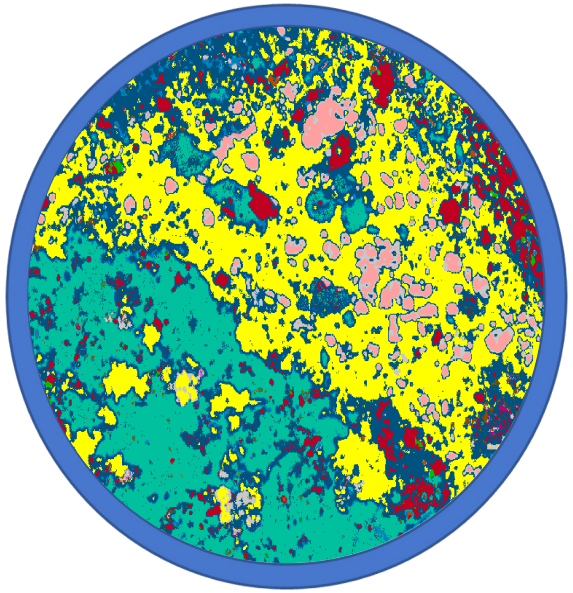


Sossego Complex Automated Mineralogy (AMICS)

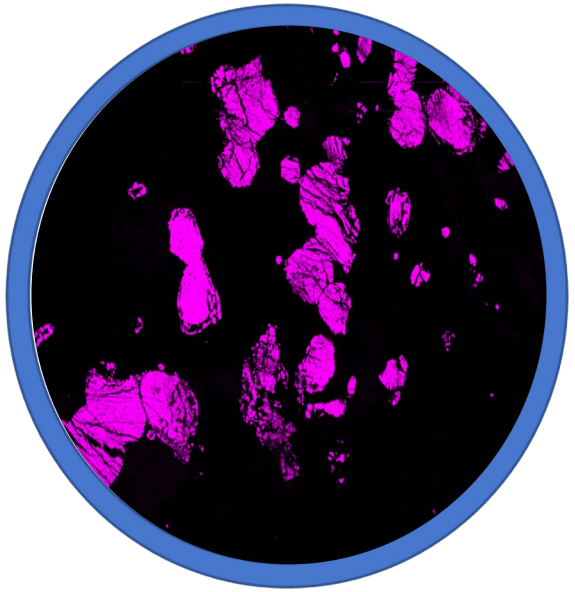
Mata



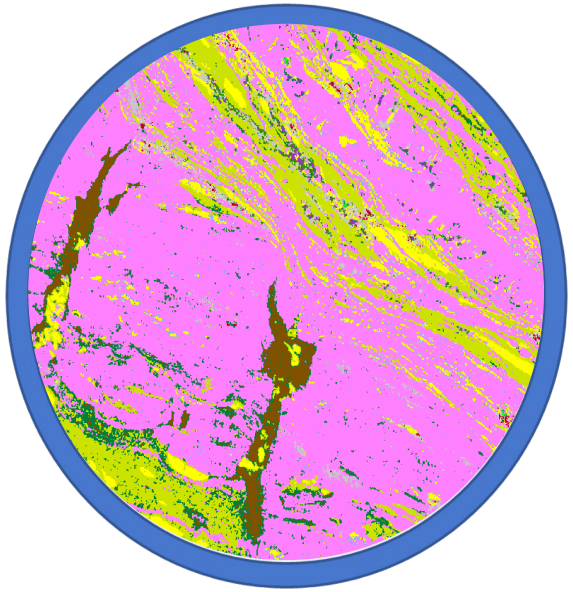
Sequeirinho



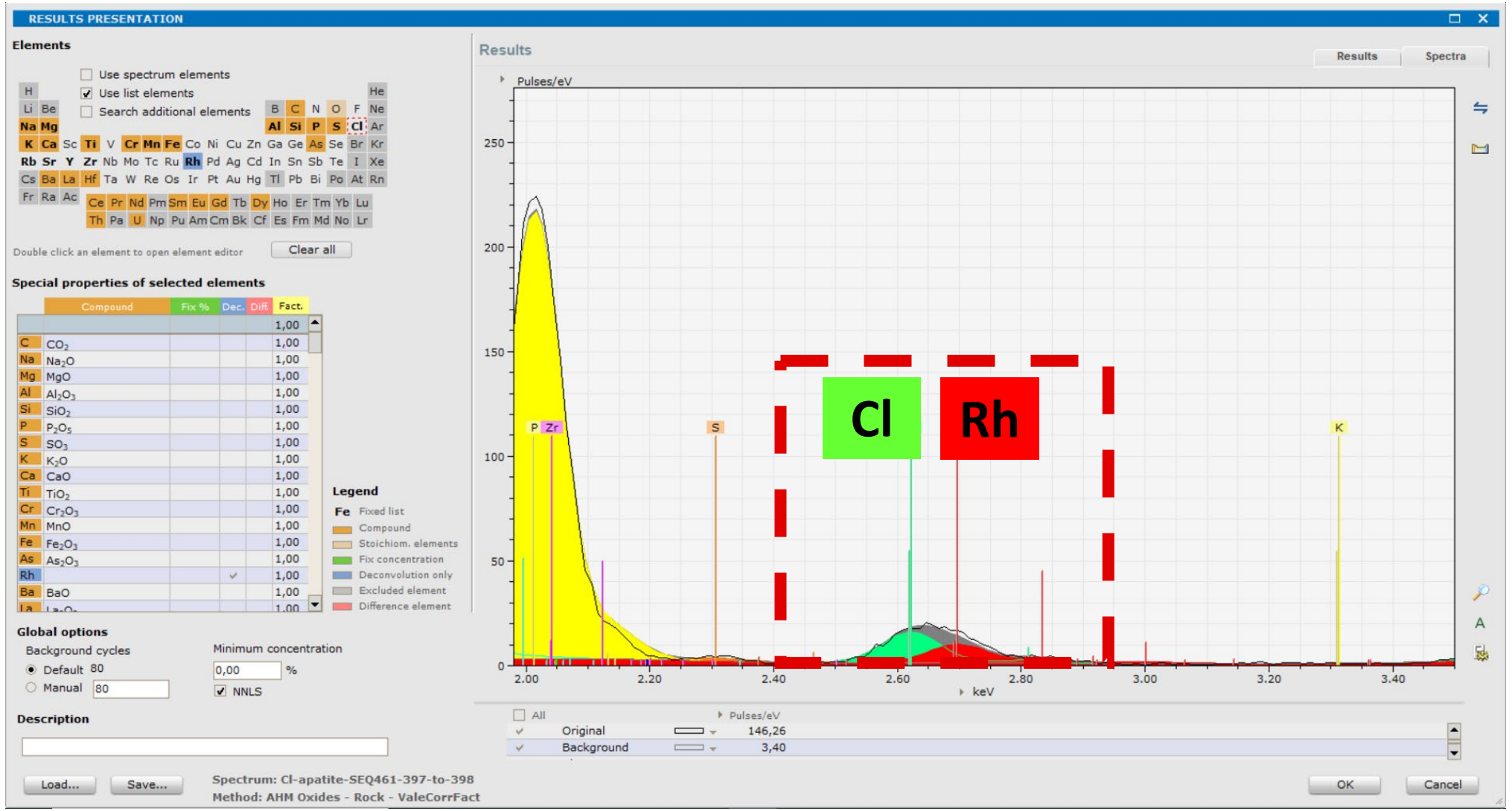
Sossego



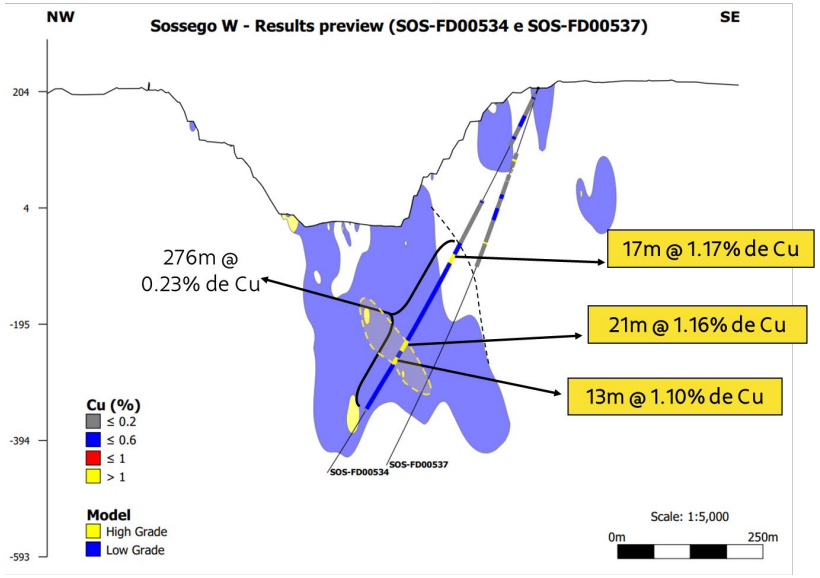
Pista

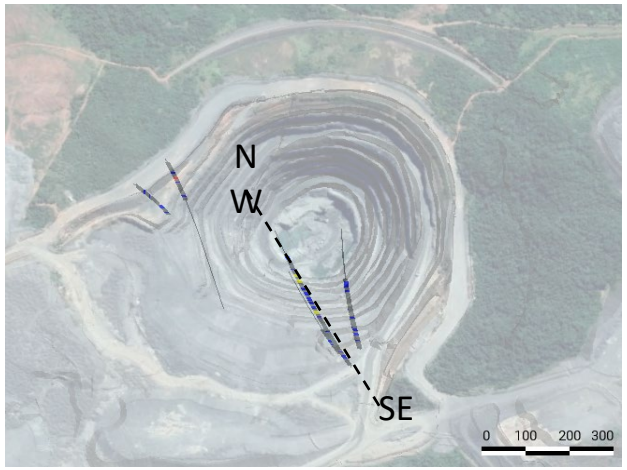


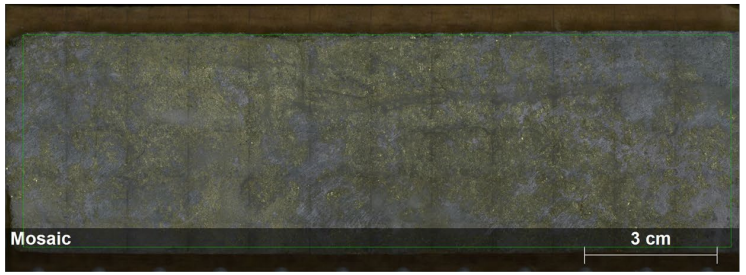
Sossego Complex Automated Mineralogy (AMICS): Penalty Elements

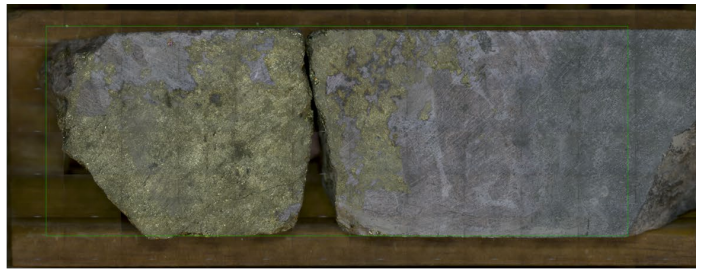


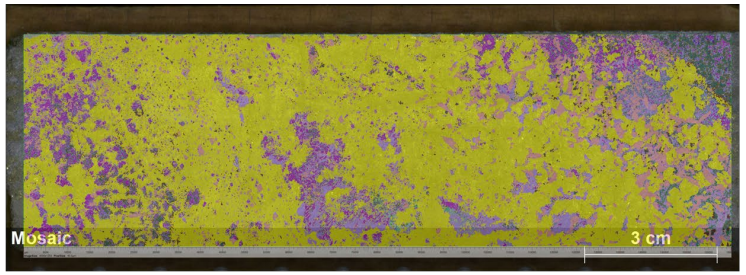
Sossego Complex Automated Mineralogy (AMICS): Penalty Elements

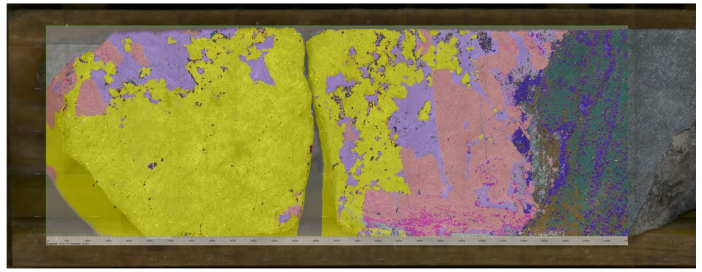


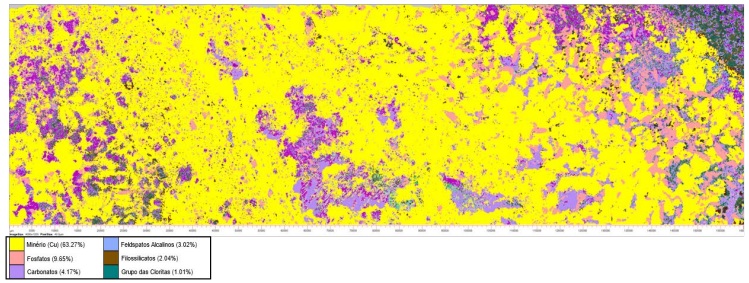


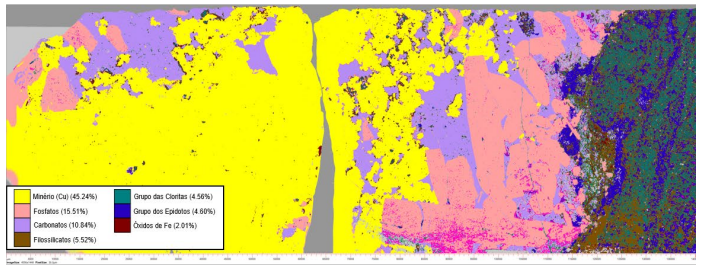




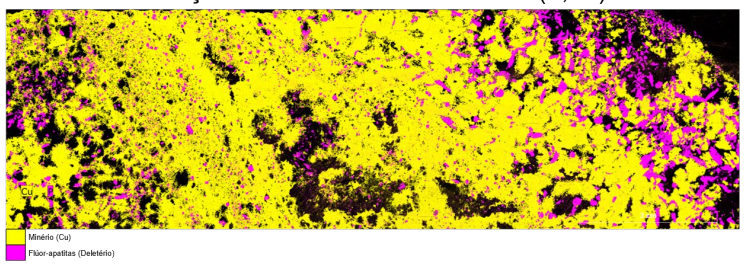




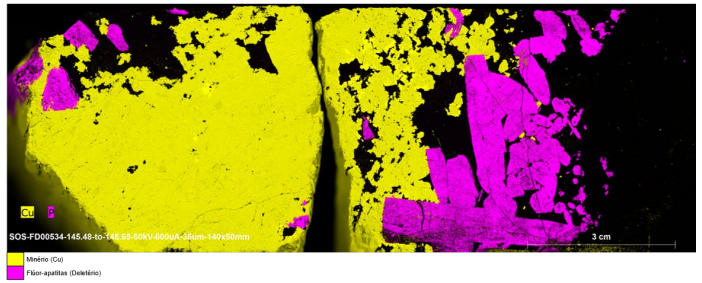




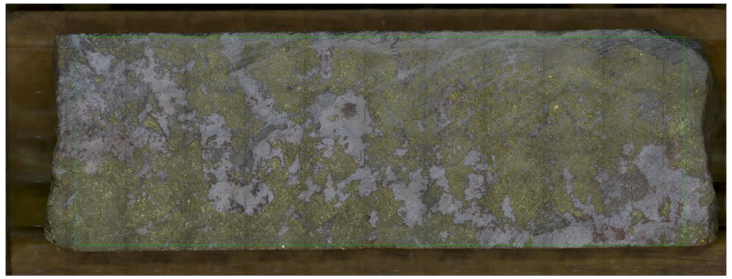
Relação textural: Cobre *vs* Fosfatos (F, Cl)

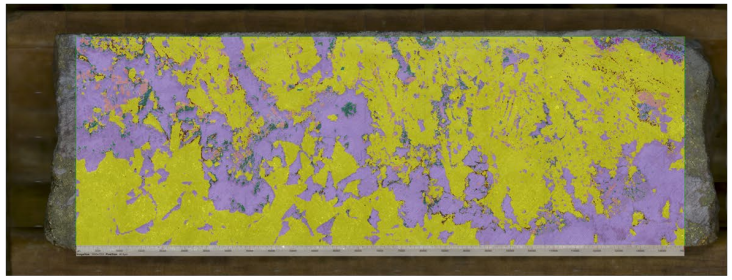


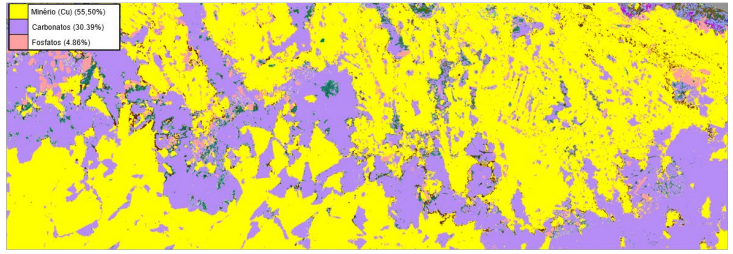
Relação textural: Cobre *vs* Fosfatos (F, Cl)

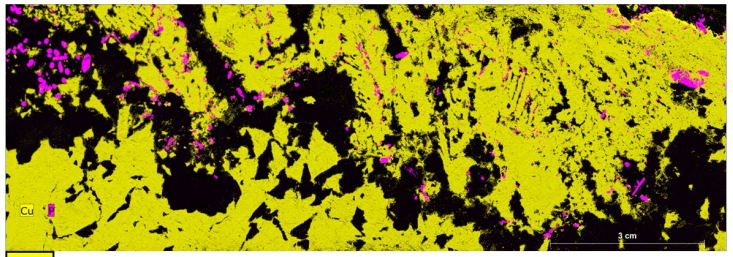


Sossego Complex Automated Mineralogy (AMICS): Penalty Elements





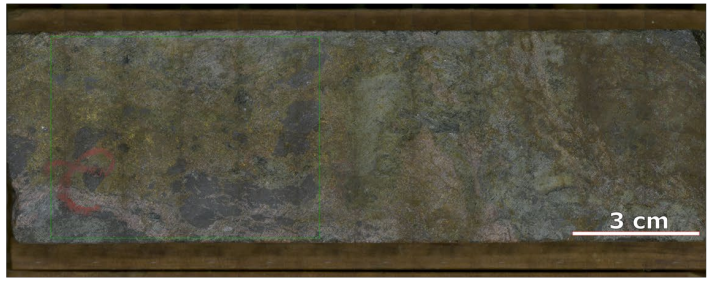


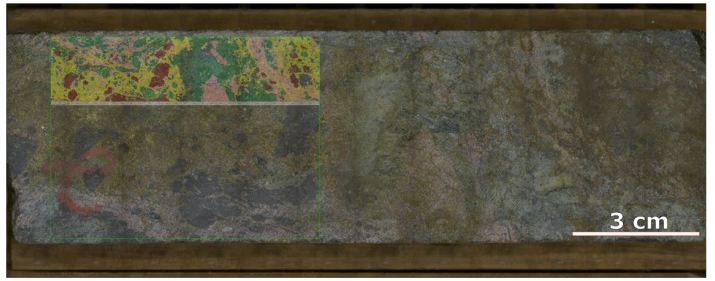


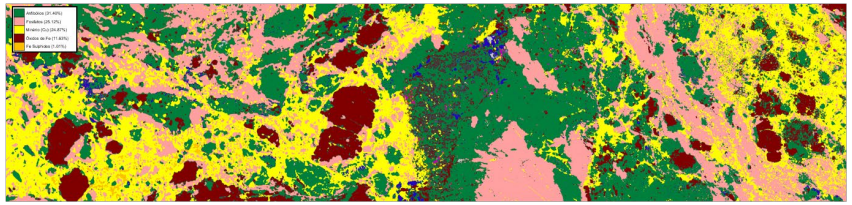
Minério (Cu)

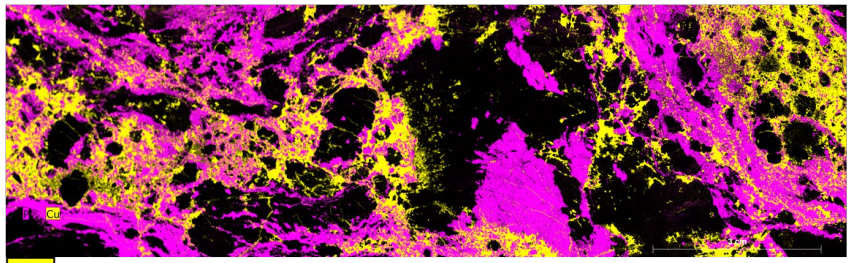
Flúor-apatitas (Deletério F, Cl)

SOSSEGO W





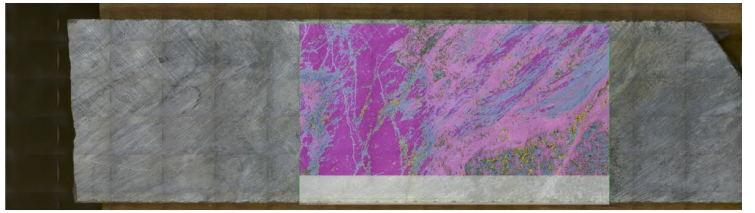


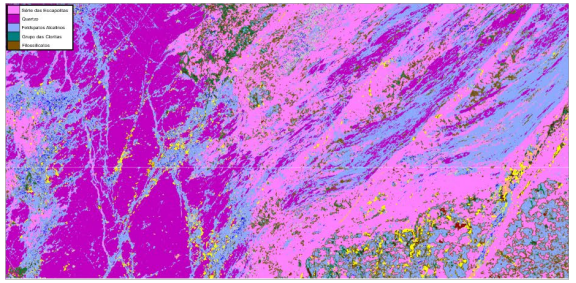


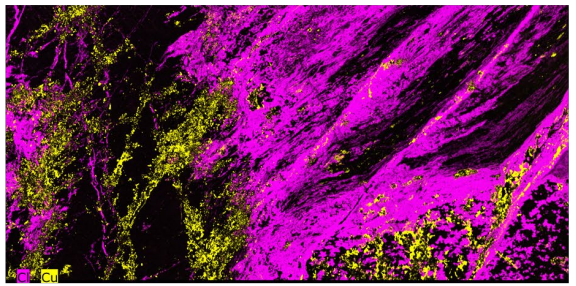
Minério (Cu)

Flúor-apatitas (Deletério F, Cl)

MATA







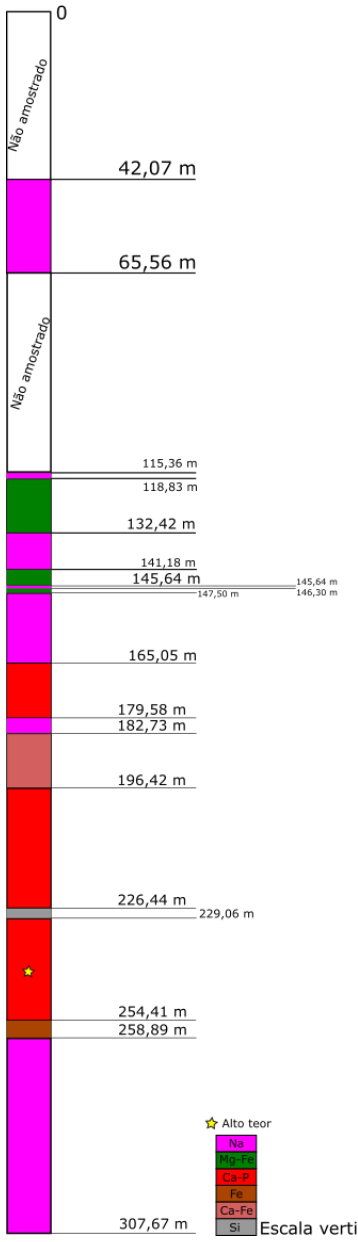
Minério (Cu)

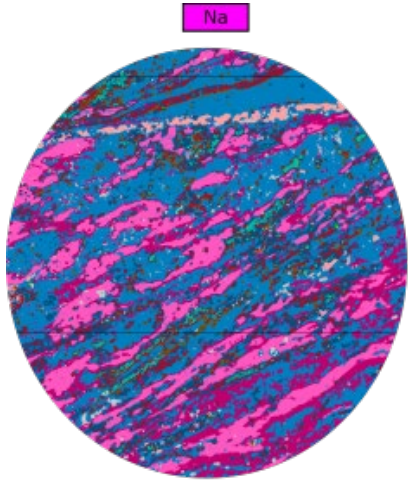
Escapolitas (Deletério Cl)

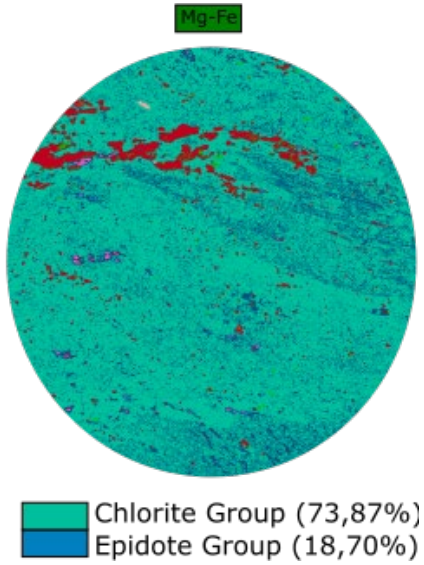
PISTA

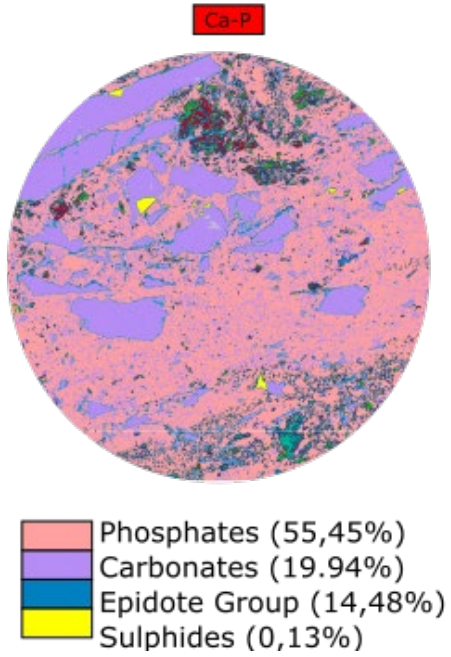
Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

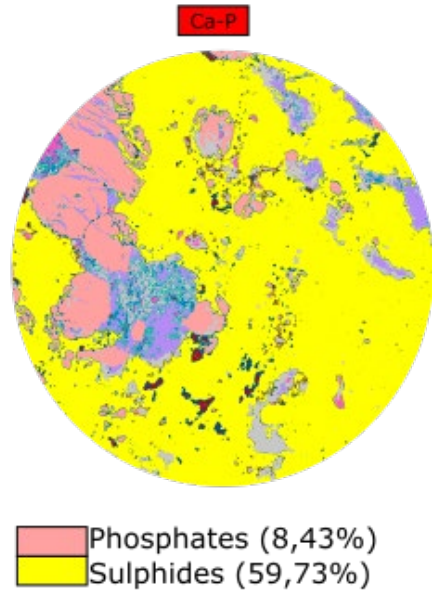
SOSD-496

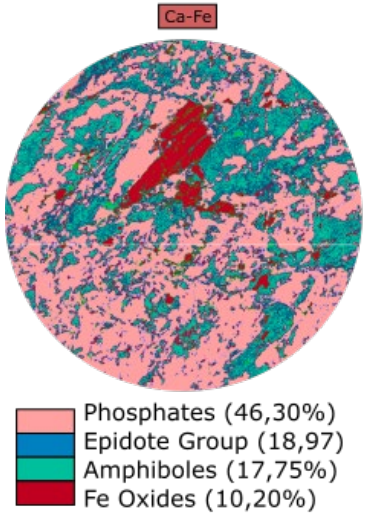


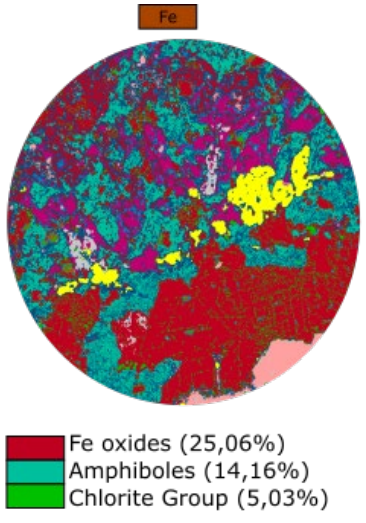






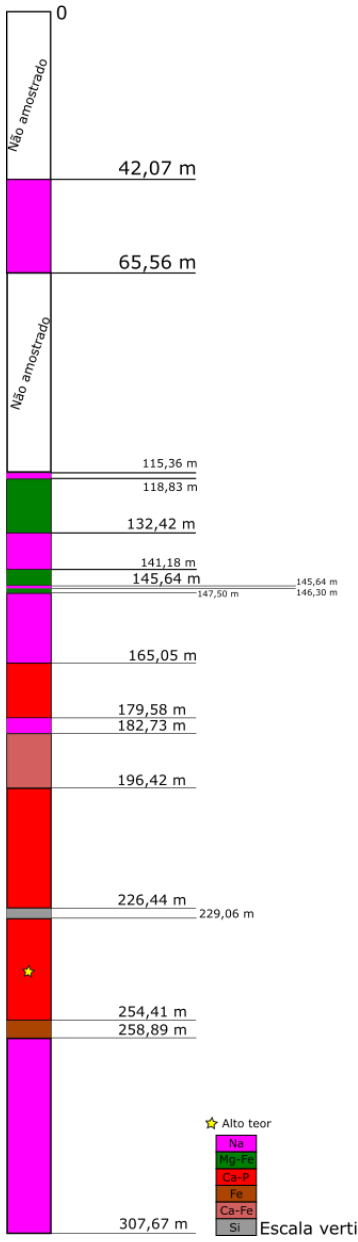


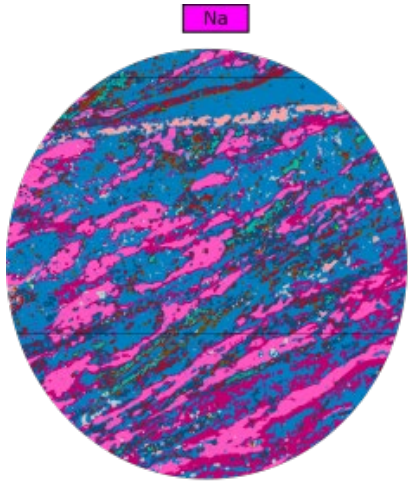


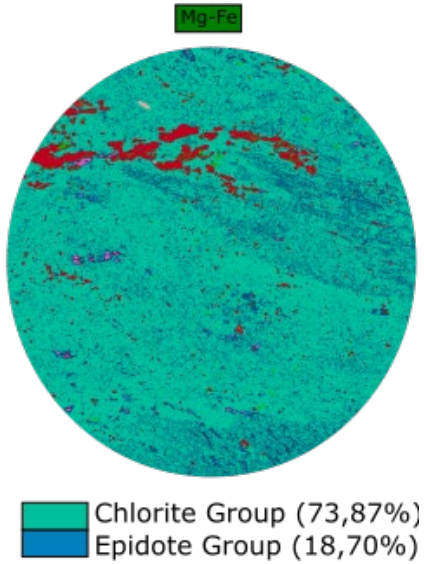


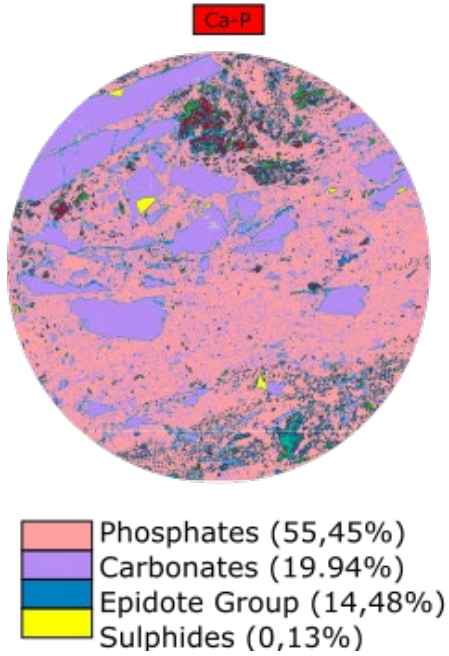
Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

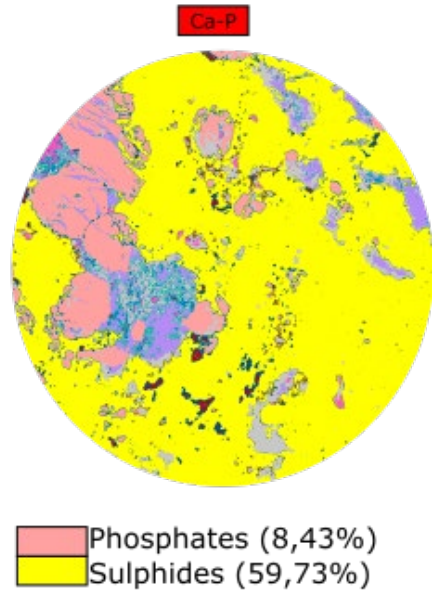
SOSD-496

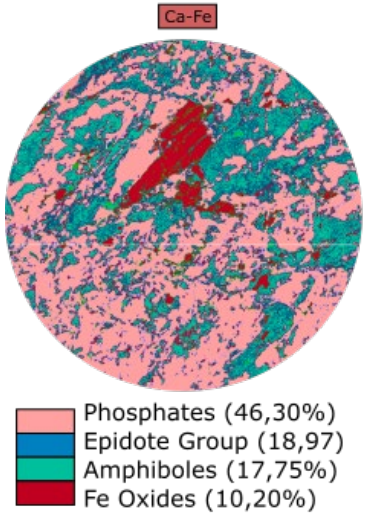


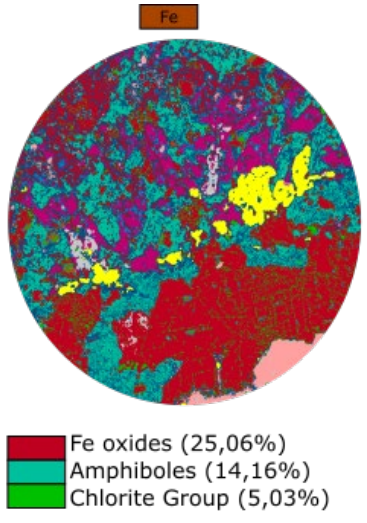


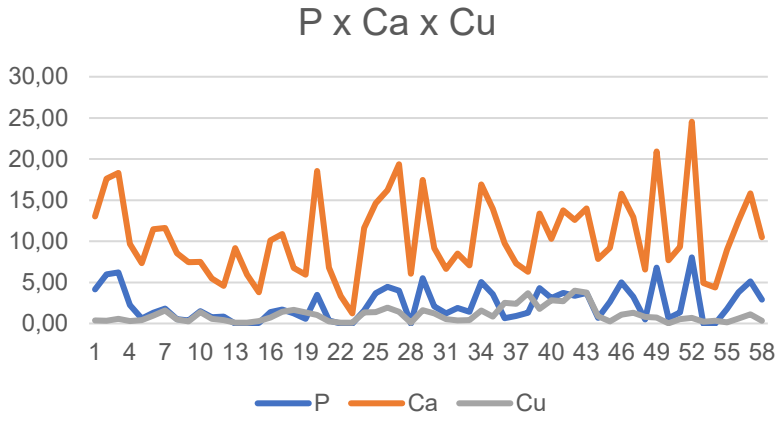




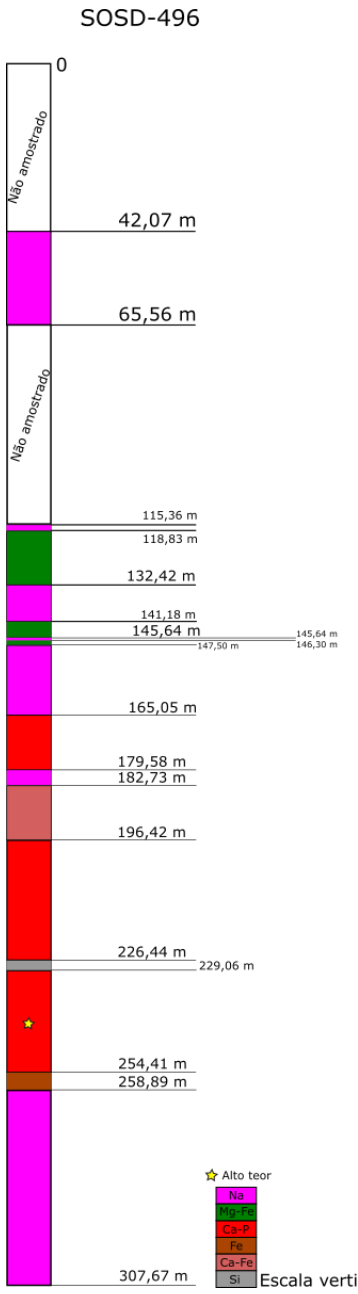


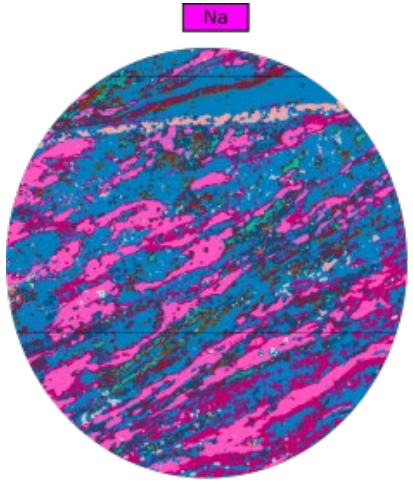


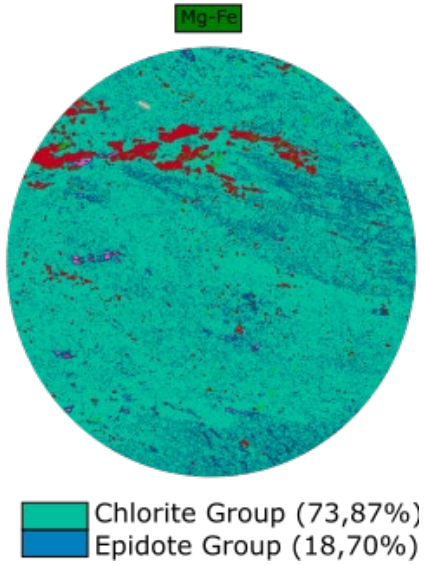


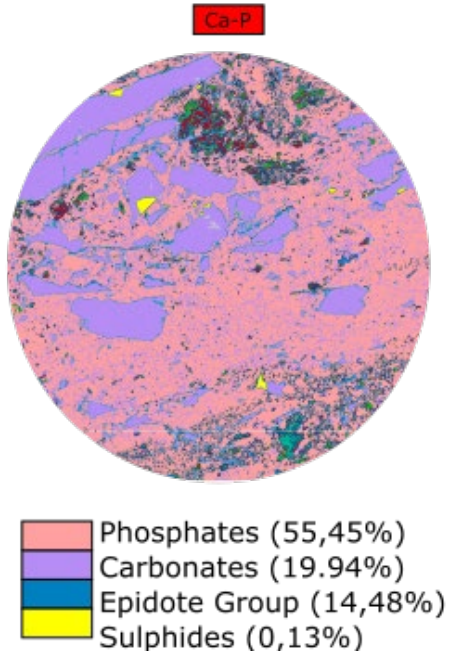


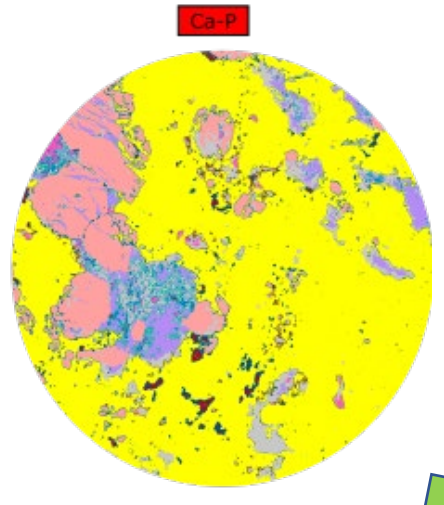
Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders

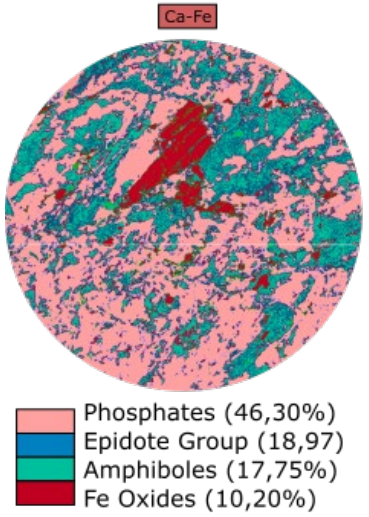


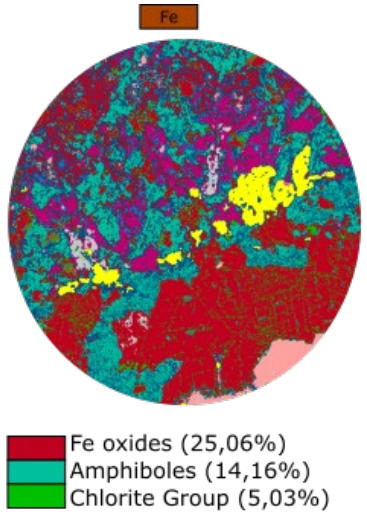




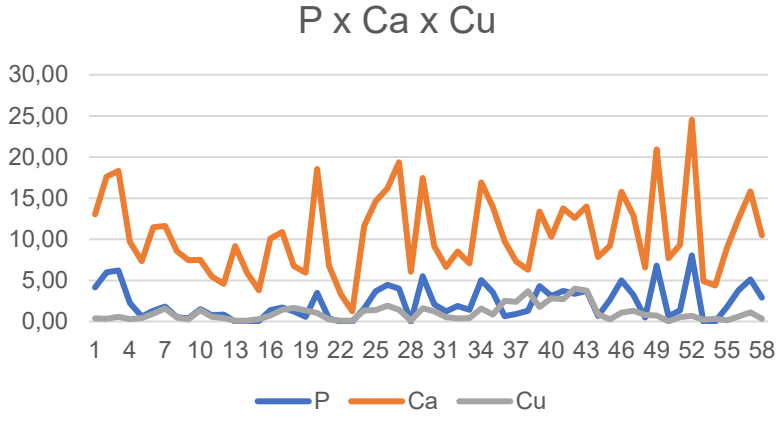




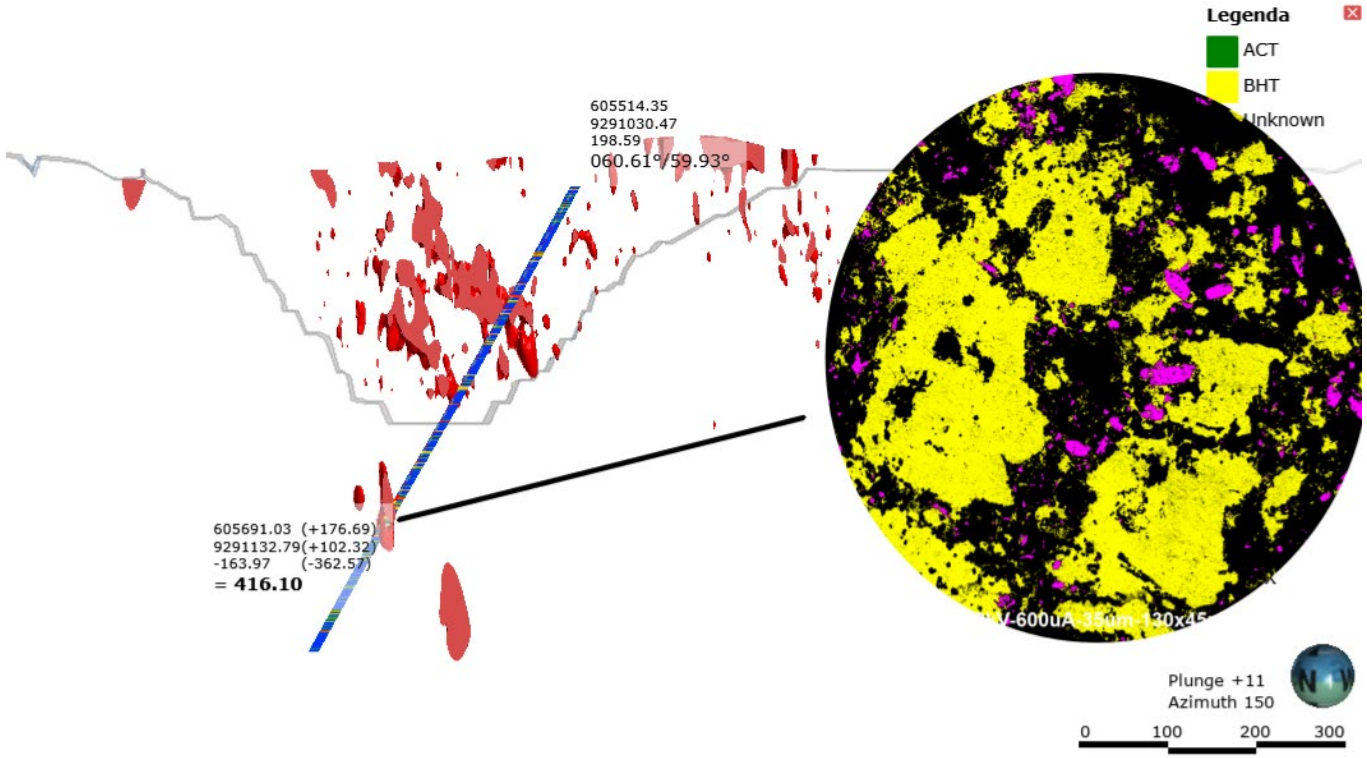


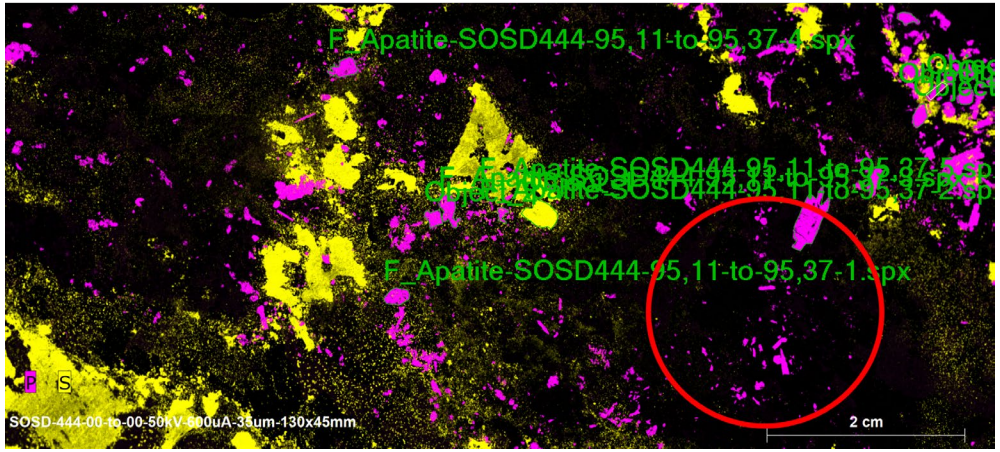


IOCG *PATHFINDERS*

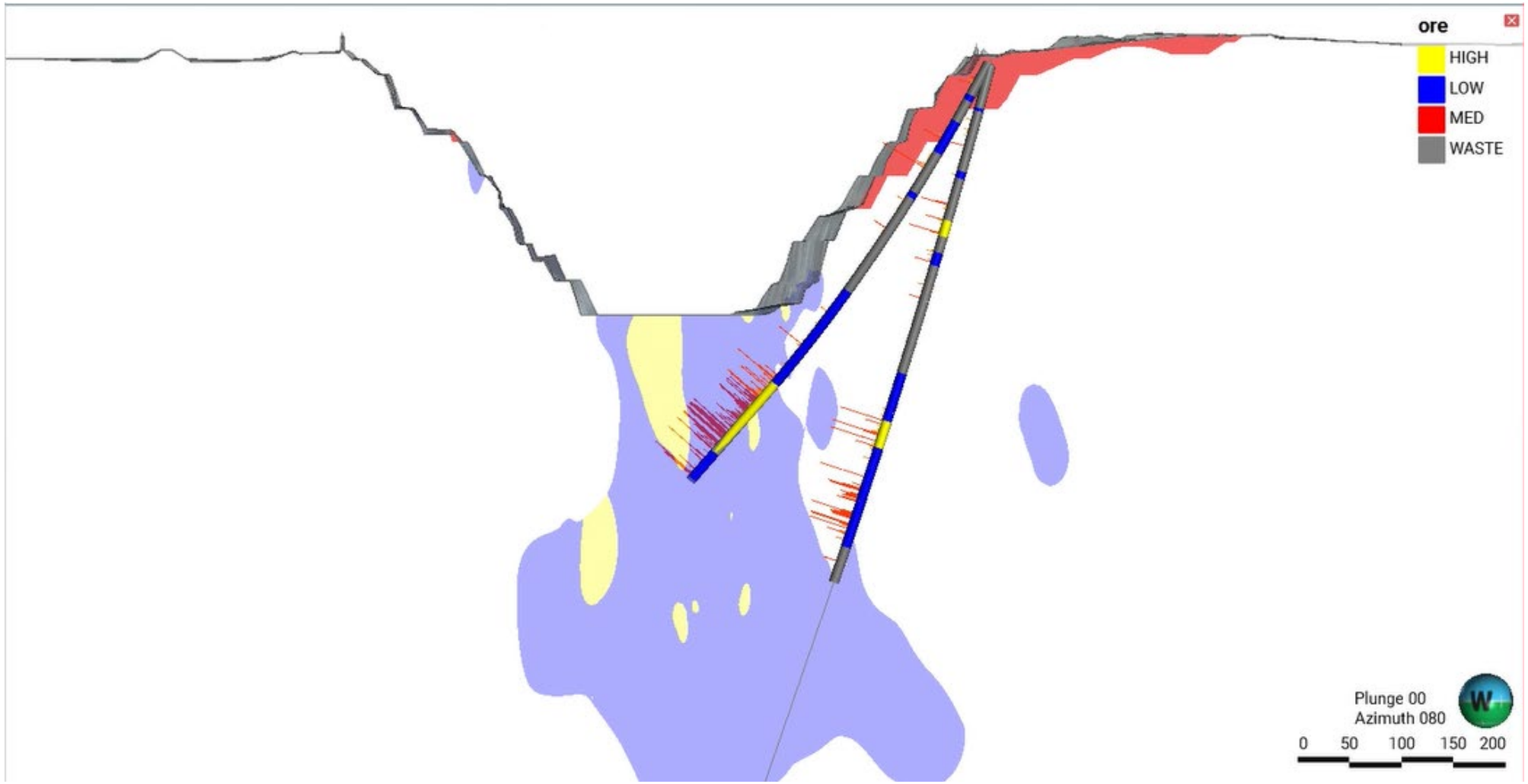


Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders





Sossego Complex Automated Mineralogy (AMICS): Copper pathfinders



Sossego Complex Automated Mineralogy (AMICS): Short Term Planning Interface

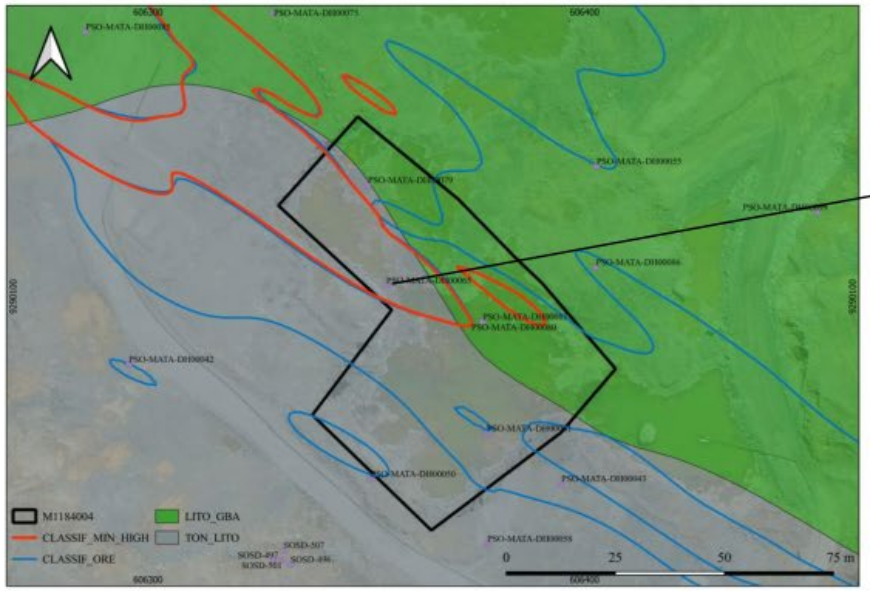
Classificação Mineralógica

M1_184_004
Polígono

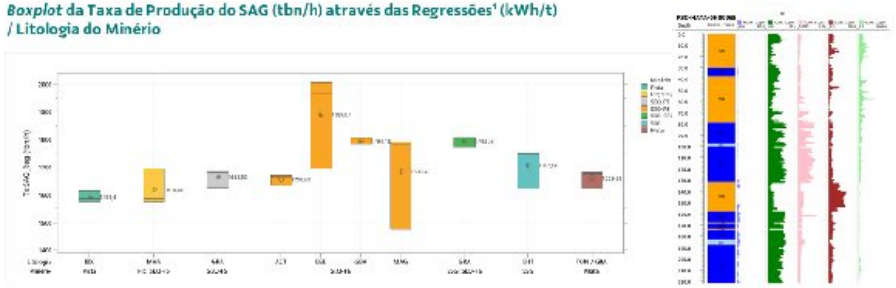
71872. Kt
Massa Prevista para compor o blend de alimentação da britagem.

0,875 Cu%
Teor Liberação

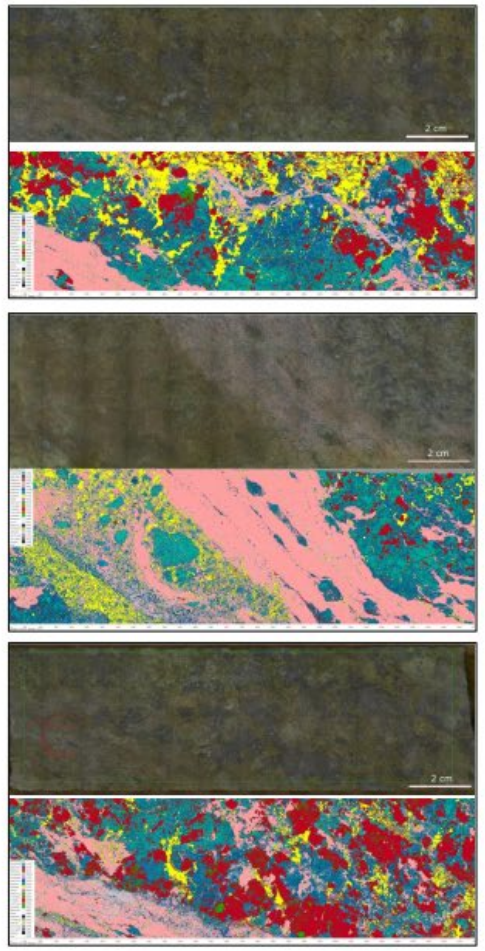
Tonalito hidrotermalizado (zona cálcico-fosfática). Brecha sulfetada (calcopirita e bornita) associada à mineralogia hidrotermal pervasiva rica em cálcio, ferro e fósforo (anfibólios cálcicos, magnetita, flúor-apatitas e cloro-apatitas).
Classificação Litológica



Boxplot da Taxa de Produção do SAG (tbn/h) através das Regressões¹ (kWh/t) / Litologia do Minério



Epidoto	Sulfetos	Anfibólio	Fosfatos
24.21%	16.36%	11.20%	11.20%



- Mineralogical paragenesis of sulphide-rich zones
- Semi-quantitative mineralogy
- Penalty elements mineralogy prediction

Sossego Complex Automated Mineralogy (AMICS): Short Term Planning Interface

M1_184_004
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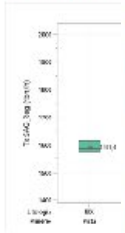
Classificação Litológica

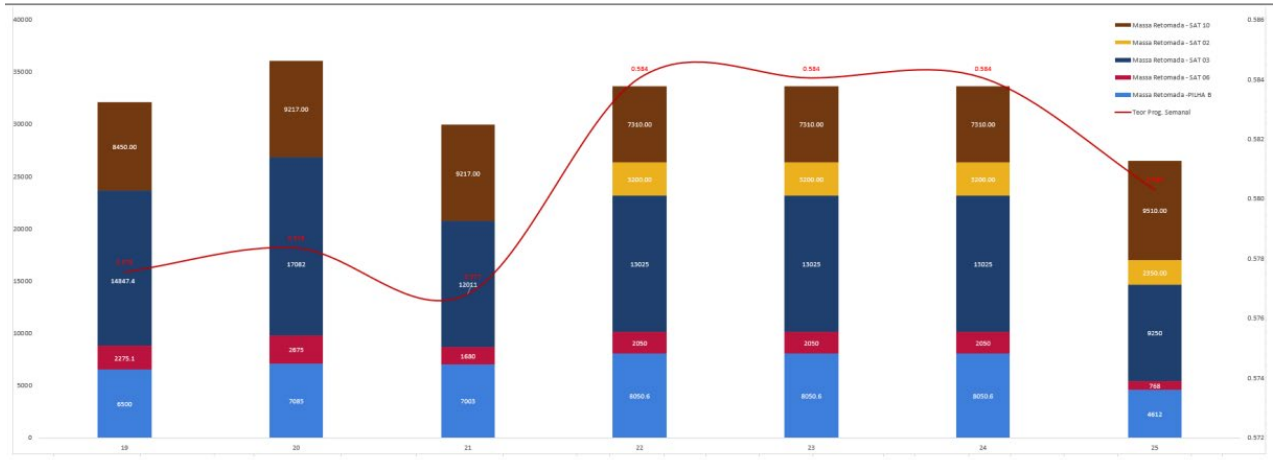
Boxplot da Taxa / Litologia do Mi

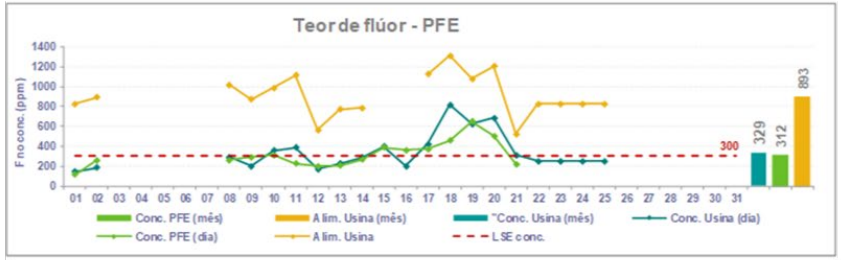


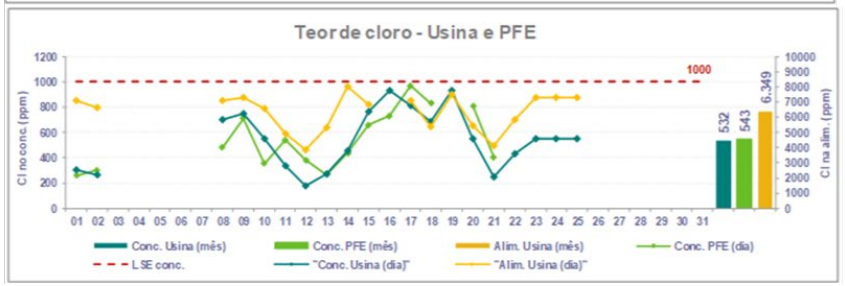
Mineral Area %		Mineral Area %		Mineral Area %	
Cl & F minerals	29.41%	Cl & F minerals	46.42%	Cl & F minerals	38.06%
U & Th minerals	1.64%	U & Th minerals	1.54%	U & Th minerals	2.42%
Y minerals	1.92%	Y minerals	3.31%	Y minerals	4.40%
REE minerals	17.63%	REE minerals	17.57%	REE minerals	16.02%
Au minerals	0.00%	Au minerals	0.00%	Au minerals	0.01%
Amphiboles	4.96%	Amphiboles	5.40%	Amphiboles	6.95%
Alkali Feldspar	0.00%	Alkali Feldspar	0.00%	Alkali Feldspar	0.00%
Phyllosilicates	0.00%	Phyllosilicates	0.02%	Phyllosilicates	0.21%
Scapolite Series	1.98%	Scapolite Series	1.92%	Scapolite Series	2.25%
Ore minerals	16.36%	Ore minerals	9.71%	Ore minerals	7.74%
Carbonates	0.11%	Carbonates	0.30%	Carbonates	0.53%
Epidote Group	2.56%	Epidote Group	1.90%	Epidote Group	3.01%
Chlorite Group	1.46%	Chlorite Group	0.40%	Chlorite Group	1.86%
Fe Oxides	17.69%	Fe Oxides	2.66%	Fe Oxides	10.45%
Native elements	0.00%	Native elements	0.00%	Native elements	0.00%
Ti silicates	0.05%	Ti silicates	0.02%	Ti silicates	0.07%
Te minerals	0.00%	Te minerals	0.00%	Te minerals	0.00%
Ti & Fe oxides	0.01%	Ti & Fe oxides	0.00%	Ti & Fe oxides	0.01%
Quartz	0.01%	Quartz	0.01%	Quartz	0.07%
Phosphates	0.00%	Phosphates	0.00%	Phosphates	0.00%
Pyroxene	0.00%	Pyroxene	0.00%	Pyroxene	0.00%
Zircon	0.00%			Zircon	0.00%
Plagioclase Feldspar	0.00%			Plagioclase Feldspar	0.00%
Unknown	4.22%			Unknown	5.95%
				Low_Counts	0.00%

- Mineralogical paragenesis of sulphide-rich zones
- Semi-quantitative mineralogy
- Penalty elements mineralogy prediction

Sossego Complex Automated Mineralogy (AMICS): Short Term Planning Interface







Salobo

Salobo Geological Map

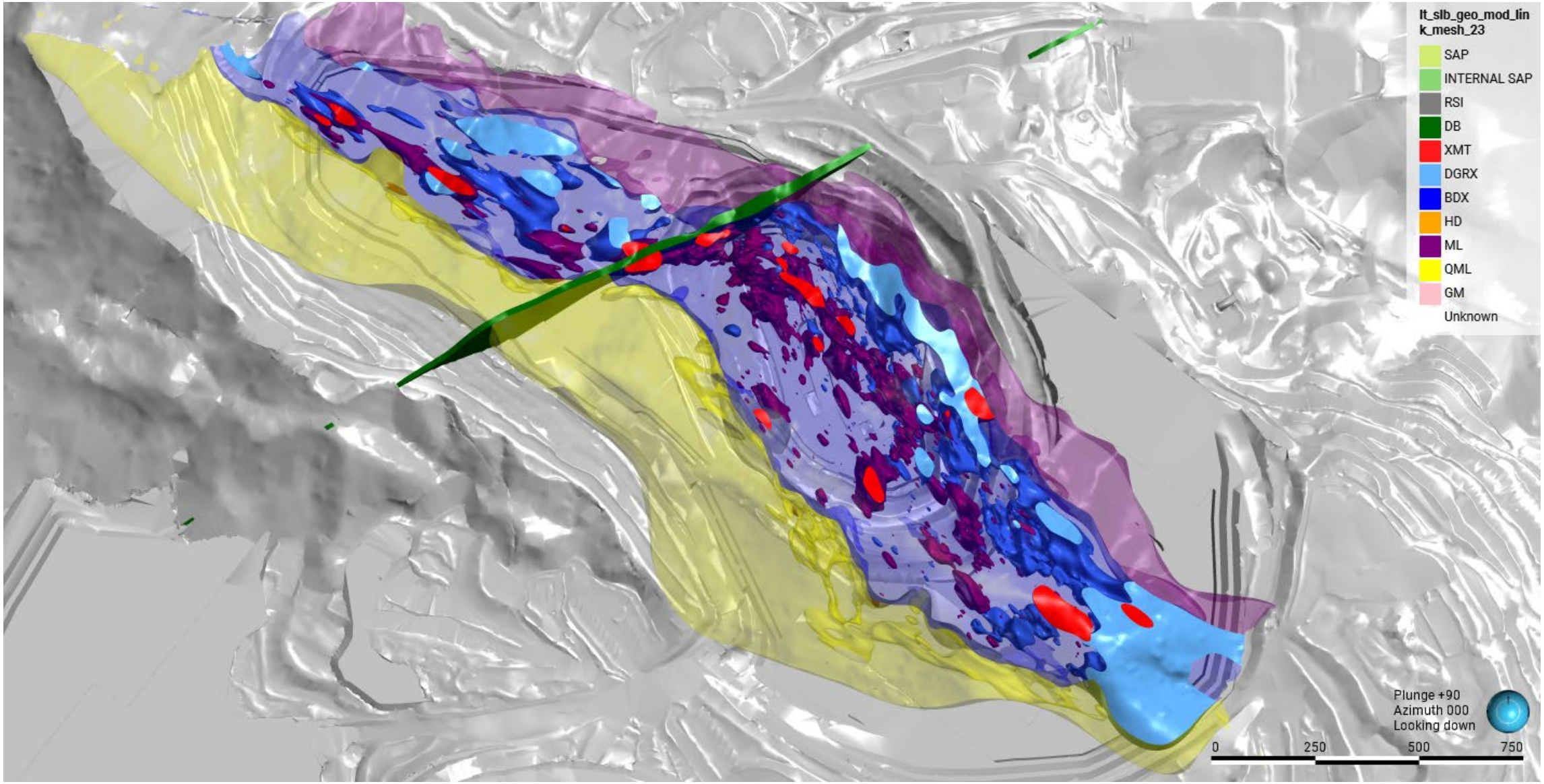
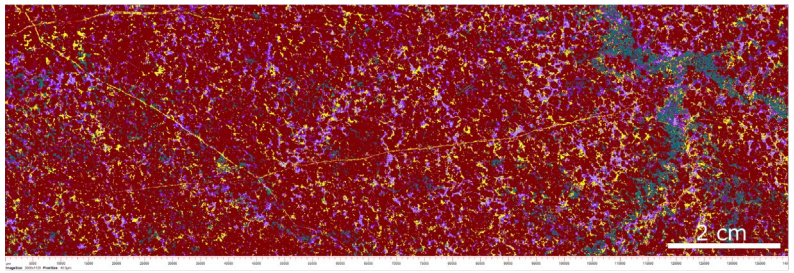
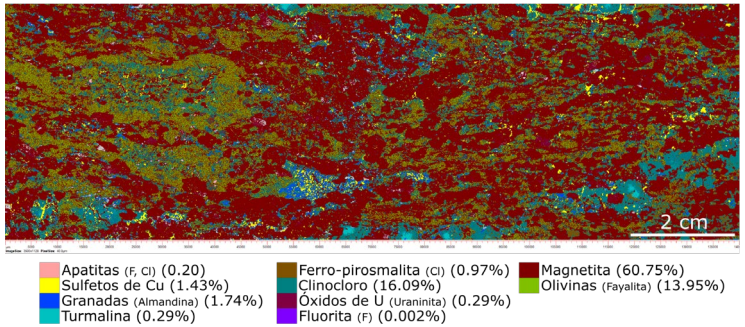
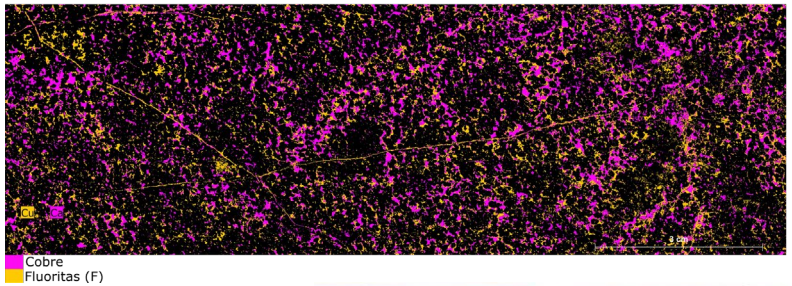


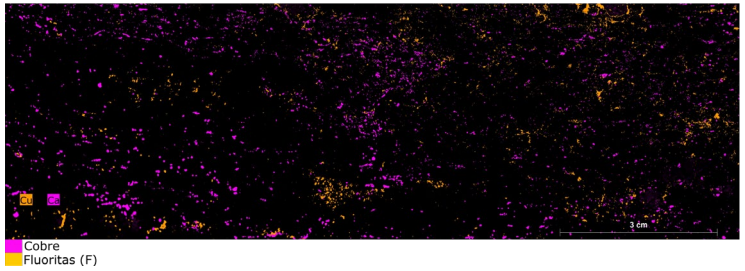
Image courtesy of Valter Oliveira (Vale Base Metals)

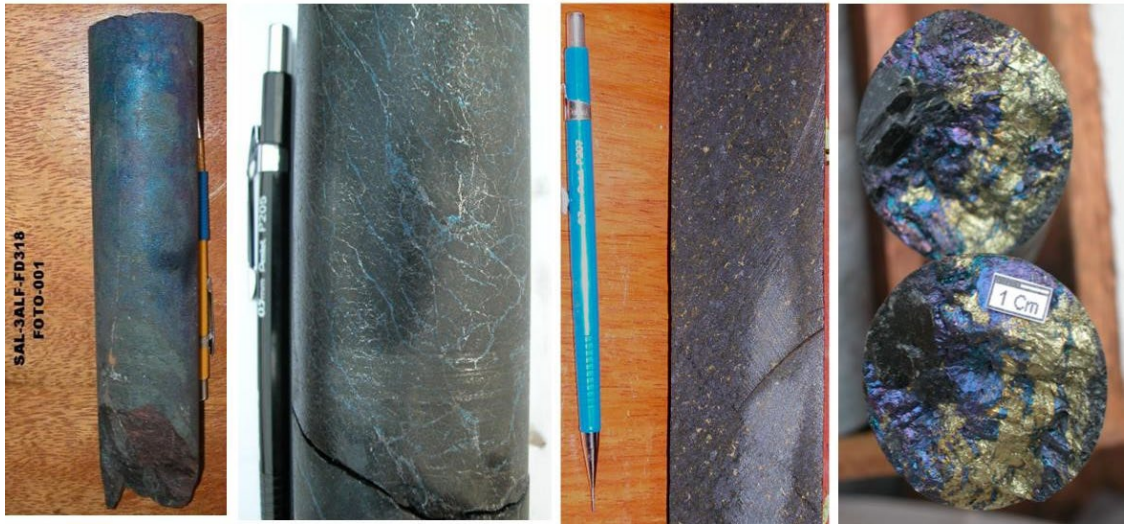
Salobo Automated Mineralogy (AMICS): Magnetic Schists Case









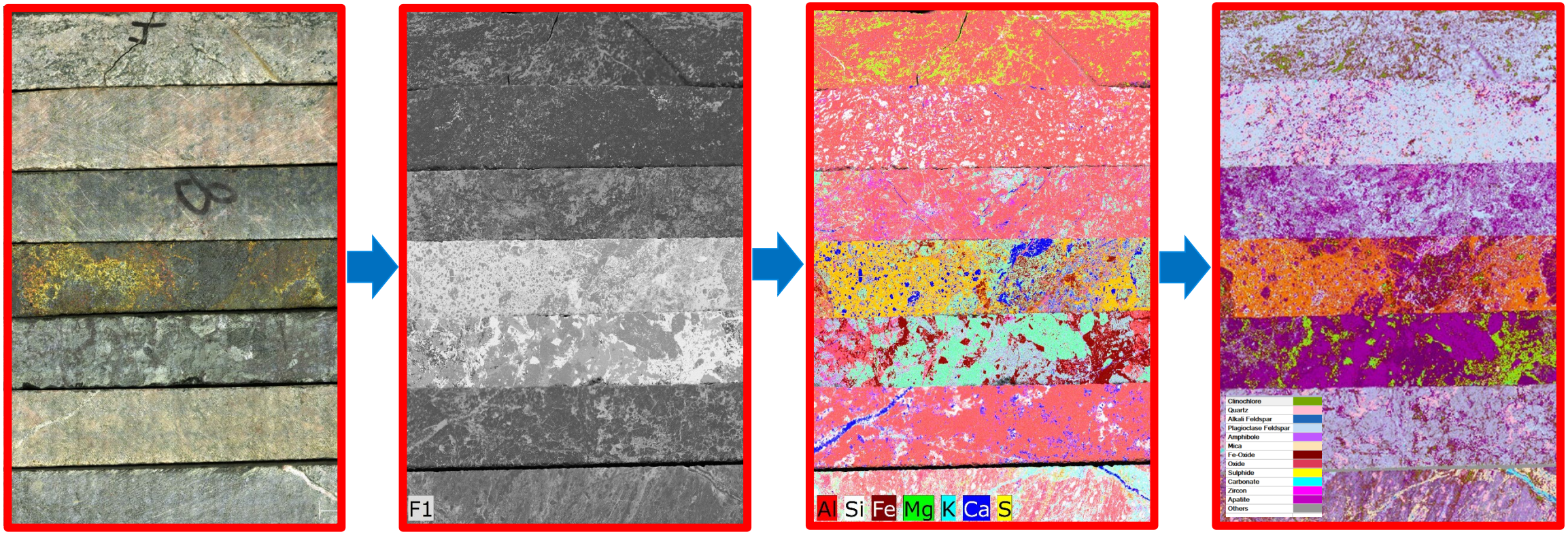


WEBINAR: GREENFIELD AND BROWNFIELD MINING EXPLORATION PROJECTS

Micro-XRF workflow examples

Analysis of Drill Core Samples: Workflow

Example of the Samples (7x Drill Cores) as analyzed in the microXRF M4 TORNADO.



Optical Image

Total X-ray Intensity Map

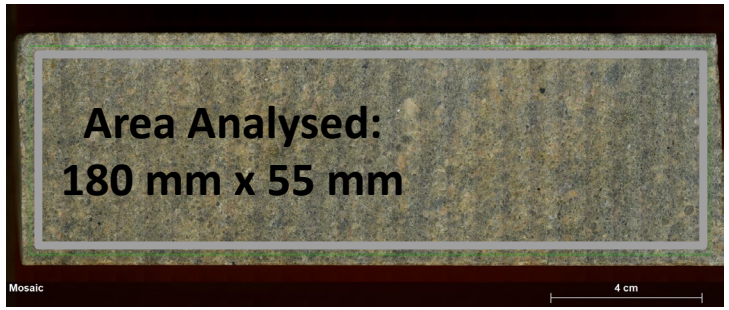
Overlaid Element X-ray Map

Mineralogical Map AMICS

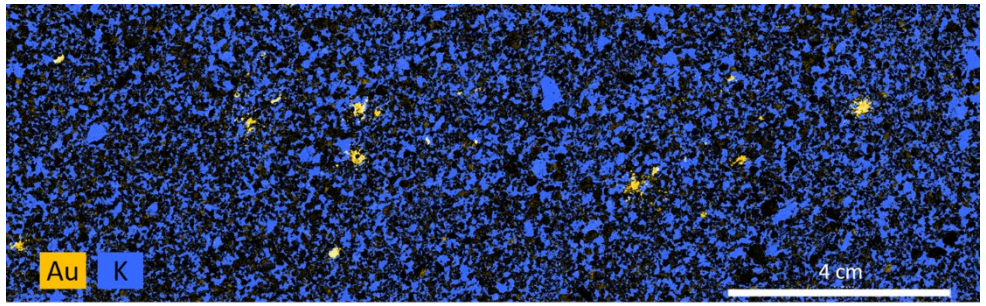
Analysis of Drill Core Samples: Workflow

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.

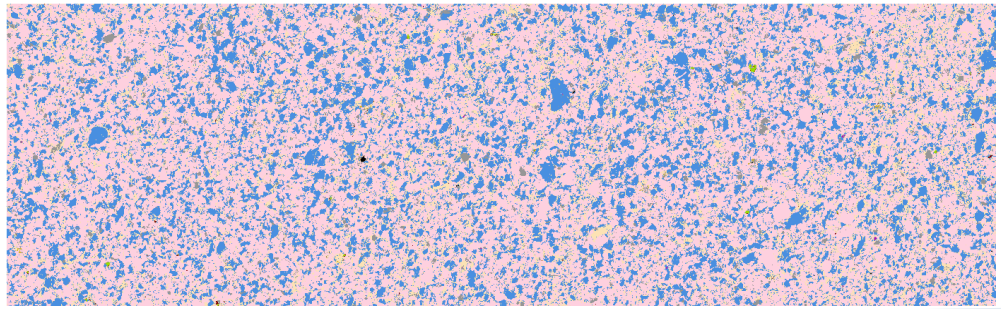
Optical



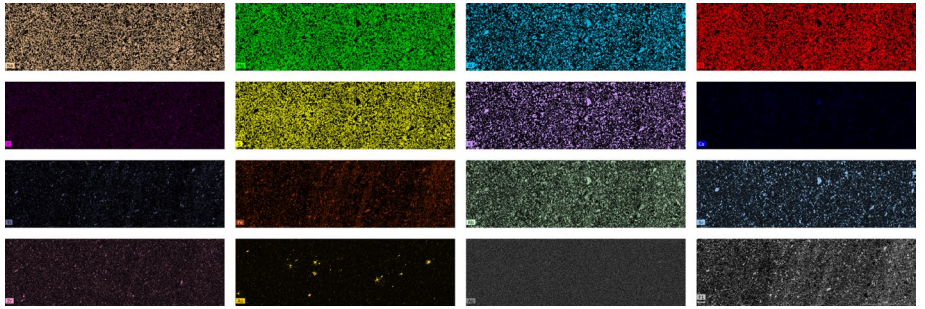
Elemental

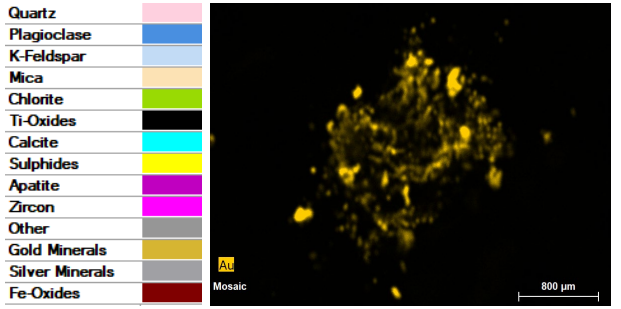


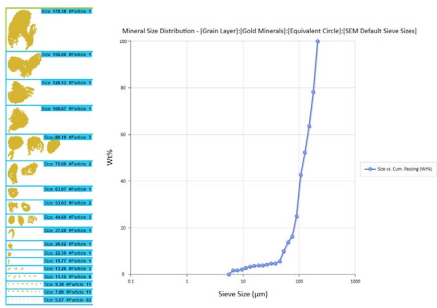
Mineralogical



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

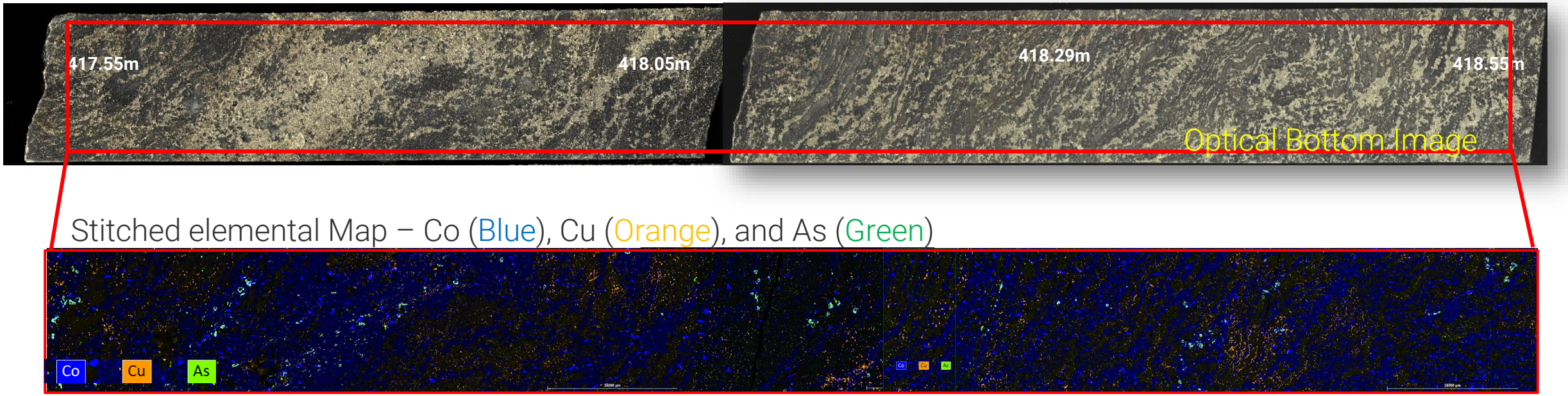






Finland: Co-Au Deposit
Drill Core Analysis

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



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.

Finland: Co-Au Deposit
Drill Core Analysis

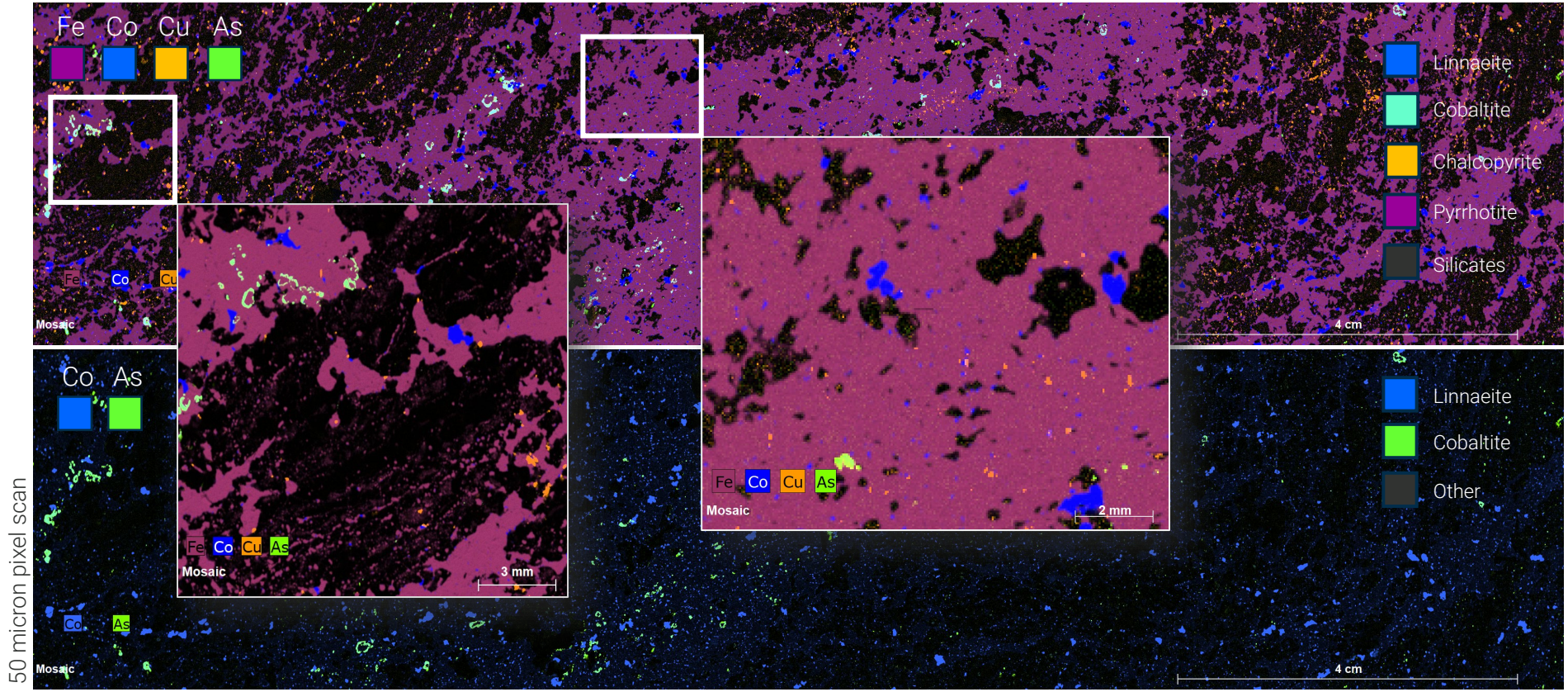
Identification of key elements of interest

Overlayed Mixed Element images can lead to mineral identification

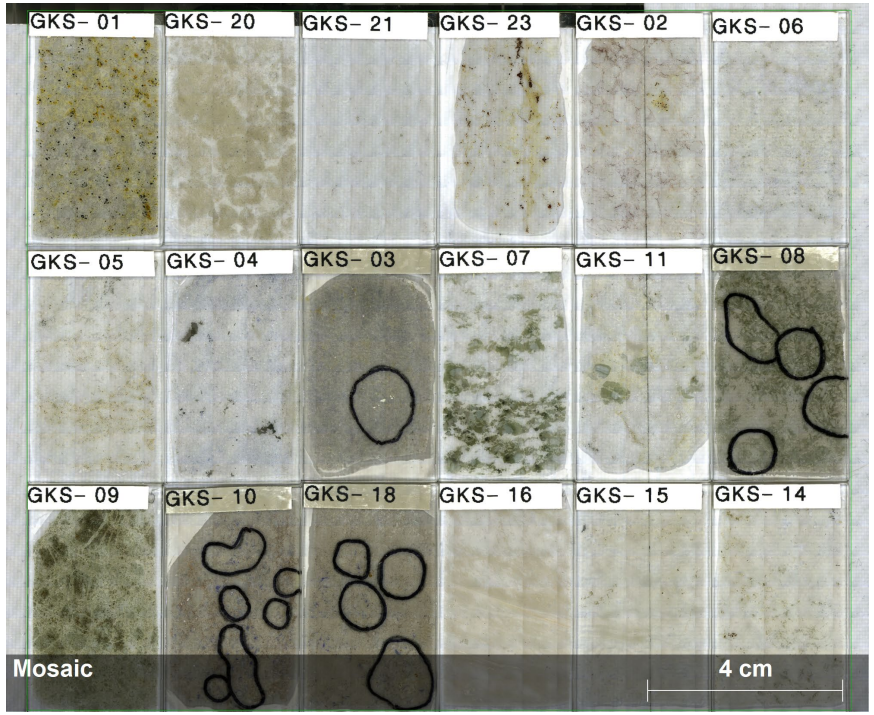
High resolution scans can identify textures and associations

PAL0163 – 417.55m

Extreme Detail

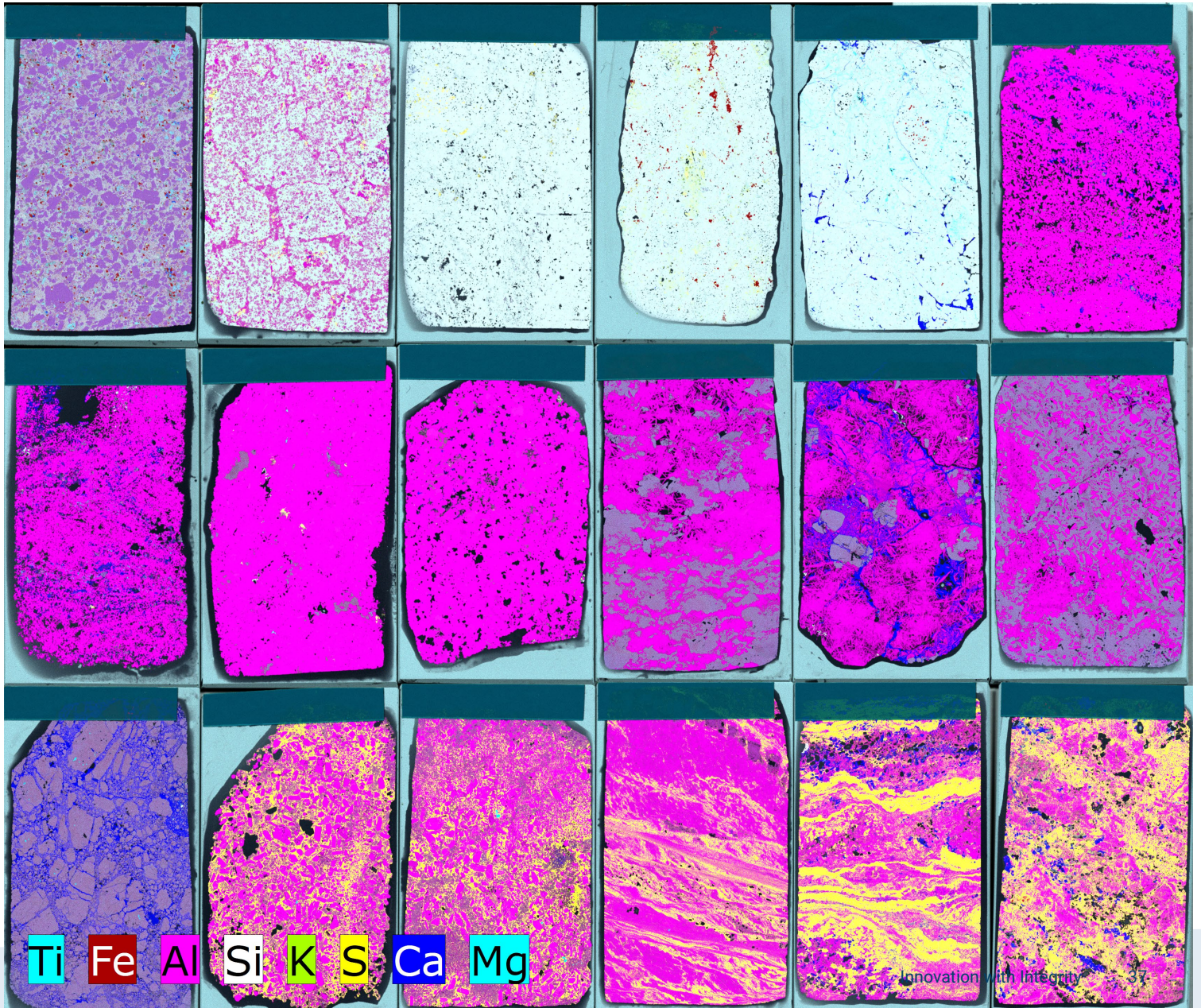


Sapphires:
Micro-XRF – Thin Sections

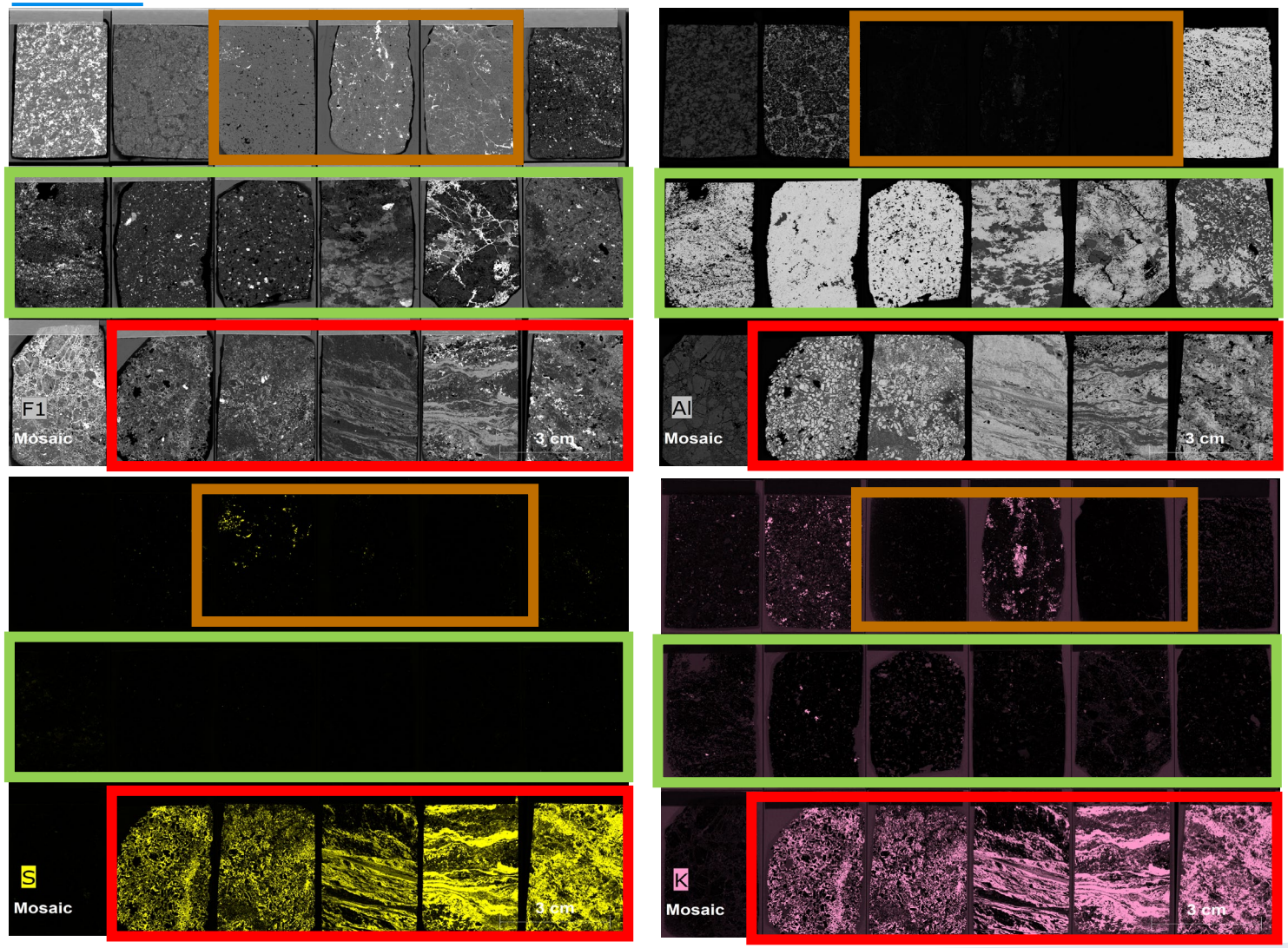


Analysis of 18 Thin Sections that represent the various lithologies observed at Portezuelo de Pajas Blancas.

Above: Optical Image
Right: Overlaid Element Intensity Maps



Sapphires:
Micro-XRF – Thin Sections



Analysis of 18 Thin Sections that represent the various lithologies observed at Portezuelo de Pajas Blancas. Individual Element Intensity Maps.

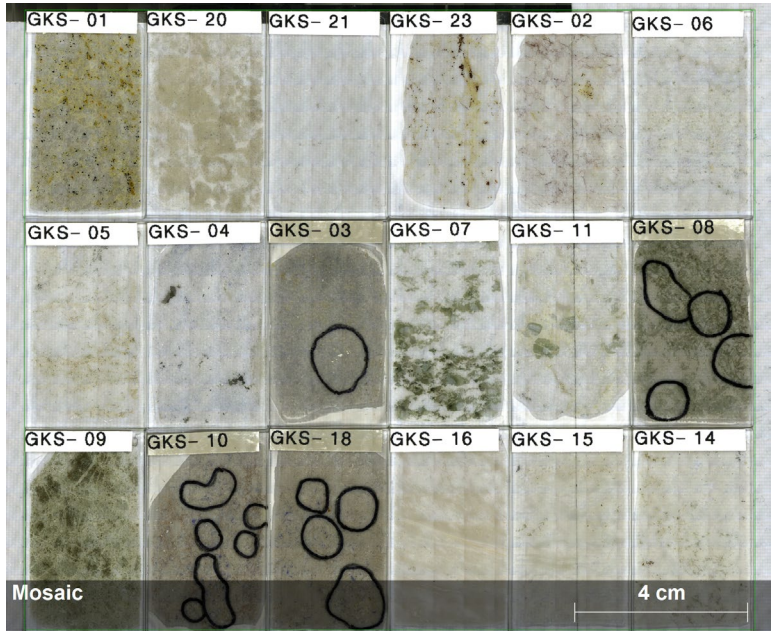
Top Left: Total X-ray Intensity (Grey)
Bottom Left: S Intensity
Top Right: Al Intensity
Bottom Right: K Intensity

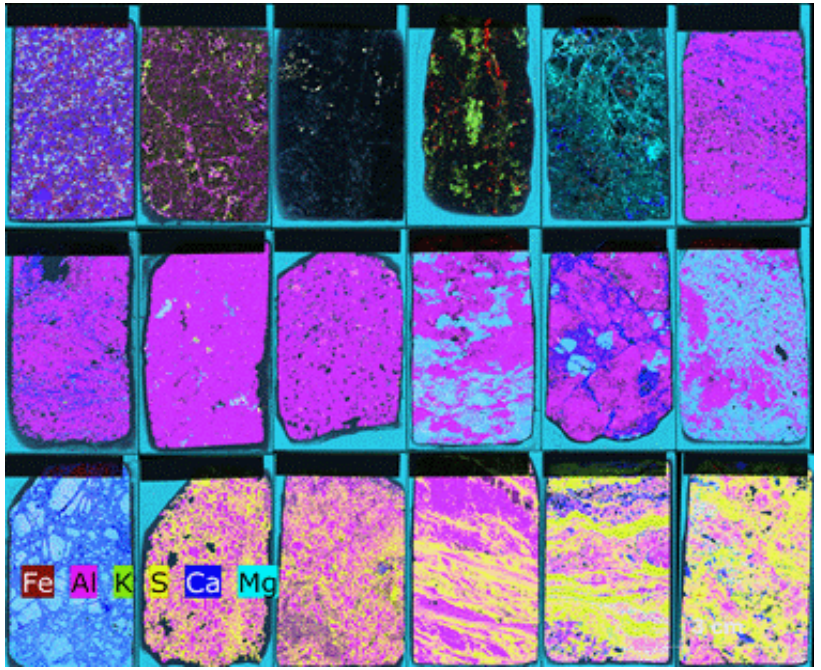
The main Sapphire bearing units are dominated by Al.

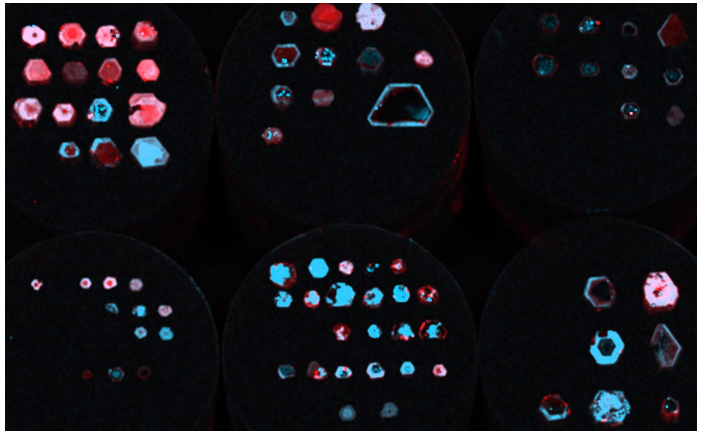
The presence of sulphur and potassium is related to Alunite $KAl_3(SO_4)_2(OH)_6$ (Alteration)

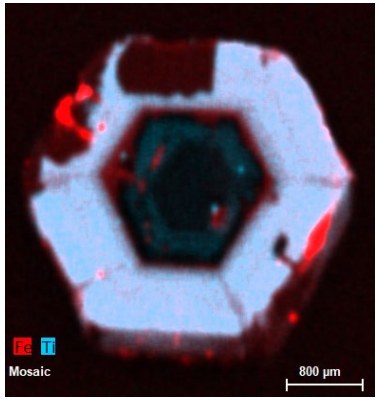
Quartzite and Hydrothermal breccia

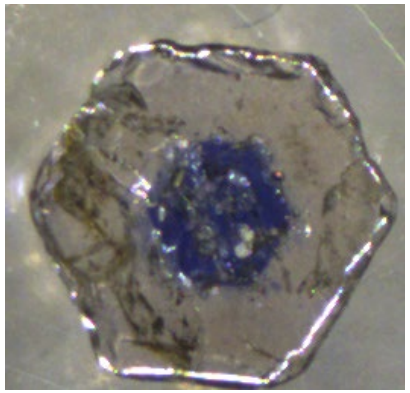
Overview:
Analytical Challenge – Multiple Samples of Different Sizes









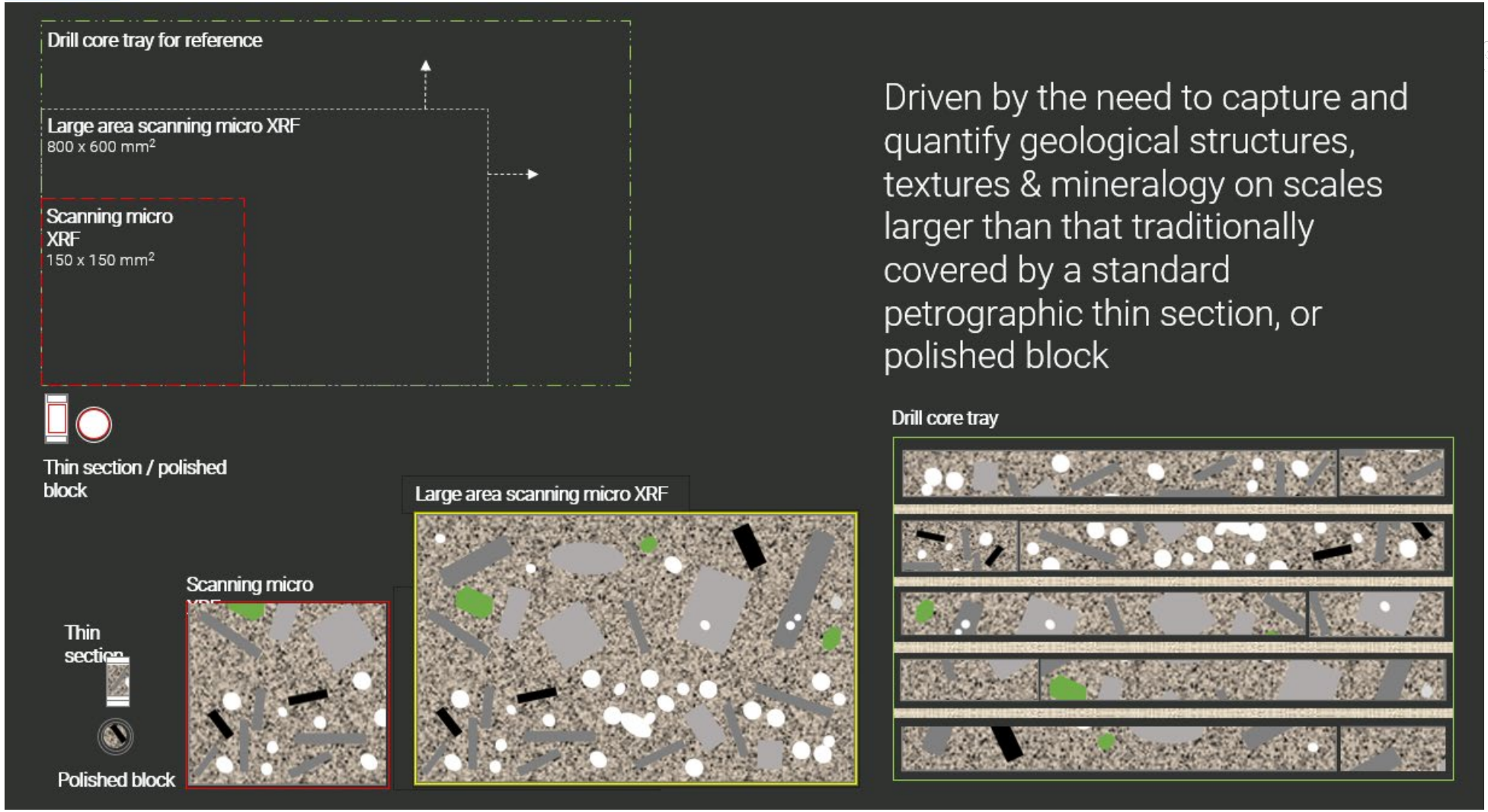


Micro-XRF (M4 TORNADO) can analyze samples of different sizes:
Left: Field Rock Samples to
Top Right: Thin Sections to
Bottom Right: Individual Crystals

Summary and Conclusions:
Greenfield and Brownfield Mining Exploration Projects

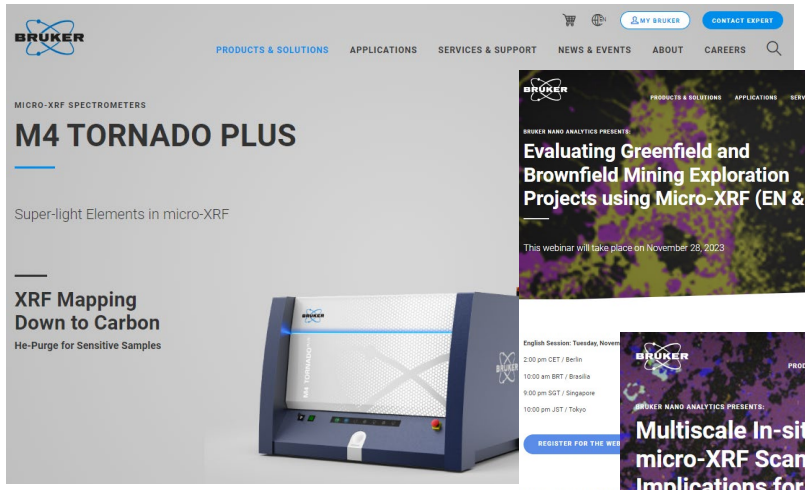
- Understanding geological samples early in any greenfield or brownfield project is important
- Micro-XRF is a flexible analytical tool providing quick analysis and relevant information for decision making
- Such information includes:
  - Elemental and Mineralogical distribution maps
  - Whole rock and Mineral compositions
  - Element deportment
  - Mineral grain sizes, distribution, and associations
- Micro-XRF can analyze a range of sample sizes and is ideal for transitioning from the field to the laboratory and for down-scaling or up-scaling information

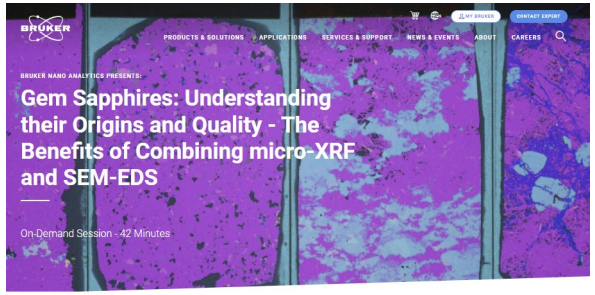
Analytical Workflow:
Multi-scale in situ non-destructive scanning micro-XRF analysis

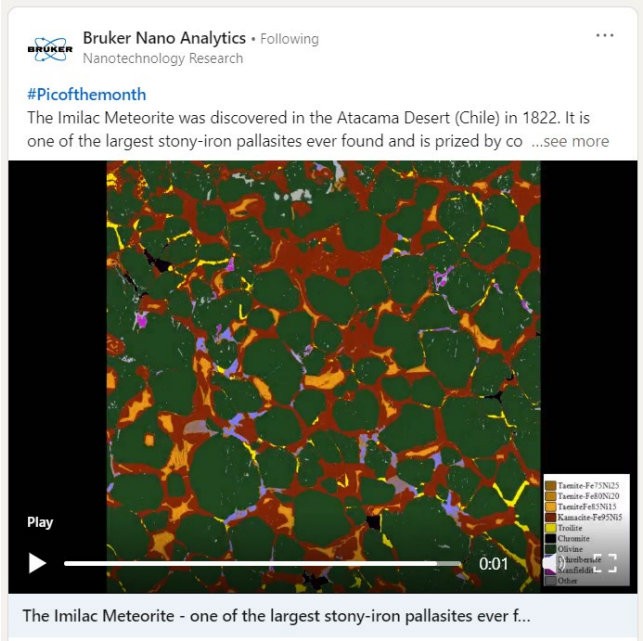


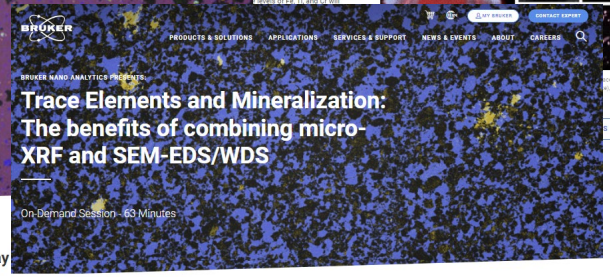
Courtesy of GTK, Alan Butcher

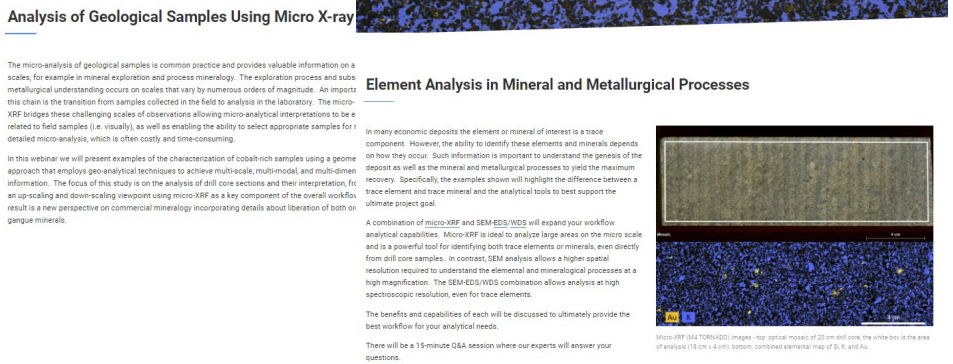
Micro-XRF
Further Information

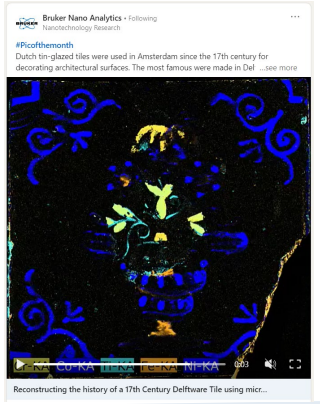












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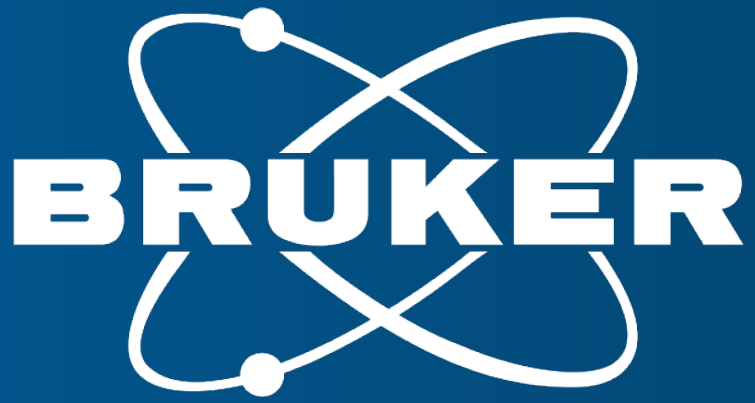

Innovation with Integrity